Engraved & printed at the Offices of the Survey of India Calcutta, 1910.

VIEW OF BANOG MOUNTAIN.

THE TERMINAL POINT OF ONE OF THE HIMALAYAN LINES OF LEVELLING, THE HEIGHT OF WHICH, 7429·23 FEET OR 2264·41 METRES, HAS BEEN DETERMINED IN ORDER THAT THE RATE OF MOUNTAIN-GROWTH MAY BE OBSERVED.

From a photograph by Mr. E. B. West, Survey of India.

ACCOUNT OF THE OPERATIONS OF

THE GREAT TRIGONOMETRICAL SURVEY OF INDIA

VOLUME XIX.

LEVELLING OF PRECISION IN INDIA

(1858-1909)

BY

COLONEL S. G. BURRARD, R.E., F.R.S.,

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VOLUME XIX.

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„ 75 table XX Col. 5 line 1 from top	„	881	„	801
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„ 85 „ 7 „ „	„	Vol. XX	„	Vols. XIXA and XIXB
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„ 103 table XXII Col. 8 line 4 from bottom	„	0·66310	„	0·69310
„ 114 line 11 from bottom	„	many	„	two
„ 123 „ 3 „	„	lower	„	higher
„ „ „ 4 „	„	higher	„	lower
„ 137 Col. 4 against bench-mark from 9 to 10	„	+ 0·005	„	− 0·002
„ „ „ 5 „ „ „ „	„	+ 0·098	„	+ 0·091
„ „ „ 6 „ „ „ „	„	− 29·358	„	− 19·835
„ „ „ 7 „ „ „ „	„	+ 0·020	„	+ 0·013
„ „ „ 8 „ „ „ „	„	− 29·338	„	− 19·822
„ „ „ 4 „ „ „ 10 to 11	„	+ 0·023	„	+ 0·030
„ 141 „ 3 „ „ „ 125 to 126	„	137·09	„	138·09
„ „ „ „ „ „ „ 126 to 127	„	138·67	„	139·67
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„ „ „ 7 „ „ „ 49 to 50	„	+ 0·002	„	+ 0·003
„ „ „ „ „ „ „ 55 to 56	„	+ 0·002	„	+ 0·003
„ „ „ 8 „ „ „ 49 to 50	„	+ 41·536	„	+ 48·537
„ „ „ „ „ „ „ 55 to 56	„	+ 43·781	„	+ 53·782
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„ 336 last Col. line 7 from top, *delete* † against − 0·790				
„ „ „ line 19 from „ „ „ − 0·662				
„ 343 last column of table line 1 from top	*for*	881	„	801
„ 424 Foot-note	„	1606·07	„	1906·07
„ 432 line 7 from top, *delete* it *after* observe				
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PREFACE.

This volume gives an account of the levelling operations carried out by the Survey of India during the fifty-two years, 1858-1909. It was originally intended to cover the period 1858-1908 only, but as delays occurred in the printing, the results of 1909 were subsequently added.

The possibility of undertaking a simultaneous adjustment of the levelling-net was first considered in 1904, and the preparation of the lists of bench-marks was begun, but the Punjab circuit had not then been completed, and the mathematical reduction could not be commenced, until the levelling on the line from Chach to Ferozepore had been finished. In 1905 an investigation of the closing errors of circuits showed that the levelling-net was much disfigured by large circuit errors in the Deccan, and it was decided to postpone the simultaneous adjustment, until the levelling from Bombay to Madras (level-lines numbered 32, 31, 25, 26, 22, 21, 14 and 8) and from Bellary to Karwar (lines numbered 16 and 17) had been revised; these revisions were not completed till 1908, and although the preparation of the lists of bench-marks had been continued without interruption, it was not till 1908, that this volume was written, and its two sequels, volumes XIXA and XIXB, were finally compiled.

To students of levelling some small contradictions may seem to exist in this volume. For example, in the references to the magnitude of the error of levelling per mile, the method employed by Colonel Hill, of dividing the total closing error on a line by the mileage, is occasionally mentioned with approval, and yet in chapter VIII the formula $\overset{\text{foot}}{0{\cdot}004}\sqrt{\text{miles}}$ was taken to express the relationship between error and distance. It was subsequently realised that neither of these systems was correct, and the formula $\pm\sqrt{(0{\cdot}004)^2M + (0{\cdot}00034)^2M^2}$ was deduced. The explanation of these changes is, that during the time, when this volume was passing through the press, I was studying Monsieur Lallemand's works on the Levelling of France, and these threw great light upon questions, that had hitherto in India been regarded as doubtful. I also gained many ideas and hints from Messrs. Tittmann and Hayford's reports on the Coast and Geodetic Survey of the United States of America, especially from Mr. Hayford's instructive appendices on levelling in the volumes for 1899 and 1903.

It was interesting to discover that on one question the French and the American authorities were at variance; Lallemand was advocating the employment of "orthometric" heights, and Hayford gave reasons for adhering to the uncorrected observed values. At the International Geodetic Conference, held in London and Cambridge in 1909, I had the privilege of discussing the question of orthometric values of height with both M. Lallemand and Mr. Hayford and with Sir George Darwin and Professor Helmert. The consensus of opinion was, that observed values of spirit-level heights required a correction for gravity before any reliable closing errors of circuits could be deduced, but opinions differed, as to whether the orthometric or the dynamic value of height should be adopted. At the advice of Professor Helmert and M. Lallemand we have in volumes XIXA and XIXB given both the orthometric and the dynamic height of every bench-mark. On page 369 of this volume are given the orthometric and dynamic heights of all junction-points and of the nine points, where the levelling issues from the sea.

On the permanence and accuracy of the Indian levelling.

This volume and its two sequels, volumes XIXA and XIXB, contain a record, for the use of posterity, of the elevation in 1858-1909 of numerous points of the land surface of India. But our successors will have to see, that the bench-marks, which are bequeathed to them, are maintained, or the Indian levelling will degenerate into a record on paper only. Although the accuracy of the Indian levelling may in places be open to criticism, yet regarded as a whole it is a great geodetic operation, and the officers, who have taken part in the observations in the field, may rest assured, that they have contributed to a scientific work, that will continue to be of value and interest for centuries, if only the bench-marks are preserved.

In the long period of levelling, from 1858 to 1909, there were possibly times of decadence, but one fact stands out clearly, and that is that in 1858 the Indian levelling was started upon correct and scientific lines. I feel indeed that we owe much to General Walker, who was the founder of Indian levelling, for the care and the thought he bestowed upon the subject, before he initiated the field-work.

But no edifice is perfect, and it is only to be expected, that after 50 years of accumulated experience the modern observers are able to discover directions of possible improvement. The standards of scientific work rise with time, and as new fields of investigation are opened, we begin to regret the absence of higher standards of accuracy in the past. A perusal of this volume will show that instrumental improvements and observational refinements have been introduced to bring the levelling abreast of modern requirements, but that on the whole the methods of General Walker have stood the test of time.

It has been frequently suggested that we should increase our out-turn of levelling at the expense of its accuracy, and that we should substitute single-levelling for double. The table on page 364 shows, that out of all the closing errors of our levelling circuits we have only two errors exceeding one foot. If we were to substitute single levelling for double, we should at once meet with closing errors of 5 to 10 feet and more. Engineers set a value now upon our levelling results, because they know them to be reliable and to rest on a scientific basis. If we reduce our standard of accuracy, our levelling will lose not only its scientific value but its practical value also.

Future levelling-operations.

The lessons, learnt from the experience of the past, will be of interest to our successors. The bench-marks at the junction-points of level-lines and at tidal observatories should have been made more permanent. Rock-cut marks are wanted in many places. No embedded bench-mark should ever again be placed in a railway station. If a new bench-mark comes to be erected on the site of an old one, the fact should be noted in the description, or confusion will ensue. If an old bench-mark is found by new levelling to have sunk, a note to this effect should be added in the *original* records. The levelling party should keep a careful account of all bench-marks, that are reported to be disturbed, and should take any opportunities that offer of having the reports verified.

New level lines are required from sea to sea and from rock to rock. It is better to start a new line from rock and to end it at rock and to connect on the way with old bench-marks, than to make the line emanate from and end at old marks on masonry. The levelling-net of the future should be self-contained and superposed on the level-net of this volume. Many lessons about levelling and bench-marks have been learnt from the revisions of lines, and nothing would do more to maintain a high standard of accuracy than the revision of a section of old levelling every year.

In connection with staff-comparisons the number of decimal places given in the tables of chapter III is fictitious and misleading; staff-comparisons should be made, after the staff has been exposed to the sun, as it is in ordinary work, and the index error of a staff should be separated from its graduation error.

Preparation of this volume.

The task of preparing the line-forms was carried out by Mr. J. Bond and by Mr. Ollenbach, and this task has proved laborious. For some years Mr. Bond and Mr. Ollenbach have been copying old records and transcribing new lists of bench-marks from them. Mr. Bond's long experience of levelling in the field proved of great value. Mr. Ollenbach also drew the level-charts for volumes XIXA and XIXB. The accuracy of the three allied volumes, XIX, XIXA, and XIXB, is greatly due to the care, which Mr. Ollenbach bestowed upon them, and to the interest which he has taken in this work.

The plates (Vol. XIX) were prepared and the charts of level-lines (Vols. XIXA and XIXB) were printed under Mr. Nichol, and I take this opportunity of expressing my obligations for the trouble he has taken to eliminate inaccuracies.

The examination of proofs was undertaken in a very thorough manner by Babu Ishan Chandra Dev, B.A., to whom I am indebted for valuable suggestions. The proofs of Volume XIXA and XIXB were corrected and passed by Mr. Shaw, Mr. Ollenbach and by Babu Bidhu Bhushan Shome; Babu Bidhu Bhushan has been very careful in checking the numerical and descriptive details.

The printing of the three volumes XIX, XIXA, and XIXB was carried out by Babu Sarat Kumar Mukerji, and the success of the publication has been largely due to the energy he has shown and to the systematic way he has controlled the numerous and successive proofs.

The calculations of the simultaneous reduction were made by Babu Mukundananda Acharya, who performed his difficult task rapidly and intelligently.

Mr. Erskine, who is in charge of the Tidal and Levelling Party, has kindly gone through all proofs of Volumes XIXA and XIXB, and has given us much help on more than one occasion. As he is about to retire from India after 30 years of service, I think it right to record my appreciation of the services he has rendered to Indian levelling during the five years he has been in charge.

Mr. Eccles has been in charge of the Computing, the Drawing and the Printing Offices of the Trigonometrical Survey during the preparation of this volume. He has done all in his power to assist and to accelerate the work. He has kept a control throughout on the computation of the orthometric corrections, and he supervised the calculations of the simultaneous reduction of the net. I have every reason to be grateful to Mr. Eccles for his co-operation.

Dehra Dun,
July 25th, 1910.

S. G. Burrard.

PART I.

HISTORICAL AND DESCRIPTIVE ACCOUNTS OF THE LEVELLING OPERATIONS.

CHAPTER I.

HISTORICAL SUMMARY.

In this volume the results of precise levelling by the Trigonometrical Survey of India have been compiled, the methods employed in adjusting the level net have been explained and the corrected values of elevations have been tabulated. Levelling operations were commenced in India in 1858, and this volume gives an account of the work performed in the half-century, 1858 to 1908.

From the origin of the Trigonometrical Survey until the year 1858 all heights in India were determined by means of vertical angles between stations of the triangulation. This method is however not very reliable. Rays of light passing from an object to an observer traverse an atmosphere which is subject to many changes and the amount by which rays are refracted is variable and uncertain. *

The method of reciprocal vertical angles is based on the supposition that the back and forward angles are equally refracted, and that the refraction is consequently eliminated in deducing the angle subtended by the excess of the higher station over the lower. But the anomalies and irregularities of the trajectories of light, in the lower strata of the atmosphere, render it highly improbable that the refraction can be equal in the back and forward observations. There are instances on record of observers sent to take simultaneous reciprocal vertical observations, finding one station to be visible from the other half an hour before the visibility was mutual, so that the observations at the first station might have been completed before this station had been seen from the second.

The method of reciprocal vertical angles was found to be particularly unsuitable on the plains of Northern India: these plains are so flat that an error in height of one or two feet is often of importance to engineers, but discrepancies between the results by vertical angles frequently exceeded ten feet and occasionally exceeded twenty feet. The surveyors had moreover reasons to fear that even these large discrepancies were not disclosing the real magnitudes of the errors, which they believed tended to accumulate systematically.

In 1858 the Indian Survey commenced a series of spirit-levels which followed the line of principal triangulation from Karachi to Attock and thence to Dehra Dun and Sironj.

From 1858 to 1875 the levelling operations were designed to satisfy the requirements of particular provinces, localities or cantonments, but in 1875 General Walker brought all the lines of level into one great scheme. His scheme consisted of a chain of tidal observatories extending from Karachi along the whole coast of India and Burma to Moulmein, each observatory furnishing a mean-sea-level datum point, and these datum points furnishing a basis for great lines of levels of the highest order of precision spread over the entire continent of India; these great lines again forming the basis of the altimetry of the whole Indian triangulation.†

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* *On the methods of determining heights*, by General Walker, Memoirs R.A.S., Vol. 33.

† A comparison of the position of Levelling in India in 1904 with that of Foreign Surveys was published as an Appendix, page 209, part II, Report of the Indian Survey Committee, 1904-1905; also in Professional Paper No. 9, Survey of India, 1905.

In the simultaneous reduction of the level net carried out in 1909 General Walker's scheme was modified to this slight extent that the values of mean-sea-level derived from observatories situated in gulfs and straits were not included.

The first levellers were Capt. J. T. Walker, R. E., Lieut. B.R. Branfill and Mr. C. J. Carty; and the mean-sea-level of Karachi harbour was originally adopted as the datum.

Between 1858 and 1908 eighty-six main-lines have been levelled; many branch-lines of levels have also been observed, and great numbers of *extra* bench-marks have been fixed on the flanks of the main and of the branch level lines.

The difference between a so-called main-line and a branch-line is simply this, that the main-line forms a part of the precise level net and the branch-line does not. The branch-line is as accurately levelled as the main-line. In future many of our existing branch-lines will be extended and will be utilized to form new level circuits.

The following table shows the eighty-six main-lines of level. Of these the first seventy-seven start from one bench-mark and end at another; the last nine lines start from a bench-mark and end at mean-sea-level as determined at a tide-gauge.

Table I contains an historical summary of the eighty-six main-lines of level.

TABLE I.

The Main-Lines of Levelling.

Line No.	From	To	Route followed	Province	Observers		Levels used		Staves used		Season
					1st Leveller	2nd Leveller	1st Leveller	2nd Leveller	1st Leveller	2nd Leveller	
1	Tanjore	Ramnad	*Viâ* Arantangi & Mimisal	Madras	H. Corkery	Narsing Dass	Rectangular	No. 4 Cylindrical	Nos. 2 & 3	Nos. 9 & 10	1885-86
2	Ramnad	Tuticorin	*Viâ* Sikkal & Vulusamudram	Madras	H. Corkery	Narsing Dass	Rectangular	No. 4 Cylindrical	Nos. 2 & 3	Nos. 9 & 10	1885-86
3	Tuticorin	Trichinopoly	*Viâ* Satur, Madura & Dindigul	Madras	H. Corkery	Narsing Dass	Rectangular	No. 4 Cylindrical	Nos. 2 & 3	Nos. 9 & 10	1886-87
4	Trichinopoly	Tanjore	*Viâ* the South Indian Railway	Madras	H. Corkery	Narsing Dass	Rectangular	No. 4 Cylindrical	Nos. 2 & 3	Nos. 9 & 10	1886-87
5	Tanjore	Negapatam	*Viâ* Nidamangalam	Madras	H. Corkery	Narsing Dass	Rectangular	No. 4 Cylindrical	Nos. 2 & 3	Nos. 9 & 10	1885-86
6	Trichinopoly	Erode	*Viâ* the Railway	Madras	H. Corkery	Narsing Dass	Rectangular	No. 4 Cylindrical	Nos. 2 & 3	Nos. 9 & 10	1886-87
7	Jalarpet	Erode	*Viâ* Salem & Morappur	Madras	G. Belcham	Narsing Dass	Rectangular	No. 4 Cylindrical	Nos. 2 & 3	Nos. 9 & 10	1884-85
8	Arkonam	Madras	*Viâ* Tiruvallur, Avade & Rayapuram	Madras	E. H. Corridon	O.N. Pushong	No. 4 Cylindrical	No. 1 Cylindrical	Nos. 04 & 05	Nos. 01 & 03	1907-08
9	Madras	Tanjore	*Viâ* Chingleput & Cuddalore	Madras	H. Corkery	Narsing Dass	Rectangular	No. 4 Cylindrical	Nos. 2 & 3	Nos. 9 & 10	1885-86
10	Arkonam	Jalarpet	*Viâ* the Railway	Madras	G. Belcham	Narsing Dass	Rectangular	No. 4 Cylindrical	Nos. 2 & 3	Nos. 9 & 10	1884-85
11	Erode	Shoranur	*Viâ* Mangalam & Palghat	Madras	G. Belcham	Narsing Dass	Rectangular	No. 4 Cylindrical	Nos. 2 & 3	Nos. 9 & 10	1884-85

TABLE I—(Continued).

The Main-Lines of Levelling.

Line No.	From	To	Route followed	Province	Observers		Levels used		Staves used		Season
					1st Leveller	2nd Leveller	1st Leveller	2nd Leveller	1st Leveller	2nd Leveller	
12	Shoranur	Beypore	*Viâ* Tirur	Madras	G. Belcham	Narsing Dass	Rectangular	No. 4 Cylindrical	Nos. 2 & 3	Nos. 9 & 10	1884-85
13	Shoranur	Cochin	*Viâ* Trichur & Narakkal	Madras	H. Corkery	Narsing Dass	Rectangular	No. 4 Cylindrical	Nos. 2 & 3	Nos. 9 & 10	1886-87
14	Arkonam	Gooty	*Viâ* Tirupati & Cuddapah	Madras	E. H. Corridon	O. N. Pushong	No. 4 Cylindrical	No. 1 Cylindrical	Nos. 04 & 05	Nos. 01 & 03	1907-08
15	Bellary	Gooty	*Viâ* Guntakal	Madras	Lt. H. J. Harman, R.E.	O. V. Norris	No. 3 Cylindrical	No. 4 Cylindrical	Nos. B1 & B2	Nos. 3 & 4	1873-74
16	Bellary	Hubli	*Viâ* Annigeri, Hesarur & Hospet	Bombay and Madras	A. M. Talati	P. N. Sur	No. 3 Cylindrical	No. 2 Cylindrical	Nos. B1 & B2	Nos. IIII & 4	1907-08
17	Hubli	Karwar	*Viâ* Kalghatgi & Arbail ghat	Bombay	A. M. Talati	P. N. Sur	No. 3 Cylindrical	No. 2 Cylindrical	Nos. B1 & B2	Nos. IIII & 4	1907-08
18	Jalarpet	Bangalore	*Viâ* Kuppam, Tyakal & Malur	Madras and Mysore	G. Belcham	Narsing Dass	Rectangular	No. 4 Cylindrical	Nos. 2 & 3	Nos. 9 & 10	1884-85
19	Bangalore	Bellary	*Viâ* Tumkur, Nelhal & Devesamudra	Madras and Mysore	Capt. J. R. Mc Cullagh, R.E.	A. H. Bryson	No. 3 Cylindrical	No. 4 Cylindrical	Not known	Not known	1874-75
20	Bezwada	Madras	*Viâ* Nellore, Ongole & Guntur	Madras	G. D. Casson	Narsing Dass	Rectangular	No. 4 Cylindrical	Nos. 3 & 4	Nos. 9, 10 & 2	1887-88
21	Raichur	Gooty	*Viâ* Adoni & Guntakal	Madras and Hyderabad	E. H. Corridon A. M. Talati	O. N. Pushong P. N. Sur	No. 3 Cylindrical „ 4 Cylindrical	No. 2 Cylindrical „ 1 Cylindrical	Nos. B1 & B2 „ 04 & 05	Nos. IIII & 4 „ 01 & 03	1906-07 1907-08
22	Raichur	Gulbarga	*Viâ* the G. I. P. Railway	Hyderabad	A. M. Talati	P. N. Sur	No. 3 Cylindrical	No. 2 Cylindrical	Nos. B1 & B2	Nos. IIII & 4	1906-07 1907-08

TABLE I—(Continued).

The Main-Lines of Levelling.

Line No.	From	To	Route followed	Province	Observers		Levels used		Staves used		Season
					1st Leveller	2nd Leveller	1st Leveller	2nd Leveller	1st Leveller	2nd Leveller	
23	Bellary	Raichur	*Viâ* Alur, Tungabhadra & Yerragiri	Madras and Hyderabad	Capt. J. R. Mc Cullagh, R.E. A. M. Talati	A.H. Bryson P. N. Sur	No. 3 Cylindrical do. do.	No. 4 Cylindrical „ 2 Cylindrical	Not known Nos. B1 & B2	Not known Nos. IIII & 4	1874-75 1907-08
24	Gulbarga	Bezwada	*Viâ* Bider & Hyderabad	Madras and Hyderabad	G. Belcham J. Bond	Narsing Dass Narsing Dass	Rectangular Rectangular	No. 1 Cylindrical Cushing's Reversible No. 1050	Nos. 5 & F „ 3 & 4	Nos. 9 & 10 „ 9 & 10	1879-80 1888-89 1889-90
25	Kedgaon	Diksal	*Viâ* the G. I. P. Railway	Bombay	E. H. Corridon	O.N. Pushong	No. 4 Cylindrical	No. 1 Cylindrical	Nos. 04 & 05	Nos. 01 & 03	1906-07
26	Diksal	Gulbarga	*Viâ* Kem, Hotgi & Dudhni	Bombay & Hyderabad	A. M. Talati	P. N. Sur	No. 3 Cylindrical	No. 2 Cylindrical	Nos. B1 & B2	Nos. IIII & 4	1906-07
27	Diksal	Nira	*Viâ* Baramati	Bombay	C. J. Neuville	Narsing Dass	Rectangular	No. 1 Cylindrical	Nos. 5 & 6	Nos. 7 & 9	1878-79
28	Kedgaon	Nira	*Viâ* Supa, Morgaon & Morti	Bombay	T. H. Rendell	Narsing Dass D. Ramchandra	Rectangular	No. 1 Cylindrical	Nos. 5 & 6	Nos. 7 & 9	1877-78
29	Nira	Hubli	*Viâ* Satara, Belgaum & Dharwar	Bombay	C. J. Neuville	Narsing Dass	Rectangular	No. 1 Cylindrical	Nos. 5 & 6	Nos. 7 & 9	1877-78 1878-79
30	Bezwada	Vizagapatam	*Viâ* Ellore, Dowlaishweram & Anakapalle	Madras	G. D. Cusson	Narsing Dass	Rectangular	No. 4 Cylindrical	Nos. 3 & 4	Nos. 2 & 10	1887-88
31	Kalyan	Kedgaon	*Viâ* Kampuli, Talegaon & Poona	Bombay	E. H. Corridon	O.N. Pushong	No. 4 Cylindrical	No. 1 Cylindrical	Nos. 04 & 05	Nos. 01 & 03	1906-07
32	Kalyan	Bombay	*Viâ* Thana & Dadar	Bombay	E. H. Corridon	O.N. Pushong	No. 4 Cylindrical	No. 1 Cylindrical	Nos. 04 & 05	Nos. 01 & 03	1906-07
33	Kalyan	Nandgaon	*Viâ* the G.I.P. Railway	Bombay	C. J. Neuville	E. J. Connor	No. 4 Cylindrical	No. 3 Cylindrical	Nos. 1 & 2	Nos. 3 & 4	1877-78

TABLE I—(Continued).

The Main-Lines of Levelling.

Line No.	From	To	Route followed	Province	Observers		Levels used		Staves used		Season
					1st Leveller	2nd Leveller	1st Leveller	2nd Leveller	1st Leveller	2nd Leveller	
34	Naudgaon	Sironj	*Viâ* Dhulia, Mhow & Bhopal	Bombay & Central India	C. J. Neuville G. Belcham	E. J. Connor Narsing Dass	No. 4 Cylindrical Rectangular	No. 3 Cylindrical Nos. 1 & 4 Cylindrical	Nos. 1 & 2 „ 2 & 3	Nos. 3 & 4 „ 9 & 10	1877-78 1883-84
35	Naudgaon	Raipur	*Viâ* Bhusaval & Nagpur	Central Provinces & Bombay	C. J. Neuville J. Bond	E. J. Connor Narsing Dass	No. 4 Cylindrical „ 4 Cylindrical & Cushing's Reversible No. 1050	No. 3 Cylindrical „ 3 Cylindrical	Nos. 1 & 2 „ B1 & B2	Nos. 3 & 4 „ N1, N2 B3 & B4	1877-78 1890-91 1891-92
36	Vizianagram	Vizagapatam	*Viâ* the East Coast Railway	Madras	J. Bond	Vinayek Narayen	No. 4 Cylindrical	No. 3 Cylindrical	Nos. B1 & B2	Nos. B3 & B4	1894-95
37	Vizianagram	Raipur	*Viâ* Jaipur, Borai & Dhamtari	Madras & Central Provinces	J. Bond	Balwant Atmaram	No. 4 Cylindrical	No. 3 Cylindrical	Nos. B1 & B2	Nos. B3 & B5	1895-96 1896-97
38	Raipur	Bilaspur	*Viâ* the Bengal-Nagpur Railway	Central Provinces	J. Bond	Narsing Dass	No. 4 Cylindrical	No. 3 Cylindrical	Nos. B1 & B2	Nos. B3 & B4	1891-92
39	Cuttack	Vizianagram	*Viâ* Ganjam & Berhampur	Bengal & Madras	J. Bond	Vinayek Narayen	No. 4 Cylindrical	No. 3 Cylindrical	Nos. B1 & B2	Nos. B3 & B4	1894-95
40	Bilaspur	Cuttack	*Viâ* Raigarh, Sambalpur & Bod	Central Provinces & Bengal	J. Bond	Vinayek Narayen, Sitaram Yeshwant, Balwant Atmaram	No. 4 Cylindrical	No. 3 Cylindrical	Nos. B1 & B2	Nos. B3 & B4	1891-92 1893-94
41	Kendrapara	Cuttack	*Viâ* Jagatpur & the Kendrapara & Gobri Canals	Bengal	J. Bond	Balwant Atmaram	No. 4 Cylindrical	No. 3 Cylindrical	Nos. B1 & B2	Nos. B3 & B4	1893-94
42	Kendrapara	False Point	*Viâ* Marsaghai	Bengal	T. H. Rendell	Narsing Dass	Rectangular	No. 4 Cylindrical	Nos. 3 & 4	Nos. 2 & 10	1881-82
43	Karachi	Tatta	*Viâ* South End Karachi Base	Sind	Capt. J. T. Walker, R. E. G. Belcham	Lt. Branfill	No. 4 Cylindrical „ 1 Cylindrical	No. 1 Cylindrical	Nos. I & K „ 8 & 1	Nos. H & C	1859-60 1893-94
44	Navanar	Sujawal	*Viâ* Mundra, Lakhpat & Moghulbhin	Bombay & Sind	J. Bond	Narsing Dass	Rectangular and Cushing's Reversible No. 1050	No. 3 Cylindrical	Nos. B1 & B2	Nos. 4 & 10	1889-90

TABLE I—(Continued).

The Main-Lines of Levelling.

Line No.	From	To	Route followed	Province	Observers: 1st Leveller	Observers: 2nd Leveller	Levels used: 1st Leveller	Levels used: 2nd Leveller	Staves used: 1st Leveller	Staves used: 2nd Leveller	Season
45	Sujawal	Tatta	*Viâ* Saidpur	Sind	J. Bond	Narsing Dass	Rectangular and Cushing's Reversible No. 1050	No. 3 Cylindrical	Nos. B1 & B2	Nos. 4 & 10	1889-90
46	Navanar	Shikarpur (Cutch)	*Viâ* Mundra & Pasura	Bombay	Capt. A. W. Baird, R. E.	Narsing Dass	Rectangular	Cylindrical	Nos. 5 & 6	Nos. 7 & 8	1874-75
47	Shikarpur (Cutch)	Jorya	*Viâ* Malia, Balamba & Hanstal	Bombay	Capt. A. W. Baird, R. E.	Narsing Dass	Rectangular	Cylindrical	Nos. 5 & 6	Nos. 7 & 8	1874-75
48	Jorya	Rajkot	*Viâ* Pardari	Bombay	Capt. A. W. Baird, R. E.	Narsing Dass	Rectangular	Cylindrical	Nos. 5 & 6	Nos. 7 & 8	1875-76
49	Rajkot	Viramgam	*Viâ* Wadhwan & thence along the B. B. & C. I. Railway	Bombay	Capt. A. W. Baird, R. E.	Narsing Dass	Rectangular	Cylindrical	Nos. 5 & 6	Nos. 7 & 8	1875-76
50	Viramgam	Shikarpur (Cutch)	*Viâ* Surel, Gokatar & Adesir	Bombay	T. H. Rendell	Damodar Ramchandra	Dumpy 765 T. Cooke & Sons	Dumpy 734 T. Cooke & Sons	Nos. 9 & 10	Nos. A & B	1875-76
51	Viramgam	Bombay	*Viâ* Ahmedabad & Surat	Bombay	Capt. A. W. Baird, R. E. & T. H. Rendell T. H. Rendell	Narsing Dass Narsing Dass	Rectangular Rectangular	Cylindrical Cylindrical	Nos. 5 & 6 „ 5 & 6	Nos. 7 & 8 „ 7 & 8	1875-76 1876-77 1877-78
52	Sujawal	Shikarpur (Sind)	*Viâ* the road to Tando Mohammad Khan & thence along the Railway *viâ* Hyderabad & Sukkur	Sind	E. H. Corridon Zille Hasnain	Zille Hasnain A. M. Talati	No. 4 Cylindrical „ 3 Cylindrical	No. 3 Cylindrical „ 2 Cylindrical	Nos. 04 & 05 „ B1 & B2	Nos. 01 & 03 „ 4, IIII & 13	1904-05 1905-06
53	Tatta	Shikarpur (Sind)	*Viâ* Jerruck, Kotri & Schwan	Sind	Capt. J. T. Walker, R. E.	Lt. B. R. Branfill & C. J. Carty	Nos. 4 & 2 Cylindrical	Nos. 1, 2, 3 & 4 Cylindrical	Nos. E, F, H & C	Nos. I, G, H, K „ B, C & G	1858-59 1859-60
54	Shikarpur (Sind)	Murghai	*Viâ* Kashmor	Sind & Punjab	Capt. J. T. Walker, R. E.	C. J. Carty Lt. B. R. Branfill	Nos. 4 & 2 Cylindrical	Nos. 1, 2, 3 & 4 Cylindrical	Nos. E, F, H & C	Nos. I, G, H, K „ B, C & G	1858-59
55	Murghai	Chach	*Viâ* Dera Ghazi Khan	Punjab	Capt. J. T. Walker, R. E.	C. J. Carty & Ramchand	Nos. 4 & 3 Cylindrical	Nos. 2 & 3 Cylindrical	Nos. E & F	Nos. A & B „ C & G	1859-60

TABLE I—(Continued).

The Main-Lines of Levelling.

Line No.	From	To	Route followed	Province	Observers		Levels used		Staves used		Season
					1st Leveller	2nd Leveller	1st Leveller	2nd Leveller	1st Leveller	2nd Leveller	
56	Chach	Ferozepore	*Viâ* Rawalpindi & Lahore	Punjab	C. Lane Zille Hasnain	Ramchand Narsing Dass A. M. Talati D. H. Luxa	No. 2 Cylindrical American 2697 No. 3 Cylindrical	No. 3 Cylindrical American 2626 No. 2 Cylindrical	Nos. L & M „ B1 & B2 „ 11 & 12	Nos. H & K „ IIII & 4 „ 0 & B3	1866-67 1905-06 1906-07
57	Murghai	Ferozepore	*Viâ* Tibbi, Gurdana & Ferozepore Cantonment	Punjab	Capt. B. R. Branfill	C. J. Carty Ramchand	Rectangular	Nos. 3 &2 Cylindrical	Nos. A, B, E & F	Nos. E, F, A & B	1860-61
58	Bilaspur	Katni	*Viâ* the Bengal Nagpur Railway	Central Provinces	J. Bond	Vinayek Narayen	No. 4 Cylindrical	No. 3 Cylindrical	Nos. B1 & B2	Nos. 3 & 5	1896-97
59	Katni	Allahabad	*Viâ* Maihar & Rewah	Central Provinces & United Provinces	J. Bond	Zille Hasnain	No. 4 Cylindrical	No. 3 Cylindrical	Nos. B1 & B2	Nos. B5 & 13	1898-99
60	Katni	Sironj	*Viâ* Damoh & Kethora	Central Provinces & Central India Agency	J. Bond and J. P. Barker	Zille Hasnain	No. 4 Cylindrical & Bolton's 82	No. 3 Cylindrical & Cushing's Reversible No. 1050	Nos. B1 & B2	Nos. B5 & 13	1898-99
61	Ferozepore	Meerut	*Viâ* Ludhiana & Ambala	Punjab & United Provinces	Capt. B. R. Branfill	C. Wood	Rectangular	Nos. 3 & 2 Cylindrical	Nos. A, B & 2	Nos. E, F, A „ B & 3	1860-61 1861-62
62	Meerut	Agra	*Viâ* Hapur, Khurja & Aligarh	United Provinces	Capt. B. R. Branfill & C. J Carty	C. Wood Ramchand	Rectangular No. 3 Cylindrical	Nos. 2 & 4 Cylindrical	Nos. A, B, E & F	Nos. G, H, C & D	1861-62
63	Agra	Sironj	*Viâ* Dholpur, Gwalior & Surantal	United Provinces & Central India	C. J. Carty	Ramchand	No. 3 Cylindrical	No. 4 Cylindrical	Nos. E & F	Nos. G & H	1861-62
64	Meerut	Lucknow	*Viâ* Moradabad & Shahjahanpur	United Provinces	C. Lane	L. H. Clarke	No. 2 Cylindrical	No. 3 Cylindrical	Nos. L & M	Nos. H & K	1867-68 1868-69
65	Lucknow	Cawnpore	*Viâ* Unao	United Provinces	C. Lane	A. W. Donnelly	No. 2 Cylindrical	No. 3 Cylindrical	Nos. L & M	Nos. F & K	1868-69
66	Cawnpore	Agra	*Viâ* Nanun & Tundla	United Provinces	Lt. H. Trotter, R. E.	Ramchand	No. 3 Cylindrical	No. 2 Cylindrical	Nos. F & H	Nos. E, G, K & L	1864-65

TABLE I—(Continued).

The Main-Lines of Levelling.

Line No.	From	To	Route followed	Province	Observers: 1st Leveller	Observers: 2nd Leveller	Levels used: 1st Leveller	Levels used: 2nd Leveller	Staves used: 1st Leveller	Staves used: 2nd Leveller	Season
67	Cawnpore	Allahabad	Vid Maharājpur & Fatehpur	United Provinces	Lt. H. Trotter, R. E.	Ramchand	No. 3 Cylindrical	No. 2 Cylindrical	Nos. F & H	Nos. E, G, K & L	1864-65
68	Lucknow	Gorakhpur	Vid Bara Banki & Fyzabad	United Provinces	C. Lane	A. W. Donnelly	No. 2 Cylindrical	No. 3 Cylindrical	Nos. L & M	Nos. F & K	1868-69 1869-70
69	Gorakhpur	Dildarnagar	Vid Azimgarh & Ghazipur	United Provinces	C. Lane	A. W. Donnelly	No. 2 Cylindrical	No. 3 Cylindrical	Nos. L & M	Nos. F & K	1869-70
70	Allahabad	Dildarnagar	Vid Madhopur & Benares along Grand Trunk Road	United Provinces	Lt. H. Trotter, R. E.	Ramchand	No. 2 Cylindrical	No. 3 Cylindrical	Nos. H & F	Nos. E & G	1863-64 1864-65
71	Gorakhpur	Purnea	Vid Bettiah, Motihari, Muzaffarpur & Darbhanga	United Provinces & Bengal	C. Lane & Capt. T. T. Carter, R. E.	A. W. Donnelly	No. 2 Cylindrical	No. 3 Cylindrical	Nos. L & M	Nos. F & K	1870-71 1871-72
72	Dildarnagar	Pirpanti	Vid Patna, Monghyr & Bhagalpur	Bengal	Lt. H. Trotter, R. E.	Ramchand	No. 2 Cylindrical	No. 3 Cylindrical	Nos. F & H	Nos. E & G	1863-64
73	Purnea	Pirpanti	Vid Karagolaghat	Bengal	Capt. T. T. Carter, R. E.	A. W. Donnelly	No. 2 Cylindrical	No. 3 Cylindrical	Nos. L & M	Nos. F & K	1871-72
74	Howrah	Pirpanti	Vid Kidderpore Docksill, Burdwan & Sahibganj	Bengal	A. W. Donnelly Lt. H. Trotter, R. E. & J. Bond	Ramchand Vinayek Narayen	No. 3 Cylindrical & Rectangular	No. 2 Cylindrical „ 3 Cylindrical	Nos. A & B „ 5 & F	Nos. E & F „ 9 & 10	1862-63 1882-83
75	Kendrapara	Howrah	Vid Balasore and Kukrahati	Bengal	G. Belcham T. H. Rendell	Narsing Dass Narsing Dass	Rectangular Rectangular	Nos. 3 & 4 Cylindrical „ 3 & 4 Cylindrical	Nos. 5 & F „ 5 & F	Nos. 9 & 10 „ 9 & 10	1881-82 1882-83
76	Purnea	Ramganj	Vid Kishenganj	Bengal	Capt. T. T. Carter, R. E.	A. W. Donnelly	No. 2 Cylindrical	No. 3 Cylindrical	Nos. L & M	Nos. F & K	1871-72
77	Howrah	Ramganj	Vid Parbatipur, Jalpaiguri & Siliguri	Bengal & Eastern Bengal and Assam	Lt. H. McC. Cowie, R. E., J. P. Barker, E. H. Corridon J. Bond G. Belcham	Zille Hasnain Vinayek Narayen Narsing Dass	No. 4 Cylindrical „ 4 Cylindrical Rectangular	No. 3 Cylindrical „ 1 Cylindrical „ 3 Cylindrical „ 3 Cylindrical	Nos. 6 & 3 „ B1 & B2 „ 4 & 5 „ F & 5	Nos. 4 & 13 „ B5 & B2 „ 6 & 13 „ 9 & 10	1899-1900 1901-02 1894-95 1882-83

TABLE I—(Continued).

The Main-Lines of Levelling.

Line No.	From	To	Route followed	Province	Observers		Levels used		Staves used		Season
					1st Leveller	2nd Leveller	1st Leveller	2nd Leveller	1st Leveller	2nd Leveller	
78	Karachi Mean-Sea-Level	Karachi	...	Sind	G. Belcham*	...	No. 1 Cylindrical	...	Nos. 8 & 1	...	1893-94
79	Bombay Mean-Sea-Level	Bombay	...	Bombay	E. H. Corridon*	O. N. Pushong	No. 4 Cylindrical	No. 1 Cylindrical	Nos. 04 & 05	Nos. 01 & 03	1906-07
80	Karwar Mean-Sea-Level	Karwar	..	Bombay	Lt. H. J. Harman, R.E.*	O. V. Norris	No. 3 Cylindrical	No. 4 Cylindrical	Nos. B1 & B2	Nos. 3 & 4	1873-74
81	Beypore Mean-Sea-Level	Beypore	...	Madras	G. Belcham*	Narsing Dass	Rectangular	No. 4 Cylindrical	Nos. 2 & 3	Nos. 9 & 10	1884-85
82	Cochin Mean-Sea-Level	Cochin	...	Madras	H. Corkery*	Narsing Dass	Rectangular	No. 4 Cylindrical	Nos. 2 & 3	Nos. 9 & 10	1886-87
83	Negapatam Mean-Sea-Level	Negapatam	...	Madras	H. Corkery*	Narsing Dass	Rectangular	No. 4 Cylindrical	Nos. 2 & 3	Nos. 9 & 10	1885-86
84	Madras Mean-Sea-Level	Madras	...	Madras	E. H. Corridon*	O. N. Pushong	No. 4 Cylindrical	No. 1 Cylindrical	Nos. 04 & 05	Nos. 01 & 03	1907-08
85	Vizagapatam Mean-Sea-Level	Vizagapatam	...	Madras	T. H. Rendell*	Narsing Dass	Not known	Not known	Not known	Nos. 2, 10 & 9	1877-78
86	False Point Mean-Sea-Level	False Point	...	Bengal	T. H. Rendell*	Narsing Dass	Rectangular	No. 4 Cylindrical	Nos. 4 & 3	Nos. 2 & 10	1881-82

The levelling officer Narsing Dass died at Bilaspur on April 5th 1892 to the great regret of his colleagues. He joined the Survey Department in 1864 and rendered valuable service for 28 years, during the greater part of which he was employed in levelling conjointly with Captain Baird, Lieutenant Trotter, Captain Carter, Messrs. Lane, Donnelly, Belcham, Neuville, Rendell, Cusson and Bond. He was a gentleman of high character, an able and energetic worker, and his devotion to duty had always been conspicuous.

* This line has been re-observed on many subsequent occasions.

The following Table II contains an alphabetical list of main-lines and has been included in order to enable the number of any particular line to be discovered without trouble.

Table III records the names of levelling officers, and Table IV divides the half-century of levelling into decades, and shows the main-lines that were observed in each successive decade.

TABLE II.

Alphabetical List of the Main-Lines of Levelling.

Main-Lines		Line No.
Agra ...	Cawnpore ...	66
" ...	Meerut ...	62
" ...	Sironj ...	63
Allahabad ...	Cawnpore ...	67
" ...	Dildarnagar ...	70
" ...	Katni ...	59
Arkonam ...	Gooty ...	14
" ...	Jalarpet ...	10
" ...	Madras ...	8
Bangalore ...	Bellary ...	19
" ...	Jalarpet ...	18
Bellary ...	Bangalore ...	19
" ...	Gooty ...	15
" ...	Hubli ...	16
" ...	Raichur ...	23
Beypore ...	Beypore Mean-Sea-Level ...	81
" ...	Shoranur ...	12
Beypore Mean-Sea-Level ...	Beypore ...	81
Bezwada ...	Gulbarga ...	24
" ...	Madras ...	20
" ...	Vizagapatam ...	30
Bilaspur ...	Cuttack ...	40
" ...	Katni ...	58
" ...	Raipur ...	38
Bombay ...	Bombay Mean-Sea-Level ...	79
" ...	Kalyan ...	32
" ...	Viramgam ...	51
Bombay Mean-Sea-Level ...	Bombay ...	79
Cawnpore ...	Agra ...	66
" ...	Allahabad ...	67
" ...	Lucknow ...	65
Chach ...	Ferozepore ...	56
" ...	Murghai ...	55
Cochin ...	Cochin Mean-Sea-Level ...	82
" ...	Shoranur ...	13
Cochin Mean-Sea-Level ...	Cochin ...	82
Cuttack ...	Bilaspur ...	40
" ...	Kendrapara ...	41
" ...	Vizianagram ...	39
Diksal ...	Gulbarga ...	26
" ...	Kedgaon ...	25
Diksal ...	Nira ...	27
Dildarnagar ...	Allahabad ...	70
" ...	Gorakhpur ...	69
" ...	Pirpanti ...	72
Erode ...	Jalarpet ...	7
" ...	Shoranur ...	11
" ...	Trichinopoly ...	6
False Point ...	False Point Mean-Sea-Level	86
" ...	Kendrapara ...	42
False Point Mean-Sea-Level ...	False Point ...	86
Ferozepore ...	Meerut ...	61
" ...	Murghai ...	57
" ...	Chach ...	56
Gooty ...	Arkonam ...	14
" ...	Bellary ...	15
" ...	Raichur ...	21
Gorakhpur ...	Dildarnagar ...	69
" ...	Lucknow ...	68
" ...	Purnea ...	71
Gulbarga ...	Bezwada ...	24
" ...	Diksal ...	26
" ...	Raichur ...	22
Howrah ...	Kendrapara ...	75
" ...	Pirpanti ...	74
" ...	Ramganj ...	77
Hubli ...	Bellary ...	16
" ...	Karwar ...	17
" ...	Nira ...	29
Jalarpet ...	Arkonam ...	10
" ...	Bangalore ...	18
" ...	Erode ...	7
Jorya ...	Rajkot ...	48
" ...	Shikarpur (Cutch) ...	47
Kalyan ...	Bombay ...	32
" ...	Kedgaon ...	31
" ...	Nandgaon ...	33
Karachi ...	Karachi Mean-Sea-Level ...	78
" ...	Tatta ...	43
Karachi Mean-Sea-Level ...	Karachi ...	78
Karwar ...	Hubli ...	17
" ...	Karwar Mean-Sea-Level ...	80
Karwar Mean-Sea-Level ...	Karwar ...	80
Katni ...	Allahabad ...	59
" ...	Bilaspur ...	58
" ...	Sironj ...	60
Kedgaon ...	Diksal ...	25
" ...	Kalyan ...	31
" ...	Nira ...	28
Kendrapara ...	Cuttack ...	41
" ...	False Point ...	42
" ...	Howrah ...	75
Lucknow ...	Cawnpore ...	65
" ...	Gorakhpur ...	68
" ...	Meerut ...	64
Madras ...	Arkonam ...	8
" ...	Bezwada ...	20
" ...	Madras Mean-Sea-Level ...	84
" ...	Tanjore ...	9
Madras Mean-Sea-Level ...	Madras ...	84
Meerut ...	Agra ...	62
" ...	Ferozepore ...	61
" ...	Lucknow ...	64
Murghai ...	Chach ...	55
" ...	Ferozepore ...	57
" ...	Shikarpur (Sind) ...	54
Nandgaon ...	Kalyan ...	33
" ...	Raipur ...	35
" ...	Sironj ...	34
Navanar ...	Shikarpur (Cutch) ...	46
" ...	Sujawal ...	44
Negapatam ...	Negapatam Mean-Sea-Level ...	83
" ...	Tanjore ...	5

TABLE II—(Continued).

Alphabetical List of the Main-Lines of Levelling.

Main-Lines		Line No.	Main-Lines		Line No.	Main-Lines		Line No.
Negapatam Mean-Sea-Level	... Negapatam ...	83	Ramnad	... Tanjore ...	1	Tanjore	... Trichinopoly ...	4
Nira	... Diksal ...	27	,,	... Tuticorin ...	2	Tatta	... Karachi ...	43
,,	... Hubli ...	29				,,	... Shikarpur(Sind)	53
,,	... Kedgaon ...	28				,,	... Sujawal ...	45
			Shikarpur (Cutch)	... Jorya ...	47	Trichinopoly	... Erode ...	6
						,,	... Tanjore ...	4
			,,	... Navanar ..	46	,,	... Tuticorin ...	3
Pirpanti	... Dildarnagar ...	72	,,	... Viramgam ...	50	Tuticorin	... Ramnad ...	2
,,	... Howrah ...	74	Shikarpur (Sind)	... Murghai ...	54	,,	... Trichinopoly ...	3
,,	... Purnea ...	73	,,	... Sujawal ...	52			
Purnea	... Gorakhpur ...	71	,,	... Tatta ...	53			
,,	... Pirpanti ...	73	Shoranur	... Beypore ...	12	Viramgam	... Bombay ...	51
,,	... Ramganj ...	76	,,	... Cochin ...	13	,,	... Rajkot ...	49
			,,	... Erode ...	11	,,	... Shikarpur (Cutch) ...	50
			Sironj	... Agra ...	63			
Raichur	... Bellary ...	23	,,	... Katni ...	60	Vizagapatam	... Bezwada ...	30
,,	... Gooty ...	21	,,	... Nandgaon ...	34	,,	... Vizianagram ...	36
,,	... Gulbarga ...	22	Sujawal	... Navanar ...	44	,,	... Vizagapatam Mean-Sea-Level ...	85
Raipur	... Bilaspur ...	38	,,	... Shikarpur(Sind)	52			
,,	... Nandgaon ...	35	,,	... Tatta ...	45			
,,	... Vizianagram ...	37				Vizagapatam Mean-Sea-Level	... Vizagapatam ...	85
Rajkot	... Jorya ...	48						
,,	... Viramgam ...	49	Tanjore	... Madras ...	9	Vizianagram	... Cuttack ...	39
Ramganj	... Howrah ...	77	,,	... Negapatam ...	5	,,	... Raipur ...	37
,,	... Purnea ...	76	,,	... Ramnad ...	1	,,	... Vizagapatam ...	36

TABLE III.

List of Officers who have been employed upon the Levelling Operations in India.

Name	Period of employment: in charge of the Levelling Operations	Period of employment: upon Levelling work in the field	Date of entering the Survey of India	Date of retirement
Captain J. T. Walker, R.E.	1858-59 1859-60	1858-59 1859-60	1853	1884
Lieut. B. R. Branfill	1860-61 1861-62 1869-70 1871-72	1858-59 1859-60 1860-61 1861-62	1859	1884
C. J. Carty	...	1858-59 1859-60 1860-61 1861-62	1848	1863
Ramchand	...	1859-60 1860-61 1861-62 1862-63 1863-64 1864-65 1866-67	...	Killed by a fall from his horse, 1867.

TABLE III—(Continued).

List of Officers who have been employed upon the Levelling Operations in India.

Name	Period of employment — in charge of the Levelling Operations	Period of employment — upon Levelling work in the field	Date of entering the Survey of India	Date of retirement
C. Wood	1889-90	1861-62	1858	Died in 1896.
Lieut. H. R. Thuillier, R. E.	1862-63	...	1859	1895
A. W. Donnelly	...	1862-63 1868-69 1869-70 1870-71 1871-72	1855	Died in 1873
W. H. Johnson	...	1862-63	1848	1866
Lieut. H. Trotter, R. E.	1863-64 1864-65	1863-64 1864-65	1863	1878
C. Lane	1866-67 1867-68 1868-69 1869-70 1870-71	1866-67 1867-68 1868-69 1869-70 1870-71	1832	1871
Narsing Dass	...	1866-67 1870-71 1871-72 1874-75 1875-76 1876-77 1877-78 1878-79 1879-80 1880-81 1881-82 1882-83 1883-84 1884-85 1885-86 1886-87 1887-88 1888-89 1889-90 1890-91 1891-92	1864	Died at Bilaspur, 1892.
L. H. Clarke	...	1867-68 1868-69	1855	1886
O. V. Norris	...	1869-70 1871-72 1873-74	1866	1874
Captain J. P. Basevi, R. E.	...	1869-70	1856	Died of exposure in the higher Himalaya, 1871.
Captain T. T. Carter, R. E.	1871-72	1871-72	1862	1887

TABLE III—(Continued).

List of Officers who have been employed upon the Levelling Operations in India.

Name	Period of employment: in charge of the Levelling Operations	Period of employment: upon Levelling work in the field	Date of entering the Survey of India	Date of retirement
Colonel A. W. Baird, R. E.	1872-73 1873-74 1874-75 1875-76 1876-77 1877-78 1878-79 1879-80 1880-81 1883-84 1884-85 1885-86	1874-75 1875-76	1868	1889
Lieut. H. J. Harman, R. E.	1873-74	1873-74	1872	Died in 1883
Captain J. R. McCullagh, R. E.	1874-75	1874-75	1869	1895
A. H. Bryson	...	1874-75	1869	
T. H. Rendell	...	1875-76 1876-77 1877-78 1880-81 1881-82	1864	1903
Damodar Ramchandra	...	1875-76		
C. J. Neuville	...	1877-78 1878-79	1855	
E. J. Connor	1901-02	1877-78	1865	1903
G. Belcham	1889-90 1894-95 1896-97	1879-80 1880-81 1882-83 1883-84 1884-85 1887-88 1893-94	1862	1900
Vinayek Narayen	...	1881-82 1887-88 1891-92 1892-93 1894-95 1895-96 1896-97	1874	1900
Major J. Hill, R. E.	1881-82 1884-85 1886-87 1887-88 1890-91 1891-92 1892-93 1893-94 1894-95 1895-96	...	1866	1895

TABLE III—(Continued).

List of Officers who have been employed upon the Levelling Operations in India.

Name	Period of employment		Date of entering the Survey of India	Date of retirement
	in charge of the Levelling Operations	upon Levelling work in the field		
Major M. W. Rogers, R. E.	1881-82 1882-83 1888-89	...	1866	1897
G. D. Casson	...	1887-88	1868	1901
J. Bond	...	1888-89 1889-90 1890-91 1891-92 1892-93 1893-94 1894-95 1895-96 1896-97 1898-99	1866	1905
Sitaram Yeshwant	...	1893-94	1873	1901
Balwant Atmaram	...	1893-94	1877	
Lieut. C. C. D. Morice, R. E.	1894-95 1895-96 1896-97	...	1891	1897
Captain S. G. Burrard, R. E.	1896-97 1897-98	...	1884	
Lieut. H. L. Crosthwait, R. E.	1897-98 1898-99 1899-1900 1900-01 1901-02	1900-01	1897	
J. P. Barker	1904-05 1905-06	1898-99 1899-1900 1900-01	1883	
Syed Zille Hasnain	...	1898-99 1899-1900 1900-01 1901-02 1902-03 1903-04 1904-05 1905-06 1906-07 1907-08	1886	
Lieut. H. McC. Cowie, R. E.	...	1899-1900	1898	
E. H. Corridon	...	1900-01 1901-02 1902-03 1903-04 1904-05 1905-06 1906-07 1907-08	1897	

TABLE III—(Continued).

List of Officers who have been employed upon the Levelling Operations in India.

Name	Period of employment: in charge of the Levelling Operations	Period of employment: upon Levelling work in the field	Date of entering the Survey of India	Date of retirement
Lieut. F. B. Tillard, R. E.	1902-03	...	1901	Died at Mussoorce of tetanus in 1903
Captain H. H. Turner, R. E.	1902-03 1903-04	1903-04	1897	
Major J. M. Burn, R. E.	1904-05	...	1891	
C. F. Erskine	1905-06 1906-07 1907-08	...	1891	
O. N. Pushong	...	1905-06 1906-07 1907-08	1903	
A. M. Talati	...	1905-06 1906-07 1907-08	1901	
Priya Nath Sur	...	1906-07 1907-08	1903	
D. H. Luxa	...	1906-07 1907-08	1904	
Dhondu Vinayek§	...	1877-1905	1873	1906

TABLE IV.

A Chronological Table showing the several Lines of Level that were observed respectively in the five successive decades.

Decade	The Numbers of the Level Lines observed in each decade	Levelling Officers employed during each decade
1858 to 1868	43‡ 53 54 55 56* 57 61 62 63 64* 66 67 70 72 74*	Captain J. T. Walker, R. E. Lieut. B. R. Branfill C. J. Carty Ramchand C. Wood A. W. Donnelly W. H. Johnson Lieut. H. Trotter, R. E. C. Lane Narsing Dass L. H. Clarke

§ Employed on connecting Bench-marks of reference at Tidal stations.
‡ Portion of line revised in decade 1888-98 owing to several bench-marks being lost.
* This line was commenced in one decade and finished in another.

TABLE IV—(Continued).

A Chronological Table showing the several Lines of Level that were observed respectively in the five successive decades.

Decade	The Numbers of the Level Lines observed in each decade	Levelling Officers employed during each decade
1868 to 1878	15 19 23* 28 29* 33 34* 35* 46 47 48 49 50 51 64* 65 68 69 71 73 76	A. W. Donnelly C. Lane Narsing Dass L. H. Clarke O. V. Norris Captain J. P. Basevi, R. E. Captain T. T. Carter, R. E. Lieut. A. W. Baird, R. E. Lieut. H. J. Harman, R. E. Lieut. J. R. McCullagh, R. E. A. H. Bryson T. H. Rendell Damodar Ramchandra C. J. Neuville E. J. Connor Dhondu Vinayek
1878 to 1888	1 2 3 4 5 6 7 9 10 11 12 13 18 20 24* 27 29* 30 34* 42 74* 75 77† 81 82 83 85 86	H. Corkery Narsing Dass T. H. Rendell C. J. Neuville Dhondu Vinayek G. Belcham Vinayek Narayen G. D. Cusson
1888 to 1898	24* 35* 36 37 38 39 40 41 43‡ 44 45 58 77† 78	Narsing Dass Dhondu Vinayek G. Belcham Vinayek Narayen J. Bond Sitaram Yeshwant Balwant Atmaram
1898 to 1908	8 14 16 17 21 22 23* 25 26 31 32 52 56* 59 60 77† 79 80 84	Dhondu Vinayek J. Bond Lieut. H. L. Crosthwait, R. E. J. P. Barker Syed Zille Hasnain Lieut. H. McC. Cowie, R. E. E. H. Corridon Captain H. H. Turner, R. E. O. N. Pushong A. M. Talati Priya Nath Sur D. H. Luxa

* This line was commenced in one decade and finished in another.
† This line was commenced in one decade, continued in another and finished in a third.
‡ Portion of line revised in decade 1888-98 owing to several bench-marks being lost.

The following table shows the principal branch-lines of levelling. The greater number of the branch-lines depend upon double-levelling, but a few are dependent upon single. Some of the branch-lines end at tidal stations, the data of which have been excluded from our determination of mean-sea-level for reasons subsequently explained. Separate numbers have not been given to the branch-lines; they have been allowed to retain the numbers of the main-lines from which they emanate, letters being affixed to distinguish branch from main.

TABLE V.

The Principal Branch-Lines of Levelling.

Line No.	From	To	Route followed	Province	Observers		Levels used		Staves used		Season
					1st Leveller	2nd Leveller	1st Leveller	2nd Leveller	1st Leveller	2nd Leveller	
1A	Ramnad	Pamban	...	Madras	H. Corkery	Narsing Dass	Rectangular	No. 4 Cylindrical	Nos. 2 & 3	Nos. 9 & 10	1885-86
3A	Tuticorin	Cape Comorin	*Viâ* Palamcottah	Madras	O. V. Norris	Single Levelling	No. 4 Cylindrical	Single Levelling	Not known	Single Levelling	1869-70
17A	Karwar	Mormugao	*Viâ* Bali	Bombay & Goa (Portuguese)	H. Corkery	Narsing Dass	Rectangular	No. 4 Cylindrical	Nos. 2 & 3	Nos. 9 & 10	1886-87
18A	Bangalore	Mangalore	*Viâ* Sakleshpur	Mysore and Madras	J. Bond	Narsing Dass	Rectangular & Cushing's Reversible No. 1050	No. 3 Cylindrical	Nos. 2, 3 & 4	Nos. 9 & 10	1888-89
24A*	Hyderabad (Deccan)	Wardha	*Viâ* the Hyderabad-Godavery Valley Railway to Bichpali, thence by road *viâ* Edalabad and Wun to Warora and thence along the G. I. P. Ry. to Wardha	Hyderabad and Central Provinces	E. H. Corridon O.N. Pushong A. M. Talati	O. N. Pushong H.St.J.Kenny P. N. Sur	No. 4 Cylindrical „ 1 Cylindrical No. 3 Cylindrical	No. 1 Cylindrical „ 4 Cylindrical No. 2 Cylindrical	Nos. 04 & 05 „ 01 & 03 Nos. B1 & B2	Nos. 01 & 03 „ 04 & 05 Nos. III1 & 4	1908-09 1908-09 1908-09
25A	Dhond	Manmad	Along the Dhond-Manmad Railway	Bombay	Vinayek Narayen Vinayak Narayen	Single Levelling	Dumpy 734 No. 1 Cylindrical	Single Levelling	Not known Nos. 2 & 3	Single Levelling	1881-82 1882-83
26A	Sholapur	Bijapur	*Viâ* Takli, Indi & Hippargi	Bombay	G. Belcham	Narsing Dass	Rectangular	No. 1 Cylindrical	Nos. F, 5 & 6	Nos. 9 & 10	1879-80

* Line 24A is one of the most important lines in India: it divides up the great Godavari circuit. It was not included among the main lines of India only because its results were not ready in time for the adjustment of the circuit errors. This adjustment could not be postponed year after year, and it had to be decided to include only those lines that had been observed by 1908.

TABLE V—(Continued).

The Principal Branch-Lines of Levelling.

Line No.	From	To	Route followed	Province	Observers		Levels used		Staves used		Season
					1st Leveller	2nd Leveller	1st Leveller	2nd Leveller	1st Leveller	2nd Leveller	
39A	Khurda	Puri	*Viâ* Jajpur	Bengal	J. Bond	Vinayek Narayen	No. 4 Cylindrical	No. 3 Cylindrical	Nos. B1 & B2	Nos. B3 & B4	1894-95
47A	Jorya	Okha	*Viâ* Navanagar & Gurgat	Bombay	Capt. A. W. Baird, R. E.	Narsing Dass	Rectangular	Cylindrical	Nos. 5 & 6	Nos. 7 & 8	1874-75
48A	Rajkot	Bhavnagar	*Viâ* Atkat, Dhola, Sanoshra & Sihor	Bombay	J. Bond	Narsing Dass	No. 4 Cylindrical	No. 3 Cylindrical	Nos. B 1 & B 2	Nos. N1 & N2	1890-91
48B	Sanoshra	Port Albert Victor	*Viâ* Noghanvadar & Dungar	Bombay	J. Bond	Narsing Dass	No. 4 Cylindrical	No. 3 Cylindrical	Nos. B1 & B2	Nos. N1 & N2	1890-91
51A	Mehmadabad	Dholka	...	Bombay	T. H. Rendell	Narsing Dass	Rectangular	Cylindrical	Nos. 5 & 6	Nos. 7 & 8	1876-77
51B	Anand	Pali	...	Bombay	T. H. Rendell	Narsing Dass	Rectangular	Cylindrical	Nos. 5 & 6	Nos. 7 & 8	1876-77
51C	Vasad	Cambay	...	Bombay	T. H. Rendell	Narsing Dass	Rectangular	Cylindrical	Nos. 5 & 6	Nos. 7 & 8	1876-77
51D	Miyagam	Dabhoi	...	Bombay	T. H. Rendell	Narsing Dass	Rectangular	Cylindrical	Nos. 5 & 6	Nos. 7 & 8	1876-77
55A	Khemwala	Multan	*Viâ* Muzaffargarh	Punjab	C. Lane	Narsing Dass	No. 2 Cylindrical	No. 3 Cylindrical	Nos. L & M	Nos. H & K	1866-67
56A	Chuch	Peshawar	*Viâ* Attock & Nowshera	Punjab & N. W. F. Province	Zille Hasnain	D. H. Luxa	American 2697	American 2626	Nos. O & B 3	Nos. 11 & 12	1906-07

TABLE V—(Continued).

The Principal Branch-Lines of Levelling.

Line No.	From	To	Route followed	Province	Observers		Levels used		Staves used		Season
					1st Leveller	2nd Leveller	1st Leveller	2nd Leveller	1st Leveller	2nd Leveller	
57A *	Ferozepore	Ahmedabad	Along the N. W. Ry. to Bhatinda, then by J. B. Ry. to Marwar Jun. and thence along the R. M. Ry. to Ahmedabad	Punjab, Rajputana and Bombay	Zille Hasnain	D. H. Luxa	American 2697	American 2626	Nos. 20 A & 20 B	Nos. 16 A & 16 B	1907-08
					Zille Hasnain D. H. Luxa	D. H. Luxa T. F. Kitchen	American 2697 American 2626	American 2626 American 2698	„ 20 A & 20 B	„ 16 A & 16 B	1908-09
57B	Palanpur	Deesa	Along the R. M. Railway	Bombay	Zille Hasnain D. H. Luxa	T. F. Kitchen	American 2697 American 2626	American 2698	Nos. 20 A & 20 B	Nos. 16 A & 16 B	1908-09
60A †	Katni	Nagpur	*Viâ* the E. I. Ry. to Jubbulpur, thence by road *viâ* Seoni to Nagpur	Central Provinces	A. M. Talati	P. N. Sur	No. 3 Cylindrical	No. 2 Cylindrical	Nos. B 1 & B 2	Nos IIII & 4	1908-09
61A ‡	Saharanpur	Mussooree	*Viâ* Dehra Dun & Rajpur	United Provinces	Capt. B. R. Branfill	C. Wood	Rectangular No. 2 Cylindrical	No. 2 Cylindrical Rectangular	A. B. & C. D.	C.D. & A. B.	1861-62§
					E.H.Corridon Capt. H. H. Turner, R.E.	Zille Hasnain	No. 4 Cylindrical Cushing's 1050 Cushing's 1151	No. 3 Cylindrical Bolton's 82 Cushing's 1151	Nos. 04 & 05	No. 01 & 03	1903-04§
					E. H. Corridon	Zille Hasnain	No. 4 Cylindrical Bolton's 24	No. 3 Cylindrical Cushing's 1151	Nos. 04 & 05	Nos. 01 & 03	1905‖
					Zille Hasnain	D. H. Luxa	American 2697	American 2626	„ 11 & 12	„ 0 & B3	1906-07‖
					E. H. Corridon	O. N. Pushong	Cushing's 1151	Cooke's 8522	Nos. 04 & 05	No. 01 & 03	1906-07$
					A. M. Talati	P. N. Sur	Cushing's 8574	Watt's 1143	„ B1 & B2	„ IIII & 4	1906-07$
61B	Nojli	Hardwar	*Viâ* Roorkee	United Provinces	Lt. H. T. Morshead, R. E.	Single Levelling	American 2625	Single Levelling	Nos. 24 A & 24 B	Single Levelling	1908
61C	Hardwar	Debra Dun	Along the cart road	United Provinces	Zille Hasnain D. H. Luxa	T. F. Kitchen T. F. Kitchen	American 2697 American 2626	American 2698 American 2698	Nos. 20 A & 20 B	Nos. 16 A & 16 B	1908-09
61D	Dehra Dun	Kalsi	*Viâ* Sahaspur	United Provinces	Lt. J. A. Field, R. E. & Lt. A. H. Gwyn, I. A.	Lt. C. G. Lewis, R.E. & Lt. C. M. Thompson, I. A.	Cushing's 8446	American 2625	Nos. 14A & 14B	Nos. 24 A & 24 B	1908

* The Ferozepore-Ahmedabad line is one of the most important lines in India: it divides up the great Rajputana circuit. It was not included among the main-lines of India for the same reason that line 24A was not included. *Vide* foot-note to line 24A.

† This line divides up the Central Provinces circuit. It was excluded from the main-lines of India for the same reason that line 24A was excluded.

‡ Lines 61A, 61B, 61C, 61D are the only Himalayan lines that have as yet been observed. The following Himalayan lines are now proposed: Siliguri to Tindharia, Bareilly to Naini Tal, Najibabad to Lansdowne, Umballa to Solon, Pathankot to Dharamkot. These lines are to be observed in order that the rate, at which the Himalaya mountains are growing in height, may be determined. We can at present form no idea as to whether the rate of growth is 1 foot in 10000 years or 1 foot in 10 years.

§ Before the earthquake of April 1905. ‖ After the earthquake of April 1905. $ Extensions from Mussooree to Landour and Banog. Cushing's level 8574 and Watt's level 1143 have been only used on the small branch extension from Mussooree to Banog. Cooke's level 8522 has been only used on the small extension from Mussooree to Landour.

TABLE V—(Continued).

The Principal Branch-Lines of Levelling.

Line No.	From	To	Route followed	Province	Observers		Levels used		Staves used		Season
					1st Leveller	2nd Leveller	1st Leveller	2nd Leveller	1st Leveller	2nd Leveller	
62A	Meerut	Dehli	*Viâ* Ghaziabad Railway Station	United Provinces and Punjab	C. Lane	Narsing Dass	No. 2 Cylindrical	No. 3 Cylindrical	Nos. L & M	Nos. H & K	1866-67
62B	Hathras	Muttra	*Viâ* the B. B. and C. I. Railway	United Provinces	E. H. Corridon	O.N. Pushong	No. 4 Cylindrical	No. 1 Cylindrical	Nos. 04 & 05	Nos. 01 & 03	1905-06
63A	Gwalior	Jhansi	*Viâ* the G. I. P. Railway	Central India & United Provinces	E. H. Corridon Zille Hasnain	O.N. Pushong D. H. Luxa	No. 4 Cylindrical American 2626	No. 1 Cylindrical American 2625	Nos. 04 & 05 „ 11 & 12	Nos. 01 & 03 „ 0 & B 3	1905-06 1906-07
64A	Bareilly	Pilibhit	*Viâ* Sitra	United Provinces	C. Lane	L. H. Clarke	No. 2 Cylindrical	No. 3 Cylindrical	Nos. L & M	Nos. F, H & K	1867-68
69A	Gorakhpur	Bharmi	*Viâ* Manza Nainsar	United Provinces	C. Lane	A. W. Donnelly	No. 2 Cylindrical	No. 3 Cylindrical	Nos. L & M	Nos. F & K	1869-70
74A	Kidderpore	Diamond Harbour	*Viâ* Kayapur & Hooghly Point Tidal Semaphore	Bengal	G. Belcham	Narsing Dass	Rectangular	No. 3 Cylindrical	Nos. 5 & F	Nos. 9 & 10	1882-83
74B	Kidderpore	Dublat	*Viâ* Thakurpukur, Fatehpur, Saugor Island Light House & Mud Point	Bengal	T. H. Rendell G. Belcham	Narsing Dass Narsing Dass	Rectangular Rectangular	No. 3 & 4 Cylindrical „ 3 Cylindrical	Nos. 5 & F „ 5 & F	Nos. 9 & 10 „ 9 & 10	1881-82 1882-83
75A	Balughata	Nijkasba (Mouth of Rasulpur River)	...	Bengal	G. Belcham	Narsing Dass	Rectangular	No. 3 Cylindrical	Nos. 5 & F	Nos. 9 & 10	1882-83
75B	Howrah	Nuddea	*Viâ* Chinsura	Bengal	G. Belcham G. Belcham	Narsing Dass Vinayek Narayen	Rectangular No. 3 Cylindrical	No. 3 Cylindrical „ 1 Cylindrical	Nos. 5 & F „ A & B	Nos. 9 & 10 „ 5 & 6	1882-83 1887-88
76A	Kishanganj	Barsoi	*Viâ* the E. B. S. Railway	Bengal	J. P. Barker	Single Levelling	No. 3 Cylindrical	Single Levelling	Nos. 13 & B2	Single Levelling	1899-1900

TABLE V—(Continued).

The Principal Branch-Lines of Levelling.

Line No.	From	To	Route followed	Province	Observers		Levels used		Staves used		Season
					1st Leveller	2nd Leveller	1st Leveller	2nd Leveller	1st Leveller	2nd Leveller	
77A	Parbatipur	Gauhati	*Viâ* Dhubri	Eastern Bengal & Assam	E. H. Corridon	Zille Hasnain	No. 4 Cylindrical	No. 3 Cylindrical	Nos. B1 & B2	Nos. 13 & 4	1901-02
77B	Parbatipur	Manihari	*Viâ* Barsoi & Katihar	Bengal & Eastern Bengal & Assam	Lt. H. McC. Cowie, R. E. J. P. Barker	Single Levelling	No. 4 Cylindrical „ 3 Cylindrical	Single Levelling	Nos. 13 & B 2 „ 4 & B 5	Single Levelling	1899-1900 1899-1900
77C	Katihar	Anchara Ghat	*Viâ* the E. B. S. Railway	Bengal & Eastern Bengal & Assam	J. P. Barker	Single Levelling	No. 3 Cylindrical	Single Levelling	Nos. 13 & B2	Single Levelling	1899-1900
77D	Poradaha	Faridpur	*Viâ* the E. B. S. Railway	Bengal & Eastern Bengal & Assam	Zille Hasnain	Single Levelling	No. 1 Cylindrical	Single Levelling	Nos. B1&IIII	Single Levelling	1899-1900
Burma A	Elephant Point	Wuntho	*Viâ* Thazi, Pyinmana, Mandalay, Sagaing & Shwebo	Burma	J. Bond E. H Corridon E. H. Corridon	Vinayek Narayen Zille Hasnain Zillo Hasnain	No. 4 Cylindrical „ 4 Cylindrical „ 4 Cylindrical	No. 3 Cylindrical „ 3 Cylindrical „ 3 Cylindrical	Nos. B 1 & B 2 „ 04 & 05 „ 04 & 05	Nos. B3 & B 4 13 & 4 „ 01 & 03	1892-93 1902-03 1903-04
Burma B	Thazi	Magwe	*Viâ* Kyaukpadaung & Yenangyaung	Burma	E. H. Corridon	Zille Hasnain	No. 4 Cylindrical	No. 3 Cylindrical	Nos. B1 & B 2	Nos. 13 & 4	1902-03

CHAPTER II.

THE LEVELS.

The levels that have been used by the Survey of India for precise levelling are enumerated in the following table:—

TABLE VI.

Description of Level	Distinctive number	Maker's name	Date of introduction
Rectangular Level ...	...	Troughton and Simms	1860
Cylindrical Level ...	No. 1	Troughton and Simms	1858
Cylindrical Level ...	No. 2	Troughton and Simms	1858
Cylindrical Level ...	No. 3	Troughton and Simms	1858
Cylindrical Level ...	No. 4	Troughton and Simms	1858
Cushing's Reversible Level	No. 1050	Cooke and Sons	1880
Cushing's Reversible Level	No. 1151*	Cooke and Sons	1888
Cushing's Reversible Level	No. 8446†	Cooke and Sons	1906
Dumpy	No. 734	Cooke and Sons	1875
Dumpy	No. 765	Cooke and Sons	1875
Bolton's Reversible Level	No. 24*	Cooke and Sons	1905
Bolton's Reversible Level	No. 82	Cooke and Sons	1896
American Binocular Level	No. 2625	George N. Saegmuller, Washington	1906
American Binocular Level	No. 2626	George N. Saegmuller, Washington	1906
American Binocular Level	No. 2697	George N. Saegmuller, Washington	1906
American Binocular Level	No. 2698	George N. Saegmuller, Washington	1906

Two other American Binocular levels, numbered 6726 and 6727, and a binocular level by T. Cooke and Sons are also in the possession of the Trigonometrical Survey, but these have not as yet been used in the field‡.

The reversible levels have been used principally for the minor branch-lines, which connect hill stations of the triangulation with the main-lines of levelling. These reversible levels are provided with folding stands suitable for steep ground, which has often to be traversed, before a leveller can reach a

* These levels were used only on Saharanpur—Mussooree line.
† This level was used only on Dehra Dun—Kalsi line.
‡ See also last foot-note to page 22 concerning the employment of Cushing's level 8574, of Watt's level 1143 and of Cooke's level 8522.

high station of the triangulation. The stands in use with the rectangular and cylindrical levels are heavy and rigid and can only be erected on level sites.

The rectangular and cylindrical levels were the instruments principally used upon main-lines from 1858 to 1906 and are still in use. In 1906 the American Binocular levels were first employed in India.

Rectangular level, (*vide* Plate II)

The telescope in the rectangular level has a total length of 24 inches. The object-glass has an effective diameter of $2\frac{1}{4}$ inches and a focal length of 21 inches. There is an eye-piece of power 39 and one of 54.

In order to secure rigidity, the telescope is enclosed in a prism, the transverse section of which is a square of 3-inch side.

The weight of the instrument is 38 lbs. and that of the stand is 28 lbs.

There are two levels mounted on the prism, each having an effective length of nine inches. Of these the level A has never been used, as it has been considered sufficient to depend upon the readings of level B.

Adjustment of the rectangular level.

The instrument is levelled very carefully by means of the foot-screws and level-tube-attachment screws, until one end of the level reads the same while the instrument makes a complete rotation round the vertical axis. In order that the recorder can detect a mistake in reading, it is advisable to adjust the bubble-tube so that one end of the bubble always reads about 10 divisions more than the other.

Cylindrical levels, (*vide* Plate III)

The cylindrical levels were originally constructed for the Punjab Canal Department at the request of Field Marshal Lord Napier of Magdala when he was Chief Engineer in the Punjab. They are very superior to ordinary levelling instruments.

The cylindrical levels are numbered 1,2,3 and 4, and are similar in construction, each having a clamp and tangent-screw fixed to the boss of the tribrach.

The vertical axis of each instrument carries a rectangular horizontal base plate. To this are attached two vertical collars, in which the telescope is fixed by small screws. Each collar is attached to the horizontal plate by antagonistic screws, by means of which the distance of the centre of the collar from the plate can be regulated. Under the telescope is placed a compass indicating the bearing of the line of sight.

The level tube on each instrument has an effective length of $8\frac{3}{4}$ inches and is carried in a protecting case triangular in transverse section. Two sides of this case are of plate-glass to enable the observer to read the positions of the ends of the bubble. The case containing the tube is mounted on the collar in which the telescope is fixed. The mounting is so arranged as to admit of the tube being adjusted vertically and laterally.

Adjustment of cylindrical levels.

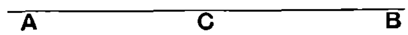
The telescope of the cylindrical levels cannot be revolved about a horizontal axis. It is, therefore, not possible to make the line of collimation coincide with the visual axis of the telescope. It is, however, possible to place the line of collimation (that is, the line joining the centre of the object-glass and the cross wire) at right angles to the vertical axis of revolution, and *as all errors of adjustment are cancelled by the method adopted of observing staves equally distant from the instrument*, it is quite sufficient to place the line of collimation at right angles to the vertical axis, in order to ensure accurate work. The above object may be achieved in two ways, (*a*) by Gauss's method and (*b*) by the "two-staff method".

(*a*) Gauss's method involves the use of two auxiliary telescopes, such as levels or theodolites fitted with horizontal wires. These are always present in the field with a levelling detachment. The auxiliary telescopes (A and B) or collimators are set up on firm stands about 20 feet apart and cross levelled, so that their object-glasses can be mutually directed on each other. The cross wires of A and B are then made mutually visible one from the other.

The level to be collimated is placed midway in the line joining the two collimators. It is first directed upon A, and the horizontal wires made to coincide by means of the foot-screws. Then the level is turned through 180° in azimuth and directed on B. If the horizontal wires are found to coincide, the line of collimation is at right angles to the vertical axis of revolution. If not, half the deviation is corrected by means of the foot-screws and half by the antagonistic screws attaching the telescope to the horizontal plate.

(*b*) The "two-staff method" is performed as follows:—
The instrument is set up at C (*Fig.* 1), exactly midway and in a line with two staves at A and B, distant two or three chains from each other;

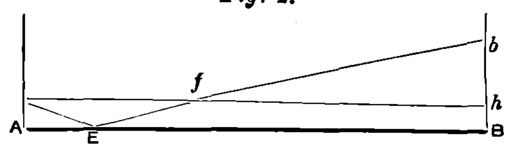
Fig. 1.



it is carefully levelled and the difference of readings, x, of the staves at A and B found: this is the true value notwithstanding the errors of adjustment, since C is the middle point of AB.

The instrument is then shifted to E (*Fig.* 2), which is between the staves, but much nearer to A than to B. It is carefully levelled and the difference of readings, z, of the staves at A and B found. If z is equal to x, the line of collimation of the telescope is perpendicular to the axis of rotation, but if not, $z - x$ is equal to bh in *Fig.* 2.

Fig. 2.



The point B is determined from the equation

$$bB = (z-x)\frac{EB}{EB-EA},$$

and the horizontal wire is made to intersect B by means of the adjusting screws under and near each extremity of the horizontal plate. This disturbs the bubble of the level, which must be corrected by its own screws. The whole operation is then repeated.

The principal statistics in regard to the cylindrical levels are as follows:—

TABLE VII.

	Level No. 1	Level No. 2	Level No. 3	Level No. 4
Total length of telescope	24 inches	24 inches	24 inches	24 inches
Aperture of telescope	$2\frac{1}{4}$,,	$2\frac{1}{4}$,,	$2\frac{1}{4}$,,	$2\frac{1}{4}$,,
Focal length	21 ,,	21 ,,	21 ,,	21 ,,
Magnifying power	24 to 43	26 to 44	26 to 44	26 to 45
Weight of instrument	23 lbs.	24 lbs.	23 lbs.	24 lbs.
Weight of stand	30 lbs.	31 lbs.	30 lbs.	31 lbs.

The telescope in Cushing's reversible level has a total length of 23 inches. The object-glass has an effective diameter of two inches and a focal length of 21 inches. There are two eye-pieces with an arrangement for pushing forward a dark glass when required: the magnifying power of these is however low, being only about 25. The effective length of the level tube is $6\frac{3}{4}$ inches. The weight of the instrument is 15 lbs. and of its stand 17 lbs. The object and eye-ends of the telescope are interchangeable by means of the following arrangement:—To the internal tube of the telescope is fixed a gun-metal socket, turned and ground with a short conical fitting and wide flange to receive the eye-end with its eye-piece and diaphragm. On the opposite end of the outer tube a precisely similar fitting receives the cell containing the object-glass, both of the ends being identical as regards the fitting. The eye-piece is attached to the telescope by two screws placed 180° apart in the flange of the socket: the screws are not intended to be taken out, but corresponding holes in the flange of the eye-end allow the latter to be inserted in the socket, when a short rotatory motion from left to right will bring it into its proper position against a stop. The object-glass has precisely the same kind of attachment, and will, like the eye-end, fit the socket at either end of the telescope.

Cushing's Reversible level.

Instead of threads, lines are finely engraved on a glass disc which fits into a sliding diaphragm. The horizontal plate and tribrach are both cast hollow underneath, securing maximum strength and rigidity with minimum weight. The attachment of the supports of the telescope is an original design: the support nearest the object-end is in contact with the plate, but is capable of a slight movement in the direction of the axis of the telescope so as to admit of the second adjustment described below, whilst the other support is provided with two large nuts for clamping and permanently securing the telescope to the plate when this adjustment has been performed.

There are three adjustments for this instrument:—*firstly*, to eliminate vertical collimation; *secondly*, to make the line of collimation perpendicular to the vertical axis; and *thirdly*, to make the bubble-tube parallel to the line of collimation. These are effected as follows:—

Adjustment of Cushing's level.

Firstly.—The instrument is set up on its stand with one foot-screw under the telescope. The small screw at the top of the object-glass cell is taken out and the cross lines focussed; the telescope is then directed on any convenient object, *e. g.*, a small circular dot on a sheet of paper placed about 20 feet from the instrument, the object focussed and bisected with the horizontal line. The eye-end is then carefully turned in its socket, from right to left, until the holes in the flange of the eye-end are opposite the heads of the screws in the socket and removed. It is replaced again but in an inverted position, care being taken to turn it from left to right until it comes to a stop, when the diaphragm will be in its proper position. If the point is still bisected the collimation is assumed to be correct, but if not, half the deviation from the horizontal line is corrected by the foot-screw under the telescope, and half by the two screws that give vertical motion to the diaphragm. This process is repeated till the adjustment is perfect.

Secondly.—The object being now bisected and all parallax eliminated, the eye-end and the object-glass cells are removed from their respective sockets and placed at the opposite ends of the telescope. If the object is still bisected on turning the telescope half round, the line of collimation is assumed perpendicular to the vertical axis; but if not, half the error is corrected by the large clamping nuts at one end of the horizontal limb, and the other half by the foot-screw under the telescope. As soon as it is found that the object and eye-ends can be reversed without any apparent change in the position of the object intersected, the small screw should be returned and the object cell made secure. It is important in changing the object-glass from end to end to keep that part of the cell which has the small screw hole in it, always uppermost.

Thirdly.—The instrument stand is levelled approximately by the legs, the telescope is turned so that its axis is parallel to a line joining two foot-screws, and the bubble is brought by means of the latter to the centre of its run. If it remains so, on turning the telescope through 180°, it is in adjustment; but if not, it must be brought half way back by the foot-screws over which it stands, and the other half by the two opposing nuts at the eye-end of the bubble-tube. The levelling is completed by turning the telescope through 90°, so that one end of the level is over the third foot-screw by which the bubble must be brought to the centre of its run. The bubble should now remain in the centre during a complete revolution, and the small cross-level can then be adjusted.

Bolton's Reversible level.

Bolton's reversible level is an improved form of the Y pattern level. The Ys have large bearing surfaces and flanges are provided on the telescope tube so that it can be turned without longitudinal shift. The flanges have holes in them, through which milled headed screws pass, entering corresponding holes in the Ys, thus ensuring the telescope being securely clamped, when the adjustments have been performed.

The aperture of the object-glass is 1·8 inches, and the focal length 14 inches; the magnifying powers are 16 and 22.

Adjustment of Bolton's Reversible level.

The following description of the adjustments of this level is taken from Mr. T. Bolton's pamphlet.

I.—*To adjust the collimation of the telescope*:—First some well-defined test object, which need not necessarily be exactly the same height or level of the instrument, is selected. The test object should not be less than 20 feet away from the observer. The instrument is placed on its stand in such a manner, that when the telescope is pointed towards the object, it lies directly over one of the foot-screws. The eye-piece is carefully pushed in or out in its tube, until the cross lines are seen as distinctly as possible, and the telescope is then focussed upon the test mark.

After all parallax has been corrected, and the test mark carefully bisected by the cross line, the binding pins and screws which hold the flanges of the telescope in the Ys are removed, the telescope is carefully revolved through 180° in its Ys, till the cross line is again horizontal. If the image is not now bisected, but falls above or below the cross line, the error is corrected half by the foot-screw underneath the telescope, and half by the antagonistic screw at the eye-end of the telescope. The operation must be repeated until accuracy is obtained.

II.—*To adjust the axis of the telescope, so that it may be exactly at right angles to the vertical axis upon which the instrument turns*:—

The telescope is focussed upon the test mark, and the image carefully bisected by the horizontal cross line, then the telescope is lifted out of its Ys and reversed, end for end, in them. If on redirecting the telescope towards the test mark, the image of the latter is no longer bisected by the cross line, the error is corrected half by the foot-screw underneath the telescope, and half by the circular lock-nuts which are placed on the adjustable Y. The above operation must be repeated, until the bisection of the image is as exact as possible, and remains quite undisturbed by the reversal of the telescope in its Ys.

III.—The bubble-tube adjustment is the same as that for the cylindrical levels.

The American Binocular level. (*Vide* plates IV and V)

An account of the American Binocular level was submitted by Mr. O. H. Tittmann, the Superintendent of the United States Coast and Geodetic Survey, to the International Geodetic Conference that met at Copenhagen in 1903. The following extract has been taken from Mr. Tittmann's report to the Conference*:—

At the beginning of the season of 1900 two precise levels of a new design which had recently been constructed were put into use. The distinguishing peculiarities of this new type of precise level, as stated in the report to the association in 1900, are, "that it stands very low on the tripod head; that the level vial is fixed relatively to the telescope and is placed as near as possible to the line of collimation, being in fact countersunk into the barrel of the telescope; that the telescope does not rest in Ys but instead is supported by trunnions in front of the middle point and by a micrometer screw

* *Comptes Rendus des séances de la quatorzième conférence générale de l'Association Géodésique Internationale*, 1904, Annexe A XI.

near its eye end. The middle half of the telescope, including the level vial, is completely shielded by an outer metallic tube, within which it is free to move as constrained by its trunnions and the micrometer screw. The nickel-iron alloy has been used almost entirely in the construction of the telescope and adjacent parts. The device for reading the bubble from the eye end agrees in its essential principles with that used on the Berthelemy level. In its design it differs radically from it. The distance between the eyepiece of the telescope and that of the reading device is adjustable to fit the distance between the eyes of the observer, so that no movement whatever is necessary to transfer the attention from the rod to the bubble".

The results which have been obtained with this instrument and the simple method of observation used with it are sufficiently remarkable as a rare combination of rapidity, economy, and accuracy to be worthy of being specially called to the notice of the association.

Between the beginning of the season of 1900 and April 9, 1903, 3900 kilometers of completed leveling have been done with these instruments. The capabilities are therefore known at this date as a matter of experience, not of theory. By completed leveling is meant that each section of the line, usually from 1 kilometer to 1·6 kilometers long, has been leveled at least twice, independently, in the forward and backward directions. If the first two results differed by more than $4^{mm}\sqrt{K}$ (in which K is the distance leveled between bench marks in kilometers), the section was releveled in both directions, or even leveled a fifth and sixth time if necessary to secure results within the prescribed limit.

The average rate of progress of a leveling party, consisting of an observer and five men, for the whole 3900 kilometers has been 106 kilometers of completed leveling per month, the time being counted from the first to the last date of leveling on each line. Even under the most adverse conditions the number of completed kilometers per month has seldom fallen below 80. One party leveled for more than seven and one-half months continuously at an average rate of 137 kilometers of completed leveling per month. During one month of this period 169 kilometers of line were completed. During this month the leveling proceeded on twenty-five days, and the total length of single line run was 359 kilometers, or an average of 14·4 kilometers per observing day. This feat was not accomplished by extremely long working hours. Making no allowances whatever for any delays or interruptions, except the stop in the middle of the day for lunch, the average number of hours of leveling per day was 7¼, and the average speed was therefore for the whole month 2 kilometers of single line per hour during the progress of the leveling. The average length of sight during this month was 83 meters.

On the most remarkable day of leveling another observer ran 25·5 kilometers of single line, none of which was afterwards found to need rerunning. The observing was done in nine hours and forty minutes, making no deduction for delays except the dinner hour, or at an average rate of 2·6 kilometers per hour. The total number of instrument stations on this day was 147. Assuming that the observer moved from station to station on the velocipede cars at an average speed of 9·7 kilometers per hour the average interval spent at each station in all manipulations and observations from the instant the tripod touched the ground until it was picked up was 2·9 minutes.

These records are sufficient to show that the instrument is capable of very quick manipulation and that the method of observation is simple and rapid. It is important to note that this rapidity of operation is also conducive to accuracy, as the interval during which the instrument may become distorted by unequal changes of temperature or other causes, or during which changes of refraction may occur, is reduced to a minimum.

The following description of the American Binocular level is taken from Mr. Hayford's valuable note on precise levelling, published as Appendix No. 3 to the Report of the Coast and Geodetic Survey for 1903:—

THE NEW PRECISE LEVEL.

Commencing with the summer of 1900 a new type of precise level was put into use in the Coast and Geodetic Survey, and a method of observation was adopted which has remained unchanged except in unimportant details since that time. Three seasons of leveling have furnished a thorough test of the instrument and method. The train of events leading up to the change is of little importance now. The justification of the present instrument and method must be found in the accuracy, rapidity and cheapness of the recent leveling. Hence, in this appendix, the first official publication in which the results of these three seasons of leveling appear, it is appropriate that detailed information in regard to the degree of success attained in the leveling since the change was made should be fully set forth.

The following description of the new instrument is reproduced, with a few and unimportant changes, from a description written by Mr. E. G. Fischer, Chief of the Instrument Division, Coast and Geodetic Survey, and the designer of the instrument.

When it became necessary to provide additional instruments for carrying out the geodetic leveling planned for the season of 1900, opportunity arose to embody in a new design the fruits of the deliberations of the committee on precise leveling of 1898-99, whose conclusions had been tried and proven with the three geodetic levels Nos. 1, 5 and 6, remodeled in the instrument shop of the Survey in the spring of 1899 and used in the field during the whole of that season. A careful study of the results obtained with these instruments proved conclusively that the use of the new alloy of iron and nickel, which was first applied in their reconstruction, and the reduction of the distance between the level and the line of collimation were decided improvements and practically eliminated errors due to temperature effects.

These facts were kept in view in designing the new instruments. As the newly adopted method of observation obviated the use of the reversible stride level and the rotating telescope, the distance between the level and the line of collimation could be reduced to a minimum by placing the former in an opening cut into the telescope and the latter could be placed within a tube-shaped support, at one end of which two pivot screws provide a horizontal axis around which the telescope can be rotated and the line of collimation put into the horizon by means of a fine motion or micrometer screw mounted at the other end. By making the support for the telescope tubular, it was not only given the strongest and lightest form, but it could be made to serve at the same time as a protection to the level mounted in the telescope. The level-reading device, in principle the same as that used in the reconstruction of levels Nos. 1, 5 and 6, being mounted at the side of the telescope at binocular distance from it, offers, with the exception of a small mirror, which is almost horizontal and fastened neither to the level nor the telescope, no additional surface to wind pressure and enables the observer to stand with head and body erect while observing the rod with one eye and the level with the other.

As has been done in designs of other instruments made for the Survey, the legs of the instrument were put as high up on the center bearing as possible and the lower part of the latter disposed of within the head of the tripod; thus not only affording room for an unusually long and therefore more durable and rigid center, but also bringing the center of gravity of the instrument much nearer to the plane of support.

THE MATERIAL IN THE NEW LEVEL.

For all those parts upon which depends the constancy of the relation between the line of collimation and the level—the telescope, the tube incasing the level vial, the drawtube, reticle ring, and the supporting cylinder—the material selected is the same as that used in the reconstruction of geodetic levels Nos 1, 5 and 6 in the spring of 1899.

The nickel-steel alloys brought out by Dr. Ch. Ed. Guillaume,* of the International Bureau of Standard Weights and Measures, had attracted considerable attention by reason of their low expansion coefficients (down to 0·000001 per degree centigrade). Inquiry established the fact that tubing and castings, almost indispensable in the construction of instruments, could not be obtained, because attempts to produce them had not yet been successful. Mr. George T. Ennis, of Washington, D.C., who furnishes the brass castings required in the shops of the Survey, was persuaded to undertake a series of trials in 1899 of alloying various kinds of steel and iron with nickel. A quantity of what in the trade is called "machinery steel" and commercially pure nickel was weighed off in the proportion of 64 of steel to 36 of nickel, the same from which Dr. Guillaume obtains a coefficient of less than one-millionth per degree centigrade. The furnaces of brass founders being supplied with air only by natural draft, it was with considerable difficulty that sufficient heat could be developed to melt the steel, and when the mixture with the nickel was finally accomplished the temperature was still too low to allow impurities to rise freely to the surface and leave the casting sound and solid. In another attempt steel turnings from the large gun forgings being assembled at the Washington ordnance yard were used, but the trial castings also proved porous.

The coefficients of these specimens, as determined from the temperatures of 0° and about 60° C., were, however, quite low, namely, three-millionths, nearly. The melting point of cast iron being much lower than that of wrought iron or steel, a trial was made with it, using the same proportion. But while the castings were now sound and free from pores the coefficient had increased to nearly five-millionths. The results of Dr. Guillaume's investigations showing that but a slight variation from the above given proportion caused a change of several units in the sixth place of the coefficient, it was thought likely that a loss of one or the other of the two metals by oxidation during the melting and mixing was the cause of this increase. For this reason a number of alloys were made of different proportions, of which one of 66⅔ parts of a medium-grained cast iron, furnished by the Brown & Sharpe Manufacturing Company, of Providence, R. I., and 33⅓ parts of which is called "grain nickel" was finally adopted. It can be cast free from sand and blowholes, and has a coefficient of 0·000004.

No thorough tests as to strength, etc., were made of this alloy, but so far as shop practice reveals its physical properties it can be said to be rather brittle, easily worked in the lathe and with the file, entirely unmalleable, and behaving practically like the better and softer grades of cast iron.† It can readily be brazed and soldered, and, unlike cast iron, very easily takes an exceptionally fine polish, resembling that of nickel. The smoothness with which it wears against itself, even under considerable pressure, should be particularly mentioned. For instance, the nickel-iron drawtubes of the three remodeled instruments of 1899, though moving in bearings of the same metal, do not show the slightest wear or looseness, though they were used in running 200, 300 and 600 miles of leveling line, respectively.

None of the acids except aqua regia will readily attack it. A rectangular piece submerged in water for twelve days showed formation of what resembled iron oxide, but only along the sharp corners and without pitting, while the surfaces remained bright. A rough test proved the specific gravity of the alloy to be between that of iron and of nickel, but below that theoretically deduced from their proportions. The nickel used in these experiments was purchased at a cost of 42 cents and the iron at 6 cents a pound, making the cost of the two-to-one alloy 18 cents per pound, which is 2 cents less than that of good brass.

The pointed screws pivoting the telescope, the screws holding in place the level tube and by which the level is adjusted, the screws holding and adjusting the reticle ring, and the fine-motion micrometer screw, upon all of which depends the constancy of the relation between the line of sight and the plane tangent to the middle point of the level vial, and which require to be of a material much harder than the casting above described, are made of nickel steel, with a coefficient of 0·000001, obtained from the Société Anonyme de Commentry-Fourchambault, 26 Place Vendôme, Paris. This alloy is well adapted for screws of all kinds, and should now entirely replace steel in the manufacture of all measuring screws, such as micrometer screws for astronomic and surveying instruments, micrometer calipers, gauges, etc., used in mechanical engineering, provided, of course, that the nuts into which such screws are threaded are made of the same material, for it is obvious that a screw with a coefficient of 0·000001 could be made to fit closely in a nut of brass whose coefficient is 0·000018 only at one certain temperature.

The material used in the construction of other portions of the instrument will be named in the description of those parts.

THE TRIPOD OF THE NEW LEVEL‡.

The tripod is of the usual form. The three legs, separating some distance above the feet into two rectangular rods, pivot in the head by means of bolts about 1cm diameter at points forming a regular hexagon. The feet consist of pointed hollow sockets about 14cm long and 3½cm diameter at the top, fitted and fastened by screws to the legs. They are made of 10 per cent aluminum bronze, an alloy but little inferior to steel in hardness and toughness. The two rods forming the leg are made of black walnut, 2cm by 3½cm, and fastened together at two points by walnut braces which are screwed between them. The tops of the legs are brass bound to guard against the splitting out of the bolt holes. In obtaining the length of the legs, which should be made to suit the observer's height, their normal angle with the ground was taken to be 60°, the vertical distance between the bolt holes in the head of the stand and the line of collimation being 13cm. The head of the stand, also of black walnut, is 4½cm thick and carries sunk into its upper surface the three V-grooved plates forming the supports for the foot screws of the instrument. In a circular recess in the lower surface is held by a ring-shaped plate *a*, a washer *b*, shaped so as to form a seat for the convex shoulder of the nut, *c*, which is threaded on the screw *d* §. This screw, 1cm·3 in diameter and of a pitch of 8 threads per centimeter, enlarges at its upper end to a cup-shaped nut, which can be screwed upon the lower end of the center socket of the instrument. The washer *b* is not confined in its recess so closely but what it can move laterally and adapt itself to any position the vertical axis may assume in relation to the head of the stand. When the instrument is set upon the stand the lower end of the center socket will come to rest upon the cup-shaped nut before the foot screws can touch their supports, thus leaving it in an unstable position and making it practically impossible for the observer to forget to secure the instrument to the stand before it is carried to the place of work. The nut *c* is loosened before observing, and tightened only when the instrument and stand are to be carried from station to station.

THE INSTRUMENT BASE AND CENTER.

The instrument base is a single piece of hard and fine-grained cast iron, furnished by the Brown & Sharpe Manufacturing Company. In its three legs, at a radial distance of 9cm, are threaded the foot screws of 9½mm diameter and 15 threads per centimeter, and having a bearing of 2cm·3. The screws are of such length as to permit a motion of 6mm above and below the normal position, thus allowing the instrument to be leveled even under unusual inclination of the head of the tripod. No position of the foot screws can prevent the fine-motion or micrometer screw from freely passing over them. The ends of the legs are split in the usual manner and provided with milled-head screws for clamping the foot screws. The clamp arm *g*, with its clamp screw *h*, is fitted into a groove near the top of the center socket, and carries at the outer end the fine-motion screw *i* for moving the telescope horizontally in azimuth. The central portion of the instrument base is bored out conically and affords a bearing throughout its length for the unusually long center (10cm), which is made of the hardest grade of tool steel, Sanderson's No. 6. It is secured against being withdrawn by a small nut screwed to its lower end. Upon its upper end is fastened permanently, by screwing and riveting, a disk or flange *j* §, of 5cm·8 diameter, made of hard cast iron, which forms the base of the supporting cylinder.

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* These alloys are protected by patents.

† As soon as nickel-steel tubing can be obtained the instruments may be considerably improved by its use. Such material will not be brittle like the material here described, and moreover will probably have a much lower coefficient of expansion.

‡ The tripods supplied to the Survey of India, with the American levels are of a whitish wood which resembles ash and the tops of the rectangular rods are not brass bound.

§ The letters refer to diagrams in the American volume, which have not been reproduced here.

THE SUPPORTING CYLINDER OF THE TELESCOPE.

This is a nickel-iron casting, as stated above. Its length is $21^{cm}\cdot 6$, its outer diameter $5^{cm}\cdot 9$, its inner diameter $5^{cm}\cdot 4$, leaving a thickness of wall of $2^{mm}\cdot 5$. At its middle point is a cylindrical boss or hub *l*, of the same diameter as the flange of the center, to which it is firmly fastened by four steel screws. Two lugs *m*, are threaded to receive the pivoting screws *n*, which are made of nickel steel, and, with their points $2^{mm}\cdot 6$ below the center of the supporting cylinder form a horizontal axis for the telescope. At a distance of $1^{cm}\cdot 2$ from the rear end and below is fastened, by two screws, the nut *o*, made of nickel iron, which carries the fine-motion or micrometer screw *p*. This latter, of 39 threads per centimeter nearly (100 per inch) and 7^{mm} diameter, is provided at its upper end with a small tip of glass hard steel, and carries, below, an adjustable micrometer head of white zylonite *q*, which is $4^{cm}\cdot 1$ in diameter and is divided into 100 parts. A hard rubber disk with milled edge, projecting beyond the micrometer head, not only protects the graduation from the fingers, but, by reason of its large diameter, facilitates the setting of the sensitive level. An index for reading the micrometer head is provided.

The supporting cylinder carries a removable eccentric ring *r* inserted into its forward end of which the inner diameter is such as to permit the telescope pivoted between the screws *n* to rotate slightly without touching. A similar ring *s* at the rear end, however, is cut out so as to permit the telescope to move up and down, above and below the normal or horizontal position, by about 2^{mm}, while the sides of the ring permit of no lateral play, but form a guide for that amount of vertical motion.

Directly in front of the micrometer screw is fastened to the supporting cylinder a small case holding an eccentric which can be rotated by a lever handle at the right side of the instrument. When the lever handle is turned up the eccentric pushes against the telescope, lifts its weight off the micrometer screw, and presses it gently against a spring sunk into the upper part of the ring *s*. In this position the instrument can be carried without the risk of jarring the telescope and thereby disturbing the level adjustment.

Against the hub *l*, on the right side of the instrument, is fastened a bracket carrying a small universal level, which is easily observed from the eye end of the telescope by means of a mirror mounted above it at an angle of 45°.

At the forward end of the supporting cylinder and below is mounted a post *t*, reaching downward between the horizontal pointing screw *i* and the spring case of the clamp arm *g*.

The upper part of the supporting cylinder has cast into it a rectangular opening with a framing *u* surrounding it. A piece of plate glass fitted into this framing by dovetail grooves, closes the opening against dust or air currents, but can quickly be moved forward for the purpose of adjusting the level by loosening a small milled head screw and turning up a hinged locking piece. Over this opening and against the sides of the framing is mounted by brass arms *v* the glass mirror *w*, arranged so as to permit of a small rotary adjustment for the purpose of adapting the level reading device to individual observers. It may be stated here that the opening in the supporting cylinder was placed as near as possible to its rear end and away from the middle of the instrument, because the level could at that place be put closer to the line of collimation without entering the cone formed by the apertures of the objective and the reticle ring.

Small grooves around the ends of the supporting cylinder afford the means of fastening, by wire rings or narrow metal bands, the leather cones *x**. They are fastened to the telescope in a similar manner, and effectively shut out dust and air currents without in the slightest degree preventing the telescope from assuming the position determined by the pivoting screws at one end and the micrometer screw at the other end of the supporting cylinder.

THE TELESCOPE OF THE NEW LEVEL.

The tube with the objective head and drawtube bearings, forming the telescope, is cast of nickel iron in one piece and bored and turned in the lathe. Its outer diameter being $4^{cm}\cdot 37$ and the inner $4^{cm}\cdot 05$, gives a thickness of wall of $1^{mm}\cdot 6$. Immediately at the eye end and at a distance of 9^{cm} from it are two constrictions forming the bearings *y* for the drawtube. A ring *z* is fitted and soldered into the telescope at the place where the 60° points of the pivoting screws *n* are bored into it ($28^{cm}\cdot 9$ from the eye end) for the purpose of strengthening it to resist strains caused by undue tightening of these screws.

The drawtube, cast solid of nickel iron and bored out, is fitted closely into its bearings, and carries within an enlargement at its outer end, by means of four nickel-steel screws, the nickel-iron reticle ring. Great care was taken to fit the threads of these screws very tightly to insure, as much as possible, invariability of the position of the reticle. One vertical and three horizontal spider threads of the finest grade obtainable are mounted upon the reticle ring. The horizontal threads are equidistant and the upper and lower embrace a space of 30^{cm} at a distance of 100^{m}. Two Steinheil eyepieces, of $12^{mm}\cdot 5$ and $9^{mm}\cdot 5$ (one-half inch and three-eighths inch), equivalent focus, to suit different weather conditions, are supplied. The objective lens is mounted in a cell cast of nickel iron. It is held in place by a spring ring, fastened with three small screws, in such manner as to hold it firmly in position, without restraining it from expanding and contracting with changes of temperature. It has a clear aperture of $4^{cm}\cdot 2$ and a focal length of 41^{cm}, giving a magnifying power of 32 diameters with the $12^{mm}\cdot 5$ and of 43 diameters with the $9^{mm}\cdot 5$ eyepiece. The drawtube is moved into focal distance in the usual way, by means of a rack and pinion, and has sufficient range to enable the observer to point on an object as near as 3·5 meters†.

Just within or under the leather cones *x* the telescope carries two enlargements or collars, which are turned to equal diameters, and serve the purpose of placing the pointing line into the geometric axis of the telescope. This adjustment is made in the shop permanently. It is done by laying the telescope with these collars, upon two metal Y supports provided with leveling foot screws. Pointing on an object and rotating the telescope in the Y's reveals any want of parallelism between the axis of the two collars and the line connecting the intersection of the vertical and middle horizontal threads and the optical center of the objective. This is corrected by means of the four screws holding the reticle ring. Since the spider threads move with the drawtube, it also must move in a line parallel to the axis of the collars, in order to preserve true collimation in any position required by focusing upon the rod at different distances. To insure this parallelism, great care was taken in making the telescopes. The objectives were centered with special care, and the collars were turned true at the same chucking under which the drawtube bearings were bored. Inasmuch as any error of collimation enters into the result of leveling only to the small amount due to differences between back and fore sights, it may be said that these instruments, as far as collimation error is concerned, are practically faultless.

In the same Y supports above mentioned, the level attached to the telescope is adjusted so that its axis is parallel to the vertical plane containing the line of collimation. This adjustment eliminates what is commonly called the "wind" of the level, and can not readily be made in the field.

The position of the forward drawtube bearing and that of the micrometer screw were selected with the view to sufficient rigidity of that part of the telescope which rests upon the micrometer screw. The point of contact with the hardened tip of the screw is a small hardened steel plate a_1, fastened into the telescope at the forward drawtube bearing. The distance between the axis of the micrometer screw and the axis of rotation formed by the pivoting screws *n** is $13^{cm}\cdot 15$ nearly, which, with the screw pitch of 39 threads per centimeter, gives a value of about 2″·6 per division of micrometer head. The distance between the axis of rotation of the telescope and the vertical center is $9^{cm}\cdot 8$.

* The letters refer to diagrams in the American volume, which have not been reproduced here.
† The instruments supplied to the Survey of India can be used up to a minimum distance of 7 metres.

THE LEVEL VIAL OF THE NEW INSTRUMENT.

The level vial was made by A. Pessler, and is of the chambered type. It is $11^{cm}\cdot5$ long, $1^{cm}\cdot5$ in diameter, and carries a graduation 8^{cm} long in 2^{mm} spaces. The length of the bubble used is about 25 div., or $5^{cm}\cdot0$. The value of a division of the level vial is $1''\cdot94$ for level No. 7 and $1''\cdot86$ for No. 8. The mounting of the vial has been attended to with special care, with the aim of securing the greatest possible constancy of adjustment. The glass vial rests within a tube of nickel iron upon the ends of four small screws b_1, piercing the tube, two at each end of the vial, 120° apart. A small tip c_1, at the end of a flat spring fastened to the tube and also piercing it, presses with sufficient force upon the vial at each end, exactly over the supporting screws, to hold it firmly in place and yet permit it to expand and contract independently of the tube. Longitudinally the vial is confined by two cork rings d_1, one at each end, which, however, leave a small clearance, so that the vial is free also in that direction. This is the manner in which all level vials, excepting only the smaller ones, have been mounted in the shops of the Survey for the past thirteen years. The level tube, with the vial thus supported, is secured to the telescope, sunk through an oblong opening close to the cone formed by the apertures of the objective and reticle ring. At the forward end it is held by a screw holding it down to a rounded support e_1, screwed to the telescope, upon which it can be moved laterally by two opposing screws for adjusting the "wind." The other end is made adjustable in the vertical for the purpose of keeping the level parallel to the line of collimation. This is the only adjustment required on the part of the observer in the field. A square-headed vertical screw f_1, of about 27 threads per centimeter and fitting closely in the level tube end, is threaded tightly into that part of the telescope forming the forward drawtube bearing. Two strong helical steel springs, one on each side, press the level tube tightly upward against the shoulder of the screw f_1.* A socket wrench, with a lever arm $7^{cm}\cdot5$ long, permits of applying rotary force to the screw without exerting any other pressure against the instrument and thereby displacing the pointing of the telescope, as is the case when using a screw-driver or capstan bar, so that this delicate adjustment is made quickly and with ease, and seldom requires to be repeated.

As already stated, the adjustment of the reticle is made permanently in the shop, the observer having no means of testing it in the field. It is of great importance, therefore, that the reticle ring should not be disturbed, but that, when necessary, the level be moved into parallelism with the pointing line.

In the instruments as originally constructed the heads of the four screws holding the reticle ring were exposed in the ordinary manner. Now (1903) the design has been so improved that the heads of these screws are completely inclosed in a protecting case and are inaccessible to the observer in the field†.

The observer, carrying the instrument from station to station, readily learns to hold it in such position as to prevent any change of the length of the bubble by establishing communication between the chamber and the interior of the vial. In the vials used for these instruments the openings in the chambers are not at the bottom, but slightly to the side.

The first of the new instruments to be used in the field was put in adjustment at Washington and sent by express to a point in Kentucky. The observer there, on beginning work with it, found it still in adjustment and continued to use it for one and one-half months; during which time the angle between the tangent to level vial at its middle point and the line of sight defined by the three horizontal lines never exceeded 3″. At the end of that time the angle suddenly became 9″ and the instrument was adjusted. After constant use for nearly one and one-half months more the record showed the greatest value of this angle to be $3''\cdot6$. The mean algebraic value of the angle during this time was a little more than 1″. This behavior in the matter of holding adjustment has been frequently approached in later work with instruments of this type. The constancy with which these instruments retain their adjustment testifies to the fine work put upon them, for which credit is due to Messrs. C. Jacomini and O. Storm, instrument makers.

THE LEVEL-READING DEVICE.

The operation of reading the position of three fine lines, the spider threads, projected upon the graduation of the level rod, is a trying one under the best conditions, and subjects the observer, when the air is hazy or unsteady, to severe strains. As it is of the highest importance that these readings be taken only at the instant when the level indicates horizontality of the line of sight, the instrument should be designed particularly with a view to the observer's comfort, so as to enable him to observe the rod and the level as nearly as possible simultaneously. It is thought that the level-reading device provided for these instruments fulfils all requirements, since only the time required for transferring mental attention from one object to another need elapse between the two observations. It is a modification of that used by Berthélemy, of Paris, in his precise level‡, which consists of two adjustable prisms mounted upon the stride level and three prisms mounted in a casing fastened to the Y support of the telescope, with a short tube immediately on the side of the latter reaching as far as the eyepiece. Besides the objectionable feature of the overloaded stride level, the design has the fault of requiring the observer to shift his head between observations upon the rod and the level.

The modified form here described was applied in the spring of 1899, when precise levels Nos. 1, 5 and 6 were remodeled, and it was amply tested in the field during the season of that year. In designing an entirely new instrument it was possible to improve greatly upon the manner of its application. Two clamp rings g, support an aluminum tube with an eye end reaching back to a point even with the eyepiece of the telescope when focused for an average distance. Against this tube is screwed a dovetail bar h_1 upon which move, within the tube, two slides i_1 and j_1 carrying the prisms k_1 and l_1. These slides are connected by arms with a lever mounted upon a stem with a milled head m_1, the rotation of which moves the prisms equally toward or away from a central point between them. This motion is provided to adjust the distance of the prisms accurately to the length of the bubble, which, during the day's work, may vary by reason of temperature changes. Those faces of the prisms which are directed toward the eye are ground to such curvatures as, with the aid of a lens mounted between them and the eye end, to reduce to that of distinct vision of the normal eye the distance from the end of the bubble to the eye, by way of the mirror w, the reflecting faces of the prisms k_1 and l_1* and the lens. For the benefit of the observer required to use glasses the eye cap of the level-reading tube is arranged to hold such a lens as he may require to enable him to observe without spectacles.

The distance between the level-reading tube and the telescope can be changed to suit each individual observer, and provision is made for the rotary adjustment of the prisms and the mirror necessary in consequence of any such change. The prisms are put in such position by means of the milled head m_1, that the ends of the bubble and the graduation marks above them are brought into view, appearing as if the bubble were very short. The lines forming the graduation upon the level vial are marked by small dots in such manner that symmetrical lines, or lines equidistant from the centre of the graduation, are readily distinguishable, thus relieving the observer of any strain in guarding against mistakes.

THE FINISH AND WEIGHT OF THE NEW LEVELS.

The telescope throughout its length—with the exception of the eye end of the drawtube and the two collars turned to equal diameters—the supporting cylinder, and the level tube were covered with a heavy coating of cloth dust of a bluish-gray color. This coating is put on by painting the

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* The letters refer to diagrams in the American volume, which have not been reproduced here.

† In the instruments supplied to the Survey of India the heads of the four screws holding the reticle ring are exposed.

‡ See page 423 and illustration opposite, in Appendix No. 8, Report for 1899, Precise Leveling in the United States.

parts with a mixture of Japan varnish, turpentine, and linseed oil, which is colored with white lead, lampblack, and ultramarine blue, to the same shade as that of the cloth dust; the latter is sifted over the freshly varnished pieces through a hair screen and pressed in with the hand. After allowing it to dry for two days and brushing off all loose cloth dust, a coating of a dilute solution of bleached shellac in alcohol is applied. The finish has the appearance of a fine quality of cloth, and affords considerable protection against sudden and temporary changes of temperature.

Other parts of the instrument, as the instrument base, mirror frame, level-reading tube, etc., are finished in black enamel of the kind introduced so extensively through the bicycle industry. It is heavy, hard though elastic, and surpasses in appearance and durability any of the black lacquers heretofore used in the art of instrument making.

The weight of the instrument is 5^{kg}·2. No doubt this can be considerably reduced when tubing made of nickel steel is obtainable in the market. The thickness of the cast tubing—about twice as great as would be necessary if wrought metal could be substituted—is considered as small as is safe to use in view of the loose texture of the alloy.

The weight of the tripod, 7^{kg}·2, is somewhat greater than that of stands formerly used for the same class of instruments. This is due to the much greater length required in order to enable the observer to stand erect, which is considered of sufficient advantage to warrant a small sacrifice in the matter of weight.

The American levels were made for the Survey of India by G. N. Saegmuller, Washington, and were tested before despatch in the Office of the Superintendent of the Coast and Geodetic Survey.

The principal statistics in regard to the American levels are as follows:—

TABLE VIII.

	Level No. 2625	Level No. 2626	Level No. 2697	Level No. 2698
Total length of telescope ...	18 inches	18 inches	18 inches	18 inches
Aperture of telescope ...	1·65 „	1·65 „	1·65 „	1·65 „
Focal length	$16\frac{1}{8}$ „	$16\frac{1}{8}$ „	$16\frac{1}{8}$ „	$16\frac{5}{8}$ „
Magnifying power ...	15 to 36	14 to 35	14 to 35	14 to 38
Weight of instrument ...	12·5 lbs.	11 lbs.	11 lbs.	11 lbs.
Weight of stand ...	14 lbs.	14 lbs.	14 lbs.	18 lbs.

CHAPTER III.

THE LEVELLING STAVES.

The Levelling Staves for the Trigonometrical Survey of India were all originally made at the canal foundry at Roorkee. At one time staves, of which those numbered N_1 and N_2 are specimens, were made hollow, but the greater number have all been of solid wood. The hollow staves were found to vary unduly in length at different seasons, and were disliked by levellers. The solid staves from Roorkee have generally been built up of strips of well-seasoned teak: in some few cases alternate strips of teak and pine have been used and in some cases seven strips of teak and two of pine have been combined to make one staff, the sections of pine being introduced in order to reduce warping. As a general rule however teak alone has been utilised, each staff being composed of five or seven strips.

Since 1900 all levelling staves for the Survey have been made at the Mathematical Instrument Office at Calcutta: there they are now being constructed and numbered in pairs, for example 10A and 10B, and 11A and 11B.

The Calcutta staves are now built up of five pieces of teak wood cut from well-seasoned old beams bought from contractors: the beams are taken from the roofs of demolished houses. In 1900 the experiment was made of boiling the wood in paraffin wax for the purpose of rendering it less liable to be affected by damp. The staves were boiled until no more air was given off by their wood, and the wax was then allowed to cool until it was solid. The staves were weighed before and after boiling in order that the amount of wax absorbed in the pores of the wood might be estimated. Of the four staves treated, the weight of one increased by 5 ounces, the weight of another remained unchanged, and the weight of the two others decreased by 4 and 5 ounces respectively. The treatment in paraffin proved a failure; the wax prevented the paint from setting properly, and it greatly increased the difficulty of graduating the painted surface. In the case of staves which have been given black graduations on white faces, the black paint is laid on first and the white paint is superposed: the white paint cannot be given many coats, as graduations are made by scraping off the white and exposing the black surface, and the machine does not remove successive layers satisfactorily.

The levelling staves have been numbered in a variety of different ways: some have been distinguished as No. 1, No. 2, No. 3, etc.; others as I, II, III, etc.; others as 01, 02, 03, etc.; others as B 1 and B 2; others as 15 A and 15 B; and others have been named A, B, C, D, etc. If the numbering had been left to the levelling officers, a system would have doubtless been devised, but the staves were given their numbers in the workshops at Roorkee and Calcutta.

Four different patterns of staves have been designed for the levelling operations in India: they are known as—

(1).	Walker's pattern ...	introduced in	1858*
(2).	Cowie's pattern ...	,,	1902
(3).	The Committee's pattern	,,	1906
(4).	Single-faced pattern ...	,,	1907

* Known also as the Great Trigonometrical Survey pattern.

Walker's pattern.

The staff designed by General Walker was introduced in 1858 and is still in use in 1909. This staff was graduated on both sides, one face being painted white with black divisions and graduated to hundredths of a foot from 0 to 10·00 feet, the other face being black, with white divisions, and divided from 5·55 to 15·55 feet. It was shod and capped with brass, the extreme graduations being laid off on the brass. It was supplied with a plummet let into its side and visible through a glass door, so that it might be adjusted to within an inch or two of the true perpendicular, and it was held in position by ropes attached to a swivel on its summit. General Walker's staff is shown in Plate VII and his system of graduation is illustrated in Plates VIII and IX.

The following explanatory extracts are taken from General Walker's original memoranda:—

The most probable source of error being in reading the levelling staves, the precaution was taken of making up staves specially figured, so as to check the readings. They were painted and divided on both faces to feet, tenths, and hundredths, one face having a white ground with black divisions, numbered from 0 to 10, the other having a black ground, with white divisions, numbered from 5·55 to 15·55. When such a staff is set up, the readings of the black and white faces, as they are presented in succession to the observer, should differ by the constant quantity 5·55. If the telescope wire intersects the commencement of a foot on one face, it will intersect the middle of an entirely different foot on the other, and consequently the observer cannot be biassed to repeat, in the second reading, a mistake which he may have made in the first. Any error, in either reading, is immediately shown up by the deviation of their difference from its normal amount 5·55, or in practice by the difference in the resulting rise, or fall, obtained from the pairs of black and white face readings, which ought to give coincident results.

The units of the levelling staves must be determined in terms of the 10-foot standard of the G. T. Survey. For this purpose a portable metal bar on which the length of the standard bar has been laid off, is taken with each party of levellers. The staves should be compared with it at least twice during the course of the season, *viz.*, at the beginning and end of the season's work. It is also advisable that additional comparisons be made every six weeks or two months, especially if the rise or fall is great, and the value of the work likely to be affected by the slight variations in length to which the staves are liable. As the wood of the staves has a tendency to shrink, a partial separation from the brass at the ends may be caused. In this case an exact foot should be taken off, with a beam compass, from any of the intermediate feet (1 to 9) all of which are defined by dots on brass pins let into the staff and the spot where one end of the compass falls on the brass should be marked, the other end being on the nearest foot. The mark will indicate the true position of the zero before separation, and if it is referred to when the staff is compared with the portable standard, no corrections for the separation will be required.

In choosing staves, at the commencement of the field operations, the observer must be careful to examine the differences between the zeros of the black and white faces of each staff. In most staves it is 5·55, but in some it is 5·60 feet; both of a pair should have the same difference in common, otherwise the observer will be perplexed and delayed by troublesome discrepancies between the results from black and white faces.

The staves must invariably rest on wooden pins driven very firmly into the ground. A hemispherical brass brad should be let into the head of each pin after it is driven, to offer a point, instead of an uncertain surface, for the staves to stand on, that they may be rotated freely, and each face presented in succession to the observer. The brad also affords a common point of reference for the successive observers, whose results may thus be compared rigorously station by station.

A satisfactory shoe for a staff is most difficult to design. General Walker's staves were shod with brass, and their soles were smooth and flat. The makers had difficulty in setting the plane of the sole truly perpendicular to the axis of the staff, and in old staves the brass shoes showed signs of wear.

In different staves the distances of their zeros above the soles of their brass shoes are not always the same. In order to guard against errors arising from this source, it has since 1900 been the practice, when closing on any bench-mark, to arrange the stations so as to bring on to the bench-mark that particular staff, which was placed on the origin. Levellers call this staff their "principal staff".

The necessity for always placing the principal staff on a bench-mark may be explained as follows:— if h_1 is the reading of No. 1 staff erected on a bench-mark, and h_2 is the reading of No. 2 staff on a neighbouring peg, and if z_1 is the distance of the zero of No. 1 staff above the surface of its bench-mark and z_2 the distance of the zero of No. 2 staff above its peg then the *observed* difference of level will be $(h_2 - h_1)$; the *true* difference of level will be $(h_2 + z_2) - (h_1 + z_1) = (h_2 - h_1) + (z_2 - z_1)$. For the deduced difference of level between two bench-marks to be correct, the quantity $(z_2 - z_1)$ must enter into the sum of the differences of elevation $\Sigma(h_2 - h_1 + z_2 - z_1)$ as many times with the negative sign as it does with the positive.

In the early days of levelling operations General Walker recognised how necessary it was, that the flat brass soles of the staves should rest upon level surfaces, and that the staves themselves should be free to rotate easily on their axes, as the different faces came to be presented in succession to the observer. To attain these objects General Walker introduced what has been known in the Survey as the "brad". The so-called brad was a small metal hemisphere, one quarter of an inch in diameter. Some brads were made with flat bases, and these were reserved for use upon the level surfaces of bench-marks; other brads were given nails projecting from their bases, and were intended to be driven and fixed into the heads of wooden pickets. When a staff was erected upon a picket, the brad formed a permanent part of the picket and was not liable to produce error. But the loose brad inserted by the staff-holder below his staff, whenever the latter was erected upon a bench-mark, was not a good design. Although precautions were taken in the first instance to secure brads of hard metal and uniform dimensions, yet in course of years different sized brads varying in diameter from a quarter to three-eighths of an inch came into use, and the staff-holders were no longer careful in their choice. These men used to carry several brads with them, some of which were new, and others very worn, and whenever a stone bench-mark was reached, they would produce a brad from their pocket at random. The use of a small brad at one bench-mark and of a larger brad at another has the same evil effect as unequal distances between zeros and soles of staves, to which reference has already been made.

In 1899 Captain Crosthwait raised several questions concerning the construction of levelling staves. Walker's pattern of staff had then been in use for 40 years, and although on the whole it had proved a very satisfactory instrument, inaccuracies in the make and in the graduation of particular staves had been brought to light. Prior to 1899 no staves had been made for many years, and in that year Captain Crosthwait found that it was necessary to replenish his stock. He obtained two new staves from the canal foundry at Roorkee, but on testing their graduations he came to the conclusion that the Roorkee machine was no longer sufficiently accurate. He found errors of 0·004 foot in 10 feet on both these staves, and these discoveries led him to examine some of the older Roorkee staves. In the lengths of one or two of the latter, errors even of 0·01 foot were discovered. These errors, it is true, were progressive rather than variable, and were to a great extent nullified by the periodical comparisons in the field between the staves and the standard bar. The Mathematical Instrument Office at Calcutta examined several staves and reported that the Roorkee graduations had been carefully carried out. But the staves had been made many years before, the Roorkee cutting instrument was now showing signs of wear, and Captain Crosthwait decided that modern levelling of precision demanded something better.

Cowie's pattern.

In 1899 Captain H. McC. Cowie, R.E., who was one of the levelling officers in Bengal, drew the attention of the Superintendent of Trigonometrical Surveys to the difficulty of observing a level staff at such a great distance as 12 chains (792 feet or 240 metres). This distance had been considered permissible, but Captain Cowie pointed out that the white face of the staff was barely readable, and that the black face could not be properly used at all. Staves were then tested at different distances at the Trigonometrical Survey Office at Dehra Dun, and Captain Cowie's contentions were confirmed. One fact there was however that required explanation, and that was, that distances of 12 chains had been employed for over 40 years without complaint or comment.* The first explanation was that men had been selected to be levelling officers on account of the keenness and strength of their sight, and the second was that distances of 12 chains and over had only been introduced under exceptionally favourable atmospheric conditions. The levellers had moreover been continually employed upon the same work, and had become

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* The staves were often erected in former days at distances from the level exceeding 12 chains (792 feet or 240 metres): the records show that distances of 14 chains (924 feet or 280 metres) were common, and that even 19 chains (1254 feet or 380 metres) and more have at times been introduced.

In 1863 General Walker wrote: "The staves are set up at distances of 8 to 10 chains of links, from the instrument, in the morning, and four "to five chains, later in the day. At 10 chains, 0·001 of a foot is easily estimable, with a power of 40, when the atmosphere is clear and steady. Twice "that quantity is with difficulty estimable at half the distance in the heat of the day, when the staves appear to dance, and the irradiation of the "white divisions over the black, causes much distortion in the appearance of the divisions, and greatly increases the difficulty of reading.

" During the course of the operations, the Karachi harbour, and several large rivers were crossed. The longest distance, between instrument and "staves, was 34 chains (of links), which occurred at Karachi; over rivers, the distances were rarely more than 17 chains. The uniformity and steadiness "of the strata of the atmosphere, over a large body of water, enable satisfactory readings to be taken at distances which would be hopelessly "impracticable over land".

On the precise levelling of the United States Coast Survey the staff-distances were allowed to "range from 50 to 150 metres according to the "condition of the weather and atmosphere". The U. S. Engineers follow the rule, "the rod should always be near enough to be seen distinctly. It will "be seldom that lengths of sight greater than 150 metres can be taken." In the Prussian Land Survey since 1879 the length of sight has not been taken over 50 metres. Wright's *Adjustment of Observations*, 1st Edition, p. 375.

experienced and dexterous. Mr. Bond, who had worked as a levelling officer for many years, showed also that he could overcome the difficulty of reading the wire against a black graduation,—a difficulty that was greatly intensified on the black face of the staff—by altering the level of the instrument and by thus bringing the wire against a white graduation.

But all these explanations combined are insufficient; the real reason, that the distance of the staff has been reduced, is that a higher degree of precision for spirit-levelling is now demanded than was formerly considered necessary, and that this degree is not attainable at distances of 12 chains. The maximum distance now allowed between level and staff is 5 chains (330 feet or 100 metres).

The reduction of the maximum staff distance to 5 chains does not retard the progress of the work to the same extent as had been anticipated. The staff is more easily read by the observer at short distances, and the loss of time from the more frequent settings of the instrument is largely compensated by the quicker readings.*

In 1900 Captain Cowie submitted a new design for a levelling staff: and in 1901 three pairs of staves of this new pattern were made at the Mathematical Instrument Office of the Survey of India at Calcutta. The main points of Cowie's design may be specified as follows:—

TABLE IX.

	Cowie's pattern.	*Walker's pattern.*
(i)	Both faces white; but for purpose of distinction the 12·5-inch unit face was given a broad red line down the full length of the staff on the side remote from the figures.	One face white, one face black.
(ii)	Zero of graduation on both faces the same.	Zero of graduation on the two faces differing by 5·550 feet.
(iii)	Unit of graduations on one face to be the foot, that on the other face to be 12·5 inches.†	Unit of graduations to be the foot on both faces.
(iv)	Zero of graduations on the wood of the staff.	Zero of graduation on the brass shoe.
(v)	Graduations were at first intended to be made according to the system illustrated in Plate X, but owing to the difficulty of cutting the chequer pattern the Mathematical Instrument Office adopted the system illustrated in Plate XI.‡	Graduations according to the system illustrated in Plate IX.
(vi)	Foot numbers inverted on the staff.	Foot numbers upright.
(vii)	Plummet to be hung between the 4-foot and 6-foot graduations.	Plummet hung between the 2-foot and 3-foot graduations.
(viii)	The shoe of the staff to be provided with a steel projecting pin, 0·625 inch in diameter.	Shoe of staff to be flat.
(ix)	A small brass cup or socket to be placed on each bench-mark and peg to receive the projecting pin.	A hemispherical brad to be placed on each bench-mark and peg for the flat shoe to rest upon.

* *See* page 375, Wright's *Adjustment of Observations*, 1st Edition: "Better work is to be looked for, if short sights are taken. Even with a first-"rate telescope sights should not be taken to exceed 100 metres".

† The second unit was at first proposed to be 13 inches, but at the request of the Mathematical Instrument Office was reduced to 12·5.

‡ Mr. Theakstone, the Mathematical Instrument maker at Calcutta tested Cowie's original system of graduation, which will be seen from Plate X to be a chequer of black and white, and expressed his opinion as follows: "There appeared to be far too many lines about, and they all seemed to be "running into one another. In graduating staves it is much easier to cut a line through and have done with it than to cut to the centre, move one "division, and then cut from the centre".

Cowie's original design of a chequer pattern of graduation was never introduced. The great advantage that he claimed for this system of graduation was, that wherever the intersecting wire might be, it would always be against some white graduation, and cut a vertical edge of black; this advantage was held to remove the difficulty of reading to the 1000th of a foot, which levellers had experienced when using the black graduations of Walker's staff. In spite however of this point in its favour the difficulty of cutting the chequer was so great as to lead to its abandonment.

Cowie's design for the socket gave rise to differences of opinion. He made the upper surface of his socket concave or cup-shaped to receive the pin from the staff, and the lower surface flat. To those sockets intended for use upon pegs he added a pin projecting from below which was designed to fit tightly into a hole in the receiving peg. It was considered that if the socket pin were fitted exactly into the hole of the peg, the levellers might be uncertain whether the socket were really home upon the head of the peg, and it was thought best to make the socket pin not only shorter but considerably smaller than the hole, so that it would fit in loosely and be merely used to prevent the socket from falling off the peg.

Captain Cowie inverted the foot-numbers so that they might appear direct when viewed through a telescope.

Cowie placed the zero of graduation upon the wood of the staff, because in dry weather a slight parting had been noticed to occur in some staves between the wood and the brass shoe. Three advantages resulted from the adoption of this position of the zero: (i) the zero error of the staff remained constant: (ii) more accurate comparisons against the standard bar were rendered possible. (iii) The possibility of observations being taken too near the ground was removed.

The next question that arose was whether the Mathematical Instrument Office at Calcutta would be able to graduate new staves of Cowie's modified pattern with sufficient accuracy. In November 1900 the machine was employed to graduate an electrum bar, and the graduations so cut were then compared with a new standard 10-foot bar by Troughton and Simms. Throughout the first 2·9 feet the graduations were accurate, accidental errors of 0·0005 foot being apparent: between 2·9 and 3·0 feet the machine divided too long, and graduations that should have been 0·01 foot wide measured 0·0115. From 3·0 feet to 10·0 feet the graduations were accurate *inter se*, but carried on the error generated between 2·9 and 3·0. The Assistant Surveyor General reported that the machine was not sufficiently accurate to be used for levelling staves.

It was then decided to graduate staves by means of a copying machine and to take the graduations from off the 10-foot standard bar. The leading screw of the copying machine was first tested for accuracy against the standard bar and was proved to be trustworthy. The graduations of the foot unit could be copied directly from the bar, but those of the 12·5-inch unit required a special arrangement. We required a space of 12·5 inches divided into 100 parts, and each part was therefore to be 0·125 inch wide. The leading screw had 10 threads to the inch, so that 1·25 revolutions would give the necessary width to the graduations.

By July 1901 the first pair of staves of Cowie's pattern had been made by the Mathematical Instrument Office, and these were tested against a standard bar at Dehra Dun at a temperature of 82° F.

The following table shows the errors of graduation that were discovered :—

TABLE X.

Face of Staff	Unit numbers on Staff	Errors of Y Staff	Errors of Z Staff
		foot	*foot*
The Foot unit	at 1	0·0000	0·0000
	at 2	0·0000	0·0000
	at 3	0·0000	0·0000
	at 4	−0·0006	0·0000
	at 5	−0·0012	0·0000
	at 6	−0·0015	−0·0002
	at 7	−0·0011	0·0000
	at 8	−0·0008	0·0000
	at 9	−0·0006	−0·0004
The 12·5 inch unit	at 3	+0·0004	+0·0004
	at 6	+0·0018	+0·0025
	at 9	+0·0030	+0·0030

The foot-face of Z staff was thus found to be accurately graduated, but that of Y staff was hardly passable. In both staves errors amounting to 0·003 were found on the 12·5-inch faces, and these were too large to accept. The staves were accordingly rejected. It should perhaps be mentioned that these staves were two of those which had been boiled in paraffin (page 35); the paraffin had prevented the paint from hardening and had blurred the edges between the white and the black graduations.

A second pair of staves of Cowie's pattern was then made at the Mathematical Instrument Office of well-seasoned teak, and the errors of graduation were tested at Dehra Dun in January 1902 by Mr. Ecoles and Lieut. Tillard, R. E., and were found to be as follows :—

TABLE XI.

Errors on the true interval from zero.

At unit number	No. 1 staff		No. 2 staff	
	Foot-face	12·5-inch face	Foot-face	12·5-inch face
	foot	*foot*	*foot*	*foot*
1	− 0·00040	− 0·00010	+ 0·00032	− 0·00013
2	− 0·00032	+ 0·00035	+ 0·00055	+ 0·00027
3	− 0·00059	+ 0·00086	− 0·00029	+ 0·00056
4	− 0·00097	+ 0·00087	− 0·00122	+ 0·00078
5	− 0·00139	+ 0·00200	+ 0·00020	+ 0·00170
6	− 0·00076	+ 0·00308	+ 0·00017	+ 0·00242
7	+ 0·00021	+ 0·00348	+ 0·00059	+ 0·00266
8	+ 0·00098	+ 0·00374	+ 0·00045	+ 0·00375

The graduations of the foot-faces were not considered sufficiently accurate, and those of the 12·5-inch faces had obviously to be rejected.

The Mathematical Instrument Office then asked that a definite degree of precision should be specified for staff graduations; whilst future work, it was explained, would be carried out as accurately as possible and whilst no superior limit to precision would be fixed, the instrument maker wished to be instructed as to the inferior limit, below which all staves would be rejected. It became necessary then to lay down a definite limit of error, and as the operation of scraping paint off a staff is essentially rougher than that of engraving a metal limb, it was recognised that no unduly refined nor impracticable limit could be fixed.

Eventually it was decided that the distance of any graduation from the zero should not be in error by more than 0·0006 foot, and this limit has now been generally accepted.

One very important step in the dividing of a staff is the location of its first graduation. The distance of the first graduation above the lower end of the pin of the shoe should not only be the same for the two faces of a staff, but should be invariable in different staves. This distance is now obtained mechanically with great accuracy.

A third pair of staves of Cowie's pattern was now made at Calcutta, and tested by Mr. Eccles at Dehra Dun against the standard steel bar by means of the comparing microscopes: two of the old Roorkee staves were also tested at the same time to see to what extent they conformed to the newly fixed standard of precision. Table XII gives the results.

TABLE XII.

Errors on the true interval from zero.

At unit number	Steel Standard bar	Staves graduated at Calcutta				Staves graduated at Roorkee	
		Staff α		Staff β		Staff No. 11	Staff (new)
		Foot-face	12·5-inch face	Foot-face	12·5-inch face		
feet		*foot*	*foot*	*foot*	*foot*	*foot*	*foot*
0·5	0·0000	− 0·0002	0·0000	0·0000	− 0·0001	+ 0·0015	+ 0·0008
1·0	0·0000	0·0000	+ 0·0002	+ 0·0002	− 0·0002	0·0013	0·0009
1·5	0·0000	− 0·0002	+ 0·0004	+ 0·0007	− 0·0002	0·0021	0·0017
2·0	− 0·0001	− 0·0002	+ 0·0005	+ 0·0010	+ 0·0002	0·0024	0·0015
2·5	0·0000	− 0·0001	+ 0·0006	+ 0·0013	0·0000	0·0028	0·0019
3·0	0·0000	+ 0·0001	+ 0·0009	+ 0·0015	+ 0·0002	0·0028	0·0019
3·5	− 0·0001	− 0·0001	+ 0·0010	+ 0·0020	+ 0·0004	0·0024	0·0019
4·0	− 0·0001	0·0000	+ 0·0011	+ 0·0024	+ 0·0004	0·0026	0·0018
4·5	− 0·0001	− 0·0001	+ 0·0012	+ 0·0025	+ 0·0007	0·0031	0·0026
5·0	− 0·0002	− 0·0002	+ 0·0014	+ 0·0026	+ 0·0009	0·0033	0·0027
5·5	− 0·0002	− 0·0003	+ 0·0014	+ 0·0029	+ 0·0011	0·0035	0·0035
6·0	− 0·0002	− 0·0006	+ 0·0016	+ 0·0031	+ 0·0013	0·0042	0·0035
6·5	− 0·0002	− 0·0006	+ 0·0017	+ 0·0030	+ 0·0014	0·0042	0·0040
7·0	− 0·0001	− 0·0004	+ 0·0018	+ 0·0032	+ 0·0017	0·0041	0·0041
7·5	− 0·0002	− 0·0005	+ 0·0020	+ 0·0037	+ 0·0019	0·0042	0·0042
8·0	− 0·0001	+ 0·0001	+ 0·0024	+ 0·0035	+ 0·0023	0·0041	0·0042
8·5	− 0·0001	+ 0·0006	+ 0·0026	+ 0·0032	+ 0·0025	0·0044	0·0056
9·0	0·0000	+ 0·0012	+ 0·0029	+ 0·0032	+ 0·0027	0·0040	0·0055
9·5	0·0000	+ 0·0019	+ 0·0030	+ 0·0033	+ 0·0029	0·0043	0·0056
10·0	+ 0·0001	+ 0·0027	...	+ 0·0032	...	0·0044	...

For the purpose of testing the accuracy of staves, the graduation of the steel bar may be accepted as errorless, its greatest error exhibited in the above table being 0·0002 foot.

The foot-face of the Calcutta Staff *a* was shown by Mr. Eccles to be practically correct, although the care with which it had been graduated had been relaxed after the 8·5 foot had been passed. From 0·0 to 8·5 feet no error could be found larger than 0·0006 foot.

The foot-face of the Calcutta Staff β was fairly correct up to 1·5 feet: then an error of 0·0010 crept in, which increased to 0·0020 at 3·5 feet, and to 0·0031 at 6·0 feet, thereafter remaining constant at about 0·0032. The foot-face of this staff had clearly not been graduated with the same extreme care and skill as that of staff a.

The 12·5-inch faces of staves a and β both exhibited considerable progressive errors, larger than admissible. The graduation of the Roorkee staves was very inferior to that of the Calcutta.

The excellent results on the foot-face of staff a showed that the Mathematical Instrument Office possessed the means of graduating staves within the limit of error laid down.

The Committee's pattern.

In 1904 Captain Turner, who was in charge of the levelling operations, found that the levelling officers after trial in the field preferred Walker's pattern of staff to Cowie's pattern and owing to their criticisms of the latter he submitted a new design.

The Superintendent of Trigonometrical Surveys referred Captain Turner's proposals to a committee, and the following extracts are made from his order appointing the committee:—

Debra Dun, dated 3rd August, 1904.

The following Committee of Officers is appointed to consider the design of levelling staves:—

Major Lenox Conyngham ... ... President.
Captain Fraser
Captain Turner
Captain Wood

For forty years General Walker's pattern of staff was in use in the Department. In 1900 it was pointed out that the wire was not clearly visible against the black face of this staff, and it was decided to get rid of the black face. Captain Cowie then designed a new staff: he altered the brad, the foot, the plummet and the form of graduation: he got rid of General Walker's difference in zero, and substituted a difference of unit. Captain Turner now proposes to alter again the brad, the foot, the plummet and the graduation: he further proposes to get rid of the difference of unit and to go back to the difference of zero.

No personal questions are involved: all the various patterns of staff have some advantages and some disadvantages, and different observers will weigh the pros and cons differently. What as a department we have to do is to make up our minds and to settle on a staff. We cannot allow the experimental stage to go on indefinitely. We want to avoid multiplicity of patterns, and we want to attain finality and uniformity. A staff is only a means to an end, and the question that the Committee has to consider is: how can that end be attained most accurately, and most economically.

The construction and graduation of a staff is a difficult matter: Captain Cowie's staves have been made in the Mathematical Instrument Office under the personal and almost daily supervision of Colonel Gore and Colonel Longe. The Mathematical Instrument Office has studied this particular pattern, but constant variations in pattern will be puzzling and confusing.

S. G. BURRARD.

After hearing the opinions of all the levelling officers the Committee issued the following report:—

Proceedings of a Committee appointed by order of the Superintendent Trigonometrical Surveys, to consider the design of levelling staves to be used for levelling of precision in the future.

Points for discussion.

The Committee had the following points put before them for discussion and final decision.

(i). Alteration to plummet box and to its position on the staff.
(ii). Alteration to the foot of the staff and brads.
(iii). The question of change of zero or change of unit on the two faces of the staff.
(iv). The nature of the graduations.

The Committee decided that—

The Plummet.

(a). The outer side of the plummet box should consist of a hinged door, so that the plummet could be easily handled if necessary.

(b). The staff should have an extra hole for the button of the plummet box below the present two, at such a distance from the lower of these that this latter will act as the lower hole for the plummet box in its upper position and as the upper hole in its lower position.

The brads and bottom of staff.

(c). The bottom of the staff to remain as at present with a steel pin, about 1 inch long and $\frac{3}{8}$ inch diameter, projecting from its centre.

The Committee desire to draw attention to the advisability of making the distance from the end of the pin to the zero of the staff exactly equal for all staves of a set.

(d). The brad to be altered in accordance with the design in the sketch in the margin; (*see* Plate XIII).

The Committee's reasons for altering the brad are:—

(1). That the staff pin should rest on a flat surface, and not in a cup.

(2). That the staff pin should be made to rest, as nearly as possible, always on the same point.

(3). That the bottom of the brad should rest on its outside edge.

(4). That the brad pin should not be longer than ½ inch, and should fit loosely into a hole in the peg larger and deeper than itself.

Change of unit and Change of zero.

The Committee then discussed under the three headings a, b, c, the question as to whether a change of unit on the two faces of the staff was preferable to a change of zero.

(a). Whether there is bias on an observer's part.

The conclusion that the Committee arrived at was, that when there was a change of zero there must always be a liability to bias. On this point therefore the change of unit was preferable to the change of zero.

(b). Whether a difference of unit gives rise to an appreciable error in conversion.

The Committee decided that any error due to conversion was so small that it might be neglected, and furthermore, that such an error was a cancelling error.

(c). Whether a change of unit throws an appreciable amount of extra work upon the recorder, whether an appreciable amount of extra time is taken up in the conversion, and whether the conversion might lead to serious mistakes in the computations in the field.

The Committee decided that none of the above objections was strong enough to override the superiority of the change of unit over the change of zero.

The present levellers of the levelling detachment were then questioned. They differed in their opinions as to the relative merits of change of zero and change of unit. The Committee after considering their evidence upheld their former decision, namely, that change of unit was better than the change of zero.

Change in the manner of graduating the staff.

The Committee discussed the subject of change of graduation, and had several designs prepared, and finally after trial in the field selected the pattern of which a drawing is shown (Plate XII). The most important alteration in this new pattern was the abolition of red, which had been found to be more difficult to see at a distance than black. The other alterations were:—

(1). Stepping the graduations so as to distinguish the low decimals from the high.

(2). Placing a dot in the centre of the staff instead of having one on each side.

(3). Putting the figures denoting feet on the opposite side of the graduations from those denoting tenths. In order to give room for these figures, the central white strip has been shifted ⅛ inch to one side of the centre line of the staff. The black divisions denoting feet cross the centre white strip of the staff, but are broken on each side giving white spaces on which intersections can be made. The divisions denoting tenths are carried to the edge of the staff on the side on which the corresponding figures are, but are not carried through on the other side. In order to avoid the confusion which sometimes arises through the similarity of 6 and 9 the sixth foot to be numbered in Roman numerals, thus:—VI.

(4). The faces are distinguished by one of them having a black strip ⅜ inch wide on the same side as the foot numerals: this black strip is broken at each foot figure.

Nature of Unit.

The above questions having been settled the Committee finally considered whether the units at present in use were the most suitable, and came to the conclusion that they were satisfactory in use and easy of manufacture: furthermore, they did not consider it necessary that in addition to the different units the faces should commence their graduations from different zeros.

G. P. Lenox Conyngham, *President.*
H. H. Turner,
H. A. Denholm Fraser,
H. Wood. } *Members.*

Mussooree.
26th August, 1904.

Single-faced pattern.

In 1907 the introduction of the American binocular level led to the abandonment of the 12·5-inch face of the staves. The three intersecting wires of the American instrument render the second face of the staves unnecessary. A triple intersection of one face of the staff provides a mean reading as accurate as that derived from a single intersection of two faces. The triplication of the intersecting wires is as certain a safeguard against mistakes in reading of whole feet or of whole tenths as the use of different zeros or different units on two faces. The pattern of levelling staff that is now being made for the Trigonometrical Survey of India is single-faced, and is given the Committee's system of graduation, as illustrated in the foot-face drawing of Plate XII. The following table describes the principal features in the graduations of the four patterns of staves that have been used at different times in India.

TABLE XIII.

Walker's pattern introduced 1858						Cowie's pattern introduced 1902						Committee's pattern introduced 1906						Single-faced pattern introduced 1907		
White face			Black face			Foot-face			12·5-inch face			Foot-face			12·5-inch face			Single face		
Unit	Extreme graduations	Divisions	Unit	Extreme graduations	Divisions	Unit	Extreme graduations	Divisions	Unit	Extreme graduations	Divisions	Unit	Extreme graduations	Divisions	Unit	Extreme graduations	Divisions	Unit	Extreme graduations	Divisions
Foot	0 to 10 feet	tenths and hundredths of a foot	Foot	5·550 to 15·550 feet	tenths and hundredths of a foot	Foot	0 to 10 feet	tenths and hundredths of a foot	12·5 inches	0 to 9·6 units	$1\frac{1}{4}$ inches and $\frac{1}{8}$th of an inch	Foot	0 to 10 feet	tenths and hundredths of a foot	12·5 inches	0 to 9·6 units	$1\frac{1}{4}$ inches and $\frac{1}{8}$th of an inch	Foot	0 to 10 feet	tenths and hundredths of a foot

Comparisons of Staves in the field.

Each levelling detachment carries with it a 10-foot Standard iron bar without which the instrumental equipment would be incomplete. Each staff is compared periodically with the standard bar, and its error of length determined.

The comparisons are made by two observers, who make independent measures of the differences in length between the standard bar and the staves by means of finely graduated scales.

The following figures have been extracted from levelling records of the season 1900-01, and will show how the true lengths of staves are determined.

COMPARISON OF STAVES (Used by 1st Leveller).

Value of 10-foot Standard Bar No. 3 { Edge A=10·0011264 ; „ B=10·0007801 } At 62° Fahrenheit.

Factor of Expansion=0·0000064 per degree per foot.

TABLE XIV.

Place and date of comparison.	Temperature.	Edge of standard bar.	Staves. Number of staff.	Staves. Face of staff.	Correction for temperature to standard bar.	Correct length of standard bar when observations were made.	Difference between staves and standard bar (staff—bar).	Corrected value of staves.	Mean of both faces on different edges.	Mean of values on edges A and B.	Difference of length of staves from 10 feet.	Mean difference of length of pairs of staves from 10 feet.	Mean correction for 10 feet for pairs of staves used in section.	REMARKS.
	F.				*foot*	*feet*	*foot*	*feet*	*feet*	*feet*	*foot*	*foot*	*foot*	
Damukdia, 9th November, 1900.	83·3	A	B 1	White	+0·0013632	10·0024896	+0·0017000	10·0041896	10·0037428	10·0039838	+0·0039838	+0·0028639		
	83·4	A	„	Black	0·0013696	·0024960	+ ·0008000	·0032960						
	83·3	B	„	White	0·0013632	·0021433	+ ·0024000	·0045433	10·0042247					
	83·5	B	„	Black	0·0013760	·0021561	+ ·0017500	·0039061						
	83·0	A	B 2	White	0·0013440	·0024704	·0000000	·0024704	10·0015172	10·0017440	+0·0017440			
	82·9	A	„	Black	0·0013376	·0024640	− ·0019000	·0005640						
	83·0	B	„	White	0·0013440	·0021241	+ ·0004500	·0025741	10·0019709					
	82·9	B	„	Black	0·0013376	·0021177	− ·0007500	·0013677						
Jaypur, 10th February, 1901.	67·0	A	B 1	White	0·0003200	·0014464	+ ·0020000	·0034464	10·0028010	1·00029099	+0·0029099	+0·0015517	+0·0022078	= correction for levelling between Damukdia and Jaypur.
	64·8	A	„	Black	0·0001792	·0013056	+ ·0008500	·0021556						
	67·5	B	„	White	0·0003520	·0011321	+ ·0021000	·0032321	10·0030187					
	66·3	B	„	Black	0·0002752	·0010553	+ ·0017500	·0028053						
	70·0	A	B 2	White	0·0005120	·0016384	− ·0008500	·0007884	10·0001538	10·0001934	+0·0001934			
	69·7	A	„	Black	0·0004928	·0016192	− ·0021000	9·9995192						
	69·8	B	„	White	0·0004992	·0012793	− ·0001500	10·0011293	10·0002331					
	70·7	B	„	Black	0·0005568	·0013369	− ·0020000	9·9993369						
Siliguri, 26th April, 1901.	72·1	A	B 1	White	0·0006464	·0017728	+ ·0006000	10·0023728	10·0020164	10·0015247	+0·0015247	+0·0002618	+0·0009067	= correction for levelling between Jaypur and Siliguri.
	71·9	A	„	Black	0·0006336	·0017600	− ·0001000	·0016600						
	72·4	B	„	White	0·0006656	·0014457	+ ·0000500	·0014957	10·0010329					
	72·0	B		Black	0·0006400	·0014201	− ·0008500	·0005701						
	72·8	A	B 2	White	0·0006912	·0018176	− ·0024000	9·9994176	9·9987144	9·9989989	−0·0010010			
	72·7	A	„	Black	0·0006848	·0018112	− ·0038000	·9980112						
	72·6	B	„	White	0·0006784	·0014585	− ·0015500	·9999085	9·9992835					
	72·6	B	„	Black	0·0006784	·0014585	− ·0028000	·9986585						

The above table has only been prepared to show the comparisons of the staves B 1 and B 2: the staves No. 4 and No. 15 were also compared with the standard bar at the same places and on the same dates.

The following tables give the results of the comparisons of staves made between 1903 and 1907.

TABLE XV.

Results of Comparison of Staves—Season 1903-04.

Place and Date of Comparison.				Staff No. 04.	Staff No. 05.	Staff No. 01.	Staff No. 03.
				foot	*foot*	*foot*	*foot*
Shwebo,	6th	November	1903	+ 0·0027293	+ 0·0039244	− 0·0000224	+ 0·0004831
Madaunghla	15th	,,	,,	+ ·0021079	+ ·0032934	− ·0001364	− ·0003206
Tangôn	24th	,,	,,	+ ·0018602	+ ·0031322	− ·0008383	− ·0003103
Kanbalu	28th	,,	,,	+ ·0020582	+ ·0029113	− ·0003451	− ·0008574
Pintha	8th	December	,,	+ ·0017063	+ ·0030655	− ·0007848	− ·0007876
Kawlin	21st	,,	,,	+ ·0016336	+ ·0027101	− ·0012633	− ·0013353
Wuntho	25th	,,	,,	+ ·0013930	+ ·0027477	− ·0007209	− ·0005313
Myitngè	4th	January	1904	+ ·0016020	+ ·0029974	− ·0011134	− ·0006649
Singaing	11th	,,	,,	+ ·0016140	+ ·0025780	− ·0007706	− ·0007092
Kumè Road	26th	,,	,,	+ ·0010336	+ ·0016399	− ·0017930	− ·0021755
Samôn	3rd	February	,,	+ ·0010046	+ ·0019103	− ·0016129	− ·0017299
Hunza	12th	,,	,,	+ ·0010925	+ ·0015939	− ·0020421	− ·0019813
Nyaungyan	22nd	,,	,,	+ ·0001146	+ ·0008011	− ·0028112	− ·0035322
Pyawbwè	29th	,,	,,	+ ·0001791	+ ·0009978	− ·0025147	− ·0031615
Shweda	6th	March	,,	+ ·0002766	+ ·0007580	− ·0030388	− ·0032780
Hngetthaik	13th	,,	,,	− ·0002997	+ ·0002536	− ·0036836	− ·0038645
Tatkôn	21st	,,	,,	− ·0005745	+ ·0000243	− ·0038338	− ·0046403
Pyôkkwe	31st	,,	,,	− ·0000629	+ ·0005260	− ·0038538	− ·0042036
Pyinmana	12th	April	,,	− ·0004839	+ ·0002377	− ·0035188	− ·0041205
Dehra Dun	29th	,,	,,	− ·0000461	+ ·0006098	− ·0034487	− ·0029614
Rajpur	9th	May	,,	− ·0009712	− ·0003842	− ·0048974	− ·0045725
Bhatta	16th	,,	,,	− ·0007759	− ·0003997	− ·0049518	− ·0048908
Mussooree	23rd	,,	,,	− ·0010676	− ·0004736	− ·0052767	− ·0050703
Mussooree	31st	,,	,,	− ·0007213	− ·0000689	− ·0048682	− ·0048367

It will be noticed that the several staves varied in length together. Their lengths responded slowly to variations in atmospheric humidity.

TABLE XVI.

Results of Comparison of Staves—Season 1904-05.

Place and Date of Comparison.				Staff No. 04.	Staff No. 05.	Staff No. 01.	Staff No. 03.
				foot	*foot*	*foot*	*foot*
Sujawal	4th	November,	1904. ...	+ 0·0007049	+ 0·0016333	− 0·0023977	− 0·0024103
Mirpur Batoro	13th	,,	,, ...	+ 0·0004124	+ 0·0014158	− 0·0029713	− 0·0028060
Bulri	21st	,,	,, ...	+ 0·0004951	+ 0·0010168	− 0·0032847	− 0·0035585
Tando Muhammad Khan	2nd	December,	,, ...	− 0·0001807	+ 0·0004141	− 0·0037720	− 0·0044737
Tando Muhammad Khan	8th	,,	,, ...	− 0·0003322	+ 0·0001773	− 0·0041505	− 0·0047086
Hyderabad (Sind)	17th	,,	,, ...	− 0·0006053	− 0·0000083	− 0·0044143	− 0·0047397
Hyderabad (Sind)	24th	,,	,, ...	− 0·0003079	+ 0·0000702	− 0·0042079	− 0·0039343
Kotri	31st	,,	,, ...	− 0·0002479	+ 0·0002270	− 0·0040604	− 0·0042355
Khatian Road	8th	January,	1905. ...	− 0·0004695	+ 0·0000025	− 0·0043192	− 0·0043568
Allahdino Sand	15th	,,	,, ...	− 0·0008912	− 0·0005038	− 0·0048319	− 0·0054163
Udero Lal	21st	,,	,, ...	− 0·0008611	+ 0·0001090	− 0·0042348	− 0·0046487
Shahdadpur	29th	,,	,, ...	− 0·0009145	− 0·0000957	− 0·0044017	− 0·0047550

TABLE XVI.—(Continued).

Results of Comparison of Staves—Season 1904-05.

Place and Date of Comparison.			Staff No. 04.	Staff No. 05.	Staff No. 01.	Staff No. 03.
			feet	*feet*	*feet*	*feet*
Lundo	4th February, 1905	...	− 0·0004469	+ 0·0003219	− 0·0040639	− 0·0043624
Nawabshah	17th "	" ...	− 0·0006147	− 0·0001084	− 0·0042644	− 0·0047770
Bandhi	26th "	" ...	− 0·0010861	− 0·0002359	− 0·0045512	− 0·0052949
Pad Idan	6th March	" ...	− 0·0007566	− 0·0001974	− 0·0044550	− 0·0051519
Bhiria Road	12th "	" ...	− 0·0008483	− 0·0000295	− 0·0043512	− 0·0048638
Mahrabpur	18th "	" ...	− 0·0012184	− 0·0004044	− 0·0048325	− 0·0054762
Setharja	25th "	" ...	− 0·0011171	− 0·0005422	− 0·0050719	− 0·0054265
Tando Masti Khan	2nd April	" ...	− 0·0012021	− 0·0008842	− 0·0055062	− 0·0062458
Khairpur Mirs	9th "	" ...	− 0·0014068	− 0·0011357	− 0·0056644	− 0·0064966
Sukkur	17th "	" ...	− 0·0018971	− 0·0012161	− 0·0058163	− 0·0073911
Dehra Dun	28th "	" ...	− 0·0024133	− 0·0018525	− 0·0066556	− 0·0077980
Rajpur	5th May	" ...	− 0·0028881	− 0·0021975	− 0·0069817	− 0·0079129

TABLE XVII.

Results of Comparison of Staves—Season 1905-06.

Place and date of Comparison.		Staff No. 04.	Staff No. 05.	Staff No. 01.	Staff No. 03.
		foot	*foot*	*foot*	*foot*
Saharanpur	10th November, 1905	− 0·0000063	+ 0·0006091	− 0·0044159	− 0·0042281
Muzaffarnagar	17th " "	+ 0·0002615	+ 0·0012807	− 0·0040097	− 0·0039911
Meerut	25th " "	− 0·0004447	+ 0·0008899	− 0·0050223	− 0·0047723
Bareilly	4th December "	− 0·0001319	+ 0·0009495	− 0·0042409	− 0·0046941
Lucknow	11th " "	− 0·0005975	+ 0·0004865	− 0·0050417	− 0·0049667
Allahabad	20th " "	− 0·0001357	+ 0·0007393	− 0·0044357	− 0·0048229
Mirzapur	29th " "	− 0·0002379	+ 0·0010839	− 0·0042161	− 0·0038911
Benares	3rd January, 1906	− 0·0000287	+ 0·0010969	− 0·0037185	− 0·0038121
Gorakhpur	14th " "	− 0·0004765	+ 0·0005171	− 0·0043707	− 0·0045861
Dhubri	21st " "	− 0·0001709	+ 0·0012355	− 0·0039581	− 0·0041831
Dhubri	30th " "	− 0·0003201	+ 0·0009895	− 0·0042259	− 0·0038849
Hathras City	8th February "	+ 0·0010927	+ 0·0023895	− 0·0028855	− 0·0025855
Mursan	15th " "	+ 0·0001017	+ 0·0011331	− 0·0043355	− 0·0038041
Muttra	25th " "	+ 0·0008785	+ 0·0019785	− 0·0032433	− 0·0033619
Agra Fort	5th March "	+ 0·0008537	+ 0·0021697	− 0·0029361	− 0·0025169
Banmor	15th " "	+ 0·0005817	+ 0·0013189	− 0·0040785	− 0·0033855
Banmor	6th April "	+ 0·0004163	+ 0·0012881	− 0·0038683	− 0·0041465

TABLE XVIII.

Results of Comparison of Staves—Season 1906-07.

Place and date of Comparison.				Staff No. B1.	Staff No. B2.	Staff No. IIII.	Staff No. 4.
				foot	*foot*	*foot*	*foot*
Sholapur	8th	November,	1906	+ 0·0049974	+ 0·0015222	+ 0·0035156	+ 0·0019385
Hotgi	18th	,,	,,	+ 0·0040515	+ 0·0006494	+ 0·0013113	+ 0·0008499
Tilati	26th	,,	,,	+ 0·0042210	+ 0·0007586	+ 0·0022587	+ 0·0017272
Kadabgaon	4th	December	,,	+ 0·0034071	+ 0·0003112	+ 0·0012399	+ 0·0008106
Dudhni	12th	,,	,,	+ 0·0035707	+ 0·0004863	+ 0·0008505	+ 0·0007097
Ghangapur	19th	,,	,,	+ 0·0040457	+ 0·0005984	+ 0·0020544	+ 0·0009902
Gulbarga	27th	,,	,,	+ 0·0033750	+ 0·0000610	+ 0·0017126	+ 0·0006673
Gulbarga	3rd	January	1907	+ 0·0041799	+ 0·0007816	+ 0·0032707	+ 0·0013581
Wadi	10th	,,	,,	+ 0·0039828	+ 0·0007141	+ 0·0037517	+ 0·0018891
Nalvar	18th	,,	,,	+ 0·0041137	+ 0·0007697	+ 0·0030166	+ 0·0013056
Yadgiri	27th	,,	,,	+ 0·0040801	+ 0·0005882	+ 0·0018511	+ 0·0008241
Saidapur	3rd	February	,,	+ 0·0033571	+ 0·0000589	+ 0·0020375	+ 0·0008720
Kistna	11th	,,	,,	+ 0·0035823	− 0·0000121	+ 0·0019955	+ 0·0007893
Raichur	24th	,,	,,	+ 0·0034619	− 0·0001555	+ 0·0007273	+ 0·0000474
Matmarri	3rd	March	,,	+ 0·0029297	− 0·0003253	+ 0·0007433	− 0·0002866
Kosgi	9th	,,	,,	+ 0·0030410	− 0·0005398	+ 0·0001946	− 0·0003116
Pakni	18th	,,	,,	+ 0·0026521	− 0·0004278	− 0·0004684	− 0·0007326
Mohol	25th	,,	,,	+ 0·0025574	− 0·0006645	− 0·0009535	− 0·0005552
Angar	2nd	April	,,	+ 0·0021312	− 0·0011205	− 0·0005127	− 0·0007410
Mudha	8th	,,	,,	+ 0·0020762	− 0·0010842	− 0·0009508	− 0·0009365
Mussooree	7th	May	,,	+ 0·0021079	− 0·0014599	− 0·0002135	− 0·0011389
Banog	27th	,,	,,	+ 0·0023463	− 0·0015376	+ 0·0012470	− 0·0009528
Banog	5th	June	,,	+ 0·0025175	− 0·0008574	+ 0·0015551	− 0·0005376

In 1899 and 1900 Mr. Eccles investigated the variations in the length of a staff following upon variations of humidity and temperature. His results were very interesting and are illustrated in Plate XIV. His account is published as Appendix I of this volume.

CHAPTER IV.

THE BENCH-MARKS.

In this chapter an account will be given of the bench-marks designed and erected by the Trigonometrical Survey during the last 50 years; an endeavour will then be made to collect together the results of our experiences and to ascertain in what directions the procedure adopted in the past may be improved upon.

Bench-marks have been classified in different ways at different times, but the following list covers practically all the bench-marks mentioned in Survey reports:—

(i.) Standard—introduced in 1904 only.
(ii.) Embedded.
(iii.) Inscribed.
(iv.) Metal bolts in masonry.
(v.) Reference and test.
(vi.) Stations of the Triangulation (Principal and Secondary).
(vii.) Revenue Survey stations.
(viii.) Railway: belonging to the Railway authorities: heights determined by the Survey.
(ix.) Irrigation: belonging to the Public Works Department: heights determined by the Survey.
(x.) Road: belonging to the Public Works Department: heights determined by the Survey.
(xi.) Marine: belonging to the Port authorities: heights determined by the Survey.

Standard Bench-marks.

The name "Standard" is not altogether satisfactory, in that bench-marks cut upon ground-rock are more likely to be permanent standards of height than many of the so-called "standard" marks themselves.

But the standard bench-marks were designed for erection in cities and towns only, where the overcrowding of population leads to the constant removal of marks. Cities and towns stand generally upon unconsolidated ground, and for these thickly populated centres the standard bench-mark is the most useful type. If therefore we regard India as a whole, we shall undoubtedly be able to find many rock-cut bench-marks superior as permanent records to the standard monoliths, but *within their own limited areas* these monoliths are the most reliable records of height.

Some of the standard bench-marks themselves stand upon rock: the one at Jodhpur was built with great care, and its site may be described as perfect. The standard bench-marks at Delhi, Nellore, Berhampur, Bhopal, Vizagapatam and Raichur were also located upon rock and possess sites of great value. The standard bench-mark at Attock rests upon hard shale, but not on the bed rock.

In some places the opportunity of founding the standard bench-marks upon ground-rock was unfortunately lost. At Agra rock sites were not wanting, but the standard bench-mark was built upon soft alluvium. At Mirzapur the standard bench-mark was founded upon clayey soil, when rock was in the neighbourhood.

The standard bench-mark is a stone monolith two feet square in section and three feet high; the upper two feet of stone surface are dressed; the top of the monolith is cut into the form of the frustum of a pyramid terminating in a square of three-inch sides. The centre of this square is the point of reference. The inscription

G. T. S.
Standard Bench-Mark
1908.

is engraved on one side of the monolith, the year of construction being the date given. The foundation for the monolith is a bed of concrete 6½ feet square, 2½ feet deep. Above the concrete the monolith is surrounded with masonry one foot high, and in this masonry there will be inserted a stone slab on which the height of the bench-mark is to be inscribed, thus*:—

The Height of the top of this Pillar is 941·75 feet above the Mean Level of the Sea.

The bench-mark is enclosed by iron railings.

A full account of the standard bench-marks and a list of the towns, in which they have been already erected, are given in Appendix No. 2 of this volume. It is to be hoped that many other towns will be presented with similar bench-marks in future.

The monolithic standard bench-mark came to be adopted as the best type of mark for cities in 1904, but, many years before this, six so-called "standard" bench-marks had been erected at sea-ports†. Two of these old standards are at Bombay and consist of large granite cubes; one is at Karachi and is a small circular masonry pillar‡; one is in the Survey office at Calcutta and consists of a large block of Chunar sand-stone: the fifth is at Madras, and is a mark cut on the old light-house§, and the sixth is at Rangoon and consists of a granite block‖. These so-called standards are inferior as records of height to marks cut upon ground rock; they were probably called "standards" by our predecessors in order to indicate that they were the most permanent marks *within their respective localities*.

Each standard bench-mark, old or new, has been placed in the custody of the local authority, civil or military, as the case may be.

Embedded Bench-marks.

The following extract from General Walker's earliest pamphlet ¶ on the results of Spirit-Levelling Operations in India contains a description of the embedded bench-mark as originally designed:—

That the Survey Levels might be made as generally and permanently useful as possible, care has been taken to leave bench-marks, at distances of about 10 miles apart, along the whole line. These usually consist of solid pyramidal blocks of stone weighing about 3½ maunds each, so that a pair form a convenient load for a camel**. They are invariably buried for safety, their tops being left flush with the ground level. A pile of earth is raised over the stone, and three mounds are erected around to attract the attention of any person in search of the mark. All the Trigonometrical Survey stations within reach, as well as all the Canal and Railway bench-marks, and all permanent mile-stones, in the neighbourhood of the operations, have been duly connected with the main-line of levels.

* The stone slabs have not as yet (1909) been inserted, as the final values of height have not been determined.

† *General Report, Survey of India*, 1885-86, page xxvi of Appendix. The Bombay marks are described on page XIX, *Spirit-Levelled Heights, Nos. 2 and 3, Bombay*.

‡ *General Report, Survey of India*, 1893-94, page lx. The Karachi pillar is on rock, *see Spirit-Levelled Heights, Karachi*, 1893-94, page VI.

§ *General Report, Survey of India*, 1892-93, page xxxvi. The mark cut on the Prince of Wales's memorial stone is the reference bench-mark for the tidal observatory, but has not been called a standard bench-mark.

‖ *General Report, Survey of India*, 1886-87, page xxxviii of Appendix.

¶ *Heights in Sind, the Punjab, N. W. Provinces and Central India*, to May 1862, page 28, para 42.

** Frustum of pyramid, 42 inches high, 18 inches square at base and 6 or 7 inches square at top. In *Tables of Heights in the Punjab, N. W. Provinces, and Oudh*, 1866-70, the dimensions given for the frustum are 24 inches high, 10 inches square at base and 6 inches square at top.

The earliest embedded bench-marks were generally inscribed thus:—

$$\frac{\text{G.T.S.}}{\text{B.M.}} \quad \text{or} \quad \begin{matrix}\text{G.T.S.}\\ \times \\ \text{B.M.}\end{matrix}$$

the letters being engraved on the spot where the levelling staff was erected. A few old bench-marks, carrying no inscriptions at all, have been unearthed in Sind and the Punjab.

In 1871 the embedded bench-marks were described as follows:—*

"Each block of stone laid down as a B.M. is the frustum of a pyramid about 42″ high, 18″ "square at base and 7″ square at top. The stone is imbedded so that its upper surface is 8″ to 12″ "*below* the surface of the ground, and is covered over with a pile of earth 2 or 3 feet high; but as the "latter is liable to be washed away, a paka pillar is built 8 feet from the block of stone; the plinth "of this pillar being on the same level as the surface of the B.M."

The stone B.M. at Dildarnagar Railway Station is an exception to this description, its upper surface being 2 or 3 inches *above* ground level.

In 1909 the embedded bench-mark was described as "a dressed stone 18 × 12 × 12 inches. A "small square hollow of 5-inch side was cut out of the upper surface of the stone to a depth of a quarter "of an inch to receive the foot of the levelling staff. The inscription

G.T.S.
□
B.M.
A. D. 1909

was cut upon the stone.

"The stone was fixed upon a bed of concrete 3 feet square and 2 feet deep, and was then surrounded "with brick masonry, the upper surfaces of the masonry and of the stone being flush".

The upper surface of the original type of embedded bench-mark was flush with the ground-level: the upper surface of the more recent type is generally 2 feet below ground-level†.

The embedded bench-mark is a satisfactory pattern, *provided that its site can be recovered.* Great numbers of our embedded bench-marks have been lost, because there are no means now of discovering their places of burial. They were laid down at certain distances from buildings, the distances being measured and noted, but in course of years the buildings have changed and can no longer be identified. In many cases the letters B.M. were cut upon the buildings, so that "the identification might be "un-"mistakeable"‡, but too much faith was placed in the permanence of buildings; the latter generally prove temporary structures and undergo rapid changes.

The plan of attracting attention by means of mounds of earth has proved a complete failure; these mounds disappear in a few years. The sites of embedded bench-marks on the line from Agra to Sironj were marked by mounds of earth, and none can be found now§.

On many lines, of which that from Saharanpur to Dehra Dun, and those in Cutch, Kathiawar and Guzerat are examples, the site of the embedded block has been marked by a special masonry pillar 3 or 4 feet high erected above ground very near the bench-mark, *but not over it*‖. The inscription

G. T. S.
B. M.

has been cut upon the side of the pillar facing the buried block. This system has proved on the whole to be successful in that it has enabled the sites of the blocks to be recovered, but the

* *Spirit-Levelled Heights, Punjab, N. W. Provinces and Oudh*, 1866-70, Section VII, page IV. *Spirit-Levelled Heights, Nos. 1 and 2, Madras Presidency*: the stone block was embedded in a four-foot cube of masonry.

† *Spirit-Levelled Heights, No. 1 Bombay*, gives the depth of the upper surface at 6 to 12 inches. In travellers' bungalows and railway stations the upper face of the stone is still, however, made flush with the pavement.

‡ *Vide* original instructions to levellers.

§ The sites of bench-marks embedded at Jora, Nurabad, Gwalior Residency and Gokulpur will only be recovered now by patient excavation of possibly large areas.

‖ 8 or 10 feet to one side.

mark-pillars have been mistaken at times for the bench-marks themselves, and this has led to confusion. The fault has lain in the inscriptions placed upon the referring pillars: these inscriptions have not been sufficiently precise*.

Of recent years the sites of embedded bench-marks, when near railway lines, have been marked by upright iron rail-posts, projecting 3 feet above ground level. Thin metal plates bearing the letters G. T. S. / B. M. have been fixed to the iron rails. This method may prove successful, if a length of several feet of each iron post is buried, if the plate is securely attached, if the lettering is inscribed and not painted, and if the post cannot be mistaken for the mark. But rail-posts are not superior to masonry pillars, and are to be regarded only as occasional alternatives suited to special localities.

Since 1905 the levellers have prepared a site-plan for each embedded mark, and have recorded upon it the position of the mark with regard to surrounding points.

In 1899-1900 a few lines of single levelling were carried out in Bengal by the Survey for the use of Railway engineers; the embedded bench-marks on these single lines were inscribed thus:—

G.T.S.
A.D. □ 1900
Minor.
B.M.

On the long lines of levels embedded bench-marks have been constructed at intervals of 10 miles.

All embedded bench-marks have been transferred to the safe custody of the local authorities,† but it cannot be said that this precaution has been efficacious.

In 1904 the Committee on Levelling, to which reference was made on page 42, called attention to the numerous instances in which embedded bench-marks had proved irrecoverable, and recommended that no more should be laid down. This recommendation has not as yet been adopted, for a bench-mark protected from man and weather is of a durable type: it is hoped that the abandonment of the embedded bench-marks will prove to be an unnecessary step, if permanent signal pillars are erected to indicate the sites of the buried blocks. Levellers are expected to pay great attention to the question of the permanence of the signal posts.

Inscribed Bench-marks.

Inscribed bench-marks are marks cut upon rocks *in situ*, upon coping-stones of bridges, upon tops of mile-stones, upon culverts, and other prominent land marks. In these cases the inscription

G.T.S.
O
B.M.

or

G.T.S.
B.M.

has been carved deeply into the stone; the foot of the levelling staff has been placed within the circle wherever a circle has been carved, and over the letters when no circle has been shown‡.

* The description of an embedded bench-mark, when published in a pamphlet, contains a note of the distance and direction of the referring pillar; no one reading the description can mistake the pillar for the mark. But bench-marks are shown with their heights upon maps, and as no descriptions can be entered upon maps, the pillars are often taken for the marks. The only safeguard is to indicate by means of the *inscription*, that the visible pillar is not the bench-mark. It is convenient for the masons to have one general inscription for all pillars; they can then carry with them inscribed slabs, ready to be erected, when the pillars are being built. It is difficult therefore to inscribe the exact position of each buried mark, but the following would suffice: *"A bench-mark of the G. T. S. has been buried near this pillar"*.

† For instructions on this point see *Trigonometrical Survey Hand-book*, 2nd Edition, page 266, para 43.

‡ In pamphlets published previous to 1887, a dot was shown at the centre of the circle; this was a mistake of the office. No circles with dots were inscribed as bench-marks. For circle without dot see *Spirit-Levelled Heights, No. 2, Madras*, 1887, and *No. 4, Madras*, 1889, page v.

In exceptional cases, such as the Dewan-i-Am in Delhi fort, or the Victoria statue at Delhi, or Sir Henry Durand's tomb at Dera Ismail Khan, where space for the letters has not been available, the bench-marks have been inscribed thus:—

B. o M. or $\overset{\circ}{\text{B. M.}}$ or o or ᐱ

In 1881 the levelling party introduced the system of laying down stone-slabs (9 inches × 9 inches × 3 inches*) with a circle thus:—

G.T.S.
o
B.M.
A. D. 1881.

During subsequent years many of these slabs have been built into plinths of obelisks, floorings of temples, parapet-walls of bridges, and other suitable buildings. At first the levelling officers seemed to regard these inlaid slabs as a minor species of embedded bench-mark, but of recent years they have correctly classified them as inscribed bench-marks. The only difference between the original form of inscribed bench-mark and the inlaid slab is, that in the former case the height-mark is cut upon the stone of a building, and in the latter case it is cut upon an unattached slab, which is subsequently fixed to a building.

As the inscribed bench-mark is the commonest form of bench-mark in India, the following list of points, on which these marks have at different times been cut, may not be without interest:—

Position of Bench-mark	Its value as a record of height.
Ground-rock	The best form of bench-mark, provided that a site is chosen that will admit of identification, and that a complete and accurate description is recorded.
Loose boulder	An immense boulder appears very permanent, but as a foundation for a bench-mark it is inferior to ground-rock, because rain and weather tend to disintegrate and wash out the soil, upon which the boulder rests. In an alluvial country large boulders are apt to be broken up for road-metalling.
Memorials and tombs ...	A bench-mark upon any valued memorial, such as a statue or an obelisk, which is likely to be carefully preserved, is a very useful record.
Church, shrine or temple ...	The floors of churches, shrines and temples are good sites: the steps of shrines are apt to be worn away by the tread of pilgrims. Places of worship are among the works of man that endure for long periods of time†.
Boundary pillar	A permanent boundary pillar is a good site, if it has been solidly built upon firm foundations. Village boundary pillars may be moved, when the settlement of the district is being revised.
Ancient building	Buildings of archæological interest offer good positions for bench-marks. The old bench-marks placed upon the city gates of Lahore and Delhi have, however, all been destroyed.

* Dimensions have varied: *Spirit-Levelled Heights, No. 5. Madras*, 1890, page v.
† The bench-marks fixed upon Ambala and Mian Mir churches in 1866 were found intact in 1907. The mark on Ambala church is the only old mark in that town, which has survived.

Position of Bench-mark	Its value as a record of height
Plinth, or floor of Jail, Post-Office, Kacheri.	Government Offices are liable to frequent change, and though they offer useful sites for bench-marks, the latter cannot be regarded as very permanent.
Travellers' bungalow ...	Very useful position for a temporary bench-mark: inferior in permanence to a Government Office.
Tanks and wells	Liable to subsidence and destruction, but useful as sites for temporary marks.
Railway Stations and Platforms.	Bad sites: they are not only very liable to change, but they are exposed to incessant vibration from the movement of trains. Some inscribed bench-marks on railway stations are however necessary for the present use of engineers.
Parapets of girder bridges ...	Liable to reconstruction, and subject to severe vibration. A bench-mark in such a site is of use to contemporary engineers, but as a perpetual record it is valueless.
Coping stones of bridges: pedestals of lamp-posts: plinths of culverts: kerb-stones.	These sites are undoubtedly of present use, but they will all disappear shortly, and marks inscribed upon them can only be regarded as temporary.
Tops of mile-stones ...	Marks upon mile-stones may possibly be of use to contemporary engineers, but as perpetual records they are valueless.

Inscribed bench-marks are erected at intervals averaging perhaps $1\frac{1}{2}$ miles*; they are not placed in the custody of local authorities, and no special steps are taken by the Survey to preserve them. In some districts the Public Works Department has arranged for periodical inspections and repairs.

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* The embedded bench-marks and a certain number of the inscribed are prepared for the Survey by the Railway and Public Works Department a few months before the levelling operations are undertaken. In the course of the operations the levelling officers are expected to supplement the bench-marks constructed by the Public Works Department; they are also expected to report if the sites selected by the Public Works Department are unsuitable. The Public Works Department *render assistance* to the Survey in this matter of bench-marks, but the responsibility for the suitability of bench-marks and of their sites *rests ultimately upon the Survey* and upon the levelling officers. The following extracts of correspondence are given here to illustrate the instructions issued annually to the Railway and Public Works Departments:—

Extract from letter No. $\frac{999}{41.H}$ dated 11th July 1907, from the Officer in Charge No. 25 Party (Tidal and Levelling), Dehra Dun, to the Manager, North-Western Railway, Lahore.

Embedded Bench-marks as per description given in the accompanying note should be built at all the railway stations from Ferozepore to Bhatinda on firm ground, where they may be out of the sphere of the vibrations of the traffic and not likely to be ever disturbed.

Inscribed Bench-marks which consist of a stone slab 9″ × 9″ × 6″ bearing the inscription G.T.S. O B.M. as per sketch in the margin should be built into the parapets of bridges and culverts at an average distance of about 2 miles apart. If no suitable bridges exist at convenient distances these Bench-marks should be built in small masonry blocks about 2 feet cube, with the upper surface of the stone flush with the masonry, near the mile-stones or chainage posts. Where the parapets of bridges are built of stone the above Bench-marks may be cut on them and no special stone slabs need be used in such cases. Two Bench-marks of the above description should also be fixed in the copings of platforms at all the railway stations.

Extract from letter No. $\frac{1053}{41.H}$ dated the 2nd July 1908, from the Officer in Charge No. 25 Party (Tidal and Levelling), Dehra Dun, to the Executive Engineer, East Berar Division, C. P.

"Embedded" Bench-marks as per description given in the accompanying note should be built in Towns and Villages along the road at a distance of about 10 to 15 miles apart near permanent State buildings or houses, *viz.*, Dâk Bungalows, Police Stations, Patels' Chauris, Jails, Tahsildars' Offices etc., or near temples, masjids, tombs etc. They should be built on firm ground and at such a distance from these permanent marks so as not likely to be ever disturbed.

Extract from letter No. $\frac{1072}{41.H}$ dated 8th July 1908, from the Officer in Charge No. 25 Party (Tidal and Levelling), Dehra Dun, to the Executive Engineer, Jubbulpore.

Inscribed Bench-marks which consist of a stone slab 9″ × 9″ × 6″ having the inscription G.T.S. O B.M. as per sketch in the margin should be built at an average distance of 2 miles apart, into the parapets of bridges, culverts or wells, masonry platforms or such paka permanent sites. Where the bridges, culverts, wells, etc., have stone parapets the above Bench-marks may be cut on them and the stone slabs need not be used in such cases

Metal bench-marks.

Metal bench-marks have not been largely used; brass and copper bolts are liable to be stolen, whilst iron is unsuitable owing to its tendency to oxidize. Still a few metal bolts, plugs and nails have been embedded as bench-marks in masonry; and the following lines of levels among others will be found to furnish examples of such marks:—lines numbered 43, 52, 61A, 71 and 73. Iron plugs were fixed at Dera Ismail Khan in 1907.

An iron plug fixed at Shikarpur (Sind) in 1860 and one fixed at the Survey office at Dehra Dun in 1861 were intact in 1909.

The height of the top of a rail of a railway line has frequently been determined opposite to station platforms*, but no mark has been placed in such a position. The determination of the height of the top of a rail is probably of use to the railway engineers, but as a Survey record it is valueless.

In certain localities iron mile-posts have been utilised by the Survey as bench-marks, and in a few places the tops of old half-buried cannons have been used.

Reference and Test Bench-marks.

Two or three bench-marks are laid down in the immediate vicinity of every tidal observatory and are connected with the tide-gauge by first-class levelling; they are called bench-marks of reference†. They are either cut on a dock-wall or on some neighbouring building or on a harbour-revetment, or on specially embedded cubical blocks. Test bench-marks have also been laid down, generally in pairs, within a few miles of tidal observatories‡. The latter are specially intended for the detection of secular changes of the relative level between land and sea. They are always connected by very careful levelling with the neighbouring tide-gauge§.

For the Cocanada tidal observatory a pair of test bench-marks were embedded near Samalkot, on the main-line of levels from Madras to Vizagapatam: this pair were situated 10 and 11½ miles respectively from Cocanada. For the Vizagapatam tidal observatory the test bench-marks were embedded near Aganampudi, 10¾ and 9½ miles distant respectively from the tide-gauge.

For the Cochin tidal observatory the test bench-marks were constructed at a distance of 22 miles from the gauge: for Karwar the distances were 10 and 11¾ miles, and for Mormugao 17 miles.

It has perhaps been a mistake to treat reference and test bench-marks as belonging to a separate class. They are as a rule ordinary inscribed or embedded bench-marks; and it is only their proximity to a tidal observatory, that enables them to be specially utilised for the detection of movements of the tide-gauge, or of secular changes in the relative levels of land and sea. Any sound bench-mark would answer the purpose equally well. Marks inscribed for instance upon ground rock in the immediate neighbourhood of a tidal observatory would furnish better "reference" or "test" marks than blocks of stone embedded in soft soil. When a decrease of height is discovered to have taken place between mean sea-level and a neighbouring bench-mark, the change has to be attributed to settlement of the mark, unless the latter is on rigid foundations.

Marks cut upon the solid rock round the harbour of Vizagapatam would have been more valuable test marks than the blocks embedded 10 miles inland. The reference bench-mark for Karachi is stated by Colonel Hill to be solidly built upon rock‖, and is therefore one of our most valuable tidal marks. The two old standard bench-marks of Bombay were presumably intended in the first instance

* See for example the lists of Survey bench-marks along the G. I. P. Railway. See also *General Report, G. T. Survey*, 1876-77, page 35a, where the heights of rails on the B. B. & C. I. railway, as determined by the Survey, are compared with the values obtained by the railway engineers.

† *Trigonometrical Survey Hand-book*, second edition, 1902, para 26 of page 165, and para 54 of page 176.

‡ For origin of test bench-marks see *General Report*, 1885-86, *Survey of India*, page xxvii Appendix; *General Report, Survey of India*, 1886-87, page 65 para. 286 and page xxxix, Appendix; *General Report, Survey of India*, 1887-88, page 65, para 303, and page xx, Appendix.

§ *See* list of test bench-marks, page xxxvii, *General Report, Survey of India*, 1890-91.

‖ There is no rock visible in the vicinity. This bench-mark was built by the Survey, but it was not in existence at the time of the early levelling operations in Karachi. *Spirit-Levelled Heights, Karachi* 1895, page VI. *General Report* 1893-94 page lx. *General Report* 1894-95 page xxxiii.

to be "test" marks, but they are both erected upon made earth, and are consequently inferior as records to marks inscribed upon ground-rock: unfortunately no marks were inscribed upon rock in Bombay.

The system of locating "test" bench-marks at distances of 8 or 10 miles inland has led to a certain want of regard for the reference bench-marks in the immediate neighbourhood of tidal observatories. The latter are however the initial marks on dry land from which the lines of level emanate, and they indicate the relative heights of land and sea. They should therefore be constructed with the greatest care. Whilst the so-called test bench-marks are too far distant for periodic determinations by levelling, the reference bench-marks in the immediate vicinity of an observatory are connected with the tide-gauge annually*.

Principal Stations of the Triangulation.

Principal Stations of the Great Trigonometrical Survey form most valuable bench-marks. When the height of any such station has been determined by spirit-levelling, the original trigonometrical value of height, obtained from the observation of vertical angles, can be corrected, and when the errors of *two* trigonometrical values have been discovered, corrections to height can be applied by interpolation to all intermediate stations of the series. Principal Stations are moreover carefully preserved, and should last for centuries; they are inspected and repaired annually.

It is difficult to lay down any invariable rule, for the guidance of levelling officers, that all Principal Stations within a certain distance of a line of levels must be connected by spirit-levelling, for in one locality a distance of 20 miles may offer many advantages and no difficulties, whereas in another locality a distance of one mile may be impassable for levelling operations.

The rule, as it stands at present is—

"If possible, all principal stations of the Great Trigonometrical Survey, in the neighbourhood "of a line of levels, should be connected by branch lines."

The application of this rule depends entirely upon the interpretation of the words "in the "neighbourhood", and our records show that different levelling officers have interpreted them differently. If a levelling officer keeps in view the aims and the objects of the levelling operations,—if his great endeavour is to enhance the value and utility of his observations and results,—he will be unwilling to pass a Principal Station of the Triangulation without connecting it by a branch line of levels. If however his chief aim is to finish his season's task and to complete his line of levels up to the terminal point, he will regard the Principal Stations on the flanks of his route as nuisances, and he will observe as few branch lines as possible.

In Peninsular India many of the Principal Stations of Triangulation have been founded upon ground-rock, and these stations, when connected by spirit-levelling, constitute bench-marks of the highest value. In the plains of Northern India the Principal Stations stand necessarily upon alluvium, and though inferior as perpetual records of altitude, they are as invariable in height as any marks on alluvium can be.

Some of the principal stations are on hill-summits and are surrounded by precipices; the levellers have then to abandon the ordinary methods of levelling and to adopt various devices in order to determine the values of height. When such courses have been pursued, the levellers should be careful in future to refrain from giving to the values so obtained any undue degree of numerical accuracy. When it is merely a question of measuring a vertical drop of perhaps 30 feet with a tape, no sensible error will probably be introduced, provided the measurement is repeated several times, and provided the tape is carefully tested. But when the levelling has to be carried up a succession of very steep

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* For disturbances of reference bench-marks *see* Major Hill's report on page xxxix of *General Report, Survey of India*, 1886-87, and subsequent reports.

slopes, which do not readily admit of vertical measurements, it is difficult to avoid some diminution of accuracy; in these cases the value of height as obtained will always be useful for the control of the trigonometrical values of height, but it will probably not possess the scientific accuracy necessary for the determination of movements of the earth's crust. It is difficult to tell from the old records, whether hill-summits have been reached by normal methods, or whether exceptional measures had to be taken.

In Appendix 6 of this volume the errors as determined by spirit-levelling of the trigonometrical values of height are tabulated. During the half century 1858-1908, 434 principal stations of triangulation have been *reported* as connected by levelling, but 156 of these proved to be only secondary stations.

Secondary stations of triangulation.

Secondary stations are as a rule well built: although no steps are taken to preserve them, many are found to last for a comparatively long time. They are frequently placed upon hill-tops, and in unfrequented spots, and are thus out of the way of men. Several secondary stations have been connected by levelling, and have proved to be useful bench-marks.

Revenue Survey marks.

In the course of the levelling operations in India the heights of Revenue Survey marks have been at times determined, but the total number so fixed is few. In the district of Howrah there are instances of Revenue Survey stations having been made to serve as bench-marks; these stations consist of blocks of stone triangular in plan and buried so that the top is flush with the surface of the ground*; they are marked thus:—

R. S.
O
1871

There is also an instance on the line between Chinsura and Nadia†, and Revenue Survey boundary pillars on the Raichur-Bellary line have been connected‡.

It is to be hoped that Revenue Survey stations will be utilised as bench-marks in the future to a greater extent than has been done in the past. The permanent Revenue Survey station is as a rule strongly built on a solid foundation, and it is carefully preserved by the district magistrate: it is situated at a distance from roads and railways and is therefore not likely to be in the way of engineers. For a perpetual record on stone, a Revenue Survey station is much to be preferred to a mile-stone.

The Revenue Surveys of India are now being placed upon more permanent and more systematic bases: their permanent stations are likely to be multiplied, and it will behove the levelling officers of the future to see that opportunities of securing sound bench-marks for cultivated areas are not lost.

Bench-marks of the Railway and Public Works Departments.

Irrigation officers have erected many trustworthy marks along the courses of canals, and these have been in places connected with the Survey net-work: when two such marks have been connected by the Survey, the heights of the intermediate marks obtained by the Irrigation officers can be corrected by interpolation. The heights of irrigation bench-marks in many provinces, and especially in the Punjab, as determined by Irrigation officers and adjusted to the Survey datum, will be of use to topographers, when new maps come to be made.

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* *Spirit-Levelled Heights, Bengal Presidency*, 1881-82-83 pp. 58, 59.
† *Spirit-Levelled Heights, Bengal Presidency*, 1887-88, page 71.
‡ *Spirit-Levelled Heights, No. 1 Madras*, 1869-85, pages 61-65; see also for Burma the *General Report, Survey of India*, 1892-93, page xxxviii Appendix.

The Siwalik range of hills has risen to its present height in recent times, and the rate of its growth furnishes a geological problem of interest*; the Ganges cuts across the Siwalik range at Hardwar, and a line of levels has been brought within the last few years from Nojli to Dehra Dun through the gap in the range carved by the great river. The head-works of the Ganges Canal are at Hardwar, and the Irrigation officers have erected many fine bench-marks there. In 1908 Lieut. Morshead was deputed to connect these bench-marks with the Survey line of levels, and thus to obtain accurate values of height, which will enable our successors to detect any upward movement of the Siwalik axis.

The Survey has levelled to great numbers of the bench-marks fixed by Railway engineers: the connection of these bench-marks has enabled all railway levels to be corrected to the Survey datum. Bench-marks near lines of railway do not as a rule survive for any length of time, and their heights are apt to vary on account of the incessant earth-tremors produced by moving trains. The heights of railway bench-marks, except such as have been actually determined by the Survey, are not of the same use to topographers as irrigation bench-marks are: the railway bench-marks are situated in less satisfactory positions, and the railway levellers in determining heights do not aim for the same degree of precision as canal levellers.

Many of the railway bench-marks are inscribed on kerb-stones and platforms: some consist of iron rails embedded in masonry pillars, and others of wooden blocks built into masonry.

The Survey determines the heights of the inscriptions of the rail-heads and of the wooden blocks, but adds no inscription of its own†. The bench-marks remain Railway Department marks: their connection by the Survey does not convert them into Survey bench-marks.

As mentioned on page 55 the height of the top of a rail of a railway line has frequently been determined for the use of railway engineers. Such determinations are useful at level-crossings. In 1875-76 Mr. Rendell determined the heights of the top flanges of the iron girders of all bridges near Viramgam: these heights were particularly wanted by the engineers, and they were not intended to be permanent Survey marks.

Marine Bench-marks.

Certain marks, called 'Marine sockets,' which have been laid down by the Port authorities for the Hooghly River Survey, have been connected by levelling to the Survey level net‡: these sockets consist of cast iron pipes about 5 feet long and 6 inches diameter, having a 2-inch flange at one end; they have been sunk into the ground up to within a foot of the flange, and they are marked with a broad arrow, and a number under the flange, such as $\overset{\wedge}{20}$. The levelling staff was placed on the top of the flange.

These Marine Bench-marks belong to the Port authorities of Calcutta; they have been erected to enable the river surveyors to detect changes in the course of the river Hooghly. They are as durable, as any marks can be, on soft water-logged alluvium. Those sockets, of which the heights have been determined by the Survey, form valuable bench-marks for the delta of the Ganges.

Bench-marks known as 'Marine Survey' bench-marks, and which belong to the Marine Survey of India, have been connected in certain places on the coast with the precise level net. There is one

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* *Sketch of the Geography and Geology of the Himalaya Mountains and Tibet*, Part I, page 30. See also third foot-note to page 22 of this volume. There is a closing error of 0·847 foot in the Hardwar-Dehra Dun-Mohan levelling circuit: we are endeavouring to localise this error.

† On the level-lines, Nandgaon-Raipur-Bilaspur-Katni-Sironj, the levellers inscribed the letters G. T. S. B. M. upon railway bench-marks. This was an incorrect course to adopt; these railway bench-marks had been already inscribed with railway values of height, derived not from mean-sea-level but from a special railway datum. Steps are being taken (1909) to have the letters G. T. S. B. M. removed.

Vide Spirit-Levelled Heights, No. 7, Bombay Presidency, page 63: bench-mark No. $\frac{2}{14}$ has inscribed upon it the value 1014·00, whilst the preliminary Survey height unadjusted is 937·77: in the case of bench-mark No. $\frac{3}{14}$ the inscribed height differs from the preliminary (unadjusted) Survey height by some 76 feet. The final adjustment will not affect the Survey values by more than a foot.

Spirit-Levelled Heights, No. 10, Madras, pages 153,155: for bench-marks Nos. 104 and 126 the inscribed and Survey heights differ by 2 feet; pages 161 to 170 of this No. 10 Madras pamphlet give numerous instances of inscribed heights differing from Survey heights. The acceptance of two values for one mark was quite wrong.

‡ *General Report, Survey of India*, 1882-83, page 51.

such bench-mark at Cocanada, one at Bhavnagar, one at False Point, one at Calicut, one on the Hooghly and others in other places.

The total number of bench-marks.

The total length of lines of double-levelling observed in India between 1858 and 1909 amounts to 17971 miles. Of the 17971 miles of double-levelling 1361 miles have had to be revised,—that is, about 8 per cent.

Between 1858 and 1909 the following numbers of bench-marks were connected by spirit-levelling :—

68 standard
1559 embedded
13920 inscribed
434 stations of triangulation, (278 principal, 156 secondary).

The average number of bench-marks that a levelling detachment will fix in one year is between 200 and 300.

The Bench-marks that have been lost.

Between 1858 and 1902 the number of Survey bench-marks *reported* to the Superintendent of Trigonometrical Surveys as lost was 795, but it is well-known that the number actually lost greatly exceeds the number reported. It is probable that the number of bench-marks now existing in good condition is barely more than two-thirds of the number originally fixed*. Our reports on losses are derived from two sources only, *viz.*, from local engineers interested in the subject, and from levelling officers, who chance to be working near an old level line. In many years no bench-marks will be reported as lost. In the year 1904-05 eighteen bench-marks were so reported; in 1906-07 two hundred and five were so reported. The reports are thus fitful and incomplete.

On one occasion in Bengal thirty-four bench-marks were destroyed within a length of 50 miles, owing to alterations made by engineers to a road.

The following letter contains instructive information :—

Letter No. C $\frac{1997}{1655}$, dated Trichinopoly, 13th March, 1891, from the Officiating Chief Engineer, South Indian Railway, to the Surveyor General of India.

SIR,—I have the honor to inform you that nearly all the bench-marks put in by the G. T. Survey on the bridges and culverts between Maniyachi and Tuticorin and between Ambatturai and the 323rd mile of this railway cannot now be considered reliable, as they have been displaced consequent on alterations to these bridges and culverts.

The bench-mark on the curb-stone of the platform at Tataparai Station sank slightly and had to be raised.

I have the honor to be,
Sir,
Your most Obedient Servant,
(Signed) W. K. STENT,
For Offg. Chief Engineer.

The number of bench-marks thus destroyed between Tuticorin and Maniyachi was 17; the number destroyed between Ambatturai and the 323rd mile was 9.

In many cases the bench-marks along railways and roads have been removed without notice being given to the Survey, and Mr. Stent's letter quoted above is a report of damage, such as is seldom received. Whilst the damage is to be deplored, a report of it is welcome.

By 1892 all the bench-marks laid down at Karachi and Manora in 1859-60 and 1883 had disappeared with the exception of one at the front entrance to Karachi Church and that was found to be sinking†.

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* *See* Colonel Hill's report on page lx of the appendix of the General Report, Survey of India, 1893-94. Colonel Hill's reports are worthy of study by levelling officers.

† *General Report, Survey of India*, 1893-94, page lx. The Karachi reference bench-mark, mentioned on page 55, was erected in 1862, and was standing in 1909.

In 1897 the bench-marks at Bushire were destroyed by a mob.

In 1906 thirty-three bench-marks out of 95 were found by a levelling officer to be missing from the Bombay-Poona line; these losses had not been reported at the time of their occurrence.

In 1906 Mr. Corridon proceeded to Gwalior to start a level-line for the connection of the new Standard Bench-Mark at Jhansi. No one of the old block-stone bench-marks embedded near Gwalior between 1858 and 1862 could be found, and Mr. Corridon had to withdraw 30 miles from Gwalior before he could discover a bench-mark to serve as an origin for his branch-line to Jhansi*. The nearest bench-mark to Gwalior that Mr. Corridon found in existence was that on Colonel Sander's monument at Maharajpur. It is significant that a bench-mark on a *monument* was the *first* discovered: in the course of years no erections appear to undergo so little change at the hands of man as memorials.

Of the 20 bench-marks fixed in or near Lahore in 1867, only 2 could be found in 1905†.

In 1907 Mr. Erskine reported that 149 bench-marks out of a total number of 461 had been lost or destroyed on the line between Bombay and Kosgi. These 461 marks had been erected in the years 1877 to 1881, and in 27 years one-third had disappeared. Mr. Erskine attributed their loss to "the extension of railway stations and platforms, the renewal of bridges and culverts, the duplication of railway "lines". In the same year Mr. Erskine reported 14 bench-marks, fixed at Ahmednagar in 1882, to be missing: "the bridge copings", he wrote, "along the railway were either being renewed or recobbled, "and many bench-marks were found to have been destroyed by this means"‡.

It was in 1904 that we decided to erect monolithic or standard bench-marks in all great cities, and it is due to the necessity of connecting these new monoliths with the nearest existing lines of levels, that the levelling officers have been able to discover many of the losses mentioned above. Numbers of the old lines of levels have not been systematically examined by levelling officers, since the original levelling was carried out, and nothing is now known of the present condition of their bench-marks. Now that the level net is being continually intersected by new branch-lines of levelling, the levellers get more frequent opportunities of inspecting old bench-marks than was formerly the case.

It is satisfactory to know that some bench-marks survive for decades; this may perhaps be largely due to chance, but we must be on the watch for cases of the survival of the fittest, and endeavour to learn from their structure and environment what qualities tend to durability. The bench-marks fixed at Mangalore in 1869-72 were found in good order in 1896.

The first lesson that we have to record as learnt from experience is, that without extraordinary foresight and care the greater number of our bench-marks will disappear in less than a century. It may be argued that such a lesson is too obvious to require learning; but we have only to study old reports, to find that our predecessors had a stronger belief, than we have now, in the durability of their Survey marks. It is common to read in old narratives before the time of Colonel Hill, that hundreds of 'permanent points' had been fixed in a season as bench-marks: recent experience teaches us that these so-called 'permanent points' were not permanent, that the word 'permanent' was a misnomer§. Colonel Hill first pointed this out in 1894.

The only safe and complete information that we can gain concerning the condition of the bench-marks on any old line of levelling is to be obtained from reports of levelling officers, when they chance to visit the scene of earlier levelling operations. Levelling officers should therefore endeavour to make their reports on losses and injuries useful and complete.

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* Narrative Report on Tidal and Levelling Operations for 1905-06, by Mr. C. F. Erskine, page 105.

† Narrative Report on Tidal and Levelling Operations for 1905-06, by Mr. C. F. Erskine, page 108.

‡ Narrative Report on Tidal and Levelling Operations for 1906-07, by Mr. C. F. Erskine, page 117.

§ *General Report, Survey of India*, 1879-80, page 48, para. 219: "337 permanent points were connected for future reference." *General Report, Survey of India*: 1880-81, page 41, para. 193—"258 permanent points on temples, parapets, bridges, etc." See also *General Report, Survey of India*, 1885-86, page xxvii, of Appendix.

Colonel Hill's reports upon bench-marks published in the Appendices to the *General Reports of the Survey of India* between 1885 and 1895 contain much valuable information and advice. For years he advocated the inspection of bench-marks by a Survey officer*.

The relative durability of triangulation stations and of levelling bench-marks.

A report upon the condition of each principal station of the triangulation is submitted annually by the local magistrate to the Superintendent of Trigonometrical Surveys, and necessary repairs are regularly carried out. But the numbers of bench-marks erected have been so great, that although many have been placed under the care of district authorities, it has not been possible to obtain periodical reports upon their condition.

The processes that endanger the lives of stations and bench-marks may be considered as falling under three categories:—

(i.) The mechanical, such as injuries caused by men and animals and by the growth of trees.

(ii.) The chemical, such as weathering and decay.

(iii.) Physiographical changes, such as movements of rivers, migrations of masses of sand, and encroachments of the sea.

Movements of the solid crust of the earth will also displace stations and marks, both vertically and horizontally, but these displacements cannot be regarded as injurious. One of our present objects in fixing marks is to ascertain *to what extent* and *at what rate* the earth's crust *is* rising or falling or changing its form, and if we have been enabled to determine crustal movements, our Survey marks, however much displaced, will have served a scientific purpose†.

The stations of the Principal Triangulation are generally built upon isolated hills away from the habitations of men; levelling bench-marks are generally erected along main roads or railways, and their numbers are increased in the vicinities of great cities. The widening of railways, the alterations to roads, the construction of canals and the expansion of towns lead to the demolition of many bench-marks annually, but these works of men seldom affect the stations of the triangulation.

The weather and the growth of jungle are the principal causes of the decay and disintegration of triangulation stations, and although these causes operate equally against bench-marks, their actions are slow, and their effects are less apparent than those of human enterprise. It is true, that between 1800 and 1820 Colonel Lambton covered a great part of the Deccan and of Madras with triangulation stations, and that now, 100 years later, we can seldom find one. But these stations of Lambton's were never inspected nor repaired; the pillars have become disintegrated by weather and jungle-growth, and his inscriptions on rock surfaces have become so worn and obscure as to be lost amid the markings of nature‡.

The rivers of northern India by their constant changes of course have in recent times swept away many of Everest's and Walker's principal stations. Encroachments of the sea have destroyed valuable geodetic mark-stones, and movements of desert sand have caused a few to be buried.

If the land surface of the earth is undergoing change, whether in the movements of great rivers, or in the migration of masses of sand, or in the denudation of hills, or in the destruction of land by the sea, the perpetual preservation of Survey marks is not possible: sooner or later they must disappear, and all the levellers can do is to observe and study the courses of nature, and to erect *a few special marks* having regard to permanence only.

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* *General Report, Survey of India*, 1894-95, page 86, para. 576: "Colonel Hill suggested it would be advantageous to have a periodical "inspection; he gave striking instances of a large number of important marks that had disappeared." It has now (1909) been decided that periodical inspections of bench-marks are imperative; it is hoped also that levelling officers will submit systematic reports upon the old bench-marks, that hey happen to meet with, when their new work intersects an old line, or when they are revising an old line.

† See foot-note to line 61 A, Table V, page 22 of this volume.

‡ The *descriptions* of Lambton's stations were wanting in detail and precision, and are now insufficient guides.

But the losses of bench-marks from natural causes are few compared to those that have to be sacrificed, as man extends his habitations and communications. The widening of a road or of a railway will lead to the simultaneous destruction of many bench-marks: the incessant alterations and additions to buildings, that continue without interruption in large cities, cause all bench-marks within urban areas to disappear in two or three decades,—except perhaps those few that have been inscribed on statues or on carefully preserved memorials. Although it is not possible to foretell accurately what the future works of man, constructive or destructive, are likely to be, nevertheless the durability of bench-marks will to a certain extent be enhanced by the foresight, with which their sites were selected. Rules may be laid down and instructions may be issued by the superintendents of surveys, but such rules or instructions can be general guides only; they can never take the place of local intelligence and foresight. Some bench-marks fixed in deserted regions may, if spared by weather, survive for a century, but none in populous places is likely to endure, unless its site has been carefully considered.

Variations in the heights of Survey marks.

A levelling bench-mark is erected in order that the height of a particular point of the earth's crust may be determined and recorded for future use. It is a worse misfortune for bench-marks to undergo changes of height than to suffer entire destruction. In the latter case the record of the levelling work is obliterated, but in the former case it is falsified. As far as *movements* of marks are concerned, stations of the principal triangulation are less liable to displacements than bench-marks. Triangulation stations are located upon hills whenever possible, and a large percentage will consequently be founded upon rigid rock, and many will be situated in unfrequented places; but the proportion of bench-marks, erected upon rock or away from the lines of traffic, is small.

Until a triangulation station is converted into a bench-mark by levelling, any change in its height up to a whole foot is immaterial, but the rise or the subsidence of a bench-mark to the extent of the one-hundredth part of a foot is a misfortune. It is the *horizontal* displacement of its mark that destroys the utility of a triangulation station; it is *vertical* displacement that renders a bench-mark false. There is but little tendency in nature towards horizontal displacement, but the force of gravity is always exerting an influence towards vertical displacement*. Heavy stone bench-marks erected upon the soft alluvium of the plains are liable to subside vertically in the course of years; and it is for this reason that rock sites for bench-marks should be chosen whenever possible.

The reports of the Survey contain so many references to the settlement and subsidence of bench-marks that it would be useless to compile any complete account. Experience has shown that no bench-mark erected upon soft soil can be trusted to maintain its original height; it is always necessary when working over alluvium to re-level some miles of old line and to re-determine the relative heights of three or four of the old bench-marks, before the former value of any one height can be accepted.

In 1885 Colonel Baird reported as follows:—

The Tidal Observatory at False Point was completely destroyed by the cyclonic sea wave which occurred on the morning of the 22nd September 1885. The Port and Customs Offices and the whole village of Hookey Tola have entirely disappeared. Bench-mark A embedded in a block of masonry has been moved about 100 yards from its site, and is of course perfectly useless as a mark of reference.

The following extracts from Colonel Hill's pamphlet on *Spirit-Levelled Heights, Karachi, 1893-94*, are taken and re-printed here as being of exceptional interest:—

The height now determined of the South End of the Karachi Base is 46·29 feet above mean-sea-level. The difference between the heights obtained in 1859-60 and in 1894 of the South End of the Karachi Base is thus 0·09 of a foot. This is not an apparent difference due to unequal values of mean-sea-level, but a real difference due to the sinking of the base-line tower, which stands on swampy land intersected by numerous creeks.

The opinion of engineers in Karachi is that since about the year 1887, when the Karachi Water-works were completed, the soil holds a considerable quantity of water and several buildings have settled in consequence. Among them is the lofty tower (150 feet high) of Holy Trinity Church, on one of the stones of which the bench-mark at the front entrance to the church has been inscribed. Before the introduction of the water-works this bench-mark, so far as is known, showed no signs of sinking, and the results obtained by the levelling to it from Manora in 1889 were considered

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* Owing partly to the fact that a triangulation station is given both an upper and lower mark-stone and partly to the comparative ease with which annual repairs can be carried out without any *horizontal* disturbance of the mark-stones, it has been possible to entrust these repairs to local engineers. But it is difficult to repair a bench-mark without altering its height, and it has been considered better to let bench-marks go to pieces rather than allow a free hand for repairs to local officials, who do not appreciate the accuracy with which heights are determined. On one occasion a local official suggested, that he should give new foundations to the bench-marks of his district.

eminently satisfactory (*vide* Departmental General Report for 1883-84, page 53) and gave a close agreement between the value of mean-sea-level then obtained and the old value of 1856. They would however have been still more satisfactory and conclusive, if bench-mark No. 10 had not then been omitted from the levelling*. In 1892 the bench-mark at the front entrance to the church was found by levelling from bench-mark No. 10 to have sunk rather more than half an inch, and in 1894 by similar levelling it was found that the settlement had increased to about three quarters of an inch. Evidences of the settlement were also plainly visible in the church tower which in sinking had created large cracks between itself and the body of the church. The bench-mark at the entrance to the church has consequently been condemned as useless.

The effects of earthquakes.

In the preface to Volume XVIII, *Account of the Operations of the Great Trigonometrical Survey*, it was shown that the difference of height between Dehra Dun and Mussooree had been decreased 5½ inches by the great earthquake of 1905. The difference of height between Dehra Dun and Mussooree was re-levelled after the earthquake, and a decrease of 5½ inches was discovered. To those who had experienced the violent vibrations of the ground during the earthquake it seemed natural to assume that settlement and subsidence had been caused; the *difference* between Dehra Dun and Mussooree had been found to be less by 5½ inches than heretofore, and it was easier to imagine that Mussooree had fallen during the vibrations rather than that Dehra Dun had risen. In the following year, 1906, after Volume XVIII had been published, 44 miles of old levelling from Dehra Dun to Saharanpur, in the opposite direction from Mussooree, were revised, and the results of this revision obliged former opinions to be modified. It was now seen that Mussooree in the Himalaya and Saharanpur in the plains were at the same relative levels after the earthquake as before: the intermediate station of Dehra Dun was higher by 5 inches both with regard to Mussooree and to Saharanpur†. This discovery freed the levelling between Dehra Dun and Mussooree from the suspicions of error mentioned in the preface of Volume XVIII, and indicated the probability of a rise of the Dehra Dun bench-marks having been caused by the earthquake rather than a sinking of the Mussooree and Saharanpur marks. The vibrations themselves must have tended to produce general subsidence: during vibration the force of gravity acting upon earth particles tends to increase the earth's surface density and to decrease its altitude. But this tendency was clearly insufficient in 1905 to counteract the elevation of Dehra Dun produced by horizontal pressure.

No precautions can be taken to avoid the effects upon bench-marks of earthquakes, but we can distribute bench-marks over areas of seismic disturbance in order to enable the effects of earthquakes to be measured.

When large segments of the earth's crust become upraised or depressed, the bench-marks of the locality must rise or sink with the crust on which they stand, and their original values of height are no longer trustworthy. With the exception of the branch-line of levelling from Saharanpur to Mussooree, no bench-marks in India have, so far as we can judge in 1909, been disturbed by earthquakes: and the line, Saharanpur-Mussooree,—the only line which we believe to have been disturbed—has been completely revised, since the earthquake of 1905 caused alterations in its height‡.

Railways and roads.

The vibrations caused by earthquakes are violent but short-lived; those caused by railway trains are less severe but perpetual. Geodesists, who have had to observe the reflexions of wires in mercury, or the oscillations of a pendulum, or even the readings of a level, have learnt to realise the difficulties and inaccuracies introduced by the proximity of passing trains. The vibrations of trains are in fact so obvious, that delicate instruments are not necessary to indicate them; they are perceptible to our unaided senses. The passage of a heavy train shakes every building in its vicinity. Now if we consider, that the permanent way of a rail-road is generally constructed upon made earth, and that it is kept in one incessant state of vibration, year in and year out, by passing trains, we must realise that this is not an ideal route for a line of permanent bench-marks§.

* The bench-mark, which Colonel Hill calls No. 10, is the reference bench-mark mentioned in the fifth foot-note to page 55.

† *General Report, Survey of India*, 1906-07, page 30, para 142.

‡ *See* foot-note to line 61 A, Table V, page 22 of this volume. The observation of the Himalayan level-lines mentioned in the third foot-note of page 22 is now (1909) being undertaken.

§ The bench-marks on the Rangoon-Mandalay railway were found to have undergone serious changes between 1893 and 1908 (*vide General Report, Survey of India*, 1892-93, Appendix, page xxxvii, and *Extracts from Narrative Reports*, 1903-04, page 164, paras 44-46). The revision of the Bombay-Madras line of levels has shown that several bench-marks have moved vertically as much as two feet in 30 years.

We have to furnish bench-marks to the railways, and we have to erect bench-marks at the stations; but these are to satisfy present requirements only. Whilst we recognise the necessity of erecting bench-marks along railways for the use of contemporary engineers, we have also to bear in mind that there are other needs to be considered. We must periodically quit these lines of disturbance and set up bench-marks at safe distances for the use of posterity. The requirements of the present and the requirements of posterity have to be satisfied in different ways. It may for instance be of some immediate use to determine the height of the top of a rail,—a step that has been frequently taken in India,—but of permanent use such a course has none. In a year or two the rail gets removed, or the sleepers are raised, or the ballast is increased. Experience has in fact shown, that the practice of confining all our bench-marks on a long line of railway to the immediate vicinity of the rails is essentially bad, and that *no more unsuitable site for a permanent bench-mark can be found than a point on the track of a railway.*

Similarly it is useless to construct *permanent* marks at railway stations: there is nothing permanent about a railway station. We can inscribe bench-marks on the platform for immediate uses, but it is futile to place our permanent marks for posterity in a structure condemned to perpetual vibration and change.

An embedded bench-mark is one that has been buried in order to be protected from damage: an embedded bench-mark is thus intended to be a permanent mark. In well-chosen and well-marked sites embedded bench-marks are probably the most enduring, and consequently the most useful, that can be devised. But to bury a bench-mark under a railway platform or close to railway lines, as has been often done on the G. I. P. Railway and in Madras, is to expose it to incessant vibration. Moreover, how is the site to be preserved? The distances of the buried mark from the edges and corners and walls of the railway buildings may be recorded, but the buildings alter annually, and after the lapse of years there is no possible way of discovering the position of the mark except by excavating the whole station. In some cases a tablet has been erected and the position of the buried mark described upon the tablet, but the wall to which the tablet is affixed is pulled down, the tablet gets erected elsewhere, and the distances recorded on it become erroneous. There is no possible way of preserving a permanent mark, if its site is non-permanent; railway stations are temporary structures, fitted to receive temporary marks, but permanent bench-marks should never be erected near them.

High roads are somewhat more suitable than railways, but even on roads the tremors caused by heavy carts may be unceasing, and roads are liable to be widened. If we erect every bench-mark for 100 miles along one road or along one railway line, and if we omit to take our level line in zig zags across it, we expose ourselves to the risk of seeing all our work swept away, when the road or railway is widened or raised, or if its alignment is altered*.

If we examine the system, under which hundreds and even thousands of our bench-marks have come to be erected along railway lines, we find that the railway lines afford *the most direct, the most level, and the most suitable routes for levelling work.* But *the most suitable route for levelling is not the most suitable line for bench-marks,* and although the levelling operations will have to be mainly confined in the future to the lines of the great roads and railways, the system of erecting occasional permanent bench-marks on both flanks of the routes and at distances of 2 or 3 miles from the main lines will have to be introduced.

The upper surface of a rail in position has been found in other countries to be an advantageous position for the levelling staff†: the operation of levelling *has been said* to be facilitated, when the staff is erected upon the iron rail instead of upon a special peg. But in such a case the iron rail is

* Experience has shown that mile-stones do not make *permanent* bench-marks: a mile-stone is conspicuous, and a levelling mark inscribed upon it may probably be of use to engineers and surveyors: but mile-stones have short lives, and they are liable to removal when the road is improved or re-aligned. No harm is done by inscribing bench-marks upon occasional mile-stones, but it is a mistake to place all the bench-marks of a route upon the mile-stones, and it is a mistake to regard the mile-stones as permanent erections.

† Mr. Corridon has tried the use of a rail in India as a staff-support and has conclusively shown, that it does not answer. "During the passage "of a train," he writes, "it will be seen that the rails move vertically through 1 or 2 inches, as each wheel in turn approaches and quits a sleeper. "Last year in Hyderabad I gave the plan a trial. The results showed large discrepancies, which however cancelled out, because I had placed alternate "pegs on the embankment and the rails. Where some length of levelling has been run along rails, and a train approaches suddenly without alternate "pegs being on the embankment, the whole morning's work may be thrown away."

The successful employment of a rail as a staff-support must depend upon the construction of the permanent way. In India the permanent way is not sufficiently rigid.

utilised merely as a means of progress; it is not made into a bench-mark; the leveller works along the railway, because it is the easiest and quickest route, but his *permanent* bench-marks he has to erect at a distance.

Classification of bench-marks.

On the first page of this chapter we showed that bench-marks had hitherto been classified as follows:—

(i.) Standard.
(ii.) Embedded.
(iii.) Inscribed.
(iv.) Metal bolts in masonry.
(v.) Reference and test.
(vi.) Stations of the Triangulation (Principal and Secondary).
(vii.) Revenue Survey stations.
(viii.) Railway. (Belonging to the Railway authorities).
(ix.) Irrigation. } (Belonging to the Public Works Department).
(x.) Road. }
(xi.) Marine. (Belonging to the Port authorities).

Now this classification is unsatisfactory, in that it is based on no principle. One bench-mark has been called 'inscribed', because it has been *cut upon* stone, but another has been called 'test' or 'reference', because it is *situated near* a tidal observatory, and a third has been called 'Public Works Department', because it *belongs to* that department. Thus one class gets its name from *method* of construction, another class from *locality*, and another class from *ownership*.

The most important quality possessed by a bench-mark is durability, and durability forms the only useful basis of classification.

In future all Indian bench-marks will be divided into two great classes, the primary and the secondary.

The primary class will include all those marks, which are likely to remain uninjured, and undisturbed, and recoverable for a century.

The secondary class will include both those that are not likely to survive, and those that are not likely to be readily found.

These two main classes can then be subdivided as follows:—

Primary Bench-marks

Sub-division	Reasons for being considered primary
1. Rock-cut	This kind of mark may always be classed as primary, provided (i.) that the inscription is cut upon solid bed-rock, (ii.) that it is very deeply cut, or protected from weather by a stone-cap, (iii.) that its recovery can be ensured by the prominence of its site and the precision of its description.
2. Interred	An interred bench-mark may be regarded as primary, provided (i.) that it is in firm soil, (ii.) that it is well-constructed after the design of the 'embedded', (iii.) that it is not situated within a mile of a railway, nor within 300 yards of a cart-road, (iv.) that its position is rendered permanently recoverable by a well-designed signal-post above ground.

Primary Bench-marks—(*Contd.*)

Sub-division	Reasons for being considered primary
3. Engraved	Under the heading 'engraved' are included those marks that have been carved with exceptional skill upon marble, or rock of value, and which have been placed upon statues, or memorials, or upon ancient buildings of archæological interest*, or upon modern buildings of architectural beauty and importance. In the absence of ground-rock an 'engraved' bench-mark is the most durable form of surface-mark for a populated or cultivated district. Asoka's pillars are examples of permanence: his inscriptions upon rock have lasted undisturbed for 20 or 30 centuries: his inscriptions upon columns have also lasted, although the columns themselves have been moved.
4. Standard	The monolithic standard bench-marks, introduced in 1904, were designed with a view to permanence: they are in the special custody of local engineers, and they will be specially protected. They should therefore constitute permanent records of height,—as permanent at least as it is possible to provide for great cities founded upon alluvium. A few of the standard bench-marks, for instance those at Jodhpur, Raichur and Delhi, are actually based upon rock.
5. Principal stations of the Triangulation.	These stations are inspected annually and are carefully preserved. Many of them are on rock, many on alluvium; those that stand on alluvium are probably as invariable in height as any marks on alluvium can be. It would not however be right to include any principal station as a primary bench-mark, unless its height had been accurately determined (*vide ante* pages 56, 57)†.

Secondary Bench-marks

Sub-division	Reasons for being considered secondary
1. Embedded	The embedded differs from the interred in one of two ways: either its signal-pillar above ground is not sufficiently permanent, or its site is not sufficiently well-chosen. The old 'embedded' bench-marks that rest in undisturbed localities, and that possess well-designed signal-pillars, can be classed now as 'interred'; but all the embedded bench-marks that have been buried in railway platforms, or near railway lines, or that were not given proper signal-pillars, should be kept in the 'embedded' division of the secondary class. It must not be assumed that bench-marks embedded along railways have been useless; in all probability they have been often utilised by contemporary engineers. But they do not deserve to be placed amongst the primary bench-marks of the Survey.
2. Inscribed	All the inscribed bench-marks of the Survey are liable to disturbance, and should be classed as secondary.

* It may be argued that archæologists would object to seeing a bench-mark placed upon an ancient building, but if the mark is artistically engraved, no exception probably would be taken.

† Spirit-Levelled heights, which have been determined by rough methods, should not be used for any scientific purpose except to furnish corrections to trigonometrical heights.

Secondary Bench-marks—(*Contd.*)	
Sub-division	Reasons for being considered secondary
3. Metal bolts in masonry ...	These bolts are seldom used; when they are employed they are built into the masonry of temporary structures, and hence can only be regarded as secondary.
4. Secondary stations of the triangulation.	No special steps are generally taken for the preservation of secondary stations, and they can only be regarded as secondary bench-marks.
5. Revenue Survey stations ...	Revenue Survey stations are not all of one pattern: some are less strongly built than others, and some are less carefully preserved than others. Whilst the Revenue Survey station forms one of the best kinds of secondary bench-marks, it will not be possible to class it as primary, until some uniform system of construction and preservation has been introduced for all provinces.
6. Railway bench-marks ...	These bench-marks are constructed by the Railway engineers for their own purposes: it is advantageous that the Survey should connect with them, but they cannot be classed among the primary bench-marks of the Survey.
7. Public Works Department bench-marks.	These bench-marks are constructed by the Irrigation and Road engineers for their own purposes: it is advantageous that the Survey should connect with them, but the engineers have the right of removing them and re-determining their heights, and hence they cannot be classed as primary.
8. Marine	Constructed by Port authorities for their own purposes: they form most useful bench-marks for the detection of river encroachments: but they cannot be classed by the Survey as primary.

The officer in charge of the levelling operations should not admit any bench-mark into the primary class without an examination of its claims. Four questions will have to be considered,—the questions of construction, of material, of site and of preservation. (i.) How has it been cut? (ii.) Upon what has it been cut? (iii.) In what site? (iv.) Is it specially preserved? We do not want vast numbers of primaries, nor do we want clusters crowded into one locality. Our present aims would be satisfied, if we could arrange for one primary bench-mark in every 1000 square miles After having for years carried lines of level without sufficient regard for the *permanence* of bench-marks, it would be absurd now to go to the other extreme and endeavour to make all bench-marks primary. Our object must be to erect great numbers of secondary marks for present uses, and to set up a few primaries for the use of the future.

The proposed classification for the future will thus be:—

Primary ... ...
1. Rock-cut.
2. Interred.
3. Engraved.
4. Standard.
5. Principal stations of triangulation.

Secondary	1. Embedded. 2. Inscribed. 3. Metal bolts. 4. Secondary stations of triangulation. 5. Revenue Survey stations. 6. Railway bench-marks. 7. Public Works Department bench-marks. 8. Marine bench-marks.

This will give 13 divisions of bench-marks instead of 11, as hitherto accepted. Of the former 11 divisions, one division, *viz.* that comprising the reference and test bench-marks, has been cut out, and two other divisions, the Irrigation and the Road, have been combined into one, *viz.* the Public Works Department. This reduces the old number of 11 divisions to 9. But four new divisions have been created, the rock-cut, the interred, the engraved and the secondary stations of triangulation making 13 in all.

The rock-cut bench-marks have been placed in a division by themselves; the old 'embedded' have been divided into (i) the 'interred', and (ii) the 'embedded', according to the relative permanence of their sites; and the old 'inscribed' have been divided into (i) the 'engraved', and (ii) the 'inscribed', according to the merits of their sites and inscriptions.

The old 'reference' and 'test' bench-marks, called at times also 'tidal', have been eliminated: every rock-cut and every interred bench-mark situated *near* a tidal observatory is a reference or tidal bench-mark. It is obviously necessary to erect primary bench-marks near every tidal observatory, but their proximity to an observatory is no reason for naming them differently.

The fundamental bench-mark or zero for India.

Some of the great European surveys have adopted certain particular bench-marks as their permanent zeros of height, and it has been necessary to consider the advisability of selecting a fundamental bench-mark for India. Any one of the following bench-marks would have been suitable as a permanent zero of reference:—

(i.) The standard bench-mark at Delhi.
(ii.) The standard bench-mark at Jodhpur.
(iii.) The standard bench-mark at Raichur.
(iv.) The principal station of triangulation at Sanichari.
(v.) The Naubatpahar bench-mark between Bider and Hyderabad, Deccan.

These bench-marks are all on rock: they are situated in regions of geological stability: they are all fairly central: and the levelling observations, by which they were connected to the level net, were everywhere carried out under favourable conditions*. Many other bench-marks in India however could be enumerated, which would be equally suitable for the fundamental and perpetual zero of reference.

But after consideration it has been decided, that no particular bench-mark ought to be defined as the perpetual and fundamental zero for India. The adoption of such a bench-mark would, it is true, enable the zero of the height-scale to be laid down; instead of having to refer to a varying datum, such as mean-sea-level, we should be able to define the zero for India, as being so many feet or millimetres below a certain point of the rock surface of the earth. But this is the only advantage, and it is open to question whether such an advantage is not more apparent than real.

In the first place we are in doubt, whether the rock surface of the earth is not itself liable to constant movement; we regard mean-sea-level as a varying datum, because its relative height with

* By 'favourable conditions' it is intended to denote both (i) firm ground, and (ii) fairly level ground. A line of levels, that has to traverse swampy ground or loose soil, is not likely to be of the highest degree of accuracy, and levelling operations to a hill-summit over rocky precipitous ground are exposed to inaccuracies from which normal levelling is free.

regard to land is obviously inconstant, but we cannot be certain that the land-surface is absolutely fixed. Even the observed variations of mean-sea-level itself may be largely due to earth-movements. The selection of a fundamental zero-point carries with it the assumption that the land-surface is immoveable. If we recognise the possibility of the land-surface rising or falling, then its advantage over the sea as a perpetual datum is only one of degree.

In the second place, whatever care we may take, no precautions can render a zero-point inviolable. Any bench-mark, however well-chosen, is liable to be destroyed by men, or by weathering, or by earthquakes, or by lightning; the selection of one particular bench-mark as the perpetual zero seems to imply that such a mark is indestructible.

For these reasons we have thought it best to adopt no particular bench-mark as the fundamental zero. The mean surface level of the Arabian Sea and of the Bay of Bengal,—determined from long-continued observations at the tidal stations *on our open coasts*,—has been accepted as the datum.

In taking this step we have had to assume that the mean-sea-levels at all our open coast stations belong to one and the same level surface, but that is our only assumption*. Having fixed upon a particular level surface as our datum, we have determined the heights of all bench-marks above that datum, and it would seem to be useless to endeavour to decide now which of the rock-cut bench-marks is likely to be the most stable and the most enduring. If our successors wish to determine the secular changes in the height of the land-surface of India, they will be better able to do so, by re-levelling to *many* of our existing primary bench-marks and by discussing all the relative changes they discover, than by assuming one of the existing bench-marks to be eternally immoveable, and all changes found with regard to it to be absolute.

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* This question is discussed more fully in chapter VIII.

CHAPTER V.

METHODS OF OBSERVATION.

A line of levels and its subdivisions.

All the main-lines of levels in India and the greater portion of the branch-lines are 'simultaneous double lines'; some few of the branch-lines are single lines.

The description 'simultaneous double line' is applied to a line of levels, which has been observed independently by two observers, who are working simultaneously, one following immediately after the other.

On a 'simultaneous double line' the observations of the two levellers are taken under practically identical conditions, and their results are consequently not so independent as on a 'fore-and-back double line', over which one observer moves throughout the line in one direction and the other observer traverses the whole line in the opposite direction. The second leveller on a 'simultaneous double line' may moreover be biassed, and his results may not furnish an independent check upon the leading leveller's work. Systematic or cumulative errors are likely therefore to be larger upon a 'simultaneous double line', than upon a 'fore-and-back double line', although the probable error deduced from the differences between the two levellers will generally appear smaller. The only advantage of the 'simultaneous double line' is, that a check by the second leveller is provided at each stage, so that a mistake is generally discovered as soon as it is made, and the complete revision of a long line becomes very seldom necessary. From an economic point of view the 'simultaneous double line' is to be recommended, being more expeditious; from a scientific point of view the 'fore-and-back double line' is superior, being subjected to more independent tests.

On a 'simultaneous double line' the progress is not continuously in the same direction, for the *direction* of work is changed daily. There is thus no more probability of error accumulating on account of the sameness of direction than there is in a 'fore-and-back double line'.

In India each line of levels has been divided into sections, the length of a section being from 1 to 4 miles, and it has been found convenient to make each day's work into a separate section. The plan of having daily sections becomes, however, impracticable, when adverse atmospheric conditions are obliging levellers to take short sights only.

Each section is made, as a rule, to commence from and to end at a bench-mark, bench-marks being erected at intervals averaging $1\frac{1}{2}$ miles. A section may comprise several bench-marks, and does not necessarily end at the first bench-mark reached.

On each line the total length of sections levelled in the forward direction is made equal to the total length of sections levelled in the backward direction. Levellers endeavour to correct the balance between the forward and backward sections at every embedded bench-mark, so that on every twelve miles of line six miles have been levelled in one direction and six in the opposite.

Each section of a line of levels is, as a rule, subdivided into an even number of staff-to-staff distances—either 10 or 12 or 14 or more. A staff-to-staff distance is the name applied to the length of line between the back-staff and forward-staff: of recent years this distance has never been allowed to exceed 10 chains (660 feet,—200 metres,—0·125 of a mile): formerly levellers would erect their staves 12 chains from the level and 24 chains from one another, or even more. (Chapter III, page 37).

The plan of subdividing each section into an *even* number of staff-to-staff distances has the advantage that it brings on to the terminal mark the *same* staff, that was erected on the initial mark, and it thus cancels the evil effects of any inequality in the distances of the zeros of the two staves above the soles of their shoes (*vide* Chapter III, page 36). When a staff has been erected upon any mark or peg, it remains there until it has been observed both from the rear and from the front,—that is, until it has served both as a fore-staff and as a back-staff*.

The level is almost always erected midway between the two staves, so that the length of a level-shot, *i. e.* the distance *from the level* to either staff, is equal to half the staff-to-staff distance†. In the passage of a wide river or of difficult ground an exceptional arrangement of level and staves may become justified. The number of stations at which the level is erected on any one section will as a rule be even.

The maximum permissible length of a level-shot has been reduced in recent years to 330 feet (*vide* Chapter III page 38): the distance of 330 feet is moreover only employed under favourable conditions; it is decreased as soon as the levellers find a difficulty in reading staff graduations to 0·001 foot. The limitation of a level-shot to 330 feet makes 660 feet the maximum staff-to-staff distance.

Steps preparatory to observation.

The methods of testing and adjusting the levels have already been described in Chapter II; the necessity for comparing staves against a standard bar has been explained in Chapter III, and the steps taken to provide bench-marks in advance of the levelling work have been referred to in Chapter IV.

The value of one division of the scale attached to the level-tube has to be accurately determined; this can be done either with a bubble-tester or with a well-graduated theodolite. When the value of one division has been discovered, a subtense table has to be prepared, in which the corrections to staff-readings are entered for different amounts of dislevelment and for different lengths of shot. If, for example, the value of one division of the scale is equal to $1''\cdot709$, the correction to the staff-reading for each level division will be—

$$1\cdot709 \times \sin 1'' \times n, \text{ where } n \text{ is the length of shot in feet.}$$

When neither a bubble-tester nor a theodolite is available, the subtense table must be prepared directly from observations of the staff: the level is directed upon a staff, erected at a measured distance, and the successive changes in the staff-readings are compared against the corresponding changes in the dislevelment of the instrument.

Before taking the field the levellers should provide themselves with maps of the country which their proposed route is to traverse; they should mark on these maps all principal stations of the triangu-

* Although it is the rule to have an even number of stations between *bench-marks*, a section and a day's work may occasionally have to be ended after an odd number of staff-to-staff distances have been levelled. In such cases no error will be introduced, if the one section is closed and the next section is commenced with the same staff erected on their junction-point. In equalising sections levellers endeavour to balance *lengths of line* and not the *numbers* of staff-to-staff distances. A 'forward' section may comprise more stations than a 'backward' section; this is of no consequence, provided the total length of forward sections is equal to the total length of backward sections.

† The level, though erected at equal distances from the two staves, is not always placed exactly in the line joining them, but it is generally very near and there occur but few exceptions to the rule that the level-shot is half the staff-to-staff distance.

lation within 12 miles of their route. Owing to the imperfections of maps it is not always possible for a leveller to decide, whether a branch-line of levels to a principal station is feasible, until he has been over the actual ground; but the advantages accruing from connections between the triangulation and the levelling are considerable, and unless a leveller notes beforehand the exact positions of the principal stations, he may pass them by without being aware of their proximity*.

Programme of observations.

The levels and their adjustments have already been described in Chapter II. Detailed instructions to levelling officers have been issued in the Hand-book of the Trigonometrical Survey. In his narrative report for 1907-08 Mr. Erskine explained the differences of procedure rendered necessary by the introduction of the American levels in place of the old cylindrical levels.

The following is a brief summary of the programme of observation:—

(1). The staves are erected upon bench-marks or upon wooden pegs driven firmly into the ground: the distance between the staves is not to exceed 660 feet. On soft or sandy ground the legs of the level are made to rest upon wooden pegs firmly driven.

(2). The staves are made vertical by means of their plummets and are guyed in position. The brads or sockets, upon which the staves stand, have been described on pages 37, 39 and 43. As mentioned on page 39 the sockets intended for use upon pegs have pins projecting from below: the sockets made for use upon bench-marks have no projecting pins†. Care is taken now to use the same socket on every bench-mark throughout a line.

(3). The distance between the staves having been carefully measured, the level is placed midway between them, and, approximately on the line joining them‡.

(4). In order to relieve the instrument of any tendency to settle in one direction, the stand should be always placed with one particular leg towards one particular staff: as this staff becomes the fore-staff and back-staff alternately, the position of the instrument is reversed at each station.

(5). The instrument is erected and levelled §: the staff-readings are taken to the nearest 0·001 foot, and the position of the bubble during each staff-reading is recorded.

(6). At every odd-numbered station the back-staff is read before the forward-staff, and at every even-numbered station the forward-staff is read before the back-staff. In practice this rule can be easily followed, if the leveller will remember that at every station one particular staff-man has to show his staff first.

(7). With Walker's staves the black faces were read before the white: with Cowie's and the Committee's staves the 12·5-inch faces were read before the foot-faces.

(8). The instrument is shaded from the direct rays of the sun by means of a canvass umbrella during observation.

(9). The temperature is recorded at the beginning and close of work both in the morning and evening.

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* It is not necessary to level to every principal station within 12 miles of the route. If a long line of levelling approaches within one station only of the triangulation, the latter should be connected if possible, but if the levelling passes near several stations in one locality, it will suffice generally, if two are connected. No rule however can be laid down, for the character of the ground intervening between the levelling line and the principal station has to be considered; in the plains of Northern India the ground is so flat, that it would be a mistake for a leveller to omit the connection of any near station, especially as trigonometrical values of height are of no great use in very level country, but in mountainous districts it would be waste of his time to endeavour to carry levelling over rocky precipitous slopes.

† The pattern of brad with the projecting pin is shown in plate XIII; the pattern *without* pin has not been depicted in the plate.

‡ At each station the magnetic bearings of the two staves were formerly taken in order to ensure that the instrument had been placed near the line joining them. The American levels are not provided with compasses.

§ If D = dislevelment of instrument, then $D = \frac{O_1 - O_2 + E_2 - E_1}{4}$, where O_1 is the reading of the object-end of the level, when the telescope is directed to the first staff, and O_2 is its reading when the telescope is directed to the second staff, and where E_1 and E_2 are the corresponding readings of the eye-end.

If V is the subtense in decimals of a foot for one division of the level at the particular length of shot, one staff-reading will have to be increased by DV, and the other staff-reading be decreased by DV; the same result will be attained by correcting the *difference* of staff-readings by 2 DV.

Limits of differences allowed.

The old rule used to be, that if the two values for the difference of level, obtained one from the white faces and the other from the black faces of the staves, differed by more than 0·005 foot, the observations were to be repeated.

The introduction of the American Binocular levels has led to the abandonment of double-faced staves, and there is consequently no longer any comparison between black and white faces. But the levellers are still able to guard against mistakes by comparing their reading of the centre wire on the staff with the mean reading of all three wires. The correct difference between the reading of the centre wire and the mean reading is now tabulated for various distances, and when a leveller finds his observed difference disagrees with the correct difference by 0·003 foot, he repeats the observations.

The two levellers compare their values for the difference of level, not only at the end of each section but *at each station.* If at any station the levellers differ by more than 0·005 foot*, *both* must repeat the observations, until their results agree within this limit†.

The method by which levellers compare their results at each station has the single advantage, that an immediate check is always provided,—that the necessity for complete revisions of long lines is rendered less frequent.

But from a scientific point of view, as has been already pointed out, this economic advantage does not compensate for the loss of the levellers' independence. When two levellers compare notes at every station, they are more liable to be biassed and more easily able to come to an agreement, than if their comparisons are made only at the ends of sections. Now that the main level net of India has been completed, and branch-lines alone remain to be observed, nothing would be gained by changing the system of comparison, that has been in vogue for 50 years; but if in the future any of our great sea-to-sea main-lines come to be revised for scientific purposes, the question of substituting sectional comparisons for stational will have to be considered.

The re-observation of a staff-to-staff distance, rendered necessary by the appearance of a discrepancy exceeding the permissible limit, is known as 're-levelling': the re-observation of a complete line of levels rendered desirable by the appearance of a large closing error is known as "revision".

The following table shows the amount of 're-levelling' that has had to be carried out during the last five years:—

TABLE XIX.

SEASON	Total number of miles levelled over	Total number of stations observed at	Number of stations from which re-levelling by both levellers was found necessary	Percentage of levelling that was found to require re-levelling
1904-05	310	4619	36	0·8
1905-06	387	4958	108	2·2
1906-07	805	11554	408	3·5
1907-08	972	12094	323	2·7
1908-09	1067	13528	500	3·7
Totals for five years	3541	46753	1375	2·9

* Originally the permissible limit was 0·006 foot, see page IV, *Heights in N. W. Provinces and Bengal, 1866.*

† For the maximum difference permissible between two levellers at the end of a section Lallemand gives $3^{mm}\cdot 0$ (*vide Le Nivellement Général de la France*, 1899, p. 40 and *Nivellement de haute precision*, p. 245). Hayford gives $4^{mm}\cdot 0 \sqrt{K}$ (*vide Annual Report Coast and Geodetic Survey U. S. A.* 1903, p. 213) where K = length of section in kilometres. If the Indian staff-distance is assumed to be 660 feet or 200 metres and the Indian limit of 0·005 foot be transposed into its metric equivalent, $1^{mm}\cdot 524$, the Indian formula may be written $1^{mm}\cdot 524 \sqrt{L}$, where L = distance levelled in units of 200 metres. If for L we substitute K, the number of kilometres in the distance levelled, the Indian formula becomes $1^{mm}\cdot 524 \times \sqrt{5} \times \sqrt{K} = 3^{mm}\cdot 4 \sqrt{K}$, or very nearly a mean between the limits prescribed by Lallemand and Hayford.

A percentage of 2·9 for re-levelling seems to be low, and it obliges us to consider the following questions:—

(i). Is our limit of permissible disagreement fixed too high? *

(ii). Have we reduced our maximum permissible length of shot (330 feet) more than was really necessary?

(iii). Are we unduly reducing our out-turn and rate of progress in order to avoid the necessities of re-levelling?

Accidental errors will presumably increase, if the permissible length of shot is increased; the percentage of re-levelling found necessary will *ceteris paribus* be presumably larger with shots of 660 feet than with shots of 330 feet.

The old records however show, that when the length of shot was allowed to be double what it is now, the percentage of re-levelling was actually less than at present.

This anomalous result can only be explained in one way,—the independence of the observers was less complete under the old rules of procedure than under the new †.

If the smallness of the percentage of re-levelling is due to a too high limit of permissible disagreement, or to the reduction of level-shots to 330 feet, we are not at present disposed to introduce any reform. But if the low percentage has been brought about by the sacrifice of time and of out-turn, we should endeavour to rectify the balance ‡. In all probability the lowness of the percentage is a result of our system of stational comparison. The one advantage claimed for this system is, that re-levelling is seldom found to be necessary. If levelling results are compared at every station, the length of re-levelling rendered necessary by the appearance of an undue discrepancy is limited to one set of observations, but if comparisons are only instituted at the ends of sections, a considerable length of line will have to be re-levelled, whenever a disagreement is met with.

It is advisable to keep the pegs of the three stations behind the second leveller in the ground, in case it is found necessary to re-level. The khalasi, whose duty it is to take out the pegs over which work has been carried, always maintains three stations intact between himself and the second leveller.

No limit has been placed upon the total divergence accumulated from the starting point between the two levellers, nor upon the rate at which this divergence accumulates.

No limit has been placed upon the closing error allowed, when a new line of levelling connects with an old bench-mark.§ These closing errors will be discussed in a subsequent chapter, and compared with the probable errors of the levelling. When, however, closing errors have appeared, which are unexpectedly and inexplicably large, the lines of level implicated have been revised throughout.

Between 1877 and 1881 a line of levels was carried through from Bombay to Madras: this line was executed with great care and with reliable instruments, but it produced circuit errors of a

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* In the 2nd footnote to page 73 we showed that our limit of error approximated very closely to Lallemand's and Hayford's: but this was on the assumption that levelling errors are mostly accidental and accumulate with $\sqrt{K}$: if we assume that levelling errors are mostly systematic and accumulate directly with K, then Lallemand's permissible error for 1 kilometre will be $3^{mm}{\cdot}0$, Hayford's will be $4^{mm}{\cdot}0$, and the Indian permissible error will be $7^{mm}{\cdot}6$.

† When the levelling operations were first started in 1858, the two levellers were instructed to take their observations independently of one another. In course of years, however, a system came into vogue, under which the advance leveller on a line used to leave his result at each station behind him for the information of the rear leveller; the latter came thus to be informed of his colleague's result, before he had taken observations himself. This system, which rendered the rear leveller liable to bias, was abolished in 1900. Since that date no information has been given by the advance leveller to the rear leveller; the latter on obtaining a result sends it forward now to the advance leveller, and it is the advance leveller who examines the divergence, and who decides whether to return and relevel or not *Trigonometrical Survey Hand-book*, page 264, para. 35, 2nd Edition.

‡ It may be held that the principal sacrifice of out-turn arises from a reduction in the lengths of shots, and that if the length of shot is kept within 330 feet, the out-turn can admit of no increase. This argument is correct to a certain extent, but still there are other precautions, such as the avoidance of unfavourable atmosphere, to which observers may be paying too great attention in their anxiety to prevent divergences of 0·005 foot. Conditions of work in India are such, that it would be inadvisable with our present levelling instruments to increase the permissible length of shot beyond 330 feet.

Hayford states that the most economical speed is secured by continually keeping length of sight such, that percentage of reobservation will be from 5 to 15. He considers a small percentage to indicate excessive caution, and he regards a moderate amount of re-running as due to an attempt on the part of the observers to attain maximum speed consistent with requisite accuracy, and not to inability to secure such observations, that no re-running would be necessary, *vide Mr. Hayford's Appendix No. 3, page 215, Annual Report 1903 Coast and Geodetic Survey, U. S. A.*

§ *General Report, Survey of India*, 1893-94, Appendix, page lxiv.

whole foot upon both its northern and southern flanks, and it closed on the mean-sea-level at Madras with an error of 2·98 feet. The magnitude of the closing errors gave rise to much discussion, and in 1906 it was decided to revise the whole line. The revision was carried out between 1906 and 1908. The results of the original and revisionary observations are compared in Part II of this volume.

Owing to the magnitude of the closing error, 0·93 foot, which appeared when the levelling connected with mean-sea-level at Karwar, the line connecting Bellary and Karwar was revised in 1907-08.

The following table gives a list of the double simultaneous lines that have been revised:—

TABLE XX.

Complete line	Line numbers from Tables I (page 5) and V (page 20)	Seasons		Length in miles	Reasons for revision
		Original work	Revision		
Bombay-Madras ...	32,31,25,26, 22,21,14,8.	1877-81	1906-08	881	Magnitude of closing error.
Bellary-Karwar ...	16,17.	1873-74	1907-08	240	Magnitude of closing error.
Karachi mean-sea-level -Tatta	78,43.	1859-60	1893-94	16	Disappearance of bench-marks at Manora and Karachi.
Saharanpur-Dehra Dun ...	61 A.	1861-62	1906-07	44	To test the effects of the earthquake of April 5th, 1905.
Dehra Dun-Mussooree ...	61 A.	1903-04	1905-06	19	To test the effects of the earthquake of April 5th, 1905.
Mandalay-Pyinmana ...	Burma A.	1892-93	1903-04	161	To investigate the causes of the changes in height, that had occurred in the case of some bench-marks at Mandalay and Thazi.

Out of the 17971 miles of double-levelling, observed between 1858 and 1909, 1361 miles, or seven and a half per cent, have had to be revised.

Precautions against errors.

Errors that can be eliminated.

(i). By the system employed in India of placing the instrument midway, and close to the line joining the two staves, the effects of the following sources of error are eliminated:—

(*a*) Collimation error. (The collimation error is determined monthly, and kept small).

(*b*) Error in the permanent adjustment of the striding-level.

(*c*) Error due to the earth's curvature.

(*d*) Error due to normal atmospheric refraction.

(ii). If the back-staff is read first at every odd-numbered station and the forward-staff first at every even station, the errors due to uniformly changing refraction will tend to cancel*.

Atmospheric refraction affects the readings of levelling staves in four different ways:—*firstly*, when the atmosphere is steady and the ground is level, refraction tends to make the reading of each staff slightly too low, but leaves the difference between the staff-readings correct, if staff distances are equal; *secondly*, when the atmosphere is steady, and the ground is sloping steeply, refraction tends to raise one staff more than another and to introduce a systematic error †; *thirdly*, when the ground is being rapidly heated by the rays of the rising sun, the lowest stratum of air becomes in its turn heated by the ground, and begins to flow upwards; this has the effect of making the readings of the staves appear to rise and fall vertically, and even to remain for a minute or two in quite abnormal positions; such conditions are unsuitable for observation; *fourthly*, when the air is bubbling, the staff-graduations appear to dance or vibrate; they are then difficult to intersect, but no systematic error is to be feared.

(iii). The height of the zero of graduation above the bottom of the staff is not the same in all staves: but the effect of a difference of staff-zero upon the height of bench-marks can be eliminated, if the particular staff that was placed on the origin is also placed on each bench-mark: if the number of stations between bench-marks is made even, one particular staff will come to be placed on every bench-mark. When the lowest graduation is laid off upon the brass, the wood of the staves has a tendency to shrink, and a separation from the brass is caused. A zero error is then introduced, and this must be allowed for in determining the zero of the staff, unless the system of reserving the same staff for erection on all bench-marks is followed.

(iv). No error will be caused by the irregularities of the axis of the instrument, if the same foot-screw is placed always towards the same staff: this system will prevent the instrument from being erected in the same position always with reference to the line being followed.

Movements of pegs.

An error may be introduced into a line of levels, if the peg upon which a day's work has closed, rises or sinks, before work is re-commenced. It is therefore always advisable to close a day's work, where possible, upon a permanent mark, such as the coping of a culvert. If no such mark is available, the pegs of the three last stations should be left in the ground, and precautions taken to guard them from being disturbed. The heights of these pegs should be check-levelled next day. It is possible that a peg may rise or sink in the interval between its support of the forward-staff and its support of the back-staff; any such movement as this should be discovered, when the results of the two levellers are compared.

Instrumental dislevelment.

No sensible error should be introduced into the results by the actual dislevelment of the instrument, if this is made small. An instrument cannot be kept exactly level; a small dislevelment is unavoidable. The amount can, however, be determined, and the requisite correction applied.

Each staff-reading must be followed without any delay by a reading of the bubble, as the dislevelment of the instrument is constantly changing.

On a long line of levels the negative level-corrections should be approximately equal to the positive. If level-corrections of one sign greatly exceed corrections with the opposite sign, the effects of an error in the value of one division of the level scale will not be eliminated. The observer can prevent a preponderance of sign in any one direction by giving to his instrument an occasional dislevelment in the other direction‡.

* Staff readings should follow one another without delay, so that they may be taken under similar atmospheric conditions. The system of triplicate wires does not allow of staff-readings following each other so rapidly, as with single wire readings.

† *See* Appendix No 4 of this volume.

‡ It has been found that the sun exercises a constant dislevelling effect upon instruments, tending to raise the end that is situated towards itself and to lower the opposite end. *See* General Walker's paper in *Vol. XXXIII, Memoirs, Royal Astronomical Society*. His introduction to *Tables of Heights in Sind, the Punjab, N.W. Provinces and Central India, 1863*, is in 1909 still worthy of study.

With the cylindrical and rectangular levels the readings of the bubble and staff could not be made simultaneously; they were necessarily consecutive, and short as the interval between them was, it was enough to cause a slight error. With the American Binocular levels the readings of the bubble and of the staff can be made simultaneously.

The determination of the dislevelment will be liable to error (i.) if the bubble is badly illuminated, (ii.) if the instrument is disturbed between the observation of a staff and the corresponding reading of the bubble. A bubble is surrounded by an apparent rim, caused by the adhesion of the liquid to the glass-tube, and this rim frequently leads to a misreading of the position of the bubble, especially with a strong light falling obliquely on the instrument*: uniform illumination, which can generally be obtained by reflectors, is thus important. In order to avoid disturbing the instrument at the critical moment the observer should endeavour to avoid moving his feet, or transferring his weight from one foot to the other, *between* his readings of the staff and of the bubble: no khalasi should be allowed to stand within 12 feet of the instrument, while observations are in progress, with the exception of the man holding the umbrella.

Errors in staff-readings.

Errors in staff-readings may arise either (i.) from the staff having varied in length, or (ii.) from actual inaccuracies in estimating the position of the wire as projected against the staff.

The tables XIV to XVIII of Chapter III illustrate the variations in length that staves are liable to undergo. These variations are the results of changes in atmospheric humidity, and they constitute a very serious source of error. In order to minimise their effects the levelling staves are now compared against a standard bar not only at the beginning and at the end of each season's work, but three or four times a month throughout the operations. In former years (1858-1903) the comparisons of the staves with the bar were less frequently made: the increased frequency of these comparisons (1903-1909) and the reduced length of level-shot (1900-1909) and the freedom of the second leveller from bias (1900-1909) are the three principal causes of the superiority of modern levelling.

It was in order to guard against inaccuracies and mistakes in estimating the position of the wire against a staff that differences of zero and of unit were introduced into the staff-faces: these differences have, however, now been allowed to disappear from the modern single-faced staves, as it is hoped that the triplication of the wires will enable the observers to diminish inaccuracies and avoid mistakes of estimation.

When the staff-graduations are viewed through a heated atmosphere and appear to dance up and down, the only remedy is to decrease the distance of the staves from the level.

When a length of shot exceeds two chains (132 feet or 40 metres) the whole numbers of feet,—as painted on the staff,—are visible in the telescope, and the triplication of wires should be a sufficient safeguard against inaccuracies or mistakes of estimation. But when a length of shot is less than one chain (66 feet or 20 metres) a foot-number, as painted on the staff, is seldom visible in the telescope, and the three wires, whilst showing the foot decimals, afford no clue as to the *whole number* of feet. In such cases the leveller has to take special precautions to avoid falling into an error of a whole foot. If he allowed such an error to creep into his work, it would probably be discovered by the second leveller. But in precise levelling the first leveller must not trust to his colleague to save him from errors of whole feet: an error of a whole foot is in levelling so serious that each leveller must devise his own safeguards. In hilly country short shots of one chain are common, and under these circumstances the triplication of the wires will not be an adequate substitute for the double-faced staves without patient and extraordinary precautions†.

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* *General Walker's Memoranda on Levelling Operations, 1868.*

† It has been decided (1909) to paint the numbers of the whole feet at every 6 inches of the staff's length; some foot-number will always then be visible in the telescope even with shots of one chain.

Systematic errors.

Systematic errors are more serious than accidental: the results of levelling on many of the Indian lines show that systematic errors, tending regularly to accumulate, are to be feared.

Variations in the lengths of staves will be liable under certain conditions to produce systematic errors, but these can be controlled by frequent staff comparisons.

When operations are being carried over a line of country which slopes always in one direction, either upwards or downwards, the rays of light from the level to the up-staff pass regularly nearer to the ground than the rays from the down-staff. In these cases the effects of refraction are not eliminated by the plan of erecting the level midway between the staves, and will tend continually to accumulate. Our knowledge of the laws of atmospheric refraction is insufficient to enable us to calculate trustworthy corrections, and the only precaution the levellers can take is to confine their operations to periods, when the temperatures of the air and of the soil are equal, and when the atmosphere seems quiescent.*

With the American Binocular levels the readings of the bubble and the staff are taken simultaneously, but with the older patterns of levels an interval necessarily occurred between the reading of the bubble and of that of the staff; this interval was believed by General Walker to be at times the cause of systematic error. However carefully the instrument might be shaded, the action of the sun, he thought, tended to produce a continual displacement of the bubble in one direction,—a displacement that was apt to occur regularly between a bubble and a staff-reading.

The division of every line of levels into back and forward sections has probably contributed to reduce systematic errors more than any other device.

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* See, however, Lallemand's method of calculating the effects of refraction, Appendix No. 4 of this volume.

Specimens of record and computation.

The following is a specimen of the field-book, when the telescope of the level is fitted with one wire, and when double-faced staves are employed. The first pair of back and forward readings are taken on one face of the staves and the second pair on the other face, as explained on page 72. Two values of the difference of height are thus obtained, and from these, when corrected for dislevelment, the mean value is abstracted. The rule for the sign of the level correction is given in the heading of the form.

Main-line from Damukdia to Siliguri.

Back Section No. (1) from G.T.S. □ B.M. *embedded at Sara Railway Station to B.M. "C" at Sara Ghat with Cylindrical B.M.*

Level No. 3. Value of 1 Division of Scale = 1″·8689. Length of Chain = 66 feet.

Rule for Correcting Dislevelment. Consider Object-End level-readings $\frac{-}{+}$ *for* $\frac{\textit{back}}{\textit{forward}}$ *staff and Eye-End level readings to be* $\frac{+}{-}$ *for* $\frac{\textit{back}}{\textit{forward}}$ *staff. Find the algebraic sum of the two Object-End and the two Eye-End readings; half this sum is the quantity with which to enter the subtense table. The correction to have the same sign as the sum. In order to facilitate recording, the proper signs have been printed in columns 3 and 4 opposite the Back and Forward staves.*

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Station No. and Staff Positions	Distance and Bearings of Staves from Instrument	Level-Readings, Dislevelment, and Corrections					Staff Readings	Approximate Differences of Level		Corrected Differences of Level		Level Reduced to Origin	Remarks	Level Correction	Total Level Correction
		Object End	Eye End	Sum	½ Sum	Correction		Rise +	Fall −	Rise +	Fall −				
Back	0·50	−74·1	+61·0				9·884						Commenced work		
Ford:	0·50	+74·0	−61·0				11·036		1·152		1·152		at 7·55 a.m. 6th		
1	Alg: Sum	−0·1	0·0	−0·1	0·05	0							Dec. 1900.		
B	312	−74·0	+60·5				4·336		1·148		1·148		Temp. 70°.		
F	132	+74·0	−61·0				5·484						Back-Staff No.		
	Alg: Sum	0	−0·5	−0·5	0·25	0							III on		
											1·150	−1·150			0
B	3·00	−71·4	+59·2				6·314						G.T.S.		
F	3·00	+72·7	−58·0				10·047		3·733		3·731		□		
2	Alg: Sum	+1·3	+1·2	+2·5	1·25	+2							B.M.		
B	322	−71·3	+59·2				0·764		3·737		3·733		A. D. 1900		
F	142	+73·5	−56·9				4·501						embedded at Sara		
	Alg: Sum	+2·2	+2·3	+4·5	2·25	+4							Railway Station.		
											3·732	−4·882		+3	+3
B	2·00	−70·5	+56·9				9·208								
F	2·00	+70·7	−56·9				9·427		0·219		0·219				
3	Alg: Sum	+0·2	0	+0·2	0·10	0									
B	338	−70·7	+56·7				3·659		0·216		0·216				
F	158	+70·7	−56·8				3·875								
	Alg: Sum	0	−0·1	−0·1	0·05	0									
											0·218	−5·100		0	+3
B	4·00	−69·8	+55·4				11·828								
F	4·00	+69·6	−55·5				10·140	1·688		1·688					
4	Alg: Sum	−0·2	−0·1	−0·3	0·15	0									
B	17	−69·7	+55·3				6·277	1·685		1·685					
F	197	+69·7	−55·2				4·592								
	Alg: Sum	0	+0·1	+0·1	0·05	0									
										1·687		−3·413		0	+3
B	4·10	−68·3	+54·6				9·447								
F	4·10	+68·6	−54·3				9·351	0·096		0·097					
5	Alg: Sum	+0·3	+0·3	+0·6	0·30	+1									
B	7	−68·6	+54·7				3·899	0·098		0·099					
F	187	+68·6	−54·3				3·801								
	Alg: Sum	0	+0·4	+0·4	0·20	+1									
										0·098		−3·315		+1	+4
B	3·80	−67·6	+53·4				8·361								
F	3·80	+66·7	−54·2				10·251		1·890		1·892				
6	Alg: Sum	−0·9	−0·8	−1·7	0·85	−2									
B	6	−67·4	+53·5				2·810		1·892		1·891				
F	186	+67·7	−53·2				4·702								
	Alg: Sum	+0·3	+0·3	+0·6	0·30	+1								—	—
B		−66·8	+54·2				8·358								
F		+68·1	−52·7				10·253		1·895		1·892				
Repld:	Alg: Sum	+1·3	+1·5	+2·8	1·40	+3									
B		−66·3	+54·3				2·806		1·899		1·894				
F		+68·7	−52·0				4·705								
	Alg: Sum	+2·4	+2·3	+4·7	2·35	+5									
										(4)	1·892	−5·207		+2	+6
B	4·00	−67·5	+52·2				11·152								
F	4·00	+66·7	−52·7				11·751		0·599		0·601				
7	Alg: Sum	−0·8	−0·5	−1·3	0·65	−2									
B	13	−67·7	+51·7				5·603		0·596		0·599				
F	193	+66·6	−52·7				6·199								
	Alg: Sum	−1·1	−1·0	−2·1	1·05	−3									
											0·600	−5·807		−3	+3
									Totals ...	1·785	7·592	−5·807			

Recorded by Balwant Atma Ram. Examined by Zille Hasnain. Levelled by Zille Hasnain. Compared by Zille Hasnain and Rikhi Ram.

The following is a specimen of the field-book, when a level with three wires is used, and when only one face of each staff is read :—

Main-Line Ferozepore to Nagaur. Forward Section No. (19) ○ on canal bridge near telegraph post $\frac{874}{14}$ to ○ on boundary pillar between telegraph posts $\frac{871}{20\&21}$. With American Level No. 2697. Value of 1 Division of Scale = 1″·4948. Length of Chain = 66 feet.

Rule for Correcting Dislevelment. Consider Object-End level-readings $\frac{-}{+}$ for $\frac{\text{back}}{\text{forward}}$ staff and Eye-End level readings to be $\frac{+}{-}$ for $\frac{\text{back}}{\text{forward}}$ staff. Find the algebraic sum of the two Object-End and the two Eye-End readings; half this sum is the quantity with which to enter the subtense tables. The correction to have the same sign as the sum. In order to facilitate recording, the proper signs have been printed in columns 3 and 4 opposite the Back and Forward staves.

A positive level correction should be added to a Rise and deducted from a Fall. A negative level correction should be deducted from a Rise and added to a Fall.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Station Number Staff Position and Chainage	*Distances and Bearings of Staves from Instrument*	*Level-Readings, Dislevelment and Corrections*					*Staff Readings*	*Sum and mean of Staff Readings*	*Approximate Differences of Level*		*Corrected Differences of Level*		*Level Reduced to Origin*	*Remarks*	*Level Correction*	*Total Level Correction*
		Object End	*Eye End*	*Sum*	*½ Sum*	*Correction*			*Rise +*	*Fall −*	*Rise +*	*Fall −*				
Back	0·99	−14·5	+14·9				2·101	6·788						Commenced work on 28th November 1907 at 7-10 a. m. Temp. 45° F. Weather clear. Back-staff No. 20A. on ○ cut on E. End of canal bridge near T. P. No. $\frac{874}{14}$.		
							2·263	2·263								
1							2·424			1·903		1·903				
Ford:	0·99	+15·0	−14·3				4·005									
							4·167	4·166								
1·98	*Alg: Sum*	+ 0·5	+ 0·6	+ 1·1	0·55	0	4·327	12·499					−1·903		0	0
Back	1·50	−14·0	+15·5				3·490	11·200								
							3·732	3·733								
2							3·978			0·021		0·020				
Ford:	1·50	+15·1	−14·3				3·508									
							3·753	3·754								
4·98	*Alg: Sum*	+ 1·1	+ 1·2	+ 2·3	1·15	+ 1	4·000	11·261					−1·923		+1	+1
Back	2·00	−14·6	+15·0				3·501	11·494								
							3·832	3·831								
3							4·161			0·093		0·093				
Ford:	2·00	+15·0	−14·6				3·595									
							3·924	3·924								
8·98	*Alg: Sum*	+ 0·4	+ 0·4	+ 0·8	0·40	0	4·252	11·771					−2·016		0	+1
Back	2·50	−16·1	+13·6				3·531	11·829								
							3·943	3·943								
4							4·355		0·895		0·895					
Ford:	2·50	+16·3	−13·3				2·636									
							3·048	3·048								
13·98	*Alg: Sum*	+ 0·2	+ 0·3	+ 0·5	0·25	0	3·459	9·143					−1·121		0	+1
Back	3·00	−15·2	+14·4				2·631	9·380								
							3·128	3·127								
5							3·621			0·524		0·524				
Ford:	3·00	+15·0	−14·8				3·155									
							3·650	3·651								
19·98	*Alg: Sum*	− 0·2	− 0·4	− 0·6	0·30	0	4·148	10·953					−1·645		0	+1
Back	3·50	−15·2	+14·7				3·261	11·523								
							3·841	3·841								
6							4·421		0·471		0·470					
Ford:	3·50	+14·8	−15·0				2·792									
							3·370	3·370								
26·98	*Alg: Sum*	− 0·4	− 0·3	− 0·7	0·35	− 1	3·947	10·109					−1·175		−1	0
Back	4·00	−14·7	+15·2				3·253	11·740								
							3·915	3·913								
7							4·572		0·539		0·539					
Ford:	4·00	+14·9	−15·0				2·711									
							3·375	3·374								
34·98	*Alg: Sum*	+ 0·2	+ 0·2	+ 0·4	0·20	0	4·035	10·121					−0·636		0	0
										Totals ...	1·904	2·540	−0·636			

Recorded by Lachman Singh. Examined by Zille Hasnain. Levelled by Zille Hasnain. Compared by Zille Hasnain and Lachman Singh.

Rate of progress.

Between 1858 and 1863 the average daily rate of progress of the levelling party was four miles on level ground. The average annual out-turn of work was 354 miles of double line, besides occasional short branches to connect places of importance. The daily duration of operations in the field was rarely less than six hours, often much more. The staves were set up at distances of 8 to 10 chains (528 to 660 feet, 160 to 200 metres) from the instrument in the morning, and at 4 or 5 chains later in the day.*

The average annual out-turn remained at about 350 miles until 1900, when the reduction of the maximum length of shot from 12 to 5 chains led to a marked decrease in the rate of progress. Between 1900 and 1908 the average annual out-turn by one levelling detachment was 260 miles. It is expected that the introduction of binocular levels and of single-faced staves will in the near future raise the out-turn considerably, but our experience is not as yet sufficient to justify any figures being given.

The daily rate of progress has necessarily varied according to the nature of the country traversed: the progress is more rapid over level ground than over slopes, and over firm ground than over soft soil †; good roads are more suitable and more accurate routes than railways, as the ballast of the latter absorbs much heat and affects the atmospheric stratum in contact with it. Even in the same region of India the daily out-turn has been found to vary considerably; between Ramnad and Tuticorin it was hardly more than 2½ miles, whereas between Trichinopoly and Tanjore it amounted almost to 4½ miles: in some districts it has been less than 2 miles.

Between 1858 and 1909 there were completed in India 17971 miles of double-levelling, of which 1361 have had to be revised; the total number of bench-marks that have been connected is 15981 (68 standard, 1559 embedded, 13920 inscribed, 434 stations of triangulation, principal and secondary).

The average cost of one mile of completed line of simultaneous double-levelling was Rs. 53- before the maximum permissible level-shot was reduced to 5 chains, and is Rs. 85 now.

It would not, however, be safe to attribute the increase of cost entirely to the reduction of the length of the level-shot. A short time after the level-shot had been reduced, the scheme for erecting monolithic standard bench-marks was introduced, (*vide* Appendix No. 2) and this has increased the cost of the levelling operations. The increased frequency of comparisons between the staves and the standard, and the plan for securing the second leveller against bias were also initiated about the same time, as the level-shot was reduced. Moreover general averages of cost have to be deduced from widely differing figures; and one year's expenditure will differ considerably from another year's, according to the distance of the work from the head-quarter office. Long initial and return journeys are expensive items, and the old head-quarters of the levelling party at Poona were more centrally situated than they are at Dehra Dun. The transfer from Poona to Dehra Dun took place very shortly before the level-shot was reduced. In the last five years too there has been a general rise of prices in India. If the several contemporaneous changes are taken into consideration, it will be found that the reduction of the level shot has perhaps increased the cost of levelling from Rs. 53 to Rs. 65 per mile, and that the additional rise from Rs. 65 to Rs. 85 must be attributed to other causes.

Levelling over steep ground.

It is difficult to maintain the accuracy of levelling operations over steep ground, which should always be avoided if possible. The spirit-levelled height of a hill-summit, which is difficult of approach,

* *Heights in Sind, the Punjab, N. W. Provinces and Central India*, 1863 page 27, para 39.

† In 1873-74 the levellers working on the Gooty-Karwar line reported that the cotton-soil gave trouble owing to its instability and owing to the strata of air above it being in a state of unrest. In 1875-76 the line from Shikarpur (Cutch) to Viramgam traversed the Ran of Cutch, which was covered by water 1 or 2 feet deep. Both the level and staves had to be erected on pegs 5 feet long: the bubble had to be read by the second observer, whilst the first was reading the staff. In 1881 a net-work of creeks had to be crossed by levelling near the mouth of the Mahanadi; this jungly swamp of about 18 miles is covered with water at high spring tides, and the stands of the instruments had frequently to be set up in water nearly 2 or 3 feet deep: as the soil was loose and slushy, special precautions had to be adopted, and Mr. Rendell had to summon his co-adjutor, Narsing Dass, from the rear to read the level at the moment he was reading the staves with the telescope, and he had then to return and perform the same duty for Narsing Dass. In 1892-93 levelling was carried across country in Burma that was under water, *vide para 519, General Report, Survey of India, 1892-93.*

is never accorded a high weight, because, whatever care is taken, it is exposed to a greater liability to error than bench-marks in the plains.

It has not been possible for the levellers to avoid steep ground altogether, because the principal stations of the triangulation are frequently situated on prominent summits, and because the connection of these summits by spirit-levelling is of great service to the triangulation, in that it enables the trigonometrical values of height to be corrected.

The earliest orders to levelling officers on the subject of steep ground are to be found in the Hand-book of Instructions for the Trigonometrical Survey, which was published in 1891; the following is an extract:—

Again supposing a great length of steep ground intervenes between the summit of a hill station and the last point levelled to. In this case a staff should be erected over the last point and a second staff laid transversely with one end resting on a convenient spot on the side of the slope while the other is supported by a man and raised or lowered till the indications of a small bubble placed on it show that it is horizontal: the reading on the vertical staff corresponding to the lower edge of the transverse staff should then be taken several times and the difference of level deduced. In this way by a succession of measurements, the top of the hill will be reached and the difference of level found.

The methods here laid down were evidently not found altogether satisfactory, for in 1902 a new hand-book of instructions was issued and the only references to exceptional methods and to steep ground are the following*:—

There are a few cases which require exceptional treatment. Thus supposing the height of a tower station has to be determined, *firstly*, when the foot can be levelled up to, and, *secondly*, when it cannot be reached. In the first case the levelling should be carried up to a peg or mark at the foot of the tower and a tape suspended from a staff laid horizontally on the summit of the tower and levelled by means of a spirit-level placed upon it. By this means a direct measurement of the difference of height between the summit of the tower and the mark levelled to, is obtained. In the second case a levelling staff should be erected on the summit of the tower and the angular elevation of two divisions, near the top and bottom of the staff, measured with a small theodolite centered over the last point levelled. The height of the summit of the tower above the eye of the observer and consequently above the levelled point can then be readily deduced.

As already mentioned, when levelling over steep ground or branch-lines to hill stations, Cushing's and Bolton's levels with the folding stands should be used.

In the General Report of the Survey of India for 1905-06 the following reference to the subject of steep ground appears†:—

A system of determining the heights of points situated on steep ground by means of cross-staves and a mason's level has been in force in the Levelling party for many years past; it was however considered unsatisfactory and the heights determined with it were only published to the nearest foot. During the past field season the system was revised and improved. A light wooden bar fitted with a pair of wires at each end with which to read the vertical staves, and a pair of brass slides carrying a slow-motion screw to hold this bar on the staves were constructed. Experimental observations were taken with the new apparatus in the field and the results obtained were found to agree within very close limits with those of spirit-levelling of precision.

This system can now be used with advantage in levelling over steep and intricate ground where the ordinary levels cannot be used.

In his narrative report for 1905-06 Mr. Erskine gave the following account of Munshi Syed Zille Hasnain's proposed method of carrying accurate height-observations over steep ground‡:—

Determination of Heights by the Horizontal Bar Method.

A system of determining the heights of points situated on steep hills by means of cross-staves and mason's level has been in force in the Levelling party for many years past. It was resorted to only in connecting some of the G. T. Survey hill stations which were found to be inaccessible by ordinary levelling operations. The system was however considered weak and the heights thus obtained were published to the nearest foot. During the past field season Munshi Syed Zille Hasnain, Sub-Assistant Superintendent, thoroughly revised this system and introduced several improvements in it to place it on a more scientific basis in order that the results obtained with it might compare more favourably with those of levelling of precision. He designed a brass slide carrying a slow-motion screw and a light wooden horizontal bar fitted with a pair of wires at each end with which to read the vertical staves. The above designs with a detailed procedure of the system, as improved by Munshi Syed Zille Hasnain, were submitted to the Superintendent, Trigonometrical Surveys, and met with his approval. A pair of brass slides and a horizontal bar were prepared and experimental observations were taken with them in the field. The results obtained were found to agree within very close limits with those of spirit-levelling of precision.

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* *Trigonometrical Survey Hand-book*, 2nd Edition, 1902, page 267, paras. 45, 46.

† Page 48, para. 230.

‡ *Extracts from Narrative Reports, Survey of India*, 1905-06, page 112.

The above system can be used with advantage in levelling over portions of steep and intricate ground occasionally met with in the course of levelling operations where the ordinary levels cannot be used.

A detailed note on the working of this system is herewith appended :—

Instruments required.

2 levelling staves with ropes and plummets complete.
2 brass slides.
1 spirit-level mounted on a metal plate containing a fairly sensitive bubble with graduations cut on it (to be adjusted before use).
1 horizontal bar (10′ × 1″ × 1½″) made of strong light wood.
1 measuring tape 50′.

Method of observation.

(i) Place the station pegs, as far as possible, at a uniform distance of about 9½ feet. Mount the staves and make them perfectly vertical by means of the plumb-lines and guy ropes.

(ii) Fix one of the brass slides on the higher staff just a little above the peg and the other slide on the lower staff approximately on a level with the former. Put the horizontal bar on the slides with the marked end of the bar on the back-staff. Place the level in the centre of the bar and by gently raising or lowering one of the slides bring the bubble roughly in the centre of its run: then firmly clamp the slides.

(iii) Adjust the bar on the slides so that the centre of the bar may be equidistant from the two staves: this condition will be satisfied when the two ends of the bar project equally from the two staves as indicated by the number of inch spaces marked at each end of the bar.

(iv) Put the level exactly in the centre of the bar with its marked end towards the mark on the bar.

(v) By means of the slow-motion screw of one of the slides bring the bubble exactly in the centre of its run. Then read the two staves where they are intersected by the plane of the two parallel wires fixed at each end of the bar. For this purpose raise or lower your eye until the two wires appear to perfectly coincide with one another: then read the staves One observer to read the back-staff and the other the forward-staff simultaneously.

(vi) Lift the horizontal bar from the slides; turn the staves 180° round on the pegs keeping the slides intact; place the bar on the slides with the same end on the same staff. The other face of the bar will now be touching the staves and any error due to the plane of each pair of the wires being out of the horizontal will thus be eliminated.

(vii) Adjust the bar as in (iii) and place the level turned end for end so that the marked end of the level will now be opposite the mark on the bar. The bubble will be found to be very nearly in the centre of its run. If it is slightly out, bring it into the centre by means of the slow-motion screw of one of the slides.

(viii) The observers should now change places and read the two staves as before.

(ix) This will give two values for the station which should not differ by more than 0·005. If they do, repeat the observations and take a double set again in the two positions of the level and the bar as before. If the two repeated values show a closer agreement, reject the first two values; if they differ by about the same amount as the first, accept the mean of all the four values.

(x) The above will complete all the observations at the first station. The back-staff should now be removed and mounted on the next forward peg and the whole process gone through in the same manner as detailed above.

(xi) Care should be taken to keep the marked end of the bar always on the *same* staff throughout the operations and every line should consist of an even number of stations. This will cancel the errors due to the planes of the two sets of wires at the two ends of bar not being in the same horizontal plane.

(xii) The observations should be recorded in the regular levelling field book exactly in the same manner as in ordinary levelling, each station being numbered consecutively and the two vertical staves being respectively called 'back' and 'forward' with reference to the direction of the line followed.

(xiii) The height so determined should be corrected for the difference of unit of staves from 10 feet.

NOTE.—It is sufficient to use only one face of the staves throughout the operations.

Levelling over wide expanses of water.

It is occasionally necessary to carry a line of levels across a broad river, but as rivers differ so fundamentally, it is not possible to lay down any general rule for all cases.

The Hooghly was crossed successfully by the method of graduated poles: a graduated pole was erected near each bank, the line joining the poles being made perpendicular to the direction of the current. The graduation, intersected by the water-surface, was read simultaneously at each pole several times, and as the Hooghly is a tidal river, the observations were able to be taken at both flood and ebb tides and at slack water. Upwards of 300 observations extending over four days were taken. A difference of level of nearly 0·17 foot was found between rising and falling tides, but the mean of the two differed by only 0·0054 foot from the level obtained at slack water. On page 56 *General Report, Survey of India, 1881-82*, General Walker stated that "the general mean may be accepted within half an inch (0·04 foot) "of the truth, and is probably much more exact than any result, which might have been obtained by "measuring the vertical angles across the river or by any other process".

The tide-pole method which had proved satisfactory in the case of the Hooghly, was found by Munshi Zille Hasnain to be unsuitable for the Indus: in the Punjab the Indus consists of a great number of separate streams, tending in some places to converge, in others to diverge, and it is not possible to determine the direction of the current of the river, as a whole, with sufficient exactitude to enable the two poles to be erected in a line perpendicular to it. The Indus was crossed by means of a level and staves, very long shots being employed.

In 1863 General Walker wrote as follows*:—

During the course of the operations, the Karachi harbor, and several large rivers were crossed. The longest distance between instrument and staves, was 34 chains (of links), which occurred at Karachi; over rivers, the distances were rarely more than 17 chains. The uniformity and steadiness of the strata of the atmosphere, over a large body of water, enable satisfactory readings to be taken at distances which would be hopelessly impracticable over land.

In 1856 the River Chenab was crossed at three points, where experiments were made to determine the amount of error to which one is liable in referring to the surface of a river, at the opposite extremities of a section across, when the breadth is too great, for a staff, on one bank, to be read from the other. Sections were selected at right angles to the stream, and pools were dug in the sand on each side, to obtain an unagitated surface of water for reference. The results, by direct levelling, differed from those referred to the margin of the stream, by 0·032, 0·039, and 0·074 feet, respectively, in the three instances, giving an average error of ·048, the average breadth of river being 12 chains.

In 1873-74 wide expanses of water had to be crossed in the Ran of Cutch: but as the water was only 1 or 2 feet deep, the ordinary methods of levelling were employed; both the instrument and staves were however erected upon large pegs 5 feet long, and the two levellers had to work together at each level, one reading the staff whilst the other read the bubble.

In 1894 Colonel Hill wrote as follows†:—

Karachi harbour being 36 chains wide at its narrowest part, where the crossing was effected, it was not possible to read directly the graduations on the staves, but readings were obtained with the help of sliding metal indicators with clamps which worked upon the staves. The back-staff was placed on the bench-mark at Humby's Pier, on the Manora side of the harbour; the instrument being set up on the opposite side of the harbour, on the Kimari Groyne, and the forward-staff being on the same groyne 36 chains to the north.

The sliding indicators, which were painted white, were moved up and down, according to signals, by clerks specially trained for the work, until the upper edge of the indicator coincided with the horizontal wire of the instrument; the clamp was then tightened and the reading recorded by the clerk who also made a fine pencil line on the staff corresponding to the level of the upper edge of the indicator, while the observer recorded the level readings at the time of observation. In this manner 10 very accordant and satisfactory sets of differences of height were obtained on two successive mornings, 20 sets in all. The indicator remained clamped on the staff after the last observation each morning until the observing officer examined and verified the last reading, he then compared the preceding readings recorded by the clerk with the pencil lines drawn on the staff.

For crossing deep-water the levellers have to adopt one of three courses:—

(i.) The pole method.
(ii.) Very long shots with their levels.
(iii.) Vertical angles measured by theodolites.

The differences between the second and third of the above methods are solely instrumental: in each method the shots have to be equally long, and abnormal refraction caused by sand-banks in the river has to be considered. With a level the telescope remains horizontal, and a special sight has to be moved up and down on the distant staff, until it is intersected by the wire of the instrument, and the graduation on the staff can be read: with a theodolite the object to be observed is fixed, and the telescope is moved in altitude, until the intersection is correct. The errors of vertical angles are due more to refraction and to intersection than to limb-graduation, and an observation of an angle of depression of five degrees can be made as accurately with a theodolite as an observation of horizontality can be made with a level. On the whole the third method of crossing rivers is more convenient instrumentally than the second, but it can be seldom adopted, because levelling detachments in the field do not carry accurate theodolites with them. The problem therefore presented by an unbridged river has, as a rule, to be solved in one of two ways, either by the pole method or by very long level-shots.

Some accounts of particular river-crossings are given in Appendix No. 5 of this volume, and the most advantageous methods for particular localities are there discussed.

* *Heights in Sind, the Punjab, N.W. Provinces and Central India*, 1863, page 27, para 41.
† *Spirit-Levelled Heights, Karachi and its Neighbourhood*, 1895 page VII.

CHAPTER VI.

THE METHODS FORMERLY ADOPTED OF DISPERSING ERRORS AND OF PUBLISHING RESULTS.

In this volume the level net of India is being treated as a whole, corrections for variations in the intensity of gravity are being applied, the circuit errors are being dispersed by the method of minimum squares, and the probable errors of the several lines are being extracted.

For the correction and deduction of spirit-levelled heights the bench-marks of India are being classified, both in this volume and in Volume XX, as *lines*, but arrangements are being simultaneously made to classify by *areas* also, for the uses of engineers and surveyors. The bench-marks are being divided into areas of square degrees, and a separate publication will be allotted to each square degree.* The particular square degree, in which every bench-mark is situated, will be given in Volume XX.

From 1858 to 1903 each line of levels was treated separately, and its results when completed were published in pamphlet form. No corrections for gravity were applied and closing errors were dispersed in an arbitrary manner.

For many years the disadvantages of this system have been apparent: pamphlets have been published giving the heights of bench-marks in certain cities, such as Agra or Calcutta, and when subsequent lines of levels have passed through these cities, the new bench-marks have had to be shown in other pamphlets. No one pamphlet can thus be trusted to give all the bench-marks in any particular locality: the pamphlets deal with routes, not with areas: when an engineer wishes to obtain descriptions of all bench-marks within his district, he must first ascertain what lines of level have traversed the district, and he must then procure the pamphlets corresponding to the several lines.

It has moreover not been possible by the arbitrary method to disperse errors completely, and there are many cases in which discrepancies between pamphlets are known to exist.

It would, however, be short-sighted and presumptuous to pass any criticism upon the methods adopted; no other suitable courses could have been devised, save those that have been pursued. It would have been impracticable to postpone the publication of results, until the whole level net had been completed; the disadvantages, that have been mentioned, were unavoidable, if results by lines had to be separately and successively published.

Although all former pamphlets and results will be superseded when this volume is published, it has been thought advisable to place on record here a brief account of the methods adopted by our predecessors in obtaining values of heights and in treating errors.

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* By a square degree is meant the area embraced by one degree of latitude and one degree of longitude.

The published pamphlets of spirit-levelled heights.

Each pamphlet contains lists of bench-marks, and their heights, and generally their distances from an initial point: an introductory chapter gives the names of the levellers employed, the route followed by the levelling, and the designations of the officials in whose custody the embedded bench-marks have been placed. It also describes the methods of observation adopted, and the treatment of closing errors.

To each pamphlet is attached a chart, illustrating the levelling route.

The following is a list of the levelling pamphlets that have been published:—

Date of publication	Title of pamphlet (abbreviated)	Seasons of Levelling	Lines of Levels
1863	Tables of Heights in Sind, the Punjab, N. W. Provinces and Central India	1858-62	(i.) Karachi to Chach (near Peshawar). (ii.) Murghai (near Dera Ghazi Khan) to Ferozepore. (iii.) Ferozepore to Sironj with branch to Dehra Dun.
1866	Tables of Heights in N.W. Provinces and Bengal	1862-65	Agra to Calcutta.
1869-71 (printed in parts)	Tables of Heights in the Punjab, N.W. Provinces and Oudh	1866-70	(i.) Ferozepore to Lahore. (ii.) Multan to Dera Ghazi Khan. (iii.) Delhi to Bareilly and Cawnpore. (iv.) Lucknow to Dildarnagar.
1872-73 (printed in parts)	Tables of Heights in N.W. Provinces and Bengal	1870-72	Gorakhpur to Pirpanti, Purnea and Sonakhoda.
1879	No. 1 Bombay. Spirit-Levelled Heights in Cutch, Kathiawar, Gujarat and Bombay	1874-78	Navanar to Hanstal and Okha, and thence to Viramgam, Ahmedabad, Baroda, Surat and Bombay.
1884 and 1889	Bengal Presidency: Spirit-Levelled Heights in Cuttack, Balasore, Sundarbans, Hooghly and Nadia districts of Bengal	1881-83, and 1887-88	False Point to Diamond Harbour and Calcutta along both banks of the Hooghly: also from Calcutta to Nadia.
1885	No. 4 Bombay. Spirit-Levelled Heights in Bombay Presidency and Central India	1877-78 and 1881-84	(i) Kalyan to Sironj. (ii.) Dhond to Manmad. (iii.) Nandgaon to Dhanvar.
1886	Spirit-Levelled Heights, No. 1 Madras	1869-85	(i.) Madras to Raichur, Bellary and Karwar. (ii.) Arkonam to Bangalore. (iii.) Tuticorin to Cape Comorin.
1886	Spirit-Levelled Heights, Nos. 2 and 3 Bombay	1877-80	(i.) Bombay to Raichur. (ii.) Kedgaon to Hubli.
1887	Spirit-Levelled Heights, No. 2 Madras	1885-86	Madras to Negapatam and Tuticorin.

Date of publication	Title of pamphlet (abbreviated)	Seasons of Levelling	Lines of Levels
1888	Spirit-Levelled Heights, No. 3 Madras	1886-87	(i.) Tuticorin to Erode. (ii.) Shoranur to Cochin. (iii.) Karwar to Mormugao.
1889	Spirit-Levelled Heights, No. 4 Madras	1887-88	Madras to Vizagapatam.
1890	Spirit-Levelled Heights, No. 5 Madras	1888-89	Bangalore to Mangalore.
1891	Spirit-Levelled Heights, No. 6 Madras	1888-90	Bider to Bezwada.
1891	Spirit-Levelled Heights, No. 5 Bombay	1889-90	Navanar to Tatta.
1892	Spirit-Levelled Heights, No. 6 Bombay	1890-91	Rajkot to Bhavnagar.
1894	Spirit-Levelled Heights, No. 1 Burma	1892-93	Elephant Point to Mandalay.
1895	Spirit-Levelled Heights, Karachi	1893-94	Manora to Karachi base-line.
1895	Spirit-Levelled Heights, Calcutta	1894-95	Details of 19 bench-marks near Calcutta.
1896	Spirit-Levelled Heights, No. 7 Bombay	1877-78 1882-83 1890-92	Nandgaon to Bilaspur.
1896	Spirit-Levelled Heights, No. 8 Central Provinces	1891-92 1893-94	Bilaspur to Kendrapara.
1896	Spirit-Levelled Heights, No. 9 Orissa	1894-95	Cuttack to Vizagapatam.
1903	Spirit-Levelled Heights, No. 10 Madras	1891-92 1894-95 1896-97 1898-99	Vizagapatam to Allahabad and Sironj.
1903	Spirit-Levelled Heights, Bengal and Assam	1899-1902	Calcutta to Sonakhoda and Dhubri.

The following table gives the names of the pamphlets in which the details of the various level-lines of this volume were originally published:—

TABLE XXI.

Numbers of level-lines (see pages 5 to 12 and 20 to 24).	Pamphlet	Numbers of level-lines (see pages 5 to 12 and 20 to 24).	Pamphlet
1, 1A, 2 ...	No. 2 Madras.	42 ...	Bengal Presidency.
3, 4 ...	No. 3 Madras.	43 ...	Sind.
3A ...	No. 1 Madras.	44, 45 ...	No. 5 Bombay.
5 ...	No. 2 Madras.	46, 47, 47A, 48, 49, 50, 51 ...	No. 1 Bombay.
6 ...	No. 3 Madras.	48A, 48B ...	No. 6 Bombay.
7, 10, 11, 12 ...	No. 1 Madras.	51A, 51B, 51C, 51D	No. 1 Bombay.
8* ...	No. 1 Madras.	52 ...	†
9 ...	No. 2 Madras.	53, 54, 55, 57 ...	Sind.
13 ...	No. 3 Madras.	55A, 56 ...	Punjab, N. W. P. and Oudh.
14* ...	No. 1 Madras.	56A ...	†
15, 16*, 17*, 18, 19	No. 1 Madras.	57A, 57B ...	†
20 ...	No. 4 Madras.	58, 59, 60 ...	No. 10 Madras.
21* ...	No. 1 Madras.	60A ...	†
17A ...	No. 3 Madras.	61, 62, 63 ...	Sind.
18A ...	No. 5 Madras.	61A* ...	Sind.
22* ...	Nos. 2 and 3 Bombay.	61B, 61C, 61D ...	†
23 ...	No. 1 Madras.	62A ...	Punjab, N. W. P. and Oudh.
24 ...	No. 6 Madras, Nos. 2 and 3 Bombay.	62B ...	†
24A ...	†	63A ...	†
25*, 26* ...	Nos. 2 and 3 Bombay.	64, 64A, 65 ...	Punjab, N. W. P. and Oudh.
25A ...	No. 4 Bombay.	66, 67 ...	N. W. P. and Bengal, 1866.
26A ...	Nos. 2 and 3 Bombay.	68, 69, 69A ...	Punjab, N. W. P. and Oudh.
27, 28, 29 ...	Nos. 2 and 3 Bombay.	70 ...	N. W. P. and Bengal, 1866.
30 ...	No. 4 Madras.	71 ...	N. W. P. and Bengal, 1873.
31*, 32* ...	Nos. 2 and 3 Bombay.	72 ...	N. W. P. and Bengal, 1866.
33, 34 ...	No. 4 Bombay.	73 ...	N. W. P. and Bengal, 1873.
35 ...	No. 7 Bombay.	74 ...	N. W. P. and Bengal, 1866.
36, 37, 38 ...	No. 10 Madras.	74A, 74B, 75, 75A, 75B	Bengal Presidency.
39, 39A ...	No. 9 Orissa.	76 ...	N. W. P. and Bengal, 1873.
40, 41 ...	No. 8 Central Provinces.		

* These lines have been revised, since the pamphlets were published, but the revised results have not been published in pamphlet form.

† Results have never been published in pamphlet form.

TABLE XXI.—(Continued).

Numbers of level-lines (see pages 5 to 12 and 20 to 24).	Pamphlet	Numbers of level-lines (see pages 5 to 12 and 20 to 24).	Pamphlet
76A, 77, 77A, 77B, 77C, 77D ...	Bengal and Assam.	83 ...	No. 2 Madras.
		84* ...	No. 1 Madras.
78 ...	Karachi.	85 ...	No. 4 Madras.
79* ...	Nos. 2 and 3, Bombay.	86 ...	Bengal Presidency.
80, 81 ...	No. 1 Madras.	Burma A* ...	No. 1 Burma.
82 ...	No. 3 Madras.	Burma B ...	†

Since 1903 no levelling pamphlets have been published.‡

It was at first intended that all pamphlets should be superseded by this volume in 1906, but when the simultaneous reduction of the closing errors came to be undertaken, the necessity for a complete revision of the whole line of levels from Bombay to Madras (900 miles) (lines numbered 32,31,25,26,22, 21,14,8) became evident, and this revision was not completed till 1908.

Twenty-four levelling pamphlets have been published in all: the first four dealt with lines of levels stretching from Karachi eastwards through the Punjab to Bengal: six treated of the lines in the Bombay Presidency, and six treated of those in Madras: one was reserved for the levels from the coast along the Hooghly, one for a short line in Calcutta, and one for Eastern Bengal and Assam. The pamphlet treating of the Central Provinces was called No. 8, that treating of Orissa No. 9, and that dealing with the line from Vizagapatam to Allahabad was named No. 10 Madras. One pamphlet was printed for Burma, and a small pamphlet for Karachi.

The original system of serially numbering pamphlets by presidencies seems to have been changed in 1896. Before that date pamphlets were numbered No. 1 Bombay, or No. 1 Madras, a separate series being reserved for each presidency: but after 1896 the numbering was according to the date of issue. Thus No. 7 appertained to Bombay, No. 8 to the Central Provinces, No. 9 to Orissa and No. 10 to Madras. The pamphlet for Eastern Bengal and Assam received no number.

Under the system of publishing successive pamphlets containing values of heights arbitrarily adjusted, it was inevitable that discrepancies would creep in: thus in the No. 5 Madras pamphlet Mr. Cole has pointed out that the values given for the heights of certain bench-marks differed from the values given for the same marks in the No. 1 Madras pamphlet. Similarly in the No. 4 and No. 5 Bombay pamphlets Colonel Baird and Mr. Cole have called attention to other discordances. There are, moreover, discordances, which have not been pointed out in any publication.

The original determinations of mean-sea-level.

In this volume the mean level of the seas surrounding the Indian peninsula has been deduced from continuous observations at several tidal observatories and has been adopted as the datum for spirit-levelled heights. A full account of the tidal observations will be given in Chapter VIII.

It is desirable however to explain in this chapter, how the mean level of the sea was determined, when it was made the datum for heights in the spirit-levelled pamphlets.

* These lines have been revised, since the pamphlets were published, but the revised results have not been published in pamphlet form.
† Results have never been published in pamphlet form.
‡ *General Report, Survey of India*, 1903-04, Appendix, page xxx; *Report of the Survey Committee*, 1904-05, part II, page 129, para 10 and page 209, para 28.

(i). The heights on the level-lines stretching over Northern India from Sind to Eastern Bengal, which were published in the four earliest pamphlets, were all referred to the mean-sea-level of Karachi harbour, and this level was determined by tidal observations at Manora extending over two semi-lunations in 1858.

(ii). The heights given in the tables of the No. 1 Bombay pamphlet for the level-lines in Cutch, Kathiawar, Gujarat and Bombay were referred to the mean level of the sea, as determined from the analysis of the observations taken at Okha with a self-registering tide-gauge in 1874-75.

(iii). The heights given in the Bengal Presidency pamphlet (1884 and 89) for the level-lines near the Hooghly were referred to the mean level of the sea at False Point, as determined from the tidal observations taken from 1881 to 1883 at the Hookey Tola Tidal Station.

(iv). The heights given in the Madras pamphlet No. 1 and the Bombay pamphlets Nos. 2, 3 and 4 were referred to the mean levels of the sea, as determined from tidal observations taken at Bombay from 1877 to 1881, at Karwar from 1879 to 1881, and at Madras from 1881 to 1884.

(v). The heights in subsequent pamphlets were made to emanate from bench-marks, the heights of which had already been fixed in the earlier pamphlets; they were made to close either on bench-marks already fixed in pamphlets or on any new tidal stations that happened to be conveniently situated. Thus the heights in the No. 2 Madras pamphlet emanated from the 2nd bench-mark of the No. 1 Madras pamphlet and closed on the tidal observatories of Negapatam (open 1881 to 1883), Pamban (open 1878 to 1882) and Tuticorin (open 1871 to 1872). The heights on one line of No. 3 Madras pamphlet emanated from one bench-mark and closed on another mark of No. 2 Madras pamphlet. Other lines of No. 3 Madras pamphlet closed on the tidal stations of Cochin, Mormugao and Karwar. The heights of No. 4 Madras pamphlet originated from a bench-mark of the No. 1 Madras pamphlet and closed on the tidal stations of Cocanada and Vizagapatam.

It is unnecessary to recapitulate in detail the exact methods adopted in every pamphlet: the values of height in the earlier pamphlets were generally accepted as fixed starting points for the later pamphlets, and when new tidal observatories came to be erected, new lines of levels were made to close upon them.

On the degree of accuracy that has been considered necessary in the past.

In this volume the probable errors of the several level-lines will be calculated in Part II, and will be compared in Part III against the closing errors of the circuits. But in the levelling pamphlets no probable errors were abstracted, and no limit of permissible closing error was laid down. Beyond the instructions to a leveller regarding the accordance of his results from different staff-faces, the only accepted rule seems to have been that the two levellers should never differ by more than 0·005 foot*.

On the lines in the Punjab, observed between 1859-1862, the following terminal differences between observers were noticed:—in 310 miles a difference of 0·72 foot, in another length of 301 miles a difference of 0·942 foot, in another length of 440 miles a difference of 0·209†.

On the lines between Calcutta and Agra, run in 1862-65, it was reported that the terminal difference between levellers never exceeded 0·4 foot.

In 1881 an error of 3 feet appeared on the line from Bombay to Madras, and this was considered very serious and gave rise to much discussion‡. General Haig's investigation of the error has been abstracted from the Levelling pamphlets, No. 1 Madras, page ix, and Nos. 2 and 3 Bombay, page ix, and is here given:—

On closing the line Bombay, Kem, Raichur, Gooty, Madras, a discrepancy presented itself making Madras mean-sea-level appear 3 feet higher than that at Bombay. A similar comparison gave Karwar mean-sea-level about 1 foot higher than Bombay,

* Chap. V of this volume, page 73.

† *Heights in Sind, the Panjab, N. W. Provinces, and Central India*, 1863.

‡ See *General Report, Survey of India*, 1880-81, page 41. "The closing discrepancy of 3 feet at Madras is materially greater than any error "previously met in the course of the levelling operations of this survey, which have been carried over many thousand miles and tested at a number of "closing points and junctions of circuits, and have been conducted with special precautions to guard against errors of all kinds, whether accidental or "cumulative".

and Madras mean-sea-level about 1 foot higher than Karwar. With reference to these discrepancies it is to be noticed that the first is materially greater—both absolutely, and relatively to the distance levelled from Bombay—than any error previously met with in the course of the levelling operations of this survey, which have been carried over many thousands of miles and tested at a number of closing points and junctions of circuits. Moreover, a very similar discrepancy, almost identical in sign and magnitude, is stated to have been met with at the close of the railway levels between Madras and Bombay.

It might be perhaps supposed that the discrepancies are partly due to differences in the sea-level; for it is well-known that there are variations in the general level of the surface of the ocean at different places, so that if compared with the surface of the spheroid, or other geometrical figure which most closely corresponds to the figure of the earth, the surface of the ocean will in some places be above and in others below that surface, owing to the attractive influences of mountains and to irregularities in the density or thickness of the earth's crust. Now Colonel A. R. Clarke, C.B., R.E., in his 'Geodesy' has investigated problems of this nature, and furnishes formulæ for calculating the difference of height of mean-sea-level at different places under certain hypotheses; and his formulæ may be applied in the present instance.

The line of levels crosses the Borghat in the Sahyadri range at a height of 2040 feet, or 0·4 of a mile in a distance of 45 miles from Bombay, and descends gradually to Madras a distance of 595 miles; the distances here given are horizontal. If we apply these data to Colonel Clarke's formulæ and assume the density of the earth above the level of the sea to be half the mean density of the earth, we find the mean-sea-level at Bombay to be 31 feet higher than that at Madras. But such differences of height, however considerable, cannot be recognised by the spirit-level; for the causes which produce them must equally affect both the spirit-levels of the instruments and the water-level of the ocean. A theoretical discrepancy would exist if a line of levels could be carried horizontally to Madras through an imaginary tunnel at the sea-level; that is, there would be theoretically a difference between the two values of height at Madras as obtained above and below ground, but this has also been calculated by Colonel Clarke's formulæ and been found to be inappreciable and altogether unrecognisable by the instrument.

Having thus shewn that the closing discrepancies of the lines of level are not to be accounted for by the existence of any real difference of sea-level at the different tidal stations, it follows that they must be due to errors of observation, and it is desirable to enquire how these can have arisen.

It seemed highly improbable that any gross error could have crept into the work, owing to the precautions taken—by the employment of independent operators and instruments, and the use of double-faced staves—to guard against such errors. However, there was one portion of the route where such an error, if it had occurred at all, was to be expected, *i.e.*, the section over the Borghat, where the ascents were very steep and the staves were sometimes so close to the levelling instrument, that the foot-marks could not be seen in the field of the telescope; to verify this section it was again levelled over; but the results of the two measurements were practically identical, the actual difference being 0·033 of a foot. Subsequently a second portion of the line from Madras to Arkonam was re-levelled, but with practically identical results.

General Walker, late Surveyor General, in explanation of the discrepancy at Madras, remarks as follows:—" But it "has long been known that all spirit-levelling Operations are liable to an accumulation of small errors which, though individually "so minute as to be barely appreciable at any single station where the instrument is set up, have a tendency to be repeated at "successive stations, and may therefore attain a considerable magnitude at the end of a long series of levels. In the operations "of this Survey it is customary to guard, as much as possible, against such errors by various expedients—such as observing the "back-staff first at one station and the forward-staff first at the next, alternating the direction of operation on successive days, or "at least executing half the work of a field season in the direction of the terminus and the other half in that of the origin; "invariably setting up the staves at equal distances from the instrument at every station; and tilting the instrument occasionally "to guard against the heating influence of the sun, or the cooling influence of the winds, acting on one side more than another, "and causing dislevelments which would be frequently repeated if not counteracted, and thus create an accumulation of error. "There is also a liability to personal misapprehension in reading the bubble of the spirit-level which may tend to produce a "considerable accumulation of error on lines of which the general direction is either towards the sun or opposite to the sun. "Owing to the level being placed above the telescope the observer gets a side view of the bubble, refracted obliquely through the "thickness of the glass tube, which is not so sharply defined as the look-down view from above. The rim round the bubble, caused "by the adhesion of the liquid to the sides of the tube, becomes so prominent that its extremities may be observed instead of those "of the bubble. When light falls obliquely and not vertically on the instrument, and either end of the telescope is pointed to-"wards the light, the outer edge of the rim at the end of the bubble towards the light is more clearly defined than the inner, "while at the opposite end of the bubble the inner edge of the rim is more clearly defined than the outer. Consequently there is a "tendency to assume the instrument to be level when the end towards the light is depressed; and though this tendency would "probably vary in magnitude with different observers, it is likely to affect all persons more or less. Obviously it is uninfluenced "by reversing the direction of operation, though it disappears whenever the direction is at right angles to that of the light. This "personal error in reading the spirit-level and setting the instrument would obviously produce a maximum effect on lines of which "the general direction is meridional, when the operations are carried on equally before and after noon; when carried on between "sun-rise and mid-day, as is more usual in this country, the direction of the line of maximum effect would be south-east and north-"west. The result would be apparently to raise the southern stations relatively to the northern ones. Now this has been found "to occur in a greater or less degree in many of the lines of levels in India connecting tidal stations. For example:—

(1). " From the mean-sea-level of the tidal station of Okha, at the entrance to the Gulf of Cutch, to that of Bombay, "there is an apparent rise of 0·33 foot; length of line 580 miles.

(2). " From the mean-sea-level of Bombay to that of Karwar, there is an apparent rise of 0·93 foot; length of line 530 "miles.

(3). " From the mean-sea-level of Karwar to that of Madras, there is an apparent rise of 0·92 foot; length of line 560 "miles.

"The apparent rise of 3 feet at Madras as compared with Bombay was generated on a line of 730 miles in length; it is "thus materially greater in proportion to the length of the line traversed than the discrepancies met with on the three other lines. "But as all discrepancies are in the same direction, and all agree in raising the southern points relatively to the northern, it "appears possible that all the operations may have been influenced by oblique illumination of the bubbles of the spirit-levels."

Since these remarks were made, the line of levels connecting Karachi with Bombay has been completed, giving a discrepancy of 0·62 foot in the opposite direction to that, which should have occurred, if General Walker's reasoning held good in all cases; and Madras and Beypore have also been connected with a similar result; hence General Walker's remarks do not satisfactorily account for the large discrepancy at Madras, nor is it possible at present to explain it in any other way.*

In Colonel Hill's report for 1886-87 the closing error at Erode was stated to be 0·281 foot, and the 'error per mile' was given for the 700 miles of line as 0·0004 foot†. Colonel Hill reported that the "apparent mean generated error of levelling in the season's work was 0·0008 foot per mile."‡

In 1894 Colonel Hill placed on record his views on the subject of accuracy in levelling; he objected to any system of restricting the permissible error within a limit of so many inches per mile, and he expressed the opinion that the close agreement between levellers insisted upon at each level-shot§ had proved a sufficient check upon accumulation of error. He prepared three tables, one showing the maximum and terminal differences between the two levellers, another giving the closing errors of level-lines at tidal stations, and a third containing the closing errors of circuits. In his discussion of accuracy and errors Colonel Hill had at his disposal fewer data than we have, and his results will necessarily be superseded by the investigations carried out in Parts II and III of this volume, but the opinions and decisions of this influential levelling officer, who was in charge of the operations from 1881 to 1895, will be of permanent interest, and have been reproduced here ||:—

I shall now add some remarks on the standard of accuracy of the Survey of India spirit-levelling operations. The rigorous procedure employed in these operations is described in Colonel Walker's "Memoranda on Levelling Operations" published in the Appendix to the Manual of Surveying for India, 3rd Edition (Thacker, Spink & Co., Calcutta, 1875), and in the introductions to the several departmental pamphlets of spirit-levelled heights. The general system, which is gradually approaching completion, consists at present of lines of double-levelling extending from tidal station to tidal station, either by more or less direct routes near the coasts, or by crossing the Peninsula from sea to sea at different latitudes, the lines sometimes interlacing and forming circuits. The lines have been planned to form junctions with the great triangulation, the heights of which they control, and to follow as much as possible the great lines of communication along rail-roads, high roads, rivers and canals. Standards of accuracy, such as are familiar elsewhere, by which the error of levelling is restricted within such limits as 1 inch per mile, 2 feet or 1 foot per 100 miles, etc., would be useless; for it is seldom that the resulting heights can be checked before the levelling has proceeded for many hundreds of miles. This renders the most rigorous precision imperative; and a very small amount of disagreement is consequently permitted between the readings of the two levellers, who work in concert and with different instruments.

The following table shows the maximum and terminal differences between the heights obtained by the two levellers along six sections of the line of levelling from Karachi, *viâ* Calcutta, to False Point:—

Section of line	Length of Section	Maximum difference between the results obtained by the two levels	Terminal difference between the results obtained by the two levels
	miles	feet	feet
Maru Pir, Upper Sind, to Dera Ghazi Khan	310	0·98	0·98
Maru Pir, Upper Sind, to Karachi	301	1·39	0·94
Dera Ghazi Khan to Chach near Attock	360	0·35	0·01
Calcuttta to Tiliagarhi	242	0·20	0·15
Tiliagarhi to Patka Gerouli	346	0·40	0·38
Agra to Patka Gerouli	343	0·15	0·06
Mean maximum difference per 100 miles ...		0·18	...

The very high standard of accuracy preserved in the Survey of India spirit-levelling operations may be realised by inspecting the following Tables I and II. Table I gives eight typical specimens of lines of levelling connecting tidal stations, and the errors shown in it were calculated on the assumption that the height of mean-sea-level is the same at all the tidal stations. Table II gives five specimens of closed circuits taken at random from the published pamphlets of spirit-levelled heights. In calculating the errors in both tables signs were disregarded, so that errors of contrary signs did not tend to neutralise each other:—

* See page 61, chapter IV of this volume.
† *General Report, Survey of India*, 1886-87, page xl.
‡ *General Report, Survey of India*, 1886-87, page 64.
§ Maximum permissible discrepancy 0·005 foot; see page 73.
|| *General Report, Survey of India*, 1893-94, page lxiv.

Table I.

	Line of levelling from mean-sea-level to mean sea-level at the undermentioned tidal stations	Length of line of levelling	Apparent terminal difference, using latest values of mean-sea-level	Resulting error per 100 miles
		miles	feet	feet
From Arabian Sea to Bay of Bengal	Karachi to False Point *viâ* Calcutta	2,500	+1·72	0·07
	Bombay to False Point direct	1,218	+1·60	0·13
	Karwar to Madras	560	+0·97	0·17
	Beypore to Madras	409	+0·64	0·16
West Coast of India	Okha to Bombay	580	+0·42	0·07
	Bombay to Karwar	530	+0·74	0·14
East Coast of India	Madras to Negapatam	269	−0·52	0·19
	Madras to Cocanada	391	−0·39	0·10

Table II.

Closed Circuit	Length of Circuit	Closing error	Error per 100 miles
	miles	feet	feet
Cawnpore-Meerut-Moradabad-Bareilly-Lucknow-Cawnpore ...	620	0·64	0·10
Dildarnagar-Gorakhpur-Lucknow-Cawnpore-Dildarnagar	602	0·05	0·01
Pirpanti-Dildarnagar-Gorakhpur-Purnea-Pirpanti	815	0·78	0·10
Kedgaon-Gulbarga-Raichur-Gooty-Bellary-Hubli-Kedgaon ...	844	1·13	0·13
Raichur-Gooty-Bellary-Raichur	236	0·16	0·07

The Survey of India does not profess to keep the errors of heights obtained by spirit-levelling within any fixed limit; but prefers turning out the very best work possible and discovering afterwards, what its errors may amount to. Spirit-levelling of which the error does not exceed 1 foot per 100 miles is generally considered to be practically perfect. It will be found that the mean error of the great spirit-levelling operations dealt with in Tables I and II is about 1 foot per 1,000 miles.

Out of the total 17971 miles of double simultaneous levelling, completed between 1858 and 1909, 1361 miles have been revised, (see Chapter IV, page 59),—mainly on account of the magnitude of the closing errors.

On the methods of dispersing closing errors in the past.

On the earliest lines of levels no questions of dispersion of error arose, and the observed values of the spirit-levelled heights were published in the earliest pamphlets without any adjustments being necessary. But as the levelling operations were expanded, new level lines came to be connected in places with old bench-marks, the heights of which had already been fixed and published.

The closing errors, that then appeared, were distributed over the *most recent* lines in order to avoid any disturbances of the published values. Under this arbitrary system infinite weight was given to the oldest lines, and relatively smaller weights to the later.

In the present volume the original observed values of height derived from field records have been taken as data, and all former arbitrary adjustments and dispersions of errors have been disregarded. As however such adjustments have affected the values of height, hitherto published in pamphlets and on maps, a few notes will now be added to illustrate and explain the former procedure.

(i). Note by General Walker dated 1869*—

The height, above the mean-sea-level of Karachi Harbour, of the G. T. S. Bench-mark at Cawnpore, as brought down directly from the Bench-mark at Meerut by the main-line of levels, is

407·75 feet

(*vide page* 12 *of Tables of Heights in N. W. Provinces and Bengal*)

The height as brought down from Meerut by the branch-line through Moradabad, Bareilly, Shahjahanpur, and Lucknow, is

407·11 feet.

Thus the two determinations differ by 0·64 foot, which cannot be considered a material discrepancy, for the two lines are of the respective lengths of 290 and 330 miles, forming a circuit of 620 miles.

As the heights on the main-line, as well as those on the branch-line as far as Bareilly, have already been published, it is not at present desirable to alter them, though this will have to be done eventually. As a provisional measure, the discrepancy of 0·64 foot has been distributed over the levels between Bareilly Church and the Bench-mark at Cawnpore, the argument being the distance in miles from Bareilly.

(ii). Note by Captain Carter dated 1872†—

In order to avoid disturbing, for the present, the tables of heights already printed, the above correction of −0·78 foot has been dispersed provisionally along the line from the Block-stone Bench-mark at Parsoni near Parsurman to the Block-stone Bench-mark at Pirpanti railway station; the argument used for dispersion being the distance in miles between these points. The length of the circuit under consideration may be reckoned thus

From Gorakhpur *viâ* Dildarnagar to Pirpanti Bench-mark	417	*miles*
„ *viâ* Purnea to „ „	398	„
Total circuit of	815	„

(iii). Note by Mr. Cole dated 1885‡—

The bench-marks at Kalyan and Dhond, from which Series i and iv originate, appertain to the line of Spirit-levels which has been carried from Bombay to Madras. This line has already been corrected for closing errors at Madras and elsewhere, and it is therefore necessary to consider the heights of the Kalyan and Dhond bench-marks as no longer susceptible of change. From Kalyan bench-mark a connection has been effected through Series i, ii and iii with bench-marks in the neighbourhood of Sironj of which the heights had been previously determined by spirit-levelling from Karachi. Three points were connected with, *viz.*, the S.W. end of the base-line, and by a branch-line, Surantal H.S. and Mohasa bench-mark; of these the first appeared to have been tampered with, the position even of the lower mark being questionable, but the other two were in good order. The comparison at Surantal gave the height as brought up from Kalyan a value 0·247 of a foot in excess of that brought up from Karachi, and at Mohasa 0·280 of a foot in the same direction.

Series iv connects Dhond with Manmad, a bench-mark in Series i, of which the value by Series iv was 1·033 of a foot in defect of that by Series i.

The discrepancies appearing at Surantal and Mohasa must of course be considered as errors, as also that at Manmad; and it has been desirable to disperse these errors before publishing the heights; because of the inconvenience which would be occasioned by having to assign different heights to the same bench-mark according to the direction from which it was reached. As Series i, ii and iii were levelled over by two observers working independently, while Series iv was levelled over by one observer only, it has been thought best to adjust the former first without regard to the latter.

Since the line from Karachi to Sironj has received no corrections, the errors at Surantal and Mohasa should be considered as generated between Karachi and Kalyan; but as they are so small, and the levels from Karachi to Sironj were executed and published many years ago and have since been employed as a basis for Canal and Railway levels, it would occasion considerable inconvenience to make any alterations in them; it has therefore been decided to distribute the errors between Kalyan and Surantal only, and this has been done by assigning corrections in proportion to the square root of the distance from Kalyan. The result has been that Series i has received a total correction of 0·123 of a foot, Series ii of 0·084 of a foot, and Series iii of 0·040 of a foot. The small discrepancy of 0·033 of a foot between Surantal and Mohasa was dispersed between these two points. After this adjustment the error at Manmad bench-mark was − 0·914 of a foot and this was distributed through Series iv in proportion to the square root of the distance from Dhond.

All branch-lines have received only constant corrections due to the change in the adopted height of the bench-marks from which they originated.

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* Heights in the Panjab, North-West Provinces and Oudh, 1866-70, page (43).

† Heights in North-West Provinces and Bengal, 1871-72, Section IX, page IV.

‡ *Spirit-Levelled Heights, No. 4 Bombay Presidency*, 1886, page VII.

(iv). Note by General Haig dated 1886 on the adjustment of the great Bombay-Madras error*—

It now remains to shew how the observed heights were treated before publication. As the publication of results of levelling operations with the closing errors unadjusted would cause considerable inconvenience in their use, it has been the custom to make a preliminary adjustment of these errors, leaving any final adjustment for future consideration when the main-lines of level shall be completed. In the present instance the error at Madras being so large and the points of junction and closing points more in number than usual, the adjustment was made by the aid of minimum squares as will be explained, the mean-sea-level being assumed constant.

Neglecting the small circuit Kedgaon, Diksal, Nira Bridge, and omitting also of necessity the line Madras-Beypore, and the junction between Jalarpet and Bangalore which were not executed at the time, the lines of level afforded four comparisons for determining closing errors:—

(1). The line connecting Bombay mean-sea-level with Madras mean-sea-level, *viâ* Kem, Raichur and Gooty.
(2). The line connecting Bombay mean-sea-level with Karwar mean-sea-level, *viâ* Poona and Hubli.
(3). The circuit from Kedgaon, *viâ* Gulbarga, Raichur, Gooty, Bellary and Hubli.
(4). The circuit from Raichur, *viâ* Gooty and Bellary.

The values of mean-sea-level forthcoming at the time the adjustment was made, are given below; but as each succeeding year's tidal observations give additional data, from which to obtain more correct values of mean-sea-level, it was known that they would, from time to time, receive slight corrections. The changes however being very small might well be dispersed afterwards without any sensible disturbance of the calculations. The values of mean-sea-level as first employed in the calculations, and as since corrected, are given by the following data:—

	Above mean-sea-level from determinations obtained to			
G.T.S. Bench-mark at the Town Hall, Bombay	1877, 19·859 feet.	Employed in the calculations.	1881, 19·795 feet.	Finally used.
G.T.S. Bench-mark at Karwar Pier	1879, 8·61 feet.		1881, 8·70 feet.	
Bed-plate of Madras Tide-gauge	1881, 23·071 feet.		1884, 23·123 feet.†	

The closing discrepancies were, using the earlier values:—

(1).	Bombay mean-sea-level lower than Madras mean-sea-level	2·98 feet.
(2).	Bombay mean-sea-level lower than Karwar mean-sea-level	0·93 „
(3).	A closing error in the circuit Kedgaon, Gulbarga, &c.	+ 1·13 „
(4).	A closing error in the circuit Raichur, Gooty, &c.	− 0·16 „

For the adjustment of these discrepancies the lines of levels were divided into sections as follows, where the differences of height of the extremities of each section are also shewn, as well as the length in miles:—

			Diff. of Height.	Length of Line.
Section	(*a*).	Bombay mean-sea-level to Kedgaon	+ 1776·89	153 miles.
„	(*b*).	Kedgaon to Gulbarga	− 285·66	200 „
„	(*c*).	Gulbarga to Raichur	− 163·69	89 „
„	(*d*).	Raichur to Gooty	− 166·51	96 „
„	(*e*).	Gooty to Madras mean-sea-level	− 1158·05	260 „
„	(*f*).	Kedgaon to Hubli	+ 262·64	269 „
„	(*g*).	Hubli to Karwar mean-sea-level	− 2038·60	113 „
„	(*h*).	Hubli to Bellary	− 556·39	140 „
„	(*k*).	Raichur to Bellary	+ 156·89	90 „
„	(*l*).	Bellary to Gooty	− 323·24	50 „

Representing the error in feet of each section by the symbol x with a corresponding subscript, the following equations resulted:—

$$
\begin{aligned}
x_a + x_b + x_c + x_d + x_e \quad &= +\,2\cdot98\\
x_a + x_f + x_g \quad &= +\,0\cdot93\\
x_b + x_c + x_d - x_f - x_h - x_l &= +\,1\cdot13\\
x_d - x_k - x_l \quad &= -\,0\cdot16
\end{aligned}
$$

For the solution of these equations the weight of the levelling of each section was taken as inversely proportional to the square root of the distance.‡

The resulting values of the errors were:—

$$
\begin{aligned}
x_a &= +0\cdot71, & x_e &= +0\cdot83, & x_h &= 0\cdot00;\\
x_b &= +0\cdot72, & x_f &= +0\cdot13, & x_k &= +0\cdot24,\\
x_c &= +0\cdot46, & x_g &= +0\cdot09, & x_l &= +0\cdot18.\\
x_d &= +0\cdot26, & & & &
\end{aligned}
$$

---

* *Spirit-Levelled Heights, Nos. 2 and 3 Bombay*, 1886, page XI.

† Prior to the present determination of mean-sea-level by Major Baird, R.E., at Madras, the value in use was that determined by Colonel DeHaviland from observations made from May to October 1821, and which gave the height of the bench-mark fixed by that officer in Fort St. George as 6·83 feet above mean-sea-level. The value is now 7·88 feet. Hence all heights referred to Colonel DeHaviland's datum require a correction of +1·05 feet to reduce to the G. T. Survey datum.

‡ This appears incorrect; the weight should be inversely as the length; see *Adjustment of Observations* by T. W. Wright, B.A., New York, 1884, page 375.

The more recent values of mean-sea-level already recorded having been received before the dispersion of the above errors had been effected, the errors of the nearest sections were changed by the difference of mean-sea-level in each case; thus

$$x_a \text{ became } = +0{\cdot}65,$$
$$x_e \quad " \quad = +0{\cdot}78,$$
$$x_g \quad " \quad = 0{\cdot}00.$$

The final correction of the individual heights was effected as follows, the square root of the distance from origin being taken as argument:—

Section (*a*). Bombay mean-sea-level to Kedgaon, distance 153 miles.

The individual corrections to the heights were:—

$-0{\cdot}06$ foot, as a constant for the new value of the Bombay mean-sea-level,

$$-\frac{0{\cdot}65}{\sqrt{153}} \times \sqrt{\text{distance from Bombay.}}$$

Section (*b*). Kedgaon to Gulbarga, distance 200 miles.

The individual corrections to the heights were:—

$-0{\cdot}71$ feet, brought forward from Section (*a*),

$$-\frac{0{\cdot}72}{\sqrt{200}} \times \sqrt{\text{distance from Kedgaon.}}$$

The short line connecting Diksal in this section with Nira Bridge in Section (*f*), distance 53 miles, was fitted in between the corrected value of Diksal and the value of Nira Bridge, as given after the adjustment of Section (*f*).

The individual corrections to the heights were:—

$-0{\cdot}99$ feet, brought up to Diksal,

$$+\frac{0{\cdot}25}{\sqrt{53}} \times \sqrt{\text{distance from Diksal.}}$$

The branch-line from Gulbarga to the Bider Base-line received a constant correction of $-1{\cdot}43$ feet brought up from Sections (*a*) and (*b*); and the branch-line from Sholapur to Bijapur, Sholapur being distant 131 miles from Kedgaon, received a constant correction of

$$-0{\cdot}71 \text{ feet, from Section } (a), -\frac{0{\cdot}72}{\sqrt{200}} \times \sqrt{131.}$$

Section (*c*). Gulbarga to Raichur, distance 89 miles.

The individual corrections to the heights were:—

$-1{\cdot}43$ feet, brought up from Sections (*a*) and (*b*),

$$-\frac{0{\cdot}46}{\sqrt{89}} \times \sqrt{\text{distance from Gulbarga.}}$$

Section (*d*). Raichur to Gooty, distance 96 miles.

The individual corrections to the heights were:—

$-1{\cdot}89$ feet, brought up from Sections (*a*), (*b*) and (*c*),

$$-\frac{0{\cdot}26}{\sqrt{96}} \times \sqrt{\text{distance from Raichur.}}$$

Section (*e*). Gooty to Madras, distance 260 miles.

The individual corrections to the heights were:—

$-2{\cdot}15$ feet, brought up from Sections (*a*) to (*d*),

$$-\frac{0{\cdot}78}{\sqrt{260}} \times \sqrt{\text{distance from Gooty.}}$$

After the completion of this adjustment the line of levels from Madras to Beypore was received from the Levelling Party. It appeared that the portion Madras–Arkonam had been re-levelled with a closing discrepancy of $0{\cdot}034$ foot at Arkonam. This discrepancy being very small was treated as an error and dispersed over the new line between Madras and Arkonam. The new values of the bench-marks common to both lines were accepted.

Section (*f*). Kedgaon to Hubli, distance 269 miles.

The individual corrections to the heights were:—

$-0{\cdot}71$ foot, brought up from Section (*a*),

$$-\frac{0{\cdot}13}{\sqrt{269}} \times \sqrt{\text{distance from Kedgaon.}}$$

Section (*g*). Hubli to Karwar, distance 113 miles.

The correction to this section should have been *nil*; but as the abstract had been made out in terms of Karwar mean-sea-level with a preliminary value of the height of the G. T. S. Bench-mark at Karwar = $8{\cdot}76$ feet, a constant correction of $-0{\cdot}06$ foot had to be applied to these recorded values to reduce them to the datum $8{\cdot}70$ feet.

Section (*h*). Hubli to Bellary, distance 140 miles.

The constant correction $-0{\cdot}06$ foot brought up from Karwar through Section (*g*) was applied throughout.

Line.—Bellary to Bangalore, distance 204 miles.

The constant correction at Bellary of $-0{\cdot}06$ foot brought up from Karwar through Section (*g*) would have been applied throughout. But Bangalore having again been levelled to, *viâ* Jalarpet, a second value of the height of Bangalore was found differing by $+0{\cdot}351$ from that brought down from Bellary: this was dispersed by simple proportion between Jalarpet and Bellary, a distance of 290 miles.

Section (*k*). Bellary to Raichur, distance 90 miles.

The individual corrections to the heights were:—

$-$ 0·06 foot, brought up from Sections (*g*) and (*h*),

$$+\frac{0 \cdot 24}{\sqrt{90}} \times \sqrt{\text{distance from Bellary.}}$$

Section (*l*). Bellary to Gooty, distance 50 miles.

The individual corrections to the heights were:—

$-$ 0·06 foot, brought up from Sections (*g*) and (*h*),

$$-\frac{0 \cdot 18}{\sqrt{50}} \times \sqrt{\text{distance from Bellary.}}$$

The heights thus corrected are equally referable to the mean-sea-level of Bombay, Madras, Karwar or Beypore.

The above few notes are typical, and have been selected almost at random from the numerous instances of adjustment: many other arbitrary dispersions of errors are described in the several pamphlets.

The essential difference between the method of dispersing errors, followed in the pamphlets, and that adopted in this volume is, that the earlier level-lines and the earlier tidal observations received in the pamphlets greater weights than the later, whereas in this volume weights are scientifically derived and are independent of date of observation.

But it is necessary to point out that in the future we shall have to relapse again into the arbitrary methods, that we are now denouncing and abandoning. In this volume the circuit errors will be adjusted, and the heights of all bench-marks erected between 1858 and 1909 will be fixed. Any level-lines subsequently observed will have to be fitted in to the adjusted level net. The lines forming the level net will thus be accorded a greater weight than those observed subsequent to the reduction of the level net: from a scientific point of view this is not quite satisfactory, seeing that the future lines of levelling, which should be more accurate and more reliable than the old, will be subordinated. But we are in the same dilemma as our predecessors, and we cannot postpone publication of results, or wait for a finality which is unattainable. Topographers and engineers, who make use of our bench-marks, only ask us to eliminate contradictions and to provide them with accordant values of height, such as they can regard as final: they deprecate frequent modifications and disturbances of values.

This volume will therefore furnish values of heights sufficiently reliable to serve all purposes for at least half a century. In 1958 it will be open to our successors to reconsider the question and to re-adjust the level net of India. By that time there should be a second level net super-imposed on the first: the second will consist of all lines observed between 1908 and 1958, and will be attached to new open-coast tidal stations, such as Porbandar and Akyab, which have not as yet been connected with the levelling network. The second level net (1908-1958) will be a more scientific work than the present one (1858-1908). It will then be interesting to see, what differences in value will occur in the heights of those bench-marks that are common to both nets.

CHAPTER VII.

THE DYNAMIC AND ORTHOMETRIC CORRECTIONS.

The rotation of the earth has given to its surface a spheroidal figure. The equatorial axis is longer than the polar, and the intensity of gravity is less at the equator than at the poles. If we imagine the earth to be enveloped in water to the height (for example) of the Tibet lakes, or 15000 feet, the surface of this envelope will not be parallel to the mean surface of the sea, as it at present exists (*vide* fig. 1, plate XV). The two surfaces will be at a maximum distance apart at the equator and will converge towards the poles. When therefore the water of any large high-level lake is in repose, and when its surface is *level*, the height of the surface above the sea is less at its northern end than at its southern, (*vide* fig. 2, plate XV).

Geodesists have therefore to consider the three following questions:—

(i). Is the whole surface of a large high-level lake to be regarded as at one and the same height, because its water is in equilibrium?

(ii). Is the northern end of such a lake to be given a smaller height than the southern end, because it is nearer to sea-level?

(iii). What value of height will be given to the two ends of the lake by ordinary spirit-levelling operations, emanating from sea-level?

If we could measure a vertical distance of 15000 feet upwards from sea-level, both in southern India and in northern India, the two points reached would be at the same *height*, but they would not be on the same level surface; and water would have a tendency to flow from the northern point to the southern.

In actual practice we judge of relative heights in two ways:—

Firstly,—by direct vertical measurement.

Secondly,—by the flow of water.

If we wish to measure the height of a Survey tower above ground-level, or the height of a tidal observatory above sea-level, we suspend a steel tape or a weighted wire, and we measure the vertical distance. But if we are laying out a canal, or endeavouring to contour ground, we trust to the evidence of water-flow, as indicated by our levels. In the former cases we have recourse to actual linear measurements, in the latter cases we determine the vertical fall by observing the position of liquid at rest.

Two methods of determining heights above sea-level are therefore in recognised use, the one depending upon linear vertical measurement, the other depending upon levels and water-flow; these two methods lead frequently to contradictory results, and we are thus called upon to introduce a system, which will reconcile discordances and furnish consistent values.

Values of height, that are derived from the observation of water-flow, have been named 'dynamic heights', and values denoting actual vertical distance above sea-level have been called 'orthometric heights'.

The ordinary field operation of spirit-levelling may be described as being made up of two parts :— (i.) the determination of a level surface by means of liquid, (ii.) the measurement of vertical distances on the staves. The operation cannot therefore be expected to furnish either dynamic or orthometric heights.

In ordinary levelling, observers assume that all level surfaces are parallel, and that all points situated at any one level surface are separated from sea-level by the same vertical distance. This assumption introduces an error into their work. If we take any two close level surfaces of the earth, they are not separated by equal distances, but at every point of their surfaces the product of the perpendicular distance separating them into the intensity of gravity at the place is constant. If, in figure 2 of plate XV, h and h' represent the vertical distances DC and FE, and if g and g' represent the intensities of gravity at C and E respectively, then $g\,h = g'\,h'$.

If then we wish to find the height of F above C, and if we correct our spirit-levelling results for spheroidal convergence, we shall obtain a different value for every different route we follow: observations along the route CDF will give for F the height h or CD, and observations along the route CEF will give for F the height h' or EF.

Ordinary spirit-levelling, uncorrected for spheroidal convergence, will also give a different value to the height of F for every different route followed; it will moreover fail to furnish either the value h or h' from any one of the routes.*

The following extract is from a note by Colonel Goulier on *Les nivellements de précision* † :—

"In geometrical levelling (*see* figure 3 of plate XV) we are accustomed to consider the distances "$A''A_1$ and $B'B_1$ to be equal, also the distances $B''B_1$ and $C'C_1$, and so on. But these equalities do not "exist, for we are able to prove that the level surface $A''B'$ is not parallel to A_1B_1, similarly $B''C'$ is not "parallel to B_1C_1. The distances A_1A'' and B_1B' are inversely proportional to the intensities of gravity "at the points A_1 and B_1, and the intensities increase from the equator to the poles. The result of the "inequality of the two distances, $A''A_1$ and $B'B_1$ is that the spirit-levelled height for the point B expresses "not, as is generally thought, the height BB_1 of the point B above sea-level, but the height BB_2 of the "point B above the line A_1B_2, which is parallel to the level-line $A''B'$. The spirit-levelled value is "therefore in error by B_1B_2.

"Similarly between B and C the levelling generates an error equal to C_1C_2, so that the spirit-levelled "height of the point C is in error by $C_1C_2 + B_1B_2 = C_1C_3$. Between D and E the error generated is "equal to E_1E_2, and the spirit-levelled value of the height of E is in error by $E_1E_5 = E_1E_2 + D_1D_2$ "$+ C_1C_2 + B_1B_2$".

We are now in a position to answer definitely the three questions propounded above (page 98)—

(i). It is correct to regard the whole surface of the lake as lying at one and the same altitude; and the value of altitude derived under this hypothesis is called its 'dynamic height'.

(ii). It is also correct to regard the northern end of the lake as lower than the southern end, and the values of altitude derived under this hypothesis are called 'orthometric heights'.

(iii). Although two different values of height, the dynamic and the orthometric, are determinable and are equally correct, yet the operation of levelling in the field produces neither the one nor the other.

* Except in the theoretical case when the total rise occurs in one latitude.

† *Comptes Rendus des Séances de l' Académie des Sciences*, Volume CV, page 270: I have taken the liberty of making a somewhat free translation in order to suit the requirements of this volume.—S. G. BURRARD.

From levelling we derive the following successive differences of altitude (*vide* fig. 3, plate XV):—

$$
\begin{aligned}
&(AA'' - BB') \\
&+ (BB'' - CC') \\
&+ (CC'' - DD') \\
&+ (DD'' - EE') \\
= (AA'' + B'B'' + C'C'' &+ D'D'' - EE' = \Sigma(dh),
\end{aligned}
$$

where every successive value of dh is measured on a different vertical. If successive level surfaces were parallel, the expression $\Sigma(dh)$ would be correct, but as this parallelism does not exist, we derive from $\Sigma(dh)$ a value of height that has no physical interpretation.

Formulæ.

The theory of levelling has been lucidly explained by M. Charles Lallemand in his *Nivellement de Haute Précision.* He shows (page 24) that the *dynamic difference of level* between two points A and B is obtained by adding to their observed difference of level the following 'dynamic correction':—

$$\int_A^B \gamma dH,$$

where

$$\gamma = \frac{g - g_{45}}{g_{45}}.$$

The following equation gives the ratio of the dynamic to the 'field' difference of height between two bench-marks:

$$\frac{\text{dynamic difference of height}}{\text{field difference of height}} = \frac{g \text{ at station of observation}}{g \text{ on same level surface in latitude } 24°}.$$

Let g_l and g_{24} represent the respective accelerations of gravity, at the height of the point considered, in latitudes $l°$ and 24°; and let $g°_l$ and $g°_{24}$ represent the corresponding accelerations at sea-level. In latitude $l°$ there is a mass of height H between sea-level and the station of observation, but at the assumed datum point in latitude 24° there is no solid matter supposed to be standing above sea-level;

$$\text{then} \quad g_{24} = g°_{24}\left(1 - \frac{2H}{R}\right)$$

$$\text{and } g_l = g°_l\left(1 - \frac{2H}{R} + \frac{3H}{4R}\right).$$

Therefore

$$\frac{\text{dynamic difference of height}}{\text{field difference of height}} = \frac{g_l}{g_{24}}$$

$$= \frac{g°_l\left(1 - \frac{2H}{R} + \frac{3H}{4R}\right)}{g°_{24}\left(1 - \frac{2H}{R}\right)} = \frac{g°_l}{g°_{24}}\left(1 + \frac{3H}{4R}\right).$$

We have decided to neglect the Bouguer term $\frac{3H}{4R}$ for two reasons :—

(1.) because its introduction does not tend to produce greater accordance between observed and theoretical values of gravity;
and (2.) because its omission from the dynamic correction does not affect the closing errors of levelling circuits.

We therefore get

$$\frac{g_l}{g_{24}} = \frac{g^{\circ}_l}{g^{\circ}_{24}}$$

$$\text{and dynamic difference of height} = \frac{g_l}{g_{24}} \times \text{field difference of height.}$$

In the case of India, Helmert's formula for g will have to be written

$$g^{\circ}_l = g^{\circ}_{24} \left\{1 - 0{\cdot}002655\left(\cos. 2l - \cos. 48^{\circ}\right)\right\}$$

Lallemand shows (page 16 of his book) that orthometric heights can be deduced from observed heights by adding to each levelled difference of height the correction :—

$$- 2a\, H. \sin. 2l.\, dl.$$

In order to convert a dynamic height into an orthometric height, it is necessary (page 32 of Lallemand's *Nivellement de Haute Précision*) to add the following quantity to the former :—

$$aH \cos. 2l + \frac{\beta}{2} H^2 \text{ (for France) or } aH\,(\cos. 2l - \cos. 48^{\circ}) + \frac{\beta}{2} H^2 \text{ (for India).}$$

In his *Schwerkraft im Hochgebirge, 1890,* Professor Helmert shows that variations in gravity along the lines of level, which form a closed circuit, will give rise to a closing error, and taking the actual results of the Bozen–Innsbruck levelled polygon he separates this closing error from the accumulated error of observation.

He gives $- 0{\cdot}0053\, H \sin. 2l.\, dl$, in which H is the mean height of the levelling section above sea-level, l is its mean latitude and dl is the difference of latitude of the two bench-marks.*

The method of computing the corrections for gravity.

We have reproduced the formulæ given by the principal authorities, and we have now only to explain the method of computation, by which observed spirit-levelled heights have been converted in this volume into dynamic and orthometric heights.

We have converted observed heights, firstly, into dynamic heights, and we have then converted the dynamic into the orthometric: as both dynamic and orthometric values have their uses and interests, we have given the two side by side in the tables of bench-marks published in Volume XX of *the Account of the Operations of the G. T. Survey of India.*

We have not taken into consideration the departures of sea-level from the spheroidal form, such as are caused by the varying attractions of mountains and by the heterogeneity of the crust.†

* See also Helmert's note, *Die sechzehnte allgemeine konferenz der Internationalen Erdmessung zu London-Cambridge*, published in Vol. 36 of *Zeitschrift für Vermessungswesen*, 1909.

† *Comptes Rendus des seances de la quinzieme conference générale de l'Association Géodésique Internationale, réunie à BudaPest, 1906.* Volume II, pages 150 to 152.

Pendulum observations have not as yet been made at a sufficient number of stations in India to enable us to derive dynamic and orthometric heights from observed values of g. As *a first approximation* we have employed theoretical values of g, and from these values we have introduced corrections to the observed heights of all bench-marks fixed during the last 50 years.

In Appendix No. 7 of this volume Mr. J. de G. Hunter has shown that 88 per cent or seven-eighths of the total error due to gravity has been eliminated by the employment of theoretical values of g.

If we had employed observed values of g, corrections for gravity would have become applicable, whatever direction a line of levels followed; but as we have only taken into account the spheroidal form of the earth, the orthometric corrections will vanish on level-lines running east and west, (since $dl = o$). The orthometric corrections will be greatest for level-lines that follow a meridional direction. They will be negative on a rising line running from south to north, and positive on a rising line running from north to south.

Preparation of tables for computers.

If dh is the difference of elevation observed by levellers between two bench-marks, and dh' is this difference corrected for spheroidal convergence and adjusted to the vertical of latitude 24°, then

$$g.\ dh = g_{24}.\ dh'$$

where g is the value of gravity in the latitude midway between the bench-marks and g_{24} is the value in latitude 24°.

Then $$dh' = \frac{g.dh}{g_{24}}$$

and $$\left(\frac{g}{g_{24}} - 1\right) dh = (dh' - dh) \text{ is the dynamic correction.}$$

Professor Helmert's formula of 1884 gives the relation between gravity at sea-level and latitude as follows :—

$$g^{\circ} = 978 \cdot 00\ (1 + 0 \cdot 005310 \sin^2 l).$$

In 1907 Professor Helmert was able, with the aid of new data, to modify the constants of this formula, and he has now given us

$$g^{\circ} = 978 \cdot 030\ (1 + 0 \cdot 005302 \sin^2 l - 0 \cdot 000007 \sin^2 2l).$$

In the pendulum operations in India Major Lenox-Conyngham has, however, already been using for some years the formula of 1884, and he does not think it advisable for the present to change it.* As the results of pendulum operations are now being accumulated in all parts of the earth, the formula connecting gravity and latitude is likely in the near future to undergo constant slight changes, and we consider it best to adhere to one formula throughout and to retain all results in similar terms. In computing the dynamic corrections for levelling we have therefore accepted Helmert's formula of 1884. In Appendix No. 7 Mr. Hunter has compared the formula of 1884 with that of 1907. The greatest discrepancies occur in the southern Indian latitudes and decrease as latitude increases. As regards the levelling correction the two formulæ give practically the same results: the discrepancy between the corrections found by the two formulæ is in latitude 8° less than one-sixteenth of the correction given by the 1884 formula.

* Pendulum Operations in India page 29. Monthly Notices, Royal Astronomical Society, March, 1909, Vol. LXIX, page 384.

If $g^\circ = 978{\cdot}00\ (1 + 0{\cdot}005310\ \sin^2 l)$ where l = latitude midway between two bench-marks,

then
$$g^\circ_{24} = 978{\cdot}00\ (1 + 0{\cdot}005310 \sin^2 24^\circ)$$

and the dynamic correction is equal to

$$dh \left\{ \frac{1 + 0{\cdot}005310 \quad \sin^2 l}{1 + 0{\cdot}005310 \quad \sin^2 24^\circ} - 1 \right\}$$

The following table for facilitating the computation of the dynamic correction has been prepared by Mr. Hunter:—

The quantity F has been calculated from the formula

$$F = 1000 \left(\frac{g}{g_{24}} - 1 \right)$$
$$= 1000 \left(\frac{1 + 0{\cdot}005310 \quad \sin^2 l}{1 + 0{\cdot}005310 \quad \sin^2 24^\circ} - 1 \right)$$

F is therefore the correction to a height of 1000 feet in latitude l; the correction F reduces the levelled height to dynamic height, with reference to an origin in latitude 24°.

The value of F has been tabulated for every tenth of a degree of latitude, from 8°·05 to 34°·05.

The table can be used as follows:—

(i). By means of levelling charts and maps each line of levels should be divided into latitudinal portions,—a separate portion being allotted to each tenth of a degree of latitude.

(ii). The observed rise (positive) or fall (negative) in height (= dh) should be taken out for each of these latitudinal portions.

(iii). We have then only to multiply dk by $\frac{F}{1000}$.

(iv). The sign will be that of the product of F and dh, and the quantity $\frac{dh.\ F}{1000}$ when added algebraically to dh will give the corresponding dynamic height.

TABLE XXII.

Latitude = l	$F=1000\left(\frac{g}{g_{24}}-1\right)$	Difference	Latitude = l	$F=1000\left(\frac{g}{g_{24}}-1\right)$	Difference	Latitude = l	$F=1000\left(\frac{g}{g_{24}}-1\right)$	Difference
8°·05	−0·77364	258	9°·05	−0·74641	290	10°·05	−0·71611	320
·15	0·77106	262	·15	0·74351	293	·15	0·71291	323
·25	0·76844	264	·25	0·74058	295	·25	0·70968	326
·35	0·76580	268	·35	0·73763	298	·35	0·70642	328
·45	0·76312	271	·45	0·73465	301	·45	0·70314	331
·55	−0·76041	274	·55	−0·73164	304	·55	−0·69983	335
·65	0·75767	277	·65	0·72860	307	·65	0·69648	338
·75	0·75490	280	·75	0·72553	311	·75	0·66310	341
·85	0·75210	283	·85	0·72242	314	·85	0·68969	344
·95	0·74927	286	·95	0·71928	317	·95	0·68625	347
9·05	−0·74641		10·05	−0·71611		11·05	−0·68278	

TABLE XXII.—(Continued).

Latitude = l	$F = 1000\left(\frac{g}{g_{24}} - 1\right)$	Difference	Latitude = l	$F = 1000\left(\frac{g}{g_{24}} - 1\right)$	Difference	Latitude = l	$F = 1000\left(\frac{g}{g_{24}} - 1\right)$	Difference
11°·05	−0·68278	350	14°·05	−0·56502	438	17°·05	−0·42159	520
·15	0·67928	353	·15	0·56064	441	·15	0·41639	523
·25	0·67575	356	·25	0·55623	444	·25	0·41116	526
·35	0·67219	359	·35	0·55179	446	·35	0·40590	529
·45	0·66860	362	·45	0·54733	448	·45	0·40061	532
·55	−0·66498	365	·55	−0·54285	453	·55	−0·39529	534
·65	0·66133	368	·65	0·53832	455	·65	0·38995	536
·75	0·65765	370	·75	0·53377	457	·75	0·38459	539
·85	0·65395	373	·85	0·52920	460	·85	0·37920	542
·95	0·65022	376	·95	0·52460	463	·95	0·37378	544
12·05	−0·64646	380	15·05	−0·51997	466	18·05	−0·36834	546
·15	0·64266	383	·15	0·51531	468	·15	0·36288	549
·25	0·63883	385	·25	0·51063	471	·25	0·35739	552
·35	0·63498	388	·35	0·50592	474	·35	0·35187	555
·45	0·63110	391	·45	0·50118	477	·45	0·34632	558
·55	−0·62719	394	·55	−0·49641	480	·55	−0·34074	560
·65	0·62325	397	·65	0·49161	482	·65	0·33514	562
·75	0·61928	400	·75	0·48679	485	·75	0·32952	565
·85	0·61528	403	·85	0·48194	488	·85	0·32387	568
·95	0·61125	407	·95	0·47706	491	·95	0·31819	570
13·05	−0·60718	409	16·05	−0·47215	493	19·05	−0·31249	572
·15	0·60309	412	·15	0·46722	496	·15	0·30677	575
·25	0·59897	415	·25	0·46226	499	·25	0·30102	578
·35	0·59482	417	·35	0·45727	502	·35	0·29524	580
·45	0·59065	420	·45	0·45225	504	·45	0·28944	583
·55	−0·58645	423	·55	−0·44721	507	·55	−0·28361	585
·65	0·58222	426	·65	0·44214	510	·65	0·27776	587
·75	0·57796	429	·75	0·43704	512	·75	0·27189	590
·85	0·57367	432	·85	0·43192	515	·85	0·26599	593
·95	0·56935	433	·95	0·42677	518	·95	0·26006	596
14·05	−0·56502		17·05	−0·42159		20·05	−0·25410	

TABLE XXII.—(Continued).

Latitude = l	$F=1000\left(\frac{g}{g_{24}}-1\right)$	Difference	Latitude = l	$F=1000\left(\frac{g}{g_{24}}-1\right)$	Difference	Latitude = l	$F=1000\left(\frac{g}{g_{24}}-1\right)$	Difference
20°·05	−0·25410	598	23°·05	−0·06438	668	26°·05	+0·14549	732
·15	0·24812	600	·15	0·05770	671	·15	0·15281	734
·25	0·24212	602	·25	0·05099	673	·25	0·16015	735
·35	0·23610	605	·35	0·04426	675	·35	0·16750	737
·45	0·23005	608	·45	0·03751	677	·45	0·17487	739
·55	−0·22397	610	·55	−0·03074	679	·55	+0·18226	741
·65	0·21787	612	·65	0·02395	681	·65	0·18967	743
·75	0·21175	615	·75	0·01714	684	·75	0·19710	745
·85	0·20560	617	·85	0·01030	686	·85	0·20455	748
·95	0·19943	620	·95	−0·00344	688	·95	0·21203	750
21·05	−0·19323	622	24·05	+0·00344	690	27·05	+0·21953	752
·15	0·18701	624	·15	0·01034	692	·15	0·22705	753
·25	0·18077	627	·25	0·01726	695	·25	0·23458	755
·35	0·17450	629	·35	0·02421	697	·35	0·24213	756
·45	0·16821	632	·45	0·03118	699	·45	0·24969	758
·55	−0·16189	634	·55	+0·03817	701	·55	+0·25727	760
·65	0·15555	636	·65	0·04518	703	·65	0·26487	762
·75	0·14919	638	·75	0·05221	705	·75	0·27249	764
·85	0·14281	641	·85	0·05926	707	·85	0·28013	766
·95	0·13640	643	·95	0·06633	710	·95	0·28779	768
22·05	−0·12997	646	25·05	+0·07343	712	28·05	+0·29547	770
·15	0·12351	648	·15	0·08055	714	·15	0·30317	772
·25	0·11703	650	·25	0·08769	715	·25	0·31089	773
·35	0·11053	652	·35	0·09484	717	·35	0·31862	774
·45	0·10401	655	·45	0·10201	719	·45	0·32636	776
·55	−0·09746	657	·55	+0·10920	721	·55	+0·33412	778
·65	0·09089	659	·65	0·11641	724	·65	0·34190	780
·75	0·08430	662	·75	0·12365	726	·75	0·34970	782
·85	0·07768	664	·85	0·13091	728	·85	0·35752	784
·95	0·07104	666	·95	0·13819	730	·95	0·36536	785
23·05	−0·06438		26·05	+0·14549		29·05	+0·37321	

TABLE XXII.—(Continued).

Latitude = l	$F=1000\left(\frac{g}{g_{24}}-1\right)$	Difference	Latitude = l	$F=1000\left(\frac{g}{g_{24}}-1\right)$	Difference	Latitude = l	$F=1000\left(\frac{g}{g_{24}}-1\right)$	Difference
29°·05	+0·37321	787	31°·05	+0·53372	819	33°·05	+0·70028	847
·15	0·38108	789	·15	0·54191	821	·15	0·70875	848
·25	0·38897	790	·25	0·55012	822	·25	0·71723	850
·35	0·39687	792	·35	0·55834	823	·35	0·72573	851
·45	0·40479	793	·45	0·56657	825	·45	0·73424	852
·55	+0·41272	795	·55	+0·57482	827	·55	+0·74276	854
·65	0·42067	797	·65	0·58309	828	·65	0·75130	855
·75	0·42864	799	·75	0·59137	829	·75	0·75985	856
·85	0·43663	801	·85	0·59966	830	·85	0·76841	857
·95	0·44464	802	·95	0·60796	832	·95	0·77698	858
30·05	+0·45266	804	32·05	+0·61628	834	34·05	+0·78556	
·15	0·46070	805	·15	0·62462	835			
·25	0·46875	807	·25	0·63297	837			
·35	0·47682	808	·35	0·64134	838			
·45	0·48490	809	·45	0·64972	839			
·55	+0·49299	811	·55	+0·65811	841			
·65	0·50110	813	·65	0·66652	842			
·75	0·50923	815	·75	0·67494	843			
·85	0·51738	816	·85	0·68337	845			
·95	0·52554	818	·95	0·69182	846			
31·05	+0·53372		33·05	+0·70028				

Conversion of dynamic into orthometric heights.

If h'' is the orthometric height of a bench-mark above sea-level and h' is the dynamic height, then

$$h''.\,g = h'.\,g_{24}$$

$$h'' = \frac{g_{24}}{g}.\,h'$$

In Mr. Hunter's table

$$F = 1000\left(\frac{g}{g_{24}} - 1\right)$$

Therefore

$$\frac{g}{g_{24}} = 1 + \frac{F}{1000} \text{ and } \frac{g_{24}}{g} = \left(1 + \frac{F}{1000}\right)^{-1}$$

$$h'' = \left(1 + \frac{F}{1000}\right)^{-1} h' = h'\left(1 - \frac{F}{1000} + \frac{F^2}{(1000)^2} - \dots\right)$$

The term $\frac{F^2}{(1000)^2}$ has very rarely any appreciable effect; the table for F given on pages 103 to 106 can consequently be utilised for the conversion from dynamic into orthometric heights, *if the signs as entered are reversed.* In a few special cases the term $\frac{F^2}{(1000)^2}$ will have to be taken into account.

Tables illustrating the magnitudes of the dynamic corrections.

The following table gives the spirit-levelled and the dynamic values of heights of certain level-lines: it has been prepared to illustrate the effects of gravity upon levelling results.

TABLE XXIII.

Level-line	Length	Observed difference of height = S	Dynamic difference of height = D	D − S
	miles	*feet*	*feet*	*foot*
Tuticorin-Trichinopoly	194·4	+ 267·286	+ 267·100	−0·186
Bangalore-Bellary	201·9	−1632·189	−1631·252	+0·937
Kalyan-Kedgaon	120·0	+1751·532	+1750·957	−0·575
Kalyan-Nandgaon	146·6	+1529·696	+1529·254	−0·442
Nandgaon-Sironj	408·8	− 75·346	− 75·285	+0·061
Sironj-Agra	259·0	− 963·010	− 963·149	−0·139
Agra-Meerut	133·1	+ 223·044	+ 223·110	+0·066
Meerut-Ferozepore	267·8	− 93·830	− 93·896	−0·066
Ferozepore-Chach	278·3	+ 369·743	+ 369·874	+0·131

The following table shows the closing errors of the 29 levelling circuits, before and after the dynamic correction has been applied to the several lines:—

TABLE XXIV.

Circuit	Length of circuit	Closing error when no correction for gravity is applied	Portion of closing error due to gravity	Portion of closing error due to observation
	miles	*foot*	*foot*	*foot*
I	414·9	−0·186	+0·003	−0·189
II	581·7	−0·481	−0·082	−0·399
III	643·1	−0·791	−0·166	−0·625
IV	238·4	+0·087	+0·001	+0·086
V	1042·9	−0·226	−0·157	−0·069
VI	813·2	+0·517	+0·101	+0·416
VII	115·8	+0·150	−0·005	+0·155
VIII	1905·3	−0·240	+0·027	−0·267
IX	1010·8	−0·743	−0·279	−0·464
X	1396·9	−0·475	−0·049	−0·426

TABLE XXIV.—(Continued).

Circuit	Length of circuit	Closing error when no correction for gravity is applied	Portion of closing error due to gravity	Portion of closing error due to observation
	miles	*feet*	*foot*	*feet*
XI	1673·4	+0·634	−0·286	+0·920
XII	920·0	−0·014	−0·112	+0·098
XIII	351·0	+0·535	+0·014	+0·521
XIV	2758·3	−0·714	+0·695	−1·409
XV	613·4	+0·150	−0·001	+0·151
XVI	1017·7	+0·620	+0·146	+0·474
XVII	708·4	+1·456	−0·010	+1·466
XVIII	635·3	+0·647	−0·032	+0·679
XIX	609·5	−0·292	−0·017	−0·275
XX	815·2	−0·821	−0·012	−0·809
XXI	959·7	+0·354	+0·027	+0·327
XXII	561·7	+0·124	+0·202	−0·078
XXIII	802·0	−0·112	+0·361	−0·473
XXIV	113·1	+0·085	+0·001	+0·084
XXV	701·1	−0·502	−0·077	−0·425
XXVI	269·2	+0·488	−0·016	+0·504
XXVII	508·6	−0·061	−0·017	−0·044
XXVIII	374·9	+0·110	−0·015	+0·125
XXIX	3001·9	−0·310	−0·256	−0·054

CHAPTER VIII.

MEAN-SEA-LEVEL.

The mean level of the sea is the zero or datum-surface, from which the elevations of the bench-marks of India have been measured. In 1909 a selection had to be made of the tidal observatories, which were to form the basis of the levelling net, and which were to furnish data for the determination of mean-sea-level. There were three alternative courses open, namely :—

(i). one reliable tidal observatory could have been chosen, and the height of the whole level net could have been based upon the mean-sea-level as determined at this point; or

(ii). the values of mean-sea-level, derived from all tidal observatories connected with the level net, could have been introduced into the levelling adjustment; or

(iii). the results obtained from selected tidal observatories could be retained, and those from other observatories rejected.

The first alternative was not considered satisfactory. The mean-sea-level at any point may be permanently influenced by winds and currents; and the tidal observations may be affected by instrumental errors. At no station does the annual determination of mean-sea-level reproduce the values obtained in former years. As these uncertainties exist, it seemed inadvisable to base the whole net upon the measurements at one port.

The second alternative plan, by which all tidal observatories were to be included, was investigated and rejected. The levelling operations have shown that the mean-sea-level in certain confined places, such as the Gulf of Cutch and the mouth of the Hooghly, is abnormal, and permanently deformed. At these points the mean water level differs from the mean surface of the open sea by amounts greater than the probable errors of levelling, and it was considered incorrect to force the levelling into accord with the tidal determinations.

So long as the error of a determination of mean-sea-level is clearly larger than the error accumulated in the levelling, the rejection of the tidal result may be considered advisable. But in the case of some tidal observatories the evidence is very doubtful. The selection or rejection of tidal stations then becomes a difficult question, and one that can only be settled arbitrarily. It must be remembered that the tidal stations are required to form the foundations of the levelling net,—that they are expected in fact to give to the levelling in their respective localities more reliable values of height than the levelling can bring from any distant tidal observatory. It is futile then to endeavour to test their reliability by means of levelling results, which they themselves are intended to control. We must either accept the one or the other as the more correct; we cannot utilise each in turn as the test of the other.

If the observed difference of elevation between the mean-sea-level at different ports, connected by levelling, is considerably greater than the error to which levelling is ordinarily liable, it may be assumed that the two sea-levels do not belong to the same level surface. But no definite conclusion can be drawn, when the observed difference of elevation is very small; in such a case the two sea-levels have not been proved to belong to one level surface. The accordance of results may be fortuitous and due to the error of the levelling having the same sign and effect as the actual difference of sea-levels, or to the levelling errors having a tendency to cancel the errors of tidal measurements.

The selection of tidal observatories on which to base the levelling net, has been therefore governed by general principles, and not by any observed accordance of results. It has been decided, *firstly*, to select *open-coast* stations, at which successive annual determinations of mean-sea-level have proved accordant, and *secondly*, to reject tidal observatories situated in channels, gulfs, creeks, or rivers, and those at which annual determinations of mean-sea-level appeared discordant.

Determination of Mean-Sea-Level as a basis for the level net.

In the following table a complete list of the tidal observatories that have been maintained by the Indian Survey is given. Those tidal stations that have been accepted as bases of the Indian level net are shown in large type. The reasons for their acceptance and for the rejection of others are explained subsequently.

TABLE XXV.

	Stations	Date of commencement of observations	Date of closing of observations	No. of years of observations from which mean-sea-level has been deduced
1	Suez	1897	1903	7
2	Perim	1898	1902	5
3	Aden	1879	1910*	29
4	Maskat	1893	1898	5
5	Bushire	1892	1901	8
6	**Karachi**	1868	1910*	40
7	Hanstal	1874	1875	1
8	Navanar	1874	1875	1
9	Okha Point	1874 1904	1875 1906	2
10	Porbandar	1898	1902	5
11	Port Albert Victor (Kathiawar)	1900	1903	4
12	Bhavnagar	1889	1894	5
13	**Bombay (Apollo Bandar)**	1878	1910*	30
14	Bombay (Prince's Dock) ...	1888	1910*	20
15	Mormugao (Goa)	1884	1889	5

* Tidal observations are being continued, but no results later than January 1908 have been utilised for the deduction of mean-sea-level.

TABLE XXV.—(Continued).

	Stations	Date of commencement of observations	Date of closing of observations	No. of years of observations from which mean-sea-level has been deduced
16	Karwar	1878	1883	5
17	Beypore	1878	1884	6
18	Cochin	1886	1892	6
19	Tuticorin	1888	1893	5
20	Minicoy	1891	1896	5
21	Galle	1884	1890	6
22	Colombo	1884	1890	6
23	Trincomalee	1890	1896	6
24	Pamban	1878	1882	4
25	Negapatam	1881	1888	5
26	Madras	1880 1895	1890 1910*	23
27	Cocanada	1886	1891	5
28	Vizagapatam	1879	1885	6
29	False Point	1881	1885	4
30	Dublat (Saugor Island) ...	1881	1886	5
31	Diamond Harbour	1881	1886	5
32	Kidderpore	1881	1910*	27
33	Chittagong	1886	1891	5
34	Akyab	1887	1892	5
35	Diamond Island	1895	1899	5
36	Bassein	1902	1903	2
37	Elephant Point	1880 1884	1881 1888	6
38	Rangoon	1880	1910*	28
39	Amherst	1880	1886	6
40	Moulmein	1880	1886	6
41	Mergui	1889	1894	5
42	Port Blair	1880	1910*	28

* Tidal observations are being continued, but no results later than January 1908 have been utilised for the deduction of mean-sea-level.

Of the 42 tidal observatories the following 20 were not available, as they were unconnected with the Indian level net :—

Tidal Station	Situation	Tidal Station	Situation
Suez ...	In Egypt	Chittagong ...	In Eastern India
Perim ...	On an island in the Red Sea	Akyab ...	In Burma
Aden ...	In Arabia	Diamond Island ...	On an island near Cape Negrais
Maskat ...	In Arabia	Bassein ...	In Burma
Bushire ...	In Persia	Elephant Point ...	In Burma
Porbandar ...	On the west coast of India: it should be connected with the level net at an early date	Rangoon ...	In Burma
		Amherst ...	In Burma
Minicoy ...	On an island in the Arabian Sea	Moulmein ...	In Burma
Galle ...	In Ceylon	Mergui ...	In Burma
Colombo ...	In Ceylon	Port Blair ...	In the Andaman islands.
Trincomalee ...	In Ceylon		

Of the remaining 22 the following nine were selected to furnish base-stations for the level net (plates I and XVI).

Arabian Sea	Karachi Bombay (Apollo Bandar) Karwar Beypore Cochin
Bay of Bengal	Negapatam Madras Vizagapatam False Point

These nine are satisfactory except that predictions of time at Negapatam are liable to be in error, and that False Point is situated at the mouth of the Mahanadi. The annual determinations of mean-sea-level at both Negapatam and False Point are, however, very accordant.

The annual determinations of mean-sea-level for Madras, Negapatam and Vizagapatam are more discordant *inter se* than the determinations at False Point or at the accepted ports of the Arabian Sea; they are, however, in closer agreement than those at Porbander, Cocanada, Diamond Harbour or the Burmese ports. Karachi is situated near the delta of the Indus, but its sea-level is apparently independent of the changing conditions of that river.

Two reliable open-coast stations were rejected (plate I), namely :—

Bombay (Prince's Dock) : ...	Rejected because it is situated too near to the other Bombay observatory, which has been already accepted.

Mormugao (Goa)	Rejected because it is only connected with the level net by a branch-line from Karwar, and Karwar is already an accepted observatory (*vide* plate I). If Mormugao had been accepted, another equation would have been formed, but no advantage would have accrued, for the influence of the Mormugao tidal determination would not have extended beyond the Mormugao-Karwar line.

Seven tidal stations were rejected because of their situations in bays or gulfs (*vide* plate I), namely:—

Hanstal ... ... Navanar	Gulf of Cutch
*Okha	At the mouth of the Gulf of Cutch
Port Albert Victor (Kathiawar) ... Bhavnagar	Gulf of Cambay
*Tuticorin ... ... *Pamban	Gulf of Manar

and the following four were rejected as being under the influence of powerful rivers (*vide* plate I):—

Cocanada	near the mouths of the Godavari.
Dublat (Saugor Island) ... Diamond Harbour	near the mouth of the Hooghly; in the delta of the Ganges.
Kidderpore	on the Hooghly.

The probable error of the mean determinations of mean-sea-level for each of the selected stations is as follows:—

TABLE XXVI.

Station	No. of years	Probable error of mean-sea-level determination	
		Of annual determination	Of final mean determination
Karachi	40	± 0·0489 foot	± 0·0077 foot
Bombay	30	± 0·0382 „	± 0·0070 „
Karwar	5	± 0·0411 „	± 0·0184 „
Beypore	6	± 0·0280 „	± 0·0114 „
Cochin	6	± 0·0321 „	± 0·0131 „
Negapatam	5	± 0·0692 „	± 0·0309 „
Madras	13	± 0·0842 „	± 0·0234 „
Vizagapatam ...	6	± 0·0824 „	± 0·0336 „
False Point	4	± 0·0329 „	± 0·0165 „
Mean ...	...	± 0·05 „	± 0·0180 „

* The tidal predictions at Okha, Tuticorin and Pamban are satisfactory. We reject these stations only because their situations place them under suspicion.

The probable error of a final determination of mean-sea-level from six years' observations at any one port may be said generally to be $\frac{0 \cdot 05}{\sqrt{6}}$, or about 0·02 foot. The probable error of levelling may be taken as 0·004 foot $\times \sqrt{M}$ where M is the length of levelling line in miles. When $M = 25$ miles, the probable error of the levelling $= 0 \cdot 004 \times \sqrt{25} = 0 \cdot 02$ foot: in other words, the probable error of levelling at the end of 25 miles is as great as the probable error of a determination of mean-sea-level.

If we regard the errors of levelling as systematic, the accumulated error in feet at the end of M miles may be taken as 0·0007 M. In this case, when $M = 25$, the levelling will be in error by 0·0175 foot.

If then there are two tidal stations situated within 25 miles of one another, it is of little use to accept both determinations of mean-sea-level as correct, as the levelling gives a more reliable value of the *difference* of elevation of the two reference tidal bench-marks than the local determinations of mean-sea-level give. The distance from the Bombay (Apollo Bandar) tidal station to the Bombay (Prince's Dock) tidal station is 3 miles, and it has been considered advisable to accept the mean-sea-level as determined at Apollo Bandar, the more exposed and the more reliable observatory, and to base all heights of bench-marks upon it, than to endeavour to adjust the levelling so as to fit it in between the determinations of mean-sea-level at both observatories.*

Of the accepted tidal stations those at Beypore and Cochin are separated by a distance of 113 miles only. This is the shortest distance intervening between two accepted stations. The probable error of the levelling from Beypore to Cochin is 0·042 foot.†

The probable error of the mean-sea-level determination at Beypore is $\pm$ 0·011, and at Cochin $\pm$ 0·013.

The probable error of the height of the tidal bench-mark at Cochin, when determined from local mean-sea-level, is $\pm$ 0·013, and when determined by levelling from Beypore is

$$\pm \sqrt{(\cdot 011)^2 + (\cdot 042)^2} = \pm 0 \cdot 043.$$

We therefore gain in accuracy, if we adjust the levelling between the two determinations of mean-sea-level at Cochin and Beypore.

The 13 rejected tidal stations have had no influence upon the simultaneous reduction of the level net. But when the level net had been reduced and its errors had been dispersed, then the respective branch-lines of levelling, connecting the level net with these stations, were brought into harmony with the *local* determinations of sea-level, *if the discrepancies were small.* The tidal measurements at the rejected stations have therefore not been completely discarded in all cases. Many of them have been allowed to influence the branch-lines connecting them, though their influence has been prevented from extending to the main-lines of the net.

In adjusting the levelling of the branch-lines to the local determinations of mean-sea-level at rejected stations we have had to exercise arbitrary judgment‡. If a determination of mean-sea-level is obviously misleading, its influence has not been allowed to extend beyond the nearest bench-mark to the observatory, but in places where the mean-sea-level appears to belong to the same level-surface as the mean-sea-level of open-coasts, the determination has been adopted and been used to control the connecting branch-line.

Harbour engineers have at times explained that they require heights of bench-marks to be given above *local* mean-sea-level, and that if local mean-sea-level is permanently raised by winds or currents

* *Account of the Operations of the G. T. Survey of India*, Vol. XVI Part II, pages 31 and 37: the mean-sea-level at Prince's Dock was higher than the mean-sea-level at Apollo Bandar by 0·076 foot in 1889, by 0·099 in 1890, by 0·070 in 1891, by 0·101 in 1892. In 1907 it was higher by 0·059 foot.

† Determined from the general formula 0·004 $\sqrt{M}$. The actual probable error determined from observations on the Beypore-Cochin lines is p. e. on Beypore-Shoranur = $\pm$ 0·0245. p. e. on Cochin – Shoranur = $\pm$ 0·0287, and the probable error of the levelling from Beypore to Cochin becomes $\pm \sqrt{(\cdot 0245)^2 + (\cdot 0287)^2} = \pm 0 \cdot 038$.

‡ *See* Part III of this volume.

above the general level-surface of the sea, then they are only concerned with this raised portion along their own coast. A national survey, however, has to consider the country as a whole, and it has to refer all heights to one and the same *level-surface.*

The system adopted for the determination of a surface-datum for India may now be summarised as follows:—

(i). The mean surface of the ocean surrounding India has been made the surface of reference,—the zero of the height-scale.

(ii). Tidal stations, at which the mean-sea-level is believed to be abnormal, have been rejected.

(iii). Nine tidal stations, situated on open-coasts, have been selected as base-stations for the levelling net.

The determination of the heights of the bench-marks which are to serve as the issue-points for the levelling from the tidal observatories.

The following bench-marks for levelling are the issue-points at the nine accepted tidal observatories,—that is, they are the terminals of the nine short main-lines, that connect the tidal observatories with the level net. They have been called issue-points, because they are the nine points of the earth's crust in India, for which heights have been derived directly from the sea.

At seven observatories the point of issue is the ordinary reference bench-mark used by the tidal officers; but at Bombay and False Point the points of issue are not the marks ordinarily employed for reference by the tidal officers.

Karachi.—The principal reference bench-mark for the tidal observatory is the terminal point of lines 43 and 78. It is a mark on a stone embedded in masonry near the north-west corner of the Mestri quarters at Manora: it is 140 yards S.W. of the observatory. It is inscribed

G.T.S.
B.M.
□ A
A.D.
1880

The bench-mark of reference is 16·139 feet* above the zero of the tide-gauge. The upper surface of the stone is a foot above ground-level. The stone is surrounded by a wooden railing.

The bench-mark has been connected yearly by levelling with the tide-gauge, and its height above the zero of the gauge has shown no change.

Bombay.—The terminal point at Bombay of lines 32, 51 and 79 is the bench-mark cut on the bottom step on the north side of the main entrance to the Town-hall.

The ordinary reference bench-mark for the two Bombay observatories is the standard bench-mark situated at the Public Works Secretariat office. This bench-mark is 30·000 feet* above the zero of the tide-gauge at Apollo Bandar, and 28·000 feet* above the zero of the tide-gauge at Prince's Dock.

The *observed* height of the reference bench-mark at Apollo Bandar above the zero of gauge is 23·930 feet and the height of the Bombay terminal bench-mark at the Town-hall is 29·972 feet above the zero of the gauge.

The height of the Apollo Bandar bench-mark above the zero of the gauge has been determined annually, and has not been found to vary. The difference of height between the Apollo Bandar bench-mark and the Town-hall bench-mark was 6·042 feet in 1877-78 and 6·048 feet in 1906-07.

* Observed, not dynamic height.

Karwar.—The terminal point at Karwar of lines 17, 17 A and 80 is a mark cut on a granite block embedded in a pillar of masonry 173 feet north of the Travellers' bungalow. This is the reference bench-mark for the observatory. It is 17·324 feet* above the zero of the gauge.

Beypore.—The principal reference bench-mark for the tidal observatory was made the terminal point at Beypore of lines 12 and 81. It was a mark inscribed upon an embedded stone, which was situated about 100 feet east of the front door of the custom-house. It was 19·707 feet* above the zero of the gauge.

In 1909, after the simultaneous reduction of the level net had been taken in hand, this bench-mark at Beypore was discovered to have been disturbed, and it will not therefore be utilised in future. The bench-mark, inscribed

G.T.S.
□ B
B.M.

and embedded at the observatory in the compound of the travellers' bungalow, will now become the reference bench-mark and issue-point for Beypore. It is 9·375 feet* in height above the mark, that was accepted as the terminal point in Beypore.

Cochin.—The terminal point at Cochin of lines 13 and 82 is the principal reference bench-mark for the tidal observatory. It is a mark cut upon a granite block, which is embedded in the verandah of the port-office about 50 yards south of the observatory. It is 8·936 feet* above the zero of the gauge.

Negapatam.—The terminal point at Negapatam of lines 5 and 83 is the principal reference bench-mark of the tidal observatory. It is a mark cut upon a flag-stone in the verandah of the port-office, and is 11·605 feet* above the zero of the gauge.

Madras.—The terminal point at Madras of lines 8, 9, 20 and 84 is a mark cut upon the west side of the memorial stone laid by the Prince of Wales in 1875 to commemorate the commencement of the harbour works. It is the principal reference bench-mark for the observatory, and is 17·970 feet* above the zero of the gauge. Its distance from the tidal observatory is 1·4 miles. It was connected by double-levelling with the tide-gauge in 1880-81, and again in 1894-95, and for a third time in 1907-08: it has also been connected in intermediate years by single-levelling. No change in its height has ever been observed.

Vizagapatam.—The terminal point of lines 30, 36 and 85 is a mark on a stone embedded in the verandah of the port-office. It is the principal reference bench-mark for the observatory, and is 18·955 feet* above the zero of the gauge.

False Point.—The terminal point of lines 42 and 86 is a mark engraved on a stone embedded in the outer wall surrounding the light-house. The principal reference bench-mark is a Marine Survey mark cut on the south-west pile of the refuge house at Hookey Tollah. The reference bench-mark is 17·951 feet* above the zero of the gauge. The *observed* height of the terminal bench-mark above the reference bench-mark is 4·509 feet*.

No one of the points of issue, which constitute the starting-points of the Indian levelling upon land, has so far been placed upon rock. The erection of new primary bench-marks in the principal harbours and ports is now being undertaken; and several marks will be inscribed upon rock, whenever outcrops occur near tidal observatories.

* Observed, not dynamic height.

The heights of the bench-marks, which consititute the issue-points for the levelling operations, have been determined as follows:—

TABLE XXVII.

	Karachi	Bombay	Karwar	Beypore	Cochin	Negapatam	Madras	Vizagapatam	False Point
No. of years of tidal observations.	40	30	5	6	6	5	13	6	4
Bed-plate of gauge above zero.	18·234	29·545	14·236	16·691	12·796	12·895	20·663	13·897	18·998
Bed-plate above bench-mark	2·095	−0·427*	− 3·088	− 3·016	3·860	1·290	2·693	− 5·058	3·462
Bench-mark above zero of gauge.	16·139	29·972	17·324	19·707	8·936	11·605	17·970	18·955	22·460
Zero of gauge below mean-sea-level.	7·191	10·226	5·552	5·383	2·364	1·990	2·259	4·829	7·559
Observed height of bench-mark above mean-sea-level	8·948	19·746	11·772	14·324	6·572	9·615	15·711	14·126	14·901
Dynamic height of bench-mark above mean-sea-level	8·949	19·740	11·766	14·314	6·568	9·608	15·702	14·121	14·898

For this table the distance of the zero of the gauge below mean-sea-level has been deduced from the observations of several years. This distance varies annually.

Each annual value for mean-sea-level is the mean of the observed heights of the tide above the zero of the tide-gauge, the height of the tide being read off the diagram at every hour throughout a year of 369 days 3 hours. The general mean value, derived from all the years of observation, is the value finally adopted.

In the following table the several annual determinations of the height of the issue-point above mean-sea-level are given for each of the nine accepted tidal stations. The variations are due not to movements of the bench-mark, but to changes in the height of mean-sea-level above the zero of the tide-gauge. It is rare that any appreciable change in the height of a reference bench-mark above the zero of the tide-gauge is discovered: the difference of height between the bench-mark and gauge-zero remains as a rule constant from year to year, but the mean-sea-level fluctuates continually between these two fixed points,—approaching nearer to the bench-mark in one year and rising higher above the zero,—receding from the bench-mark in another year and descending closer to the zero.

* Bed-plate of gauge above bench-mark at Apollo Bandar = 5·615 feet. Bench-mark at town-hall above bench-mark at Apollo Bandar = 6·042 feet by levelling in 1877-78 and 6·048 feet by levelling in 1906-07.

TABLE XXVIII.

Height of bench-mark of issue above mean-sea-level.

Year*	Karachi	Bombay	Karwar	Beypore	Cochin	Negapatam	Madras	Vizagapatam	False Point
1868	8·990								
1869	8·848								
1870	8·875								
1871	9·032								
1872	9·088								
1873	9·060								
1874	8·987								
1875	8·986								
1876	9·005								
1877	8·932								
1878	8·808	19·707	11·674	14·322					
1879	8·831	19·788	11·783	14·315				13·964	
1880	8·872	19·785	11·760	14·295				14·038	
1881	8·960	19·724	11·809	14·295		9·609		14·146	14·908
1882	9·079	19·778	11·832	14·312		9·557		14·143	14·863
1883	8·947	19·715		14·406				14·142	14·867
1884	8·941	19·716						14·325	14·968
1885	8·933	19·668				9·794			
1886	8·914	19·705			6·514	9·557			
1887	8·987	19·762			6·577	9·558			
1888	9·006	19·723			6·629				
1889	8·984	19·763			6·515				
1890	8·996	19·742			6·591				
1891	9·025	19·816			6·605				
1892	8·896	19·687							
1893	8·936	19·763							
1894	8·922	19·735							
1895	8·948	19·770					15·795		
1896	8·949	19·739					15·992		
1897	8·925	19·726					15·691		
1898	8·897	19·640					15·670		
1899	8·947	19·776					15·598		
1900	9·074	19·796					15·802		
1901	8·988	19·744					15·688		
1902	8·833	19·662					15·876		
1903	8·857	19·651					15·636		
1904	8·929	19·781					15·666		
1905	9·013	19·906					15·632		
1906	8·915	19·831					15·524		
1907	8·811	19·784					15·676		
Mean ...	8·948	19·746	11·772	14·324	6·572	9·615	15·711†	14·126	14·901
p. e. of mean determination ...	±0·0077	±0·0070	±0·0184	±0·0114	±0·0131	±0·0309	±0·0234	±0·0336	±0·0165
p. e. of single annual determination ...	±0·0489	±0·0382	±0·0411	±0·0280	±0·0321	±0·0692	±0·0842	±0·0824	±0·0329

* From 1868 to 1891 the mean-sea-level for Karachi was computed for each year from May 1st to the following May 1st: from 1892 onwards it was computed from January 1st of each year. For Karwar the mean-sea-level was computed each year from March 1st, for Beypore from December 1st, for Cochin from January 25th, for Vizagapatam from February 3rd, for Negapatam from December 6th, 1881-82 and 1882-83, and from March 20th, 1885-86, 1886-87, 1887-88: *vide Accounts of the Operations of the G. T. Survey of India, Vol. XVI*, pages 10, 45, 49, 53, 79, 94.

† This is the mean of values derived since the new observatory was opened.

The variations of Mean-Sea-Level with time.

When we refer to variations of mean-sea-level, we mean always *variations relative to the level of the land surface.* The movements of the earth's crust are of two descriptions,—the gradual and the sudden; there are, firstly, the slow imperceptible elevations and subsidences of possibly immense areas, and, secondly, the sudden changes caused by earthquakes.

As has been explained on page 63 (Chapter IV) the branch-line of levels, 61A, from Saharanpur to Mussooree is the only line in India, that has, so far as we know, been disturbed by an earthquake. We have moreover no evidence that any of our bench-marks have been disturbed by slow gradual movements of the earth's crust. In table XXVIII on page 118 we have given the annual determinations of mean-sea-level made at nine different tidal observatories, and we have been unable to detect in them any tendency to constant change in one direction. The mean-sea-level has been shown, it is true, to vary annually, but it seems to oscillate from year to year about one mean position.

Variations of mean-sea-level may be considered under four headings:—

(i). Variations caused by changes in the forms of the solid crustal basins, containing the oceans.

(ii). Variations caused by increases or decreases of the amount of water on the earth.

(iii). Variations produced by abnormal meteorological conditions, and ocean currents.

(iv). Variations due to movements of the earth's rotation-axis and centre of gravity.

(i). The form and depths of the ocean beds are constantly changing; subsidences were observed to follow the Peruvian and Sicilian earthquakes, and the Krakatoa and west Indian eruptions. If the oceanic bed is deepened in any one place, a change in mean-sea-level will occur on distant coasts.

(ii). Although observations of the tides have been made in Europe for many decades, no persistent change in the amount of water on the earth has been detected. In some years evaporation may perhaps be greater over one particular ocean than in other years, and the amount of ice accumulating at the poles and on land may at times become abnormally large; during such periods mean-sea-level may be lower than usual, but it will recover, when normal meteorological conditions are established.

(iii). The determination of mean-sea-level from one whole year's tidal observations will differ at certain places from the general mean of all the years, if the barometric pressure or rainfall or wind direction have been exceptional. The pressure of the atmosphere undergoes oscillations of long period, and the height of mean-sea-level varies accordingly. The deltas of rivers occupy long portions of the coasts of India, and the height of mean-sea-level in the vicinity of these deltas is affected by the rainfall on the mountains forming the sources of the rivers. It is probable also that the strength of ocean currents varies from year to year with the force of the monsoon, and the height of mean-sea-level may be temporarily influenced by this cause.

(iv). Movements of the earth's rotation-axis and of the earth's centre of gravity will cause changes in the height of mean-sea-level, and as the periods of these movements are longer than a year, annual determinations of mean-sea-level will necessarily disagree. The nodal tide, which has a period of 19 years, will also tend to produce differences between annual determinations of mean-sea-level.

A large area of Cutch is barely elevated at all above the mean level of the sea, and is frequently under water at high tide. Forty years ago it was believed that the coast of India between Karachi and Bombay was slowly subsiding with regard to the sea. To test the correctness of this view tidal observations were made in 1874-75 at Okha, and the relative heights of land and sea were determined. After a lapse of 30 years the observatory at Okha was re-opened, and a fresh determination of mean-sea-level was made*.

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* *General Report, Survey of India*, 1874-75, page 16, para 64 and page 53a, para (18). *Report to the Board of Scientific Advice for* 1905-06, page 67. *General Report, Survey of India*, 1903-04, page 51.

The tidal observatory was connected by spirit-levelling, both in 1874 and 1906, with several bench-marks situated at different distances from the coast, the most distant being 11 miles from Okha. The observations of 1905-06 showed that the land was higher with regard to mean-sea-level by 0·05 foot than it was in 1874-75. This result indicated an increase of elevation, and did not support any theory of subsidence. Having regard however to the annual variations of mean-sea-level exhibited in Table XXVIII, we are not justified in accepting the observed increase in elevation of the land of Cutch as real. All that we are able to say is that *no relative movement of land and sea has been detected.* The determination of mean-sea-level from one whole year's observations frequently differs at Karachi and Bombay (*see* table XXVIII) from the general mean value of all the years by more than 0·05 foot.

In 1902 the mean level of the sea for the whole year was higher than the average,—

at Karachi by 0·12 foot,

at Bombay by 0·08 foot,

at Aden by 0·14 foot.

At Madras, however, it was lower than the average by 0·17 foot. In 1902, therefore, though the mean level of the Arabian Sea was unduly high, a corresponding elevation was not observable in the Bay of Bengal.

In the following year, 1903, the mean-sea-level was higher than the average throughout Indian waters,—

at Aden by 0·12 foot,

at Karachi by 0·09 foot,

at Bombay by 0·10 foot,

at Madras by 0·08 foot,

at Rangoon by 0·03 foot,

in the Andamans by 0·15 foot.

In 1891 both the Arabian Sea and the Bay of Bengal were low; the mean-sea-level at Karachi was 0·08 foot too low, that at Bombay 0·07 foot too low, that at Calcutta 0·16 foot, that at Rangoon 0·24 foot, that at the Andamans 0·11 foot,—all too low.

In table XXIX we show for 40 tidal observatories in Indian waters:—

(i.) The mean annual variation of mean-sea-level from the general mean of all the years of observation.

(ii.) The maximum variation from the general mean ever obtained from a whole year's observations of mean-sea-level.

(iii.) The average errors of tidal predictions in both time and height.

TABLE XXIX.

Tidal Station	Years of observation: From	Years of observation: To	Mean of yearly variation of sea-level from general mean: Number of years of data utilised	Mean of yearly variation of sea-level from general mean: Variation	Greatest difference ever obtained between two annual values of mean-sea-level: Between years	Greatest difference ever obtained between two annual values of mean-sea-level: Difference	Errors in predictions: Latest year available for comparison	Errors in predictions: Number of years of data utilised	Average errors of time in minutes: High water	Average errors of time in minutes: Low water	Average errors of height in feet: High water	Average errors of height in feet: Low water
				foot		*feet*						
Suez	1897	1903	7	0·049	1900 & 1903	0·212	1903	5	14	15	0·33	0·42
Perim	1898	1902	5	0·035	1900 & 1902	0·119	1902	3	13	12	0·25	0·17
Aden	1879	1910*	29	0·042	1882 & 1902	0·236	1907	25	10	11	0·08	0·08
Maskat	1893	1898	5	0·019	1895 & 1896	0·065	1897	3	13	8	0·17	0·17
Bushire	1892	1901	8	0·061	1892 & 1900	0·258	1900	5	14	29	0·42	0·33
Karachi	1868	1910*	40	0·057	1872 & 1878	0·280	1907	36	8	12	0·25	0·17
Okha Point ...	1874 1904	1875 1906	2	0·026	1874 & 1905	0·052	1905	1	9	11	0·33	0·33
Porbandar	1898	1902	2	0·035	1900 & 1901	0·070	1901	2	17	11	0·42	0·58
Port Albert Victor (Kathiawar)	1900	1903	4	0·080	1900 & 1903	0·211	1903	2	14	16	0·50	0·42
Bhavnagar	1889	1894	5	0·069	1890 & 1893	0·192	1893	3	13	20	0·67	1·00
Bombay (Apollo Bandar) ...	1878	1910*	30	0·044	1898 & 1905	0·266	1907	26	8	8	0·25	0·25
Bombay (Prince's Dock) ...	1888	1910*	20	0·077	1892 & 1905	0·405	1907	16	10	8	0·25	0·25
Mormugao (Goa)	1884	1889	5	0·044	1885 & 1888	0·126	1888	2	10	10	0·25	0·33
Karwar...	1878	1883	5	0·044	1878 & 1882	0·158	1883	3	15	17	0·25	0·33
Beypore	1878	1884	6	0·027	1881 & 1883	0·111	1884	4	20	24	0·25	0·33
Cochin	1886	1892	6	0·038	1886 & 1888	0·115	1891	4	15	9	0·17	0·17
Tuticorin	1888	1893	5	0·044	1891 & 1892	0·113	1892	3	9	9	0·25	0·17
Minicoy	1891	1896	5	0·033	1891 & 1892	0·095	1895	3	12	13	0·17	0·17
Galle	1884	1890	6	0·041	1885 & 1888	0·130	1889	2	11	12	0·17	0·17
Colombo	1884	1890	6	0·044	1886 & 1888	0·172	1889	3	12	12	0·17	0·25
Trincomalee	1890	1896	6	0·066	1891 & 1892	0·217	1895	3	28	29	0·25	0·17
Pamban	1878	1882	4	0·025	1878 & 1880	0·093	1882	2	29	30	0·17	0·17
Negapatam	1881	1888	5	0·072	1882 & 1885	0·237	1887	2	18	40	0·17	0·25
Madras ...	1880 1895	1890 1910*	13	0·095	1896 & 1906	0·468	1907	9	9	9	0·17	0·17
Cocanada	1886	1891	5	0·090	1886 & 1888	0·334	1890	3	8	8	0·33	0·33
Vizagapatam	1879	1885	6	0·084	1879 & 1884	0·361	1884	4	11	13	0·33	0·33
False Point	1881	1885	4	0·037	1882 & 1884	0·105	1884	2	15	13	0·25	0·25
Dublat (Saugor Island) ...	1881	1886	5	0·056	1882 & 1885	0·236	1885	2	13	15	0·42	0·42
Diamond Harbour	1881	1886	6	0·070	1882 & 1885	0·207	1885	2	13	16	0·58	0·50
Kidderpore	1881	1910*	27	0·261	1886 & 1894	1·260	1907	23	18	25	0·58	0·67
Chittagong	1886	1891	5	0·106	1886 & 1888	0·328	1890	3	16	21	0·67	0·67
Akyab	1887	1892	5	0·074	1888 & 1889	0·254	1891	3	8	8	0·25	0·33
Diamond Island	1895	1899	5	0·085	1896 & 1897	0·193	1898	2	14	12	0·33	0·33
Bassein	1902	1903	2	0·104	1902 & 1903	0·207	...	...	...	...	...	...
Elephant Point ...	1880 1884	1881 1888	5	0·164	1884 & 1885	0·673	1887	3	12	13	0·58	0·58
Rangoon	1880	1910*	28	0·099	1880 & 1891	0·517	1907	24	13	15	0·42	0·67
Amherst	1880	1886	6	0·157	1881 & 1885	0·663	1885	3	11	16	0·58	1·25
Moulmein ...	1880 1909	1886 1910*	6	0·178	1883 & 1884	0·591	1885	3	16	12	0·58	0·67
Mergui	1889	1894	5	0·041	1889 & 1891	0·182	1893	3	12	14	0·33	0·42
Port Blair	1880	1910*	28	0·067	1886 & 1903	0·358	1907	24	9	8	0·17	0·17

We note from the table,—

(i.) that the mean-sea-level at riverain ports, such as Kidderpore, Elephant Point and Moulmein, varies widely in different years,

(ii.) that the variations in the Arabian Sea, Maskat to Cochin, are uniformly less than the variations in the Bay of Bengal, Negapatam to Port Blair,

* Tidal observations are being continued.

(iii.) that tidal predictions of height at Bhavnagar in the Gulf of Cambay, and at Amherst in the Gulf of Martaban, and at riverain stations, Kidderpore, Chittagong, Rangoon and Moulmein are less correct than at the open-coast tidal stations,

(iv.) that tidal predictions of time are as a rule less in error at open-coast observatories than at places like Bhavnagar in the Gulf of Cambay, Pamban in the straits of Manar, and Kidderpore in the Hooghly.

With the exception of Kidderpore in the river Hooghly no tidal observatory furnishes evidence of any persistent or continuous change in one direction in the height of mean-sea-level.

The mean level of the Hooghly at Calcutta during the ten years from 1885 to 1894 was 0·54 foot higher than the mean level during the next ten years 1895 to 1904. If such a large and persistent difference appeared at any open-coast observatory, it might be attributed to an elevation of the land. At an open-coast observatory, if there has been neither elevation nor subsidence of land, the mean-sea-level derived from any *ten* consecutive years of results will not be found to differ from the general mean of all observations by 0·05 foot. A persistent difference of level of over half a foot at Calcutta between the two decades cannot, however, be regarded as evidence that the land at Calcutta is rising; it must be attributed to a diminution of water in the Hooghly.*

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* The following correspondence relates to the diminution of water in the Hooghly:—

Office of the Superintendent, Trigonometrical Surveys,
30th April 1909.

From Superintendent, Trigonometrical Surveys.
To
The Secretary to the Government of Bengal,
Irrigation Department,
Calcutta.

The tide predictions for Kidderpore are becoming very inaccurate. I beg to enquire whether any recent irrigation projects above Calcutta have been reducing the water in the Hooghly or altering its flow. Will you kindly advise me as to the principal sources from which the Hooghly receives its water supply. Is the Ganges its principal feeder in every month of the year?

I have, etc.,
S. BURRARD,

Mr. Sibold's Note on the Nadia Rivers.—
The Principal Sources of the Hooghly River.

The Hooghly River (so named) starts from Nadia the confluence of (1) the Bhagirathi and (2) the Bhairab-Jellingi rivers; lower down the Hooghly at a distance of some 25 miles (3) the Mathabhanga River enters the Hooghly on its left bank. All these three rivers are effluent rivers from the Ganges (taking off at Bishwanathpur, Akriganj and Dewanganj) which must therefore be considered as the principal source of supply. Each of these rivers will now be treated separately.

(1) *Bhagirathi River.*—The total length from Ganges to Nadia 158 miles. This river receives its supply from the Ganges, but in its downward course several minor hill streams supplement the supply in the rains, being practically dry in the summer months. The Babla Nadi 6 miles above Katwa and the Adjai River at Katwa are the two leading tributaries of any importance; they drain the undulating country comprising the Districts of Birbhum and portions of Burdwan and Sonthal Parganas, and the supply necessarily during the dry season is very scanty and practically non-existent. There is another tributary Mirzapore Khal, entering the Hooghly some 10 miles below Nadia; this has a small catchment of local drainage and is of little importance.

The Collectors of Burdwan and Birbhum Districts were addressed on this subject and have reported that the Adjai and Babla streams have not been in any way interfered with by canal, tank, and water supply projects which would diminish their ordinary discharge.

(2) *Bhairab-Jellingi River.*—Total length from Ganges to Nadia 146 miles. This river has no tributaries of any kind and there has not been any canal project or scheme of any kind which would diminish or increase the supply.

(3) *Mathabhanga River.*—Total length from Ganges to Chakda junction with Hooghly river 137 miles. This river has instead of tributaries three effluent streams, the Koomer, Cobaduck and Ichamutti. These are more or less in a moribund condition and draw off water into the Jessore District. There is no reason to believe that they draw off more water now than in the past; if anything the first two, named Koomer and Cobaduck, have deteriorated very considerably within recent years and the water going down the main river (*Mathabhanga*) *is more than it used to be.*

All these three rivers—Bhagirathi, Bhairab-Jellingi and Mathabhanga have, during recent years, had their entrances blocked and closed up during the dry months of the year *i.e.* January to June. This state of affairs is not usual—in one series of years they are closed, followed by another series when they are open—in the latter case the discharge is never so very great that it would materially interfere with tidal predictions at Kidderpore. No systematic discharge observations have been taken during the summer but some observations this year indicate that in spite of the entrances being blocked these rivers contributed collectively a discharge of at least 2127 cusecs as an average of five dry months, January to May 1909, measured at points on the river above the tidal limits. This discharge is of course percolation water and indirectly it is Ganges water and the Ganges may be considered as the principal feeder in every month of the year.

In conclusion it may be remarked that there is no canal tank or water supply project of any magnitude which would have caused the variations of the tide at Kidderpore and the river discharges during the floods are the same as before, and the dry season perhaps less than formerly, owing to the entrances systematically closing in recent years.

C. W. SIBOLD,
Executive Engineer,
Nadia Rivers Division.

16-7-09.

At the open-coast station of Karachi the mean-sea-level, derived from observations extending over the 11 years, 1881 to 1891, is 0·031 foot lower than the general mean value, and the level derived from the 11 years, 1897 to 1907, is 0·022 foot higher: and variations as large as these are rarely met with on the open coast.

On the differences in the height of the surface of the mean sea at different places.

We have already mentioned (page 109) that the mean level of the water in gulfs and rivers does not generally accord with the mean level surface of the open ocean. We have also shown (page 114) that levelling operations are not sufficiently accurate to detect minute differences between the sea-levels of distant coasts. But it may be of interest to consider the results of the Indian levelling as a whole and to examine, whether we have any reason for doubting that the mean sea surface of the open ocean surrounding India is everywhere at the same level.

The peninsula of India protrudes from Asia and separates the Arabian Sea from the Bay of Bengal: we can compare the elevation of the mean sea surface of the Arabian Sea with that of the Bay of Bengal by four trans-peninsular lines of level which are entirely independent and which terminate on each coast at exposed tidal stations. (*See* plates I and XVI).

TABLE XXX.

Line of Level	Lines of Level	Mean Latitude	Length	Probable error of levelling	Difference of Elevation	
					Arabian Sea – Bay of Bengal	
					Observed	Dynamic
			Miles		*feet*	*feet*
Karachi-False Point ...	78, 43, 53, 54, 57, 61, 64, 65, 67, 70, 72, 74, 75, 42, 86	23°	2494	±0·200	−0·661	−0·802
Bombay-Vizagapatam	79, 32, 31, 25, 26, 24, 30, 85	18°	907	±0·120	−0·905	−1·057
Karwar-Madras ...	80, 17, 16, 15, 14, 8, 84	14°	552	±0·094	−1·499	−1·523
Cochin-Negapatam ...	82, 13, 11, 6, 4, 5, 83	10°	348	±0·075	−0·688	−0·614

The four determinations of the difference of elevation of the two seas all have the same sign, and furnish a mean value of 0·999 foot for the difference.

The probable errors of the levelling are very much smaller than the differences of level, and there do appear at first sight some grounds for concluding that the mean surface of the Bay of Bengal is nearly a foot higher than the mean surface of the Arabian Sea. But on further investigation no such conclusion is found to be tenable.

If for instance we take the line of levelling from Karachi to False Point along a longer route than what we have done in table XXX, and if we select it *viâ* Chach, Ferozepore, Lucknow and Gorakhpur, a course of 3002 miles, we find that the sea-level at False Point is 0·054 foot higher than at Karachi. In table XXX the sea-level at False Point is shown 0·802 foot lower than at Karachi.

Such contradictions between results lead us to assume that the apparent differences of height between sea levels are due to accumulated errors of levelling, and that the actual differences, if any exist, must be less than the errors of levelling. If this view is correct, it is clear that the probable error of levelling must be larger than $0.004\sqrt{M}$ at which we have taken it. The subject of probable errors will be dealt with in Part III of this volume.

We can also examine by the aid of levelling results whether the mean surface of the Arabian Sea appears to have the same elevation at all exposed tidal stations on the west coast of India, and whether the mean surface of the Bay of Bengal adheres to the same elevation throughout the east coast. We can test the constancy of the elevation of the mean surfaces of the two seas at different points by means of seven independent coastal lines of levels (Plates I and XVI).

TABLE XXXI.

Line of Level	Lines of Level	Mean Latitude	Length	Probable error of levelling	Difference of Elevation (Northern Station)-(Southern Station)	
			Miles		Observed *foot*	Dynamic *foot*
Karachi-Bombay ...	78, 43, 45, 44, 46, 50, 51, 79	22°	864	±0·118	+0·889	+0·848
Bombay-Karwar ...	79, 32, 31, 28, 29, 17, 80	17°	562	±0·095	+0·124	−0·078
Karwar-Beypore ...	80, 17, 16, 19, 18, 7, 11, 12, 81	13°	802	±0·113	−0·112	−0·473
Beypore-Cochin ...	81, 12, 13, 82	11°	113	±0·043	+0·085	+0·084
False Point-Vizagapatam	86, 42, 41, 39, 36, 85	19°	375	±0·077	−0·110	−0·125
Vizagapatam-Madras ...	85, 30, 20, 84	15°	509	±0·090	+0·061	+0·044
Madras-Negapatam ...	84, 9, 5, 83	12°	269	±0·066	−0·488	−0·504

The largest discrepancy +0·848 occurs between Karachi and Bombay, but if we follow another levelling route, namely through Jorya and Rajkot, a total length of 960 miles, the discrepancy +0·848 becomes reduced to +0·327; and if a change in the levelling route can bring about such a considerable reduction, the inference is warranted that the differences of elevation exhibited in table XXXI are due only to errors of levelling.

We can make one further endeavour to detect real differences in the elevations of mean-sea-level at different ports by comparing the closing errors of the 'inland' circuits with the closing errors of the 'land and sea' circuits. By an 'inland' circuit of levelling is meant a circuit, in which the levelling commences from and ends at the same point and throughout which the levelling is continuous and complete. In a 'land and sea' circuit the levelling starts from sea-level at one point, and ends at sea-level at another point. In a 'land and sea' circuit the surface of the sea is assumed to be at the same elevat ionat the two points, where it is connected with the levelling.

In the two following tables the closing errors, firstly, of inland circuits, and, secondly, of land-and-sea circuits are exhibited. The circuits, to which the several numbers respectively belong, are shown in plate XVI.

TABLE XXXII.

Circuits of levelling, which are inland and independent of tidal observations.

Circuit number	Closing error	Length of circuit	Closing error per mile	Closing error / √length in miles
	feet	miles	foot	foot
I	− 0·189	414·9	0·00046	0·0093
II	− 0·399	581·7	0·00069	0·0165
III	− 0·625	643·1	0·00097	0·0247
IV	+ 0·086	238·4	0·00036	0·0056
V	− 0·069	1042·9	0·00007	0·0021
VI	+ 0·416	813·2	0·00051	0·0146
VII	+ 0·155	115·8	0·00134	0·0144
VIII	− 0·267	1905·3	0·00014	0·0061
IX	− 0·464	1010·8	0·00046	0·0146
X	− 0·426	1396·9	0·00030	0·0114
XI	+ 0·920	1673·4	0·00055	0·0225
XII	+ 0·098	920·0	0·00011	0·0032
XIII	+ 0·521	351·0	0·00148	0·0278
XIV	− 1·409	2758·3	0·00051	0·0268
XV	+ 0·151	613·4	0·00025	0·0061
XVI	+ 0·474	1017·7	0·00047	0·0149
XVII	+ 1·466	708·4	0·00207	0·0551
XVIII	+ 0·679	635·3	0·00107	0·0269
XIX	− 0·275	609·5	0·00045	0·0111
XX	− 0·809	815·2	0·00099	0·0283
Average closing error of inland circuits ...			0·00066	0·0171

TABLE XXXIII.

Land-and-sea circuits, in which the levelling starts from one tidal observatory and ends at another.

Circuit number	Closing error	Length of circuit	Closing error per mile	Closing error / √length in miles
	foot	miles	foot	foot
XXI	+ 0·327	959·7	0·00034	0·0106
XXII	− 0·078	561·7	0·00014	0·0033
XXIII	− 0·473	802·0	0·00059	0·0167
XXIV	+ 0·084	113·1	0·00074	0·0079
XXV	− 0·425	701·1	0·00061	0·0161
XXVI	+ 0·504	269·2	0·00187	0·0307
XXVII	− 0·044	508·6	0·00009	0·0020
XXVIII	+ 0·125	374·9	0·00033	0·0065
XXIX	− 0·054	3001·9	0·00002	0·0010
Average closing error of land-and-sea circuits			0·00053	0·0105

In table XXXIII the lengths given for the land-and-sea circuits are the lengths of levelling only, and do not include the over-sea distances between tidal observatories.

The errors of levelling appear to be systematic rather than accidental, and we have consequently shown here *the closing error per mile.*

The average closing error per mile of inland circuit is 0·00066, and of land-and-sea circuit is 0·00053 : the closing error per mile is actually less in the case of the land-and-sea circuits than for the inland circuits.

The closing errors of inland circuits are due to *errors of levelling only.*

The closing errors of the land-and-sea circuits are the aggregates resulting from three separate sources of discrepancy, namely,

(i). Errors of levelling,
(ii). Errors of mean-sea-level determinations,
(iii). Differences in elevation of mean-sea-level at different places.

A consideration of tables XXXII and XXXIII has shown us that the average error of levelling in inland circuits is greater than the combined result of all three sources of discrepancy, which affect land-and-sea circuits. The conclusion seems therefore fully justified, that errors of levelling are relatively large enough to mask both the errors of mean-sea-level determinations and the actual differences in elevation of mean-sea-level. The mean surface of the *open* sea surrounding the coasts of India is everywhere so nearly at the same elevation, that levelling operations are insufficiently accurate to detect differences, if any such exist. The differences of mean-sea-level derived from levelling between east and west coasts cannot therefore be regarded as real.

Though the mean surface of the open sea may be considered to be situated at the same elevation on all open-coasts, the figures in the following table will show that the mean-water-level in gulfs and estuaries cannot be equally trusted.

TABLE XXXIV.

Land-and-water circuits in which the levelling connects tidal observatories on gulfs or rivers.

Circuit	Closing error	Length of circuit	Closing error per mile	Closing error / √length in miles
*Gulf of Cutch.**	foot	miles	foot	foot
Okha-Hanstal	0·571	127·3	0·00449	0·0506
Closing error for gulf	...	...	0·00449	0·0506
River Hooghly.				
Diamond Harbour-False Point	0·958	241·8	0·00396	0·0616
Diamond Harbour-Dublat (Saugor Island) ...	0·777	53·4	0·01455	0·1063
Kidderpore-Diamond Harbour	1·872	28·8	0·06500	0·3488
Kidderpore-False Point	2·830	270·6	0·01046	0·1720
Average closing error for a tidal river ...	...	...	0·02349	0·1722

* The closing error (field value) between Navanar and Hanstal appears to be 0·093 foot : in the *General Report Great Trigonometrical Survey of India*, 1875-76, page 12, and Appendix, page 17-a, the error is given at 0·193 foot, which was probably a numerical mistake. In the introduction to Spirit-Level pamphlet No. 1 Bombay, the closing error between Okha and Hanstal is incorrectly stated to be 5 inches.

The Gulf of Cutch is open to the prevailing south-west winds, whose influence cannot be eliminated, and mean-sea-level is higher, by 0·571 foot, at the head of the gulf than it is at the mouth.

The following is an abstract of the results of tables XXXII to XXXIV :—

TABLE XXXV.

Average closing errors per mile	
	foot
For inland circuits	0·00066
For land-and-sea circuits (open-coasts)	0·00053
For land-and-water circuits on a gulf	0·00449
For land-and-water circuits on a tidal river	0·02349

Although the differences in the elevation of mean-sea-level at different open-coast ports are so small, that the levelling is insufficiently accurate to detect them, yet in gulfs and tidal rivers the changes in the elevation of mean-sea-level are so considerable and so rapid, that levelling brings them to light without difficulty. On the Gulf of Cutch the closing error per mile, 0·00449, is more than six times as large as the average closing error of the inland circuits of levelling, and on the tidal river Hooghly the average closing error per mile, 0·02349, is thirty-five times as large as the average of the inland circuits. These great increases in the closing errors are due to actual differences in the elevation of the mean surface of the water.

LEVELLING OPERATIONS.

PART II.

RESULTS OF THE OBSERVATIONS ON THE MAIN-LINES OF LEVELLING.

PART II.

SECTION (1). DESCRIPTIONS OF JUNCTION-POINTS AND TERMINALS.

SECTION (2). RESULTS OBTAINED FROM SIMULTANEOUS DOUBLE-LEVELLING.

SECTION (3). RESULTS OF REVISIONS.

Section (1).—DESCRIPTIONS OF JUNCTION-POINTS AND TERMINALS.

Descriptions of the bench-marks that form the terminals and junction-points of the main-lines of levelling.

Name of terminal or junction-point	Description of Bench-marks	Inscription
Agra	Cut on surface of north side, east end, of coping of platform of goods station Agra. (This bench-mark has been destroyed).	×
Allahabad	Embedded on top of glacis of north-eastern gate of fort	G.T.S. ● B.M.
Arkonam	Embedded at railway station between railway mail service office and plague examination shed	G.T.S. □ B.M.
Bangalore	South-west end of base-line, upper brass plug	⊙
Bellary	Cut on a stone of a paved drain, which carries the water from the ditch round the fort, to the great tank	G.T.S. ○ B.M.
Beypore	Embedded at the tidal observatory, 100 feet east of the front door of the custom house. This was formerly the reference bench-mark for the tidal observatory. *See* page 116, chapter VIII	G.T.S. □ B.M. A
Bezwada	Cut on a stone in pavement of eastern verandah of the travellers' bungalow ...	G.T.S. □ B.M.
Bilaspur	Embedded at south-west corner of second pillar of verandah from west of railway station	G.T.S. B.M. □
Bombay	Cut on bottom step on north side of main entrance to town-hall: *see* page 115, chapter VIII	G.T.S. ○ B.M.
Cawnpore ...	Embedded 7 feet south-east of canal milestone No. 137	None
Chach	South-west end of Chach base-line, upper mark-stone of pillar, dot on brass ...	None
Cochin	Embedded in the centre of the verandah of the port-office, about 50 yards south of the tidal observatory. This is the reference bench-mark for the tidal observatory: *see* page 116, chapter VIII	G.T.S. □ B.M. A
Cuttack	Embedded between judge's court and the municipal dispensary	G.T.S. □ B.M.
Diksal	Embedded in the railway enclosure near pointsman's houses at the south-west end of the railway station	G.T.S. □ B.M.
Dildarnagar ...	Embedded 12 paces from north-east corner of railway station	G.T.S. / B.M.

Name of terminal or junction-point	Description of Bench-marks	Inscription
Erode	Embedded at railway station, 10 feet from south-west corner of engine-shed ...	G.T.S. □ B.M.
False Point ...	Engraved on a stone embedded in outside wall surrounding light-house: *see* page 116, chapter VIII	G.T.S. O B.M.
Ferozepore ...	Embedded due west of volunteer instructor's house. The sentry box of quarter guard of old horse artillery lines, near which this mark was originally placed, is in ruins	None
Gooty	Embedded 6 feet and 32 feet respectively from south-west and north-west corners of goods shed at the railway station	G.T.S. □ B.M.
Gorakhpur ...	Engraved on second step at west door-way of church	G.T.S. / B.M.
Gulbarga	Embedded in 1906 to the east of the station building of the railway station. This mark is 0·650 foot lower than the bench-mark embedded in 1878	G.T.S. □ B.M.
Howrah	Cut on east end of 2nd step at main entrance to porch at railway station ...	G.T.S. ⊙ B.M.
Hubli	Embedded in the compound of the travellers' bungalow, 139 feet from the north-east of the stables and 96 feet from the south-west corner of the kitchen ...	G.T.S. □ B.M.
Jalarpet	Embedded opposite the south wall of the semaphore tower on the Beypore line and in front of the station	G.T.S. □ B.M.
Jorya	Embedded 145 feet west of north-west tower of the town wall of Jorya on which is the G. T. Survey station	G.T.S. □ B.M.
Kalyan	Embedded in the northern passenger platform of railway station	G.T.S. □ B.M.
Karachi	Embedded close to and north-west of harbour works mestri quarters and 140 yards south-west of tidal observatory. It is the reference bench-mark of the observatory: *see* page 115, chapter VIII	G.T.S. B.M. □ A A.D. 1880
Karwar	Embedded 173 feet from the north-west corner of the travellers' bungalow. This is the reference bench-mark for the tidal observatory: *see* page 116, chapter VIII	G.T.S. □ B.M.
Katni	Cut on east platform of East Indian railway station, in front of telegraph office ...	G.T.S. O B.M.
Kedgaon	Embedded within the railway enclosure at the railway station	G.T.S. □ B.M.
Kendrapara ...	Embedded in sub-divisional kachahri compound	G.T.S. □ B.M.

Name of terminal or junction-point	Description of Bench-marks	Inscription
Lucknow	Embedded 37 feet east of Kalubir's *Than* (platform)	None
Madras	Cut on the plinth, west side of memorial stone laid by the Prince of Wales. This is the reference bench-mark for the tidal observatory: *see* page 116, chapter VIII	G.T.S. ○ B.M.
Meerut	Marked on stone slab opposite north pillar of central western door-way of Meerut Church	+
Murghai	Embedded on high ground between road and canal	None
Nandgaon	Embedded near north end of railway station platform	G.T.S. □ B.M.
Navanar	Embedded in centre of the sand hill at Navanar tidal station ...	G.T.S. □ B.M. O
Negapatam ...	Embedded in the port-office verandah opposite custom-office window. This is the reference bench-mark for the tidal observatory: *see* page 116, chapter VIII	G.T.S. ○ B.M. A
Nira	Embedded 10 feet and 31 feet west of the north-west and south-west corners of the travellers' bungalow	G.T.S. □ B.M.
Pirpanti	Embedded at north-west corner of station house of railway station ...	G.T.S. / B.M.
Purnea	Embedded 40 feet from west wall of the joint magistrate's kachahri ...	G.T.S. / B.M.
Raichur	Embedded opposite north wall of the water tank between the station house and engine shed	G.T.S. □ B.M.
Raipur	Embedded in north side of the railway station, between windows of telegraph office and store room	G.T.S. B.M. □
Rajkot	Embedded north of a paka well called Parade-ka-bauli. Has been destroyed ...	G.T.S. □ B.M.
Ramganj	North-east end of Sonakhoda base-line, lower mark-stone. The mark is cut on brass.	⊙
Ramnad	Embedded 22 and 7 feet respectively from south-west and south-east corners of Ganpati's temple (Puliyarkoil) situated at south-east corner of Kenikkarai tank	G.T.S. □ B.M.
Shikarpur (Cutch) ...	Embedded 75 feet north of Mahadeo's temple	G.T.S. □ B.M.
Shikarpur (Sind) ...	Iron plug driven horizontally into north wall of Shikarpur kachahri ...	Iron plug
Shoranur	Embedded near the south-east corner of tank-house at the east end of the railway station	. G.T.S. □ B.M.
Sironj	North-east end of base-line, upper mark-stone	⊙

Name of terminal or junction-point	Description of Bench-marks	Inscription
Sujawal	Embedded in front verandah of Mukhtyarkár's kachahri	G.T.S. □ B.M.
Tanjore	Embedded in the angle formed by the north wall of the old goods shed and the east wall of the goods office at the railway station	G.T.S. □ B.M.
Tatta	Embedded in a mound on which Tatta dâk bungalow is built	O
Trichinopoly ...	Embedded at railway station west of the station house and near north-east corner of lamp room	G.T.S. □ B.M.
Tuticorin	Embedded in the verandah floor of port-office under staircase. Has been destroyed.	G.T.S. □ B.M.
Viramgam ...	Embedded on foot-path, close to the wall of the town and 10 feet north of it and close to the west side of the door-way of Gulwadi gate	G.T.S. □ B.M.
Vizagapatam ...	Embedded in the verandah of the port-office. It is the reference bench-mark of the tidal observatory: *see* page 116, chapter VIII	G.T.S. □ C B.M.
Vizianagram ...	Embedded on south side of permanent way inspector's quarters	G.T.S. □ B.M.

Section (2).—RESULTS OBTAINED FROM SIMULTANEOUS DOUBLE-LEVELLING.

* Line No. 1. Tanjore to Ramnad.

Bench-marks		Distance from Tanjore	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Tanjore (mean result by two levellers).	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Tanjore
From	To		From mark to mark (= *d*)	Total from Tanjore		Total from Tanjore	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	6·52	+ 0·047	+ 0·047	– 16·112	+ 0·011	– 16·101
2	3	10·13	+ 0·007	+ 0·054	– 46·176	+ 0·032	– 46·144
3	4	12·16	+ 0·009	+ 0·063	– 60·404	+ 0·042	– 60·362
4	5	13·00	+ 0·004	+ 0·067	– 61·226	+ 0·043	– 61·183
5	6	20·21	+ 0·036	+ 0·103	– 44·517	+ 0·031	– 44·486
6	7	22·14	– 0·001	+ 0·102	– 26·742	+ 0·018	– 26·724
7	8	23·34	+ 0·006	+ 0·108	– 42·235	+ 0·029	– 42·206
8	9	27·36	– 0·015	+ 0·093	– 56·552	+ 0·039	– 56·513
9	10	29·49	+ 0·005	+ 0·098	– 29·358	+ 0·020	– 29·338
10	11	35·31	+ 0·023	+ 0·121	– 55·212	+ 0·039	– 55·173
11	12	38·47	+ 0·011	+ 0·132	– 57·602	+ 0·040	– 57·562
12	13	46·52	– 0·036	+ 0·096	– 34·966	+ 0·024	– 34·942
13	14	48·65	+ 0·026	+ 0·122	– 47·236	+ 0·033	– 47·203
14	15	50·10	+ 0·005	+ 0·127	– 56·319	+ 0·039	– 56·280
15	16	53·79	– 0·014	+ 0·113	– 89·678	+ 0·062	– 89·616
16	17	54·62	– 0·011	+ 0·102	– 94·220	+ 0·066	– 94·154
17	18	54·65	+ 0·002	+ 0·104	– 92·640	+ 0·065	– 92·575
18	19	55·84	+ 0·012	+ 0·116	–102·117	+ 0·071	–102·046
19	20	56·83	+ 0·013	+ 0·129	–108·528	+ 0·075	–108·453
20	21	57·82	+ 0·005	+ 0·134	–113·538	+ 0·079	–113·459
21	22	58·36	– 0·008	+ 0·126	–110·720	+ 0·077	–110·643
22	23	60·82	+ 0·015	+ 0·141	–132·564	+ 0·093	–132·471
23	24	61·81	+ 0·002	+ 0·143	–139·307	+ 0·098	–139·209
24	25	62·75	– 0·001	+ 0·142	–147·384	+ 0·104	–147·280
25	26	63·10	– 0·006	+ 0·136	–152·861	+ 0·108	–152·753
26	27	65·81	– 0·043	+ 0·093	–170·679	+ 0·121	–170·558
27	28	66·63	0·000	+ 0·093	–180·415	+ 0·128	–180·287
28	29	68·05	+ 0·002	+ 0·095	–184·771	+ 0·131	–184·640
29	30	68·18	– 0·006	+ 0·089	–183·079	+ 0·130	–182·949
30	31	68·91	– 0·021	+ 0·068	–183·979	+ 0·131	–183·848
31	32	69·38	+ 0·012	+ 0·080	–187·217	+ 0·133	–187·084
32	33	70·39	– 0·021	+ 0·059	–188·225	+ 0·134	–188·091
33	34	73·36	+ 0·013	+ 0·072	–184·617	+ 0·131	–184·486
34	35	74·99	– 0.019	+ 0·053	–183·292	+ 0·130	–183·162
35	36	75·55	– 0·003	+ 0·050	–187·940	+ 0·134	–187·806
36	37	77·60	– 0·011	+ 0·039	–186·289	+ 0·133	–186·156
37	38	79·30	– 0·017	+ 0·022	–182·215	+ 0·130	–182·085
38	39	80·71	+ 0·028	+ 0·050	–185·600	+ 0·132	–185·468
39	40	81·50	+ 0·002	+ 0·052	–178·556	+ 0·127	–178·429
40	41	82·58	+ 0·014	+ 0·066	–178·254	+ 0·127	–178·127
41	42	83·81	+ 0·011	+ 0·077	–182·635	+ 0·130	–182·505
42	43	84·91	– 0·024	+ 0·053	–176·351	+ 0·126	–176·225
43	44	95·14	– 0·036	+ 0·017	–177·539	+ 0·127	–177·412
44	45	104·72	+ 0·029	+ 0·046	–176·661	+ 0·126	–176·535
45	46	105·95	+ 0·005	+ 0·051	–183·265	+ 0·131	–183·134
46	47	106·26	– 0·004	+ 0·047	–183·073	+ 0·131	–182·942
47	48	111·81	– 0·014	+ 0·033	–177·939	+ 0·128	–177·811
48	49	114·80	+ 0·059	+ 0·092	–172·745	+ 0·124	–172·621
49	50 †	114·81	– 0·002	+ 0·090	–173·543	+ 0·125	–173·418

Difference of dynamic height, Tanjore to Ramnad = – 173·418 feet.

Length of line in miles = M = 114·81. $\Sigma d^2 = 0{\cdot}018978$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745 \sqrt{\dfrac{\Sigma d^2}{4\mathrm{M}}} = \pm\, 0{\cdot}0043$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745 \sqrt{\dfrac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0465$.

* Bench-mark No. 1 is the mark at Tanjore described on page 136. † Bench-mark No. 50 is the mark at Ramnad described on page 135.

Line No. 2. Ramnad to Tuticorin.

Bench-marks From	Bench-marks To	Distance from Ramnad	Discrepancy between levellers (First – Second leveller): From mark to mark (= d)	Discrepancy between levellers (First – Second leveller): Total from Ramnad	Observed elevation above (+) or below (–) Ramnad (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Ramnad	Dynamic height above (+) or below (–) Ramnad
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1 *	2	1·27	– 0·002	– 0·002	+ 1·037	– 0·001	+ 1·036
2	3	8·20	0·000	– 0·002	+ 6·699	– 0·005	+ 6·694
3	4	8·21	+ 0·001	– 0·001	+ 8·037	– 0·006	+ 8·031
4	5	8·27	– 0·011	– 0·012	+ 60·034	– 0·045	+ 59·989
5	6	16·64	+ 0·002	– 0·010	+ 9·362	– 0·007	+ 9·355
6	7	19·40	– 0·004	– 0·014	+ 3·939	– 0·003	+ 3·936
7	8	21·52	+ 0·018	+ 0·004	+ 12·904	– 0·010	+ 12·894
8	9	23·89	+ 0·008	+ 0·012	+ 14·979	– 0·012	+ 14·967
9	10	27·83	+ 0·027	+ 0·039	+ 4·944	– 0·005	+ 4·939
10	11	32·01	+ 0·024	+ 0·063	+ 1·561	– 0·003	+ 1·558
11	12	40·48	+ 0·001	+ 0·064	+ 1·958	– 0·003	+ 1·955
12	13	41·05	– 0·016	+ 0·048	+ 1·042	– 0·002	+ 1·040
13	14	43·50	– 0·013	+ 0·035	+ 20·112	– 0·016	+ 20·096
14	15	46·61	+ 0·004	+ 0·039	+ 7·917	– 0·007	+ 7·910
15	16	47·04	– 0·020	+ 0·019	+ 3·775	– 0·004	+ 3·771
16	17	47·09	– 0·001	+ 0·018	+ 10·122	– 0·009	+ 10·113
17	18	51·41	+ 0·017	+ 0·035	+ 3·498	– 0·004	+ 3·494
18	19	52·21	+ 0·009	+ 0·044	+ 5·122	– 0·006	+ 5·116
19	20	54·22	+ 0·004	+ 0·048	+ 17·544	– 0·015	+ 17·529
20	21	55·23	+ 0·011	+ 0·059	+ 9·197	– 0·009	+ 9·188
21	22	55·69	+ 0·010	+ 0·069	+ 13·346	– 0·012	+ 13·334
22	23	55·70	– 0·002	+ 0·067	+ 10·137	– 0·010	+ 10·127
23	24	57·26	– 0·002	+ 0·065	+ 17·494	– 0·015	+ 17·479
24	25	58·27	0·000	+ 0·065	+ 22·207	– 0·019	+ 22·188
25	26	59·40	– 0·019	+ 0·046	+ 27·416	– 0·023	+ 27·393
26	27	61·28	+ 0·008	+ 0·054	+ 49·506	– 0·040	+ 49·466
27	28	62·31	+ 0·006	+ 0·060	+ 56·716	– 0·045	+ 56·671
28	29	63·32	+ 0·003	+ 0·063	+ 61·323	– 0·049	+ 61·274
29	30	65·99	– 0·007	+ 0·056	+ 32·122	– 0·027	+ 32·095
30	31	66·83	– 0·002	+ 0·054	+ 30·123	– 0·025	+ 30·098
31	32	67·69	– 0·011	+ 0·043	+ 21·270	– 0·018	+ 21·252
32	33	68·87	0·000	+ 0·043	+ 13·675	– 0·012	+ 13·663
33	34	69·88	– 0·007	+ 0·036	+ 5·272	– 0·006	+ 5·266
34	35	70·89	– 0·018	+ 0·018	+ 2·907	– 0·004	+ 2·903
35	36	71·89	+ 0·002	+ 0·020	– 4·607	+ 0·002	– 4·605
36	37	73·73	– 0·010	+ 0·010	– 9·532	+ 0·006	– 9·526
37	38	74·23	0·000	+ 0·010	– 13·753	+ 0·009	– 13·744
38	39	74·51	– 0·011	– 0·001	– 14·155	+ 0·009	– 14·146
39	40 †	74·61	+ 0·001	0·000	– 13·169	+ 0·008	– 13·161

Difference of dynamic height, Ramnad to Tuticorin = – 13·161 feet.

Length of line in miles = M = 74·61. $\Sigma d^2 = 0\cdot004540$.

Probable error of the mean result per mile of double-levelling $= 0\cdot6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0\cdot0026$.

Probable error of the difference of elevation between the terminal bench-marks $= 0\cdot6745 \sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0\cdot0227$.

* Bench-mark No. 1 is the mark at Ramnad described on page 135. † Bench-mark No. 40 is the mark at Tuticorin described on page 136.

Line No. 3. Tuticorin to Trichinopoly.

Bench-marks From	Bench-marks To	Distance from Tuticorin	Discrepancy between levellers (*First—Second leveller*) From mark to mark (= *d*)	Discrepancy between levellers Total from Tuticorin	Observed elevation above (+) or below (−) Tuticorin (mean result by two levellers)	Dynamic correction deduced from mark to mark Total from Tuticorin	Dynamic height above (+) or below (−) Tuticorin
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·01	0·000	0·000	− 2·518	+ 0·002	− 2·516
2	3	0·11	+ 0·002	+ 0·002	− 0·982	+ 0·001	− 0·981
3	4	0·39	+ 0·001	+ 0·003	− 0·578	+ 0·001	− 0·577
4	5	1·96	+ 0·011	+ 0·014	+ 7·406	− 0·005	+ 7·401
5	6	4·86	+ 0·010	+ 0·024	+ 29·328	− 0·022	+ 29·306
6	7	6·96	+ 0·013	+ 0·037	+ 67·707	− 0·051	+ 67·656
7	8	8·10	− 0·032	+ 0·005	+ 82·288	− 0·062	+ 82·226
8	9	9·76	− 0·020	− 0·015	+ 91·120	− 0·069	+ 91·051
9	10	11·01	− 0·016	− 0·031	+ 90·124	− 0·068	+ 90·056
10	11	11·92	+ 0·011	− 0·020	+ 95·033	− 0·072	+ 94·961
11	12	12·75	0·000	− 0·020	+ 96·943	− 0·074	+ 96·869
12	13	14·01	+ 0·004	− 0·016	+ 106·547	− 0·082	+ 106·465
13	14	15·60	+ 0·025	+ 0·009	+ 133·948	− 0·102	+ 133·846
14	15	17·48	+ 0·004	+ 0·013	+ 177·611	− 0·135	+ 177·476
15	16	18·34	− 0·010	+ 0·003	+ 198·751	− 0·151	+ 198·600
16	17	18·46	+ 0·006	+ 0·009	+ 197·589	− 0·150	+ 197·439
17	18	19·70	+ 0·028	+ 0·037	+ 215·872	− 0·164	+ 215·708
18	19	20·50	+ 0·012	+ 0·049	+ 223·705	− 0·170	+ 223·535
19	20	21·28	− 0·002	+ 0·047	+ 218·654	− 0·166	+ 218·488
20	21	22·56	− 0·008	+ 0·039	+ 220·785	− 0·168	+ 220·617
21	22	24·72	− 0·013	+ 0·026	+ 271·866	− 0·206	+ 271·660
22	23	25·62	− 0·009	+ 0·017	+ 285·857	− 0·217	+ 285·640
23	24	26·95	− 0·014	+ 0·003	+ 300·477	− 0·228	+ 300·249
24	25	28·21	− 0·011	− 0·008	+ 285·483	− 0·217	+ 285·266
25	26	29·95	+ 0·007	− 0·001	+ 285·118	− 0·217	+ 284·901
26	27	31·11	+ 0·009	+ 0·008	+ 293·888	− 0·223	+ 293·665
27	28	32·26	+ 0·010	+ 0·018	+ 306·935	− 0·233	+ 306·702
28	29	33·10	0·000	+ 0·018	+ 316·278	− 0·239	+ 316·039
29	30	33·48	− 0·006	+ 0·012	+ 320·024	− 0·242	+ 319·782
30	31	34·47	+ 0·003	+ 0·015	+ 335·081	− 0·253	+ 334·828
31	32	35·52	− 0·001	+ 0·014	+ 347·603	− 0·262	+ 347·341
32	33	36·14	0·000	+ 0·014	+ 343·721	− 0·259	+ 343·462
33	34	37·72	− 0·012	+ 0·002	+ 334·977	− 0·253	+ 334·724
34	35	39·50	− 0·030	− 0·028	+ 328·301	− 0·248	+ 328·053
35	36	40·38	− 0·004	− 0·032	+ 317·044	− 0·240	+ 316·804
36	37	40·62	− 0·012	− 0·044	+ 312·059	− 0·236	+ 311·823
37	38	41·24	+ 0·016	− 0·028	+ 296·092	− 0·224	+ 295·868
38	39	41·99	+ 0·006	− 0·022	+ 283·326	− 0·214	+ 283·112
39	40	42·04	− 0·002	− 0·024	+ 278·958	− 0·211	+ 278·747
40	41	42·98	+ 0·001	− 0·023	+ 267·207	− 0·202	+ 267·005
41	42	44·16	+ 0·001	− 0·022	+ 264·126	− 0·200	+ 263·926
42	43	44·96	− 0·005	− 0·027	+ 253·161	− 0·192	+ 252·969
43	44	45·89	− 0·017	− 0·044	+ 236·813	− 0·180	+ 236·633
44	45	47·13	+ 0·004	− 0·040	+ 205·598	− 0·157	+ 205·441
45	46	48·10	− 0·005	− 0·045	+ 215·353	− 0·164	+ 215·189
46	47	49·51	− 0·013	− 0·058	+ 224·692	− 0·171	+ 224·521
47	48	50·50	− 0·011	− 0·069	+ 214·348	− 0·164	+ 214·184
48	49	51·29	− 0·010	− 0·079	+ 212·689	− 0·163	+ 212·526
49	50	53·77	+ 0·014	− 0·065	+ 204·456	− 0·157	+ 204·299
50	51	54·52	− 0·009	− 0·074	+ 204·204	− 0·157	+ 204·047
51	52	55·12	− 0·001	− 0·075	+ 201·652	− 0·155	+ 201·497
52	53	55·17	+ 0·002	− 0·073	+ 201·400	− 0·155	+ 201·245
53	54	56·45	− 0·012	− 0·085	+ 211·767	− 0·162	+ 211·605
54	55	57·39	− 0·001	− 0·086	+ 222·645	− 0·170	+ 222·475
55	56	58·83	+ 0·020	− 0·066	+ 242·348	− 0·185	+ 242·163
56	57	59·86	+ 0·005	− 0·061	+ 231·635	− 0·177	+ 231·458
57	58	60·64	+ 0·012	− 0·049	+ 231·437	− 0·177	+ 231·260
58	59	62·30	+ 0·009	− 0·040	+ 262·270	− 0·199	+ 262·071
59	60	63·74	− 0·021	− 0·061	+ 252·258	− 0·192	+ 252·066
60	61	64·14	+ 0·001	− 0·060	+ 252·158	− 0·192	+ 251·966

* Bench-mark No. 1 is the mark at Tuticorin described on page 136.

Line No. 3. Tuticorin to Trichinopoly.—(Continued).

Bench-marks From	Bench-marks To	Distance from Tuticorin	Discrepancy between levellers (First – Second leveller): From mark to mark (= d)	Discrepancy between levellers (First – Second leveller): Total from Tuticorin	Observed elevation above (+) or below (–) Tuticorin (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Tuticorin	Dynamic height above (+) or below (–) Tuticorin
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	64·94	+ 0·004	– 0·056	+ 258·745	– 0·197	+ 258·548
62	63	65·48	+ 0·009	– 0·047	+ 260·465	– 0·198	+ 260·267
63	64	67·13	– 0·009	– 0·056	+ 284·445	– 0·216	+ 284·229
64	65	68·26	+ 0·006	– 0·050	+ 297·358	– 0·226	+ 297·132
65	66	69·42	+ 0·006	– 0·044	+ 295·461	– 0·225	+ 295·236
66	67	70·38	– 0·009	– 0·053	+ 298·781	– 0·227	+ 298·554
67	68	71·80	– 0·025	– 0·078	+ 328·461	– 0·249	+ 328·212
68	69	71·85	0·000	– 0·078	+ 327·575	– 0·248	+ 327·327
69	70	72·63	– 0·025	– 0·103	+ 322·376	– 0·244	+ 322·132
70	71	73·88	– 0·001	– 0·104	+ 335·982	– 0·254	+ 335·728
71	72	74·97	+ 0·013	– 0·091	+ 354·582	– 0·268	+ 354·314
72	73	76·35	– 0·005	– 0·096	+ 384·557	– 0·290	+ 384·267
73	74	77·50	+ 0·007	– 0·089	+ 377·739	– 0·285	+ 377·454
74	75	78·84	+ 0·008	– 0·081	+ 355·193	– 0·268	+ 354·925
75	76	79·40	– 0·002	– 0·083	+ 356·167	– 0·269	+ 355·898
76	77	82·09	– 0·038	– 0·121	+ 370·951	– 0·280	+ 370·671
77	78	83·40	+ 0·021	– 0·100	+ 379·027	– 0·286	+ 378·741
78	79	85·74	– 0·031	– 0·131	+ 388·953	– 0·293	+ 388·660
79	80	87·06	– 0·028	– 0·159	+ 392·757	– 0·296	+ 392·461
80	81	87·81	+ 0·007	– 0·152	+ 407·045	– 0·306	+ 406·739
81	82	87·88	+ 0·003	– 0·149	+ 404·202	– 0·304	+ 403·898
82	83	88·94	+ 0·011	– 0·138	+ 406·657	– 0·305	+ 406·352
83	84	89·83	+ 0·013	– 0·125	+ 424·995	– 0·318	+ 424·677
84	85	91·58	+ 0·001	– 0·124	+ 437·261	– 0·327	+ 436·934
85	86	92·51	– 0·005	– 0·129	+ 436·870	– 0·327	+ 436·543
86	87	94·40	– 0·022	– 0·151	+ 461·808	– 0·345	+ 461·463
87	88	96·33	+ 0·018	– 0·133	+ 448·300	– 0·335	+ 447·965
88	89	97·00	– 0·009	– 0·142	+ 433·928	– 0·325	+ 433·603
89	90	97·60	+ 0·001	– 0·141	+ 432·171	– 0·324	+ 431·847
90	91	98·53	+ 0·014	– 0·127	+ 433·179	– 0·325	+ 432·854
91	92	98·79	– 0·005	– 0·132	+ 431·435	– 0·324	+ 431·111
92	93	99·38	– 0·007	– 0·139	+ 442·330	– 0·332	+ 441·998
93	94	101·02	– 0·004	– 0·143	+ 452·288	– 0·339	+ 451·949
94	95	102·22	+ 0·025	– 0·118	+ 462·205	– 0·346	+ 461·859
95	96	103·57	+ 0·015	– 0·103	+ 468·009	– 0·350	+ 467·659
96	97	104·63	– 0·001	– 0·104	+ 483·292	– 0·361	+ 482·931
97	98	106·17	+ 0·011	– 0·093	+ 498·115	– 0·372	+ 497·743
98	99	107·83	– 0·011	– 0·104	+ 501·284	– 0·374	+ 500·910
99	100	109·09	+ 0·022	– 0·082	+ 513·058	– 0·383	+ 512·675
100	101	110·57	– 0·004	– 0·086	+ 532·320	– 0·397	+ 531·923
101	102	111·69	– 0·005	– 0·091	+ 536·066	– 0·400	+ 535·666
102	103	111·74	– 0·002	– 0·093	+ 537·934	– 0·401	+ 537·533
103	104	112·50	+ 0·011	– 0·082	+ 542·062	– 0·404	+ 541·658
104	105	113·41	+ 0·001	– 0·081	+ 556·579	– 0·415	+ 556·164
105	106	114·86	– 0·011	– 0·092	+ 576·991	– 0·429	+ 576·562
106	107	116·09	– 0·011	– 0·103	+ 612·186	– 0·454	+ 611·732
107	108	117·60	– 0·008	– 0·111	+ 646·951	– 0·479	+ 646·472
108	109	118·91	– 0·013	– 0·124	+ 669·568	– 0·495	+ 669·073
109	110	120·27	+ 0·018	– 0·106	+ 675·118	– 0·500	+ 674·618
110	111	120·66	– 0·016	– 0·122	+ 679·354	– 0·503	+ 678·851
111	112	122·10	– 0·014	– 0·136	+ 721·733	– 0·532	+ 721·201
112	113	123·43	– 0·028	– 0·164	+ 777·654	– 0·572	+ 777·082
113	114	123·44	– 0·002	– 0·166	+ 777·601	– 0·572	+ 777·029
114	115	125·18	+ 0·007	– 0·159	+ 798·897	– 0·587	+ 798·310
115	116	126·62	– 0·012	– 0·171	+ 849·359	– 0·623	+ 848·736
116	117	128·33	– 0·030	– 0·201	+ 940·286	– 0·688	+ 939·598
117	118	130·13	+ 0·005	– 0·196	+ 989·163	– 0·723	+ 988·440
118	119	131·03	– 0·001	– 0·197	+ 972·887	– 0·712	+ 972·175
119	120	132·29	– 0·016	– 0·213	+ 958·302	– 0·701	+ 957·601
120	121	133·64	+ 0·015	– 0·198	+ 918·704	– 0·673	+ 918·031

Line No. 3. Tuticorin to Trichinopoly.—(Continued).

Bench-marks		Distance from Tuticorin	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Tuticorin (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Tuticorin
From	To		From mark to mark (= d)	Total from Tuticorin		Total from Tuticorin	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
121	122	135·43	+ 0·010	– 0·188	+ 926·659	– 0·679	+ 925·980
122	123	136·61	– 0·008	– 0·196	+ 915·920	– 0·671	+ 915·249
123	124	137·01	+ 0·006	– 0·190	+ 915·647	– 0·671	+ 914·976
124	125	137·06	+ 0·003	– 0·187	+ 915·465	– 0·671	+ 914·794
125	126	137·09	– 0·011	– 0·198	+ 908·513	– 0·666	+ 907·847
126	127	138·67	+ 0·023	– 0·175	+ 878·384	– 0·645	+ 877·739
127	128	140·53	+ 0·028	– 0·147	+ 858·668	– 0·631	+ 858·037
128	129	141·52	– 0·013	– 0·160	+ 858·171	– 0·631	+ 857·540
129	130	143·05	+ 0·004	– 0·156	+ 860·097	– 0·632	+ 859·465
130	131	144·24	– 0·020	– 0·176	+ 876·355	– 0·643	+ 875·712
131	132	145·85	– 0·001	– 0·177	+ 911·534	– 0·668	+ 910·866
132	133	147·13	– 0·002	– 0·179	+ 960·451	– 0·702	+ 959·749
133	134	147·16	+ 0·002	– 0·177	+ 960·290	– 0·702	+ 959·588
134	135	149·35	+ 0·016	– 0·161	+ 988·901	– 0·722	+ 988·179
135	136	151·16	– 0·019	– 0·180	+ 1045·056	– 0·761	+ 1044·295
136	137	152·28	+ 0·011	– 0·169	+ 1078·270	– 0·784	+ 1077·486
137	138	153·33	+ 0·007	– 0·162	+ 1065·074	– 0·775	+ 1064·299
138	139	154·49	– 0·014	– 0·176	+ 1007·078	– 0·734	+ 1006·344
139	140	155·53	+ 0·005	– 0·171	+ 967·587	– 0·707	+ 966·880
140	141	156·80	+ 0·015	– 0·156	+ 907·956	– 0·665	+ 907·291
141	142	157·85	+ 0·004	– 0·152	+ 866·073	– 0·636	+ 865·437
142	143	159·77	+ 0·051	– 0·101	+ 804·927	– 0·593	+ 804·334
143	144	160·48	+ 0·006	– 0·095	+ 788·574	– 0·582	+ 787·992
144	145	161·89	0·000	– 0·095	+ 733·457	– 0·543	+ 732·914
145	146	163·20	– 0·008	– 0·103	+ 705·509	– 0·523	+ 704·986
146	147	163·29	+ 0·008	– 0·095	+ 704·172	– 0·522	+ 703·650
147	148	164·19	– 0·004	– 0·099	+ 680·071	– 0·505	+ 679·566
148	149	165·18	– 0·005	– 0·104	+ 656·214	– 0·488	+ 655·726
149	150	167·25	0·000	– 0·104	+ 602·126	– 0·450	+ 601·676
150	151	168·67	– 0·016	– 0·120	+ 574·202	– 0·430	+ 573·772
151	152	169·27	+ 0·015	– 0·105	+ 563·969	– 0·423	+ 563·546
152	153	169·96	+ 0·009	– 0·096	+ 555·940	– 0·417	+ 555·523
153	154	171·36	+ 0·040	– 0·056	+ 508·267	– 0·383	+ 507·884
154	155	171·98	– 0·003	– 0·059	+ 506·242	– 0·382	+ 505·860
155	156	172·00	– 0·005	– 0·064	+ 506·006	– 0·382	+ 505·624
156	157	172·44	– 0·002	– 0·066	+ 504·804	– 0·381	+ 504·423
157	158	173·92	– 0·012	– 0·078	+ 474·632	– 0·360	+ 474·272
158	159	175·09	– 0·007	– 0·085	+ 456·114	– 0·347	+ 455·767
159	160	176·56	+ 0·015	– 0·070	+ 428·265	– 0·327	+ 427·938
160	161	177·73	– 0·010	– 0·080	+ 413·989	– 0·317	+ 413·672
161	162	178·99	+ 0·013	– 0·067	+ 400·142	– 0·307	+ 399·835
162	163	180·14	– 0·003	– 0·070	+ 394·140	– 0·303	+ 393·837
163	164	181·09	+ 0·004	– 0·066	+ 385·599	– 0·297	+ 385·302
164	165	181·41	– 0·012	– 0·078	+ 380·328	– 0·293	+ 380·035
165	166	182·98	+ 0·008	– 0·070	+ 369·483	– 0·285	+ 369·198
166	167	183·00	+ 0·002	– 0·068	+ 368·901	– 0·285	+ 368·616
167	168	184·03	– 0·029	– 0·097	+ 347·100	– 0·270	+ 346·830
168	169	185·56	– 0·007	– 0·104	+ 330·024	– 0·258	+ 329·766
169	170	186·57	– 0·002	– 0·106	+ 310·332	– 0·244	+ 310·088
170	171	187·86	– 0·006	– 0·112	+ 289·123	– 0·229	+ 288·894
171	172	190·08	– 0·008	– 0·120	+ 264·025	– 0·212	+ 263·813
172	173	191·95	– 0·016	– 0·136	+ 248·298	– 0·201	+ 248·097
173	174	192·46	– 0·015	– 0·151	+ 247·443	– 0·200	+ 247·243
174	175*	194·37	– 0·016	– 0·167	+ 267·286	– 0·186	+ 267·100

Difference of dynamic height, Tuticorin to Trichinopoly = + 267·100 feet.

Length of line in miles = M = 194·37. $\Sigma d^2 = 0·032197$.

Probable error of the mean result per mile of double-levelling $= 0·6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm 0·0043$.

Probable error of the difference of elevation between the terminal bench-marks $= 0·6745 \sqrt{\frac{\Sigma d^2}{4}} = \pm 0·0605$.

* Bench-mark No. 175 is the mark at Trichinopoly described on page 136.

Line No. 4. Trichinopoly to Tanjore.

Bench-marks From	Bench-marks To	Distance from Trichinopoly	Discrepancy between levellers (First – Second leveller): From mark to mark (= *d*)	Discrepancy between levellers (First – Second leveller): Total from Trichinopoly	Observed elevation above (+) or below (–) Trichinopoly (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Trichinopoly	Dynamic height above (+) or below (–) Trichinopoly
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·06	– 0·003	– 0·003	– 0·372	0·000	– 0·372
2	3	1·22	– 0·001	– 0·004	– 12·540	+ 0·008	– 12·532
3	4	2·30	– 0·024	– 0·028	– 7·963	+ 0·005	– 7·958
4	5	4·08	– 0·025	– 0·053	– 28·764	+ 0·020	– 28·744
5	6	5·47	+ 0·012	– 0·041	– 51·367	+ 0·036	– 51·331
6	7	6·32	– 0·021	– 0·062	– 46·787	+ 0·033	– 46·754
7	8	6·92	– 0·010	– 0·072	– 39·584	+ 0·028	– 39·556
8	9	7·44	– 0·006	– 0·078	– 36·788	+ 0·026	– 36·762
9	10	9·14	– 0·008	– 0·086	– 43·644	+ 0·031	– 43·613
10	11	10·29	– 0·014	– 0·100	– 42·853	+ 0·030	– 42·823
11	12	12·57	+ 0·026	– 0·074	– 63·963	+ 0·045	– 63·918
12	13	13·52	+ 0·002	– 0·072	– 73·755	+ 0·052	– 73·703
13	14	15·31	– 0·019	– 0·091	– 85·027	+ 0·060	– 84·967
14	15	16·37	+ 0·010	– 0·081	– 90·995	+ c·064	– 90·931
15	16	16·82	+ 0·005	– 0·076	– 93·134	+ 0·065	– 93·069
16	17	17·56	+ 0·011	– 0·065	– 95·991	+ 0·067	– 95·924
17	18	18·92	– 0·027	– 0·092	– 94·447	+ 0·066	– 94·381
18	19	20·32	+ 0·008	– 0·084	– 85·476	+ 0·060	– 85·416
19	20	21·11	– 0·001	– 0·085	– 93·600	+ 0·066	– 93·534
20	21	22·02	– 0·006	– 0·091	– 93·608	+ 0·066	– 93·542
21	22	23·38	– 0·004	– 0·095	– 99·992	+ 0·070	– 99·922
22	23	24·67	– 0·011	– 0·084	–106·056	+ 0·074	–105·982
23	24	26·01	– 0·020	– 0·104	–114·297	+ 0·080	–114·217
24	25	27·29	+ 0·020	– 0·084	–109·098	+ 0·076	–109·022
25	26	29·05	+ 0·009	– 0·075	– 91·917	+ 0·064	– 91·853
26	27	30·05	+ 0·033	– 0·042	– 80·379	+ 0·056	– 80·323
27	28†	31·05	+ 0·022	– 0·020	– 80·388	+ 0·056	– 80·332

Difference of dynamic height, Trichinopoly to Tanjore = – 80·332 feet.

Length of line in miles = M = 31·05. $\Sigma d^2 = 0{\cdot}006900$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745 \sqrt{\dfrac{\Sigma d^2}{4M}} = \pm\, 0{\cdot}0050.$

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745 \sqrt{\dfrac{\Sigma d^2}{4M}} = \pm\, 0{\cdot}0280.$

* Bench-mark No. 1 is the mark at Trichinopoly described on page 136. † Bench-mark No. 28 is the mark at Tanjore described on page 136.

Line No. 5. Tanjore to Negapatam.

Bench-marks		Distance from Tanjore	Discrepancy between levellers (First—Second leveller)		Observed elevation above (+) or below (—) Tanjore (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (—) Tanjore
From	To		From mark to mark (= d)	Total from Tanjore		Total from Tanjore	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	2·01	+ 0·002	+ 0·002	− 41·063	+ 0·028	− 41·035
2	3	4·31	− 0·019	− 0·017	− 50·073	+ 0·034	− 50·039
3	4	5·29	− 0·016	− 0·033	− 52·630	+ 0·036	− 52·594
4	5	7·43	− 0·010	− 0·043	− 59·781	+ 0·041	− 59·740
5	6	8·70	− 0·010	− 0·053	− 66·739	+ 0·046	− 66·693
6	7	9·24	+ 0·005	− 0·048	− 72·881	+ 0·050	− 72·831
7	8	9·30	+ 0·002	− 0·046	− 72·705	+ 0·050	− 72·655
8	9	10·27	+ 0·020	− 0·026	− 77·575	+ 0·054	− 77·521
9	10	12·26	+ 0·008	− 0·018	− 87·706	+ 0·061	− 87·645
10	11	12·52	− 0·001	− 0·019	− 87·872	+ 0·061	− 87·811
11	12	14·47	+ 0·006	− 0·013	− 100·872	+ 0·070	− 100·802
12	13	16·12	− 0·038	− 0·051	− 110·503	+ 0·077	− 110·426
13	14	17·20	− 0·019	− 0·070	− 114·064	+ 0·080	− 113·984
14	15	17·66	+ 0·002	− 0·068	− 117·824	+ 0·083	− 117·741
15	16	17·85	+ 0·008	− 0·060	− 118·414	+ 0·083	− 118·331
16	17	18·56	+ 0·003	− 0·057	− 116·864	+ 0·082	− 116·782
17	18	18·60	− 0·006	− 0·063	− 115·350	+ 0·081	− 115·269
18	19	19·44	− 0·005	− 0·068	− 117·128	+ 0·082	− 117·046
19	20	20·76	0·000	− 0·068	− 126·950	+ 0·089	− 126·861
20	21	21·92	+ 0·004	− 0·064	− 132·407	+ 0·093	− 132·314
21	22	23·06	0·000	− 0·064	− 131·041	+ 0·092	− 130·949
22	23	23·67	0·000	− 0·064	− 127·891	+ 0·090	− 127·801
23	24	25·34	+ 0·013	− 0·051	− 136·450	+ 0·096	− 136·354
24	25	26·75	+ 0·010	− 0·041	− 141·368	+ 0·100	− 141·268
25	26	28·25	− 0·010	− 0·051	− 144·968	+ 0·103	− 144·865
26	27	30·07	+ 0·007	− 0·044	− 146·176	+ 0·104	− 146·072
27	28	30·08	− 0·001	− 0·045	− 148·062	+ 0·105	− 147·957
28	29	31·57	− 0·004	− 0·049	− 149·463	+ 0·106	− 149·357
29	30	33·03	+ 0·002	− 0·047	− 154·894	+ 0·110	− 154·784
30	31	33·68	− 0·008	− 0·055	− 153·750	+ 0·109	− 153·641
31	32	35·10	+ 0·007	− 0·048	− 162·368	+ 0·115	− 162·253
32	33	35·84	+ 0·020	− 0·028	− 161·932	+ 0·115	− 161·817
33	34	37·22	− 0·001	− 0·029	− 164·439	+ 0·117	− 164·322
34	35	38·79	+ 0·013	− 0·016	− 167·748	+ 0·119	− 167·629
35	36	40·14	− 0·011	− 0·027	− 172·112	+ 0·122	− 171·990
36	37	40·81	+ 0·001	− 0·026	− 174·051	+ 0·123	− 173·928
37	38	43·17	− 0·020	− 0·046	− 173·867	+ 0·123	− 173·744
38	39	44·22	− 0·002	− 0·048	− 179·874	+ 0·127	− 179·747
39	40	44·59	+ 0·001	− 0·047	− 176·024	+ 0·124	− 175·900
40	41	46·56	+ 0·015	− 0·032	− 187·082	+ 0·132	− 186·950
41	42	47·26	− 0·001	− 0·033	− 182·859	+ 0·129	− 182·730
42	43	47·71	− 0·005	− 0·038	− 180·581	+ 0·128	− 180·453
43	44	47·80	+ 0·003	− 0·035	− 180·508	+ 0·128	− 180·380
44	45	48·22	+ 0·006	− 0·029	− 189·062	+ 0·134	− 188·928
45	46	48·28	+ 0·003	− 0·026	− 183·639	+ 0·130	− 183·509
46	47†	48·29	+ 0·003	− 0·023	− 183·643	+ 0·130	− 183·513

Difference of dynamic height, Tanjore to Negapatam = − 183·513 feet.

Length of line in miles = M = 48·29. $\Sigma d^2 = 0{\cdot}005273$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm\, 0{\cdot}0035$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745 \sqrt{\frac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0245$.

* Bench-mark No. 1 is the mark at Tanjore described on page 136. † Bench-mark No. 47 is the mark at Negapatam described on page 135.

Line No. 6. Trichinopoly to Erode.

Bench-marks		Distance from Trichinopoly	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Trichinopoly (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Trichinopoly
From	To		From mark to mark (= d)	Total from Trichinopoly		Total from Trichinopoly	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·06	– 0·003	– 0·003	– 0·372	0·000	– 0·372
2	3	0·32	– 0·004	– 0·007	– 1·065	+ 0·001	– 1·064
3	4	1·37	+ 0·009	+ 0·002	– 23·240	+ 0·016	– 23·224
4	5	2·53	+ 0·011	+ 0·013	– 44·927	+ 0·031	– 44·896
5	6	3·51	+ 0·004	+ 0·017	– 40·159	+ 0·027	– 40·532
6	7	4·76	+ 0·018	+ 0·035	– 42·025	+ 0·028	– 41·997
7	8	7·06	+ 0·021	+ 0·056	– 35·947	+ 0·024	– 35·923
8	9	8·47	+ 0·029	+ 0·085	– 31·155	+ 0·020	– 31·135
9	10	9·68	+ 0·015	+ 0·100	– 27·295	+ 0·017	– 27·278
10	11	11·86	– 0·005	+ 0·095	– 19·301	+ 0·011	– 19·290
11	12	14·28	+ 0·003	+ 0·098	– 12·948	+ 0·007	– 12·941
12	13	15·83	+ 0·008	+ 0·106	– 9·373	+ 0·004	– 9·369
13	14	17·82	– 0·006	+ 0·100	+ 4·330	– 0·006	+ 4·324
14	15	18·62	+ 0·017	+ 0·117	+ 5·596	– 0·007	+ 5·589
15	16	20·22	+ 0·028	+ 0·145	+ 9·753	– 0·010	+ 9·743
16	17	20·63	+ 0·006	+ 0·151	+ 11·122	– 0·011	+ 11·111
17	18	22·91	+ 0·046	+ 0·197	+ 19·944	– 0·017	+ 19·927
18	19	22·95	0·000	+ 0·197	+ 17·339	– 0·015	+ 17·324
19	20	23·66	+ 0·002	+ 0·199	+ 17·911	– 0·015	+ 17·896
20	21	25·81	+ 0·003	+ 0·202	+ 24·662	– 0·020	+ 24·642
21	22	26·41	+ 0·003	+ 0·205	+ 31·275	– 0·025	+ 31·250
22	23	28·73	– 0·014	+ 0·191	+ 43·326	– 0·033	+ 43·293
23	24	28·86	– 0·003	+ 0·188	+ 40·188	– 0·031	+ 40·157
24	25	29·18	– 0·006	+ 0·182	+ 41·749	– 0·032	+ 41·717
25	26	31·88	+ 0·019	+ 0·201	+ 49·358	– 0·037	+ 49·321
26	27	33·77	– 0·015	+ 0·186	+ 57·081	– 0·042	+ 57·039
27	28	35·33	– 0·003	+ 0·183	+ 62·778	– 0·046	+ 62·732
28	29	35·84	– 0·004	+ 0·179	+ 71·803	– 0·052	+ 71·751
29	30	37·14	+ 0·014	+ 0·193	+ 68·889	– 0·050	+ 68·839
30	31	38·47	+ 0·011	+ 0·204	+ 72·933	– 0·053	+ 72·880
31	32	39·50	– 0·001	+ 0·203	+ 84·805	– 0·061	+ 84·744
32	33	40·84	– 0·009	+ 0·194	+ 95·757	– 0·069	+ 95·688
33	34	42·25	– 0·012	+ 0·182	+ 93·530	– 0·068	+ 93·462
34	35	43·74	+ 0·009	+ 0·191	+ 104·152	– 0·076	+ 104·076
35	36	45·03	– 0·003	+ 0·188	+ 107·135	– 0·078	+ 107·057
36	37	46·09	– 0·014	+ 0·174	+ 112·485	– 0·082	+ 112·403
37	38	46·59	+ 0·008	+ 0·182	+ 116·667	– 0·085	+ 116·582
38	39	46·89	– 0·005	+ 0·177	+ 117·889	– 0·086	+ 117·803
39	40	46·94	0·000	+ 0·177	+ 114·313	– 0·083	+ 114·230
40	41	47·34	– 0·006	+ 0·171	+ 118·088	– 0·086	+ 118·002
41	42	48·40	– 0·013	+ 0·158	+ 133·441	– 0·096	+ 133·345
42	43	49·74	– 0·004	+ 0·154	+ 162·392	– 0·116	+ 162·276
43	44	51·43	– 0·035	+ 0·119	+ 230·923	– 0·163	+ 230·760
44	45	52·80	– 0·011	+ 0·108	+ 236·488	– 0·167	+ 236·321
45	46	53·98	– 0·015	+ 0·093	+ 229·597	– 0·162	+ 229·435
46	47	55·15	+ 0·007	+ 0·100	+ 220·863	– 0·156	+ 220·707
47	48	56·09	+ 0·002	+ 0·102	+ 232·540	– 0·164	+ 232·376
48	49	56·13	0·000	+ 0·102	+ 231·383	– 0·163	+ 231·220
49	50	57·64	+ 0·013	+ 0·115	+ 171·635	– 0·122	+ 171·513
50	51	58·80	+ 0·010	+ 0·125	+ 149·926	– 0·107	+ 149·819
51	52	58·92	– 0·021	+ 0·104	+ 150·164	– 0·107	+ 150·057
52	53	61·01	+ 0·023	+ 0·127	+ 152·763	– 0·109	+ 152·654
53	54	62·64	– 0·010	+ 0·117	+ 158·776	– 0·113	+ 158·663
54	55	63·54	+ 0·010	+ 0·127	+ 157·785	– 0·112	+ 157·673
55	56	63·88	– 0·010	+ 0·117	+ 157·616	– 0·112	+ 157·504
56	57	65·88	+ 0·010	+ 0·127	+ 160·199	– 0·114	+ 160·085
57	58	67·33	– 0·004	+ 0·123	+ 168·652	– 0·120	+ 168·532
58	59	68·58	+ 0·002	+ 0·125	+ 172·636	– 0·123	+ 172·513
59	60	69·83	+ 0·011	+ 0·136	+ 181·630	– 0·129	+ 181·501
60	61	71·26	+ 0·018	+ 0·154	+ 181·849	– 0·129	+ 181·720

* Bench-mark No. 1 is the mark at Trichinopoly described on page 186.

Line No. 6. Trichinopoly to Erode.—(Continued).

Bench-marks		Distance from Trichinopoly	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Trichinopoly (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Trichinopoly
From	To		From mark to mark (= d)	Total from Trichinopoly		Total from Trichinopoly	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	72·75	+ 0·015	+ 0·169	+ 182·306	– 0·129	+ 182·177
62	63	73·85	– 0·009	+ 0·160	+ 206·148	– 0·145	+ 206·003
63	64	75·60	+ 0·012	+ 0·172	+ 222·686	– 0·156	+ 222·530
64	65	75·65	+ 0·002	+ 0·174	+ 220·667	– 0·155	+ 220·512
65	66	76·16	+ 0·005	+ 0·179	+ 221·693	– 0·156	+ 221·537
66	67	77·42	+ 0·015	+ 0·194	+ 234·336	– 0·165	+ 234·171
67	68	78·87	+ 0·006	+ 0·200	+ 243·710	– 0·171	+ 243·539
68	69	80·14	– 0·002	+ 0·198	+ 241·718	– 0·170	+ 241·548
69	70	81·68	+ 0·011	+ 0·209	+ 250·626	– 0·176	+ 250·450
70	71	82·64	– 0·003	+ 0·206	+ 244·547	– 0·172	+ 244·375
71	72	84·50	– 0·032	+ 0·174	+ 252·465	– 0·178	+ 252·287
72	73	85·82	– 0·028	+ 0·146	+ 261·670	– 0·184	+ 261·486
73	74	86·83	– 0·001	+ 0·145	+ 267·849	– 0·188	+ 267·691
74	75	86·87	0·000	+ 0·145	+ 267·851	– 0·188	+ 267·663
75	76	86·93	– 0·002	+ 0·143	+ 268·879	– 0·189	+ 268·690
76	77*	87·02	+ 0·008	+ 0·151	+ 265·439	– 0·186	+ 265·253

Difference of dynamic height, Trichinopoly to Erode = + 265·253 feet.

Length of line in miles = M = 87·02. $\Sigma d^2 = 0\cdot013925$.

Probable error of the mean result per mile of double-levelling $= 0\cdot6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0\cdot0043$.

Probable error of the difference of elevation between the terminal bench-marks $= 0\cdot6745 \sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0\cdot0398$.

* Bench-mark No. 77 is the mark at Erode described on page 134.

Line No. 7. Jalarpet to Erode.

Bench-marks		Distance from Jalarpet	Discrepancy between levellers (First—Second leveller)		Observed elevation above (+) or below (−) Jalarpet (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Jalarpet
From	To		From mark to mark (= d)	Total from Jalarpet		Total from Jalarpet	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	3·15	+ 0·004	+ 0·004	− 50·174	+ 0·031	− 50·143
2	3	4·98	− 0·022	− 0·018	− 48·971	+ 0·030	− 48·941
3	4	5·02	− 0·003	− 0·021	− 45·802	+ 0·028	− 45·774
4	5	6·44	− 0·016	− 0·037	− 66·956	+ 0·041	− 66·915
5	6	7·76	+ 0·017	− 0·020	− 83·389	+ 0·051	− 83·338
6	7	9·77	+ 0·013	− 0·007	− 73·963	+ 0·046	− 73·917
7	8	12·12	+ 0·019	+ 0·012	− 78·471	+ 0·049	− 78·422
8	9	12·70	+ 0·002	+ 0·014	− 91·956	+ 0·059	− 91·897
9	10	12·95	− 0·004	+ 0·010	− 97·375	+ 0·062	− 97·313
10	11	14·21	0·000	+ 0·010	− 115·899	+ 0·074	− 115·825
11	12	15·02	+ 0·012	+ 0·022	− 117·925	+ 0·075	− 117·850
12	13	16·66	+ 0·001	+ 0·023	− 90·237	+ 0·057	− 90·180
13	14	19·31	− 0·010	+ 0·013	− 57·931	+ 0·037	− 57·894
14	15	19·36	− 0·003	+ 0·010	− 54·997	+ 0·035	− 54·962
15	16	20·50	+ 0·017	+ 0·027	− 29·032	+ 0·018	− 29·014
16	17	21·30	+ 0·006	+ 0·033	− 5·979	+ 0·003	− 5·976
17	18	21·55	+ 0·001	+ 0·034	+ 0·849	− 0·001	+ 0·848
18	19	24·49	− 0·007	+ 0·027	+ 0·344	− 0·001	+ 0·343
19	20	26·03	− 0·011	+ 0·016	− 44·428	+ 0·028	− 44·400
20	21	27·76	− 0·017	− 0·001	− 79·524	+ 0·050	− 79·474
21	22	29·16	− 0·005	− 0·006	− 108·879	+ 0·069	− 108·810
22	23	29·61	+ 0·015	+ 0·009	− 103·258	+ 0·066	− 103·192
23	24	30·76	+ 0·003	+ 0·012	− 81·909	+ 0·053	− 81·856
24	25	32·08	+ 0·007	+ 0·019	− 59·379	+ 0·039	− 59·340
25	26	33·39	+ 0·007	+ 0·026	− 26·401	+ 0·018	− 26·383
26	27	33·99	− 0·007	+ 0·019	− 13·833	+ 0·010	− 13·823
27	28	34·02	+ 0·001	+ 0·020	− 13·160	+ 0·010	− 13·150
28	29	35·03	− 0·016	+ 0·004	+ 9·133	− 0·004	+ 9·129
29	30	35·52	+ 0·009	+ 0·013	+ 25·296	− 0·014	+ 25·282
30	31	37·02	− 0·004	+ 0·009	+ 73·474	− 0·045	+ 73·429
31	32	38·52	− 0·017	− 0·008	+ 74·059	− 0·045	+ 74·014
32	33	40·42	+ 0·012	+ 0·004	+ 100·955	− 0·062	+ 100·893
33	34	41·33	+ 0·020	+ 0·024	+ 108·034	− 0·066	+ 107·968
34	35	41·73	+ 0·008	+ 0·032	+ 111·778	− 0·069	+ 111·709
35	36	43·33	− 0·015	+ 0·017	+ 137·021	− 0·085	+ 136·936
36	37	44·51	− 0·018	− 0·001	+ 162·100	− 0·101	+ 161·999
37	38	46·01	− 0·005	− 0·006	+ 136·802	− 0·085	+ 136·717
38	39	47·61	− 0·016	− 0·022	+ 76·484	− 0·046	+ 76·438
39	40	48·01	− 0·008	− 0·030	+ 68·036	− 0·041	+ 67·995
40	41	48·10	+ 0·001	− 0·029	+ 60·451	− 0·036	+ 60·415
41	42	48·38	− 0·001	− 0·030	+ 54·028	− 0·032	+ 53·996
42	43	50·08	+ 0·020	− 0·010	+ 16·462	− 0·008	+ 16·454
43	44	51·01	+ 0·013	+ 0·003	+ 38·847	− 0·022	+ 38·825
44	45	51·74	− 0·004	− 0·001	+ 70·296	− 0·042	+ 70·254
45	46	53·94	− 0·004	− 0·005	+ 155·014	− 0·097	+ 154·917
46	47	56·05	+ 0·017	+ 0·012	+ 122·259	− 0·076	+ 122·183
47	48	57·50	− 0·005	+ 0·007	+ 40·370	− 0·023	+ 40·347
48	49	58·60	+ 0·019	+ 0·026	− 22·141	+ 0·018	− 22·123
49	50	60·01	− 0·017	+ 0·009	− 74·001	+ 0·052	− 73·949
50	51	60·05	− 0·003	+ 0·006	− 74·126	+ 0·052	− 74·074
51	52	61·25	− 0·018	− 0·012	− 108·943	+ 0·075	− 108·868
52	53	62·21	− 0·001	− 0·013	− 152·167	+ 0·103	− 152·064
53	54	63·08	− 0·003	− 0·016	− 181·443	+ 0·122	− 181·321
54	55	64·91	+ 0·011	− 0·005	− 251·589	+ 0·168	− 251·421
55	56	66·83	− 0·022	− 0·027	− 324·160	+ 0·215	− 323·945
56	57	67·17	− 0·001	− 0·028	− 332·595	+ 0·220	− 332·375
57	58	69·20	− 0·028	− 0·056	− 299·237	+ 0·198	− 299·039
58	59	70·93	+ 0·004	− 0·052	− 295·697	+ 0·195	− 295·502
59	60	72·34	+ 0·007	− 0·045	− 313·605	+ 0·207	− 313·398
60	61	74·75	+ 0·002	− 0·043	− 401·349	+ 0·265	− 401·084

* Bench-mark No. 1 is the mark at Jalarpet described on page 184.

Line No. 7. Jalarpet to Erode.—(Continued).

Bench-marks		Distance from Jalarpet	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Jalarpet (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Jalarpet
From	To		From mark to mark (= d)	Total from Jalarpet		Total from Jalarpet	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	76·15	– 0·012	– 0·055	– 445·017	+ 0·294	– 444·723
62	63	77·79	– 0·022	– 0·077	– 460·574	+ 0·304	– 460·270
63	64	79·54	+ 0·005	– 0·072	– 464·795	+ 0·307	– 464·488
64	65	80·73	+ 0·018	– 0·054	– 449·721	+ 0·297	– 449·424
65	66	81·88	– 0·008	– 0·062	– 432·879	+ 0·286	– 432·593
66	67	83·12	– 0·006	– 0·068	– 425·076	+ 0·280	– 424·796
67	68	84·16	– 0·011	– 0·079	– 445·645	+ 0·294	– 445·351
68	69	85·73	– 0·018	– 0·097	– 497·891	+ 0·328	– 497·563
69	70	87·56	– 0·017	– 0·114	– 534·612	+ 0·352	– 534·260
70	71	87·61	+ 0·002	– 0·112	– 538·228	+ 0·355	– 537·873
71	72	89·08	+ 0·002	– 0·110	– 506·833	+ 0·334	– 506·499
72	73	89·79	+ 0·004	– 0·106	– 484·196	+ 0·319	– 483·877
73	74	90·38	+ 0·002	– 0·104	– 456·769	+ 0·301	– 456·468
74	75	92·78	+ 0·015	– 0·089	– 355·476	+ 0·234	– 355·242
75	76	94·49	– 0·020	– 0·109	– 353·882	+ 0·233	– 353·649
76	77	96·58	+ 0·003	– 0·106	– 396·331	+ 0·261	– 396·070
77	78	98·27	– 0·016	– 0·122	– 441·532	+ 0·291	– 441·241
78	79	98·33	– 0·003	– 0·125	– 441·552	+ 0·291	– 441·261
79	80	98·37	+ 0·001	– 0·124	– 445·594	+ 0·294	– 445·300
80	81	100·46	+ 0·003	– 0·121	– 520·333	+ 0·344	– 519·989
81	82	102·51	0·000	– 0·121	– 584·041	+ 0·387	– 583·654
82	83	104·56	– 0·009	– 0·130	– 652·745	+ 0·433	– 652·312
83	84	106·92	+ 0·025	– 0·105	– 734·523	+ 0·488	– 734·035
84	85	108·77	– 0·002	– 0·107	– 808·598	+ 0·538	– 808·060
85	86	110·37	0·000	– 0·107	– 793·089	+ 0·528	– 792·561
86	87	110·70	+ 0·003	– 0·104	– 778·607	+ 0·519	– 778·088
87	88	110·76	– 0·001	– 0·105	– 777·589	+ 0·518	– 777·071
88	89*	110·85	+ 0·004	– 0·101	– 781·026	+ 0·520	– 780·506

Difference of dynamic height, Jalarpet to Erode = – 780·506 feet.

Length of line in miles = M = 110·85. $\Sigma d^2 = 0{\cdot}012047$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4\text{M}}} = \pm\, 0{\cdot}0035$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0370$.

* Bench-mark No. 89 is the mark at Erode described on page 134.

Line No. 8. Arkonam to Madras.

Bench-marks		Distance from Arkonam	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Arkonam (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Arkonam
From	To		From mark to mark (= d)	Total from Arkonam		Total from Arkonam	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	5·06	– 0·011	– 0·011	– 87·727	+ 0·053	– 87·674
2	3	6·54	+ 0·016	+ 0·005	– 94·292	+ 0·057	– 94·235
3	4	7·89	– 0·004	+ 0·001	– 103·365	+ 0·062	– 103·303
4	5	9·20	+ 0·019	+ 0·020	– 104·122	+ 0·062	– 104·060
5	6	10·51	– 0·010	+ 0·010	– 108·774	+ 0·065	– 108·709
6	7	12·36	+ 0·001	+ 0·011	– 125·594	+ 0·075	– 125·519
7	8	15·02	– 0·010	+ 0·001	– 129·285	+ 0·077	– 129·208
8	9	16·03	– 0·001	0·000	– 134·009	+ 0·080	– 133·929
9	10	16·74	– 0·009	– 0·009	– 141·299	+ 0·084	– 141·215
10	11	18·57	+ 0·007	– 0·002	– 148·942	+ 0·089	– 148·853
11	12	20·08	+ 0·003	+ 0·001	– 160·492	+ 0·096	– 160·396
12	13	22·02	– 0·012	– 0·011	– 172·893	+ 0·103	– 172·790
13	14	23·70	+ 0·020	+ 0·009	– 170·345	+ 0·101	– 170·244
14	15	24·21	+ 0·006	+ 0·015	– 173·556	+ 0·103	– 173·453
15	16	26·00	– 0·010	+ 0·005	– 186·686	+ 0·111	– 186·575
16	17	26·50	+ 0·001	+ 0·006	– 191·790	+ 0·114	– 191·676
17	18	28·09	+ 0·001	+ 0·007	– 205·267	+ 0·122	– 205·145
18	19	29·72	– 0·007	0·000	– 213·333	+ 0·127	– 213·206
19	20	30·58	+ 0·006	+ 0·006	– 219·991	+ 0·131	– 219·860
20	21	33·99	– 0·005	+ 0·001	– 245·023	+ 0·146	– 244·877
21	22	34·53	+ 0·008	+ 0·009	– 252·667	+ 0·151	– 252·516
22	23	35·26	– 0·005	+ 0·004	– 257·636	+ 0·154	– 257·482
23	24	37·27	– 0·006	– 0·002	– 260·300	+ 0·156	– 260·144
24	25	40·47	+ 0·007	+ 0·005	– 276·611	+ 0·166	– 276·445
25	26	42·97	– 0·010	– 0·005	– 278·876	+ 0·167	– 278·709
26	27	43·80	+ 0·006	+ 0·001	– 278·084	+ 0·166	– 277·918
27	28	44·05	– 0·001	0·000	– 278·521	+ 0·166	– 278·355
28	29†	44·09	– 0·003	– 0·003	– 277·439	+ 0·165	– 277·274

Difference of dynamic height, Arkonam to Madras = – 277·274 feet.

Length of line in miles = M = 44·09. $\Sigma d^2 = 0{\cdot}002275$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm\, 0{\cdot}0024$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745 \sqrt{\frac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0161$.

* Bench-mark No. 1 is the mark at Arkonam described on page 133. † Bench-mark No. 29 is the mark at Madras described on page 135.

Line No. 9. Madras to Tanjore.

Bench-marks		Distance from Madras	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (−) Madras (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Madras
From	To		From mark to mark (= d)	Total from Madras		Total from Madras	
		miles	foot	foot	feet	foot	feet
1*	2	0·04	+ 0·003	+ 0·003	− 1·082	+ 0·001	− 1·081
2	3	0·73	+ 0·018	+ 0·021	− 0·702	+ 0·001	− 0·701
3	4	2·25	− 0·006	+ 0·015	− 5·994	+ 0·004	− 5·990
4	5	2·55	+ 0·001	+ 0·016	− 3·138	+ 0·002	− 3·136
5	6	3·29	+ 0·007	+ 0·023	− 0·998	+ 0·001	− 0·997
6	7	4·51	+ 0·007	+ 0·030	+ 8·242	− 0·004	+ 8·238
7	8	6·82	+ 0·021	+ 0·051	+ 6·615	− 0·003	+ 6·612
8	9	7·68	+ 0·014	+ 0·065	+ 8·852	− 0·004	+ 8·848
9	10	8·53	+ 0·012	+ 0·077	+ 16·837	− 0·009	+ 16·828
10	11	10·01	− 0·006	+ 0·071	+ 20·709	− 0·011	+ 20·698
11	12	10·11	+ 0·001	+ 0·072	+ 18·426	− 0·010	+ 18·416
12	13	10·74	− 0·006	+ 0·066	+ 20·110	− 0·011	+ 20·099
13	14	11·94	− 0·010	+ 0·056	+ 36·984	− 0·021	+ 36·963
14	15	12·60	+ 0·001	+ 0·057	+ 51·936	− 0·030	+ 51·906
15	16	13·69	+ 0·003	+ 0·060	+ 58·057	− 0·034	+ 58·023
16	17	15·00	+ 0·015	+ 0·075	+ 61·652	− 0·036	+ 61·616
17	18	15·80	− 0·003	+ 0·072	+ 67·285	− 0·039	+ 67·246
18	19	17·26	+ 0·014	+ 0·086	+ 82·193	− 0·048	+ 82·145
19	20	18·64	− 0·025	+ 0·061	+ 57·642	− 0·033	+ 57·609
20	21	19·63	0·000	+ 0·061	+ 72·135	− 0·042	+ 72·093
21	22	20·71	− 0·017	+ 0·044	+ 95·450	− 0·056	+ 95·394
22	23	20·80	− 0·005	+ 0·039	+ 97·729	− 0·057	+ 97·672
23	24	22·27	+ 0·013	+ 0·052	+ 81·182	− 0·047	+ 81·135
24	25	24·05	+ 0·028	+ 0·080	+ 86·212	− 0·050	+ 86·162
25	26	24·50	+ 0·001	+ 0·081	+ 95·622	− 0·055	+ 95·567
26	27	26·40	− 0·023	+ 0·058	+ 122·775	− 0·072	+ 122·703
27	28	28·13	+ 0·009	+ 0·067	+ 145·871	− 0·086	+ 145·785
28	29	28·80	− 0·007	+ 0·060	+ 162·275	− 0·096	+ 162·179
29	30	30·11	− 0·018	+ 0·042	+ 140·218	− 0·082	+ 140·136
30	31	31·38	+ 0·003	+ 0·045	+ 126·159	− 0·073	+ 126·086
31	32	31·41	+ 0·002	+ 0·047	+ 124·166	− 0·072	+ 124·094
32	33	32·11	− 0·005	+ 0·042	+ 124·836	− 0·072	+ 124·764
33	34	33·62	− 0·007	+ 0·035	+ 129·508	− 0·075	+ 129·433
34	35	34·79	− 0·011	+ 0·024	+ 114·590	− 0·066	+ 114·524
35	36	36·54	+ 0·009	+ 0·033	+ 112·566	− 0·065	+ 112·501
36	37	36·58	− 0·001	+ 0·032	+ 112·625	− 0·065	+ 112·560
37	38	38·04	− 0·004	+ 0·028	+ 131·787	− 0·077	+ 131·710
38	39	39·18	+ 0·017	+ 0·045	+ 143·351	− 0·084	+ 143·267
39	40	39·44	+ 0·005	+ 0·050	+ 131·197	− 0·077	+ 131·120
40	41	40·48	+ 0·014	+ 0·064	+ 118·636	− 0·069	+ 118·567
41	42	41·48	+ 0·002	+ 0·066	+ 93·597	− 0·053	+ 93·544
42	43	42·57	+ 0·011	+ 0·077	+ 76·618	− 0·042	+ 76·576
43	44	43·98	+ 0·020	+ 0·097	+ 71·719	− 0·039	+ 71·680
44	45	44·68	− 0·012	+ 0·085	+ 70·254	− 0·038	+ 70·216
45	46	45·48	+ 0·002	+ 0·087	+ 61·023	− 0·033	+ 60·990
46	47	46·75	− 0·015	+ 0·072	+ 57·257	− 0·031	+ 57·226
47	48	47·86	+ 0·017	+ 0·089	+ 65·127	− 0·036	+ 65·091
48	49	49·06	+ 0·021	+ 0·110	+ 69·659	− 0·039	+ 69·620
49	50	50·08	+ 0·004	+ 0·114	+ 67·817	− 0·038	+ 67·779
50	51	50·48	− 0·005	+ 0·109	+ 65·853	− 0·037	+ 65·816
51	52	51·89	+ 0·014	+ 0·123	+ 75·396	− 0·043	+ 75·353
52	53	52·95	− 0·011	+ 0·112	+ 86·357	− 0·050	+ 86·307
53	54	54·18	+ 0·016	+ 0·128	+ 107·905	− 0·064	+ 107·841
54	55	54·83	− 0·004	+ 0·124	+ 122·513	− 0·073	+ 122·440
55	56	56·10	+ 0·001	+ 0·125	+ 120·390	− 0·072	+ 120·318
56	57	56·86	− 0·015	+ 0·110	+ 132·154	− 0·079	+ 132·075
57	58	57·66	+ 0·003	+ 0·113	+ 145·829	− 0·088	+ 145·741
58	59	59·61	+ 0·008	+ 0·121	+ 126·623	− 0·076	+ 126·547
59	60	60·37	+ 0·001	+ 0·122	+ 119·503	− 0·072	+ 119·431
60	61	61·60	+ 0·008	+ 0·130	+ 116·860	− 0·070	+ 116·790

* Bench-mark No. 1 is the mark at Madras described on page 135.

Line No. 9. Madras to Tanjore.—(Continued).

Bench-marks From	Bench-marks To	Distance from Madras	Discrepancy between levellers (First – Second leveller): From mark to mark (= d)	Discrepancy between levellers (First – Second leveller): Total from Madras	Observed elevation above (+) or below (–) Madras (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Madras	Dynamic height above (+) or below (–) Madras
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	63·08	– 0·015	+ 0·115	+ 108·497	– 0·065	+ 108·432
62	63	64·16	+ 0·012	+ 0·127	+ 91·202	– 0·054	+ 91·148
63	64	65·73	+ 0·014	+ 0·141	+ 76·491	– 0·045	+ 76·446
64	65	67·08	– 0·008	+ 0·133	+ 90·198	– 0·054	+ 90·144
65	66	67·91	+ 0·001	+ 0·134	+ 83·643	– 0·050	+ 83·593
66	67	69·52	+ 0·034	+ 0·168	+ 101·206	– 0·061	+ 101·145
67	68	70·11	– 0·011	+ 0·157	+ 113·696	– 0·069	+ 113·627
68	69	70·81	+ 0·009	+ 0·166	+ 111·797	– 0·068	+ 111·729
69	70	72·11	– 0·005	+ 0·161	+ 128·443	– 0·079	+ 128·364
70	71	73·10	+ 0·009	+ 0·170	+ 138·575	– 0·085	+ 138·490
71	72	74·36	– 0·001	+ 0·169	+ 161·371	– 0·099	+ 161·272
72	73	75·31	+ 0·009	+ 0·178	+ 154·213	– 0·095	+ 154·118
73	74	76·61	+ 0·040	+ 0·218	+ 130·674	– 0·080	+ 130·594
74	75	77·22	+ 0·004	+ 0·222	+ 129·133	– 0·079	+ 129·054
75	76	77·28	+ 0·001	+ 0·223	+ 130·410	– 0·080	+ 130·330
76	77	78·51	+ 0·013	+ 0·236	+ 108·854	– 0·066	+ 108·788
77	78	79·94	+ 0·012	+ 0·248	+ 117·864	– 0·071	+ 117·793
78	79	80·93	+ 0·006	+ 0·254	+ 137·681	– 0·084	+ 137·597
79	80	81·99	– 0·002	+ 0·252	+ 128·160	– 0·078	+ 128·082
80	81	83·14	0·000	+ 0·252	+ 146·361	– 0·090	+ 146·271
81	82	83·43	– 0·011	+ 0·241	+ 152·310	– 0·094	+ 152·216
82	83	85·58	– 0·010	+ 0·231	+ 135·045	– 0·083	+ 134·962
83	84	87·16	– 0·022	+ 0·209	+ 126·669	– 0·078	+ 126·591
84	85	87·70	– 0·014	+ 0·195	+ 122·269	– 0·076	+ 122·193
85	86	89·03	– 0·001	+ 0·194	+ 123·468	– 0·077	+ 123·391
86	87	90·04	+ 0·006	+ 0·200	+ 125·830	– 0·078	+ 125·752
87	88	92·39	+ 0·004	+ 0·204	+ 114·972	– 0·071	+ 114·901
88	89	92·40	+ 0·001	+ 0·205	+ 110·732	– 0·068	+ 110·664
89	90	93·28	+ 0·026	+ 0·231	+ 99·730	– 0·061	+ 99·669
90	91	95·11	+ 0·006	+ 0·237	+ 104·947	– 0·064	+ 104·883
91	92	96·91	– 0·005	+ 0·232	+ 114·297	– 0·070	+ 114·227
92	93	98·03	+ 0·005	+ 0·237	+ 121·937	– 0·075	+ 121·862
93	94	99·37	+ 0·003	+ 0·240	+ 122·002	– 0·075	+ 121·927
94	95	100·30	+ 0·005	+ 0·245	+ 125·861	– 0·078	+ 125·783
95	96	100·36	– 0·003	+ 0·242	+ 127·592	– 0·079	+ 127·513
96	97	101·17	– 0·010	+ 0·232	+ 122·916	– 0·076	+ 122·840
97	98	102·43	– 0·020	+ 0·212	+ 118·789	– 0·073	+ 118·716
98	99	103·94	+ 0·007	+ 0·219	+ 112·359	– 0·069	+ 112·290
99	100	104·44	– 0·004	+ 0·215	+ 112·375	– 0·069	+ 112·306
100	101	105·28	– 0·013	+ 0·202	+ 101·952	– 0·062	+ 101·890
101	102	107·47	+ 0·018	+ 0·220	+ 95·940	– 0·058	+ 95·882
102	103	109·02	– 0·012	+ 0·208	+ 95·818	– 0·058	+ 95·760
103	104	109·73	– 0·001	+ 0·207	+ 87·192	– 0·052	+ 87·140
104	105	111·56	– 0·016	+ 0·191	+ 74·185	– 0·044	+ 74·141
105	106	112·49	+ 0·005	+ 0·196	+ 68·013	– 0·040	+ 67·973
106	107	112·62	0·000	+ 0·196	+ 66·963	– 0·039	+ 66·924
107	108	113·96	+ 0·002	+ 0·198	+ 60·099	– 0·034	+ 60·065
108	109	115·53	+ 0·004	+ 0·202	+ 52·640	– 0·029	+ 52·611
109	110	117·03	+ 0·012	+ 0·214	+ 49·947	– 0·027	+ 49·920
110	111	119·16	– 0·017	+ 0·197	+ 38·768	– 0·020	+ 38·748
111	112	120·44	– 0·009	+ 0·188	+ 32·178	– 0·016	+ 32·162
112	113	120·65	+ 0·005	+ 0·193	+ 32·542	– 0·016	+ 32·526
113	114	121·85	– 0·015	+ 0·178	+ 23·267	– 0·010	+ 23·257
114	115	123·56	– 0·017	+ 0·161	+ 13·031	– 0·003	+ 13·028
115	116	125·27	+ 0·014	+ 0·175	+ 10·267	– 0·001	+ 10·266
116	117	126·71	– 0·014	+ 0·161	+ 3·351	+ 0·004	+ 3·355
117	118	127·77	– 0·017	+ 0·144	– 0·736	+ 0·007	– 0·729
118	119	129·08	– 0·018	+ 0·126	– 6·561	+ 0·011	– 6·550
119	120	129·42	+ 0·010	+ 0·136	– 7·249	+ 0·012	– 7·237
120	121	130·95	– 0·013	+ 0·123	+ 2·427	+ 0·005	+ 2·432

Line No. 9. Madras to Tanjore.—(Continued).

Bench-marks From	Bench-marks To	Distance from Madras	Discrepancy between levellers (First – Second leveller): From mark to mark (=d)	Discrepancy between levellers (First – Second leveller): Total from Madras	Observed elevation above (+) or below (–) Madras (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Madras	Dynamic height above (+) or below (–) Madras
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
121	122	132·67	– 0·005	+ 0·118	+ 0·918	+ 0·006	+ 0·924
122	123	134·01	0·000	+ 0·118	– 3·691	+ 0·009	– 3·682
123	124	135·75	0·000	+ 0·118	– 2·152	+ 0·008	– 2·144
124	125	136·35	– 0·011	+ 0·107	– 2·225	+ 0·008	– 2·217
125	126	136·38	+ 0·001	+ 0·108	– 0·634	+ 0·007	– 0·627
126	127	137·69	+ 0·022	+ 0·130	– 1·894	+ 0·008	– 1·886
127	128	139·10	+ 0·030	+ 0·160	– 0·650	+ 0·007	– 0·643
128	129	142·11	– 0·018	+ 0·142	– 0·606	+ 0·007	– 0·599
129	130	143·72	+ 0·005	+ 0·147	– 1·698	+ 0·008	– 1·690
130	131	144·63	+ 0·002	+ 0·149	– 2·628	+ 0·009	– 2·619
131	132	146·11	+ 0·007	+ 0·156	– 2·287	+ 0·009	– 2·278
132	133	146·24	+ 0·003	+ 0·159	– 4·613	+ 0·010	– 4·603
133	134	147·50	+ 0·005	+ 0·164	– 3·455	+ 0·009	– 3·446
134	135	148·73	– 0·006	+ 0·158	– 2·961	+ 0·009	– 2·952
135	136	149·86	– 0·010	+ 0·148	– 1·556	+ 0·008	– 1·548
136	137	150·85	+ 0·004	+ 0·152	+ 1·109	+ 0·006	+ 1·115
137	138	152·84	– 0·010	+ 0·142	+ 1·082	+ 0·006	+ 1·088
138	139	152·90	– 0·002	+ 0·140	+ 1·928	+ 0·005	+ 1·933
139	140	153·86	+ 0·004	+ 0·144	+ 1·087	+ 0·006	+ 1·093
140	141	155·15	+ 0·010	+ 0·154	+ 3·482	+ 0·005	+ 3·487
141	142	155·32	– 0·004	+ 0·150	+ 2·138	+ 0·006	+ 2·144
142	143	157·18	– 0·004	+ 0·146	+ 6·812	+ 0·003	+ 6·815
143	144	157·41	– 0·002	+ 0·144	+ 5·560	+ 0·004	+ 5·564
144	145	159·58	– 0·016	+ 0·128	+ 4·254	+ 0·005	+ 4·259
145	146	160·49	– 0·023	+ 0·105	+ 6·561	+ 0·004	+ 6·565
146	147	161·94	+ 0·012	+ 0·117	+ 2·880	+ 0·007	+ 2·887
147	148	162·72	– 0·007	+ 0·110	+ 3·222	+ 0·007	+ 3·229
148	149	163·52	+ 0·004	+ 0·114	+ 5·536	+ 0·006	+ 5·542
149	150	163·56	– 0·001	+ 0·113	+ 5·490	+ 0·006	+ 5·496
150	151	164·42	+ 0·015	+ 0·128	+ 2·877	+ 0·008	+ 2·885
151	152	165·44	– 0·021	+ 0·107	+ 1·340	+ 0·009	+ 1·349
152	153	167·12	+ 0·001	+ 0·108	+ 6·901	+ 0·005	+ 6·906
153	154	168·50	+ 0·001	+ 0·109	+ 10·276	+ 0·003	+ 10·279
154	155	169·76	– 0·011	+ 0·098	+ 12·022	+ 0·002	+ 12·024
155	156	171·35	+ 0·007	+ 0·105	+ 10·295	+ 0·003	+ 10·298
156	157	172·87	+ 0·028	+ 0·133	+ 14·994	0·000	+ 14·994
157	158	174·25	– 0·018	+ 0·115	+ 20·831	– 0·004	+ 20·827
158	159	175·70	– 0·005	+ 0·110	+ 31·420	– 0·011	+ 31·409
159	160	175·75	– 0·008	+ 0·102	+ 30·770	– 0·011	+ 30·759
160	161	176·33	+ 0·010	+ 0·112	+ 24·393	– 0·007	+ 24·386
161	162	176·95	+ 0·008	+ 0·120	+ 27·055	– 0·009	+ 27·046
162	163	177·43	+ 0·020	+ 0·140	+ 27·077	– 0·009	+ 27·068
163	164	178·06	– 0·005	+ 0·135	+ 29·552	– 0·010	+ 29·542
164	165	179·76	+ 0·005	+ 0·140	+ 32·032	– 0·011	+ 32·021
165	166	181·11	– 0·015	+ 0·125	+ 39·139	– 0·016	+ 39·123
166	167	182·26	+ 0·005	+ 0·130	+ 36·913	– 0·015	+ 36·898
167	168	183·53	– 0·019	+ 0·111	+ 40·051	– 0·017	+ 40·034
168	169	185·14	+ 0·009	+ 0·120	+ 50·166	– 0·024	+ 50·142
169	170	185·15	– 0·001	+ 0·119	+ 50·118	– 0·024	+ 50·094
170	171	185·78	+ 0·007	+ 0·126	+ 47·574	– 0·022	+ 47·552
171	172	187·03	– 0·016	+ 0·110	+ 56·665	– 0·028	+ 56·637
172	173	188·01	– 0·009	+ 0·101	+ 50·174	– 0·024	+ 50·150
173	174	188·75	+ 0·009	+ 0·110	+ 51·135	– 0·025	+ 51·110
174	175	190·05	+ 0·003	+ 0·113	+ 57·219	– 0·029	+ 57·190
175	176	191·62	+ 0·012	+ 0·125	+ 59·577	– 0·030	+ 59·547
176	177	192·70	+ 0·013	+ 0·138	+ 61·299	– 0·031	+ 61·268
177	178	193·15	+ 0·014	+ 0·152	+ 63·985	– 0·033	+ 63·952
178	179	194·48	– 0·006	+ 0·146	+ 66·246	– 0·034	+ 66·212
179	180	195·13	– 0·012	+ 0·134	+ 70·344	– 0·037	+ 70·307
180	181	195·23	+ 0·004	+ 0·138	+ 68·705	– 0·036	+ 68·669

Line No. 9. Madras to Tanjore.—(Continued).

Bench-marks		Distance from Madras	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Madras (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Madras
From	To		From mark to mark (= d)	Total from Madras		Total from Madras	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
181	182	195·82	+ 0·007	+ 0·145	+ 75·238	− 0·041	+ 75·197
182	183	197·10	− 0·021	+ 0·124	+ 68·999	− 0·037	+ 68·962
183	184	198·34	+ 0·022	+ 0·146	+ 73·085	− 0·040	+ 73·045
184	185	199·64	− 0·029	+ 0·117	+ 75·833	− 0·042	+ 75·791
185	186	200·70	− 0·015	+ 0·102	+ 82·931	− 0·047	+ 82·884
186	187	202·13	− 0·008	+ 0·094	+ 92·200	− 0·053	+ 92·147
187	188	203·21	− 0·004	+ 0·090	+ 83·627	− 0·047	+ 83·580
188	189	204·02	+ 0·006	+ 0·096	+ 89·123	− 0·051	+ 89·072
189	190	204·08	+ 0·001	+ 0·097	+ 88·479	− 0·051	+ 88·428
190	191	204·62	+ 0·008	+ 0·105	+ 86·723	− 0·050	+ 86·673
191	192	205·98	+ 0·013	+ 0·118	+ 89·927	− 0·052	+ 89·875
192	193	207·14	− 0·011	+ 0·107	+ 93·579	− 0·055	+ 93·524
193	194	208·54	+ 0·010	+ 0·117	+ 98·789	− 0·059	+ 98·730
194	195	209·77	+ 0·013	+ 0·130	+ 101·228	− 0·060	+ 101·168
195	196	210·91	− 0·001	+ 0·129	+ 100·556	− 0·059	+ 100·497
196	197	212·10	− 0·024	+ 0·105	+ 109·784	− 0·065	+ 109·719
197	198	212·45	− 0·002	+ 0·103	+ 112·550	− 0·067	+ 112·483
198	199	213·11	+ 0·002	+ 0·105	+ 111·795	− 0·066	+ 111·729
199	200	213·15	+ 0·005	+ 0·110	+ 113·220	− 0·067	+ 113·153
200	201	214·25	− 0·011	+ 0·099	+ 111·715	− 0·066	+ 111·649
201	202	215·16	− 0·007	+ 0·092	+ 115·659	− 0·069	+ 115·590
202	203	215·73	− 0·002	+ 0·090	+ 108·358	− 0·064	+ 108·294
203	204	216·89	+ 0·005	+ 0·095	+ 125·149	− 0·076	+ 125·073
204	205	218·07	− 0·002	+ 0·093	+ 144·595	− 0·089	+ 144·506
205	206	219·20	− 0·008	+ 0·085	+ 176·666	− 0·111	+ 176·555
206	207*	219·28	− 0·001	+ 0·084	+ 178·035	− 0·112	+ 177·923

Difference of dynamic height, Madras to Tanjore = + 177·923 feet.

Length of line in miles = M = 219·28. $\Sigma d^2 = 0·029464$.

Probable error of the mean result per mile of double-levelling $= 0·6745\sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0·0039.$

Probable error of the difference of elevation between the terminal bench-marks $= 0·6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0·0579.$

* Bench-mark No. 207 is the mark at Tanjore described on page 136.

Line No. 10. Arkonam to Jalarpet.

Bench-marks From	Bench-marks To	Distance from Arkonam	Discrepancy between levellers (First − Second leveller): From mark to mark (= d)	Discrepancy between levellers (First − Second leveller): Total from Arkonam	Observed elevation above (+) or below (−) Arkonam (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Arkonam	Dynamic height above (+) or below (−) Arkonam
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·03	0·000	0·000	+ 2·560	− 0·002	+ 2·558
2	3	0·97	− 0·009	− 0·009	+ 14·797	− 0·009	+ 14·788
3	4	2·36	− 0·006	− 0·015	+ 38·838	− 0·024	+ 38·814
4	5	4·31	+ 0·016	+ 0·001	+ 52·796	− 0·033	+ 52·763
5	6	5·56	+ 0·014	+ 0·015	+ 56·184	− 0·035	+ 56·149
6	7	6·36	+ 0·009	+ 0·024	+ 59·468	− 0·037	+ 59·431
7	8	7·31	+ 0·018	+ 0·042	+ 61·935	− 0·038	+ 61·897
8	9	10·21	+ 0·030	+ 0·072	+ 94·692	− 0·058	+ 94·634
9	10	11·45	− 0·001	+ 0·071	+ 114·043	− 0·070	+ 113·973
10	11	12·04	+ 0·005	+ 0·076	+ 118·741	− 0·073	+ 118·668
11	12	13·28	+ 0·013	+ 0·089	+ 126·595	− 0·078	+ 126·517
12	13	14·82	− 0·018	+ 0·071	+ 140·222	− 0·086	+ 140·136
13	14	16·63	− 0·035	+ 0·036	+ 156·188	− 0·096	+ 156·092
14	15	18·04	− 0·006	+ 0·030	+ 183·183	− 0·112	+ 183·071
15	16	20·83	+ 0·002	+ 0·032	+ 239·790	− 0·147	+ 239·643
16	17	21·98	− 0·001	+ 0·031	+ 264·205	− 0·162	+ 264·043
17	18	22·58	− 0·004	+ 0·027	+ 286·673	− 0·175	+ 286·498
18	19	22·68	+ 0·006	+ 0·033	+ 284·638	− 0·174	+ 284·464
19	20	24·66	− 0·007	+ 0·026	+ 323·022	− 0·197	+ 322·825
20	21	26·01	+ 0·007	+ 0·033	+ 344·813	− 0·210	+ 344·603
21	22	27·45	+ 0·009	+ 0·042	+ 347·939	− 0·212	+ 347·727
22	23	28·61	− 0·002	+ 0·040	+ 342·389	− 0·209	+ 342·180
23	24	29·00	+ 0·001	+ 0·041	+ 341·437	− 0·208	+ 341·229
24	25	30·51	− 0·009	+ 0·032	+ 339·413	− 0·207	+ 339·206
25	26	31·53	+ 0·012	+ 0·044	+ 331·897	− 0·202	+ 331·695
26	27	33·64	− 0·003	+ 0·041	+ 352·474	− 0·215	+ 352·259
27	28	36·35	+ 0·043	+ 0·084	+ 384·901	− 0·235	+ 384·666
28	29	37·81	+ 0·007	+ 0·091	+ 406·915	− 0·248	+ 406·667
29	30	37·92	− 0·005	+ 0·086	+ 404·166	− 0·246	+ 403·920
30	31	39·16	+ 0·016	+ 0·102	+ 419·430	− 0·255	+ 419·175
31	32	40·51	+ 0·003	+ 0·105	+ 443·113	− 0·270	+ 442·843
32	33	41·59	0·000	+ 0·105	+ 462·382	− 0·282	+ 462·100
33	34	42·14	+ 0·002	+ 0·107	+ 468·762	− 0·286	+ 468·476
34	35	42·92	+ 0·010	+ 0·117	+ 472·733	− 0·288	+ 472·445
35	36	43·62	+ 0·003	+ 0·120	+ 477·381	− 0·291	+ 477·090
36	37	45·02	− 0·011	+ 0·109	+ 492·081	− 0·300	+ 491·781
37	38	46·00	− 0·017	+ 0·092	+ 497·995	− 0·304	+ 497·691
38	39	47·99	− 0·018	+ 0·074	+ 507·278	− 0·309	+ 506·969
39	40	48·85	+ 0·005	+ 0·079	+ 516·757	− 0·314	+ 516·443
40	41	49·87	+ 0·005	+ 0·084	+ 527·298	− 0·320	+ 526·978
41	42	50·61	+ 0·007	+ 0·091	+ 534·548	− 0·324	+ 534·224
42	43	52·01	− 0·017	+ 0·074	+ 557·666	− 0·338	+ 557·328
43	44	53·16	+ 0·013	+ 0·087	+ 576·807	− 0·350	+ 576·457
44	45	53·19	+ 0·001	+ 0·088	+ 570·929	− 0·346	+ 570·583
45	46	54·44	+ 0·008	+ 0·096	+ 582·794	− 0·353	+ 582·441
46	47	54·88	− 0·005	+ 0·091	+ 588·130	− 0·356	+ 587·774
47	48	56·43	− 0·014	+ 0·077	+ 590·290	− 0·357	+ 589·933
48	49	57·86	+ 0·001	+ 0·078	+ 604·924	− 0·366	+ 604·558
49	50	59·25	+ 0·010	+ 0·088	+ 632·779	− 0·383	+ 632·396
50	51	60·35	− 0·001	+ 0·087	+ 632·556	− 0·383	+ 632·173
51	52	61·56	+ 0·015	+ 0·102	+ 654·428	− 0·396	+ 654·032
52	53	62·99	+ 0·018	+ 0·120	+ 657·739	− 0·398	+ 657·341
53	54	63·05	+ 0·002	+ 0·122	+ 658·904	− 0·399	+ 658·505
54	55	63·83	+ 0·013	+ 0·135	+ 671·426	− 0·407	+ 671·019
55	56	64·06	− 0·003	+ 0·132	+ 676·507	− 0·410	+ 676·097
56	57	66·28	+ 0·009	+ 0·141	+ 693·989	− 0·421	+ 693·568
57	58	66·60	0·000	+ 0·141	+ 700·053	− 0·425	+ 699·628
58	59	68·82	+ 0·008	+ 0·149	+ 737·618	− 0·448	+ 737·170
59	60	70·19	+ 0·009	+ 0·158	+ 771·434	− 0·469	+ 770·965
60	61	71·07	+ 0·013	+ 0·171	+ 772·825	− 0·470	+ 772·355

* Bench-mark No. 1 is the mark at Arkonam described on page 133.

Line No. 10. Arkonam to Jalarpet.—(Continued).

Bench-marks		Distance from Arkonam	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Arkonam (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Arkonam
From	To		From mark to mark (= d)	Total from Arkonam		Total from Arkonam	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	72·91	− 0·014	+ 0·157	+ 794·751	− 0·484	+ 794·267
62	63	74·32	+ 0·012	+ 0·169	+ 806·029	− 0·491	+ 805·538
63	64	76·07	− 0·011	+ 0·158	+ 818·419	− 0·498	+ 817·921
64	65	78·01	+ 0·008	+ 0·166	+ 841·559	− 0·512	+ 841·047
65	66	78·82	− 0·004	+ 0·162	+ 850·260	− 0·517	+ 849·743
66	67	80·16	+ 0·010	+ 0·172	+ 858·323	− 0·522	+ 857·801
67	68	81·40	− 0·004	+ 0·168	+ 866·828	− 0·527	+ 866·301
68	69	83·56	+ 0·006	+ 0·174	+ 893·859	− 0·544	+ 893·315
69	70	84·34	+ 0·003	+ 0·177	+ 909·754	− 0·554	+ 909·200
70	71	85·34	+ 0·011	+ 0·188	+ 938·360	− 0·572	+ 937·788
71	72	87·28	− 0·012	+ 0·176	+ 981·473	− 0·599	+ 980·874
72	73	88·70	− 0·002	+ 0·174	+ 1008·153	− 0·616	+ 1007·537
73	74	89·30	+ 0·005	+ 0·179	+ 1029·496	− 0·629	+ 1028·867
74	75*	89·31	+ 0·002	+ 0·181	+ 1026·968	− 0·627	+ 1026·341

Difference of dynamic height, Arkonam to Jalarpet = + 1026·341 feet.

Length of line in miles = M = 89·31 $\Sigma d^2 = 0{\cdot}010235$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0{\cdot}0036$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0{\cdot}0341$.

* Bench-mark No. 75 is the mark at Jalarpet described on page 134.

Line No. 11. Erode to Shoranur.

Bench-marks		Distance from Erode	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Erode (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Erode
From	To		From mark to mark (= d)	Total from Erode		Total from Erode	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	1·35	− 0·021	− 0·021	+ 42·201	− 0·028	+ 42·173
2	3	2·98	+ 0·014	− 0·007	+ 92·548	− 0·062	+ 92·486
3	4	4·11	− 0·003	− 0·010	+ 130·812	− 0·088	+ 130·724
4	5	6·96	− 0·001	− 0·011	+ 243·017	− 0·096	+ 242·921
5	6	8·97	− 0·006	− 0·017	+ 313·724	− 0·143	+ 313·581
6	7	9·60	+ 0·008	− 0·009	+ 313·891	− 0·143	+ 313·748
7	8	10·51	+ 0·018	+ 0·009	+ 334·791	− 0·157	+ 334·634
8	9	11·80	+ 0·009	+ 0·018	+ 367·102	− 0·179	+ 366·923
9	10	12·80	+ 0·006	+ 0·024	+ 382·055	− 0·189	+ 381·866
10	11	13·27	− 0·001	+ 0·023	+ 384·851	− 0·191	+ 384·660
11	12	14·83	+ 0·015	+ 0·038	+ 396·778	− 0·199	+ 396·579
12	13	18·77	+ 0·014	+ 0·052	+ 354·891	− 0·170	+ 354·721
13	14	20·11	+ 0·005	+ 0·057	+ 332·500	− 0·155	+ 332·345
14	15	21·25	+ 0·009	+ 0·066	+ 365·017	− 0·177	+ 364·840
15	16	23·27	− 0·013	+ 0·053	+ 438·208	− 0·227	+ 437·981
16	17	23·31	+ 0·002	+ 0·055	+ 441·350	− 0·229	+ 441·121
17	18	24·14	0·000	+ 0·055	+ 424·953	− 0·218	+ 424·735
18	19	24·71	+ 0·008	+ 0·063	+ 416·192	− 0·212	+ 415·980
19	20	26·01	+ 0·004	+ 0·067	+ 412·582	− 0·209	+ 412·373
20	21	27·24	− 0·002	+ 0·065	+ 412·869	− 0·209	+ 412·660
21	22	27·80	+ 0·004	+ 0·069	+ 410·543	− 0·208	+ 410·335
22	23	28·74	+ 0·001	+ 0·070	+ 410·447	− 0·208	+ 410·239
23	24	31·65	+ 0·002	+ 0·072	+ 449·489	− 0·235	+ 449·254
24	25	31·69	− 0·005	+ 0·067	+ 449·635	− 0·235	+ 449·400
25	26	32·44	+ 0·005	+ 0·072	+ 451·679	− 0·236	+ 451·443
26	27	33·50	− 0·016	+ 0·056	+ 458·017	− 0·240	+ 457·777
27	28	35·02	+ 0·015	+ 0·071	+ 480·427	− 0·255	+ 480·172
28	29	35·86	− 0·004	+ 0·067	+ 485·136	− 0·258	+ 484·878
29	30	36·58	+ 0·011	+ 0·078	+ 504·910	− 0·272	+ 504·638
30	31	36·71	+ 0·001	+ 0·079	+ 512·028	− 0·277	+ 511·751
31	32	38·21	+ 0·005	+ 0·084	+ 520·797	− 0·283	+ 520·514
32	33	40·13	− 0·014	+ 0·070	+ 541·631	− 0·297	+ 541·334
33	34	40·68	− 0·002	+ 0·068	+ 557·372	− 0·308	+ 557·064
34	35	41·19	+ 0·003	+ 0·071	+ 555·318	− 0·307	+ 555·011
35	36	42·19	+ 0·015	+ 0·086	+ 568·354	− 0·316	+ 568·038
36	37	42·63	+ 0·003	+ 0·089	+ 580·986	− 0·325	+ 580·661
37	38	42·97	− 0·005	+ 0·084	+ 584·420	− 0·327	+ 584·093
38	39	45·12	+ 0·003	+ 0·087	+ 610·498	− 0·352	+ 620·146
39	40	47·08	0·000	+ 0·087	+ 632·710	− 0·360	+ 632·350
40	41	47·86	− 0·001	+ 0·086	+ 644·385	− 0·368	+ 644·017
41	42	51·16	+ 0·020	+ 0·106	+ 693·153	− 0·401	+ 692·752
42	43	52·62	+ 0·016	+ 0·122	+ 692·116	− 0·400	+ 691·716
43	44	53·26	− 0·021	+ 0·101	+ 702·412	− 0·407	+ 702·005
44	45	54·93	− 0·010	+ 0·091	+ 732·567	− 0·427	+ 732·140
45	46	57·76	− 0·006	+ 0·085	+ 751·914	− 0·440	+ 751·474
46	47	58·51	+ 0·014	+ 0·099	+ 767·953	− 0·451	+ 767·502
47	48	59·76	+ 0·019	+ 0·118	+ 742·790	− 0·434	+ 742·356
48	49	61·59	+ 0·013	+ 0·131	+ 676·838	− 0·388	+ 676·450
49	50	62·05	0·000	+ 0·131	+ 670·505	− 0·384	+ 670·121
50	51	63·17	+ 0·008	+ 0·139	+ 628·027	− 0·355	+ 627·672
51	52	64·47	+ 0·001	+ 0·140	+ 574·770	− 0·318	+ 574·452
52	53	64·56	+ 0·001	+ 0·141	+ 577·083	− 0·319	+ 576·764
53	54	65·49	− 0·024	+ 0·117	+ 562·733	− 0·309	+ 562·424
54	55	66·90	− 0·003	+ 0·114	+ 491·387	− 0·260	+ 491·127
55	56	69·33	+ 0·017	+ 0·131	+ 392·266	− 0·192	+ 392·074
56	57	70·11	− 0·008	+ 0·123	+ 336·040	− 0·153	+ 335·887
57	58	70·59	+ 0·001	+ 0·124	+ 307·733	− 0·134	+ 307·599
58	59	72·34	− 0·017	+ 0·107	+ 173·030	− 0·041	+ 172·989
59	60	73·21	+ 0·002	+ 0·109	+ 151·807	− 0·026	+ 151·781
60	61	75·18	− 0·002	+ 0·107	+ 11·773	+ 0·071	+ 11·844

* Bench-mark No. 1 is the mark at Erode described on page 194.

Line No. 11. Erode to Shoranur.—(Continued).

Bench-marks		Distance from Erode	Discrepancy between levellers (First—Second leveller)		Observed elevation above (+) or below (−) Erode (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Erode
From	To		From mark to mark (=d)	Total from Erode		Total from Erode	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	76·14	− 0·004	+ 0·103	− 64·829	+ 0·124	− 64·705
62	63	77·96	− 0·006	+ 0·097	− 113·494	+ 0·158	− 113·336
63	64	80·13	+ 0·003	+ 0·100	− 163·156	+ 0·192	− 162·964
64	65	80·17	+ 0·001	+ 0·101	− 163·141	+ 0·192	− 162·949
65	66	80·19	0·000	+ 0·101	− 163·229	+ 0·192	− 163·037
66	67	80·74	+ 0·009	+ 0·110	− 167·912	+ 0·195	− 167·717
67	68	82·59	+ 0·008	+ 0·118	− 200·031	+ 0·217	− 199·814
68	69	83·67	+ 0·010	+ 0·128	− 229·858	+ 0·238	− 229·620
69	70	84·94	− 0·012	+ 0·116	− 237·243	+ 0·243	− 237·000
70	71	85·83	− 0·011	+ 0·105	− 247·272	+ 0·250	− 247·022
71	72	88·55	− 0·002	+ 0·103	− 285·053	+ 0·276	− 284·777
72	73	88·59	+ 0·002	+ 0·105	− 280·719	+ 0·273	− 280·446
73	74	88·88	+ 0·020	+ 0·125	− 287·809	+ 0·278	− 287·531
74	75	89·66	− 0·009	+ 0·116	− 301·025	+ 0·287	− 300·738
75	76	91·36	+ 0·010	+ 0·126	− 319·149	+ 0·299	− 318·850
76	77	92·76	+ 0·009	+ 0·135	− 324·175	+ 0·303	− 323·872
77	78	94·38	− 0·018	+ 0·117	− 336·573	+ 0·311	− 336·262
78	79	94·46	− 0·002	+ 0·115	− 341·650	+ 0·315	− 341·335
79	80	96·39	0·000	+ 0·115	− 348·231	+ 0·320	− 347·911
80	81	98·05	− 0·031	+ 0·084	− 363·376	+ 0·330	− 363·046
81	82	99·55	− 0·019	+ 0·065	− 374·181	+ 0·338	− 373·843
82	83	101·29	+ 0·008	+ 0·073	− 390·989	+ 0·350	− 390·639
83	84	102·46	0·000	+ 0·073	− 399·327	+ 0·356	− 398·971
84	85	103·36	+ 0·001	+ 0·074	− 397·877	+ 0·355	− 397·522
85	86	104·97	+ 0·021	+ 0·095	− 417·411	+ 0·369	− 417·042
86	87	106·54	+ 0·001	+ 0·096	− 422·127	+ 0·372	− 421·755
87	88	106·69	− 0·007	+ 0·089	− 422·772	+ 0·372	− 422·400
88	89	107·98	+ 0·024	+ 0·113	− 424·106	+ 0·373	− 423·733
89	90	108·61	− 0·009	+ 0·104	− 428·471	+ 0·376	− 428·095
90	91	109·94	0·000	+ 0·104	− 424·368	+ 0·373	− 423·995
91	92	111·94	+ 0·011	+ 0·115	− 427·226	+ 0·375	− 426·851
92	93	113·06	+ 0·006	+ 0·121	− 440·423	+ 0·384	− 440·039
93	94	114·43	+ 0·019	+ 0·140	− 442·872	+ 0·385	− 442·487
94	95*	115·99	+ 0·011	+ 0·151	− 442·375	+ 0·385	− 441·990

Difference of dynamic height, Erode to Shoranur = − 441·990 feet.

Length of line in miles = M = 115·99. $\Sigma d^2 = 0{\cdot}011171$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0{\cdot}0033$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745 \sqrt{\frac{\Sigma d}{4}} = \pm\ 0{\cdot}0356$.

* Bench-mark No. 95 is the mark at Shoranur described on page 135.

Line No. 12. Shoranur to Beypore.

Bench-marks		Distance from Shoranur	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Shoranur (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Shoranur
From	To		From mark to mark (= d)	Total from Shoranur		Total from Shoranur	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·07	+ 0·006	+ 0·006	+ 0·383	− 0·000	+ 0·383
2	3	1·19	− 0·014	− 0·008	+ 12·604	− 0·008	+ 12·596
3	4	2·31	− 0·011	− 0·019	− 3·881	+ 0·003	− 3·878
4	5	3·47	+ 0·009	− 0·010	− 3·832	+ 0·003	− 3·829
5	6	4·60	+ 0·018	+ 0·008	− 18·388	+ 0·013	− 18·375
6	7	6·24	− 0·006	+ 0·002	− 27·585	+ 0·019	− 27·566
7	8	7·04	− 0·002	0·000	− 9·897	+ 0·007	− 9·890
8	9	8·98	− 0·009	− 0·009	− 33·046	+ 0·023	− 33·023
9	10	10·36	+ 0·010	+ 0·001	− 29·252	+ 0·020	− 29·232
10	11	11·13	+ 0·014	+ 0·015	− 31·307	+ 0·021	− 31·286
11	12	12·21	− 0·006	+ 0·009	− 45·258	+ 0·031	− 45·227
12	13	12·91	− 0·006	+ 0·003	− 54·679	+ 0·037	− 54·642
13	14	14·54	+ 0·015	+ 0·018	− 50·533	+ 0·034	− 50·499
14	15	15·49	− 0·010	+ 0·008	− 46·508	+ 0·031	− 46·477
15	16	17·72	+ 0·003	+ 0·011	− 58·657	+ 0·039	− 58·618
16	17	18·49	0·000	+ 0·011	− 50·109	+ 0·033	− 50·076
17	18	18·54	+ 0·002	+ 0·013	− 54·699	+ 0·036	− 54·663
18	19	19·00	+ 0·005	+ 0·018	− 58·904	+ 0·039	− 58·865
19	20	21·35	− 0·018	0·000	− 70·153	+ 0·047	− 70·106
20	21	24·12	+ 0·003	+ 0·003	− 71·484	+ 0·048	− 71·436
21	22	25·65	− 0·001	+ 0·002	− 73·335	+ 0·049	− 73·286
22	23	26·00	+ 0·001	+ 0·003	− 74·942	+ 0·050	− 74·892
23	24	26·65	− 0·011	− 0·008	− 79·213	+ 0·053	− 79·160
24	25	27·87	− 0·019	− 0·027	− 80·637	+ 0·054	− 80·583
25	26	27·91	− 0·005	− 0·032	− 80·769	+ 0·054	− 80·715
26	27	27·92	+ 0·001	− 0·031	− 85·802	+ 0·058	− 85·744
27	28	29·66	− 0·016	− 0·047	− 64·569	+ 0·043	− 64·526
28	29	31·65	+ 0·005	− 0·042	− 71·592	+ 0·048	− 71·544
29	30	32·80	+ 0·003	− 0·039	− 71·446	+ 0·048	− 71·398
30	31	32·87	− 0·006	− 0·045	− 71·934	+ 0·048	− 71·886
31	32	34·52	+ 0·029	− 0·016	− 66·396	+ 0·044	− 66·352
32	33	36·23	− 0·021	− 0·037	− 63·774	+ 0·042	− 63·732
33	34	37·77	− 0·021	− 0·058	− 59·733	+ 0·039	− 59·694
34	35	37·83	− 0·002	− 0·060	− 66·699	+ 0·044	− 66·655
35	36	38·47	+ 0·004	− 0·056	− 66·169	+ 0·044	− 66·125
36	37	40·42	+ 0·009	− 0·047	− 71·529	+ 0·048	− 71·481
37	38	41·44	− 0·002	− 0·049	− 79·002	+ 0·053	− 78·949
38	39	42·84	+ 0·005	− 0·044	− 86·534	+ 0·058	− 86·476
39	40	43·56	+ 0·018	− 0·026	− 85·072	+ 0·057	− 85·015
40	41	45·08	+ 0·011	− 0·015	− 80·281	+ 0·054	− 80·227
41	42	45·26	+ 0·001	− 0·014	− 85·349	+ 0·058	− 85·291
42	43	46·55	+ 0·001	− 0·013	− 82·901	+ 0·057	− 82·844
43	44	46·61	− 0·004	− 0·017	− 82·966	+ 0·057	− 82·909
44	45	47·24	− 0·013	− 0·030	− 74·251	+ 0·051	− 74·200
45	46	47·25	+ 0·002	− 0·028	− 73·614	+ 0·051	− 73·563
46	47†	47·27	+ 0·004	− 0·024	− 82·989	+ 0·057	− 82·932

Difference of dynamic height, Shoranur to Beypore = − 82·932 feet.

Length of line in miles = M = 47·27. $\Sigma d^2 = 0{\cdot}005284$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4\mathrm{M}}} = \pm\ 0{\cdot}0036$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0{\cdot}0245$.

* Bench-mark No. 1 is the mark at Shoranur described on page 135. † Bench-mark No. 47 is the mark at Beypore described on page 133.

Line No. 13. Shoranur to Cochin.

Bench-marks From	Bench-marks To	Distance from Shoranur	Discrepancy between levellers (First − Second leveller) From mark to mark (= d)	Discrepancy between levellers Total from Shoranur	Observed elevation above (+) or below (−) Shoranur (mean result by two levellers)	Dynamic correction deduced from mark to mark Total from Shoranur	Dynamic height above (+) or below (−) Shoranur
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·38	− 0·003	− 0·003	− 15·169	+ 0·010	− 15·159
2	3	0·47	− 0·003	− 0·006	− 3·773	+ 0·002	− 3·771
3	4	0·70	− 0·002	− 0·008	− 2·995	+ 0·001	− 2·994
4	5	1·25	− 0·023	− 0·031	+ 53·442	− 0·038	+ 53·404
5	6	2·25	− 0·008	− 0·039	+ 43·621	− 0·031	+ 43·590
6	7	4·25	− 0·010	− 0·049	+ 60·929	− 0·043	+ 60·886
7	8	6·28	+ 0·008	− 0·041	+ 52·550	− 0·037	+ 52·513
8	9	8·34	+ 0·035	− 0·006	− 8·304	+ 0·005	− 8·299
9	10	9·33	+ 0·006	0·000	+ 29·426	− 0·021	+ 29·405
10	11	10·32	− 0·009	− 0·009	+ 35·694	− 0·025	+ 35·669
11	12	11·31	− 0·009	− 0·018	+ 53·206	− 0·037	+ 53·169
12	13	13·31	+ 0·015	− 0·003	− 17·610	+ 0·013	− 17·597
13	14	14·31	− 0·007	− 0·010	− 20·122	+ 0·015	− 20·107
14	15	15·30	− 0·007	− 0·017	− 24·160	+ 0·018	− 24·142
15	16	16·28	+ 0·013	− 0·004	− 47·564	+ 0·034	− 47·530
16	17	17·29	− 0·002	− 0·006	− 67·476	+ 0·048	− 67·428
17	18	18·28	− 0·016	− 0·022	− 78·171	+ 0·056	− 78·115
18	19	21·41	+ 0·006	− 0·016	− 43·223	+ 0·031	− 43·192
19	20	22·40	+ 0·011	− 0·005	− 57·044	+ 0·041	− 57·003
20	21	23·41	+ 0·023	+ 0·018	− 51·251	+ 0·037	− 51·214
21	22	24·42	− 0·009	+ 0·009	− 20·833	+ 0·016	− 20·817
22	23	25·41	− 0·019	− 0·010	− 40·800	+ 0·030	− 40·770
23	24	26·74	+ 0·011	+ 0·001	− 72·008	+ 0·052	− 71·956
24	25	26·84	− 0·003	− 0·002	− 69·285	+ 0·050	− 69·235
25	26	27·85	− 0·008	− 0·010	− 86·407	+ 0·062	− 86·345
26	27	28·84	− 0·005	− 0·015	− 78·604	+ 0·056	− 78·548
27	28	29·84	+ 0·007	− 0·008	− 57·414	+ 0·041	− 57·373
28	29	30·85	− 0·015	− 0·023	− 58·397	+ 0·042	− 58·355
29	30	31·83	− 0·015	− 0·038	− 68·326	+ 0·049	− 68·277
30	31	33·82	+ 0·014	− 0·024	− 71·911	+ 0·052	− 71·859
31	32	33·92	+ 0·002	− 0·022	− 78·358	+ 0·056	− 78·302
32	33	34·82	0·000	− 0·022	− 76·260	+ 0·055	− 76·205
33	34	35·82	+ 0·019	− 0·003	− 79·187	+ 0·057	− 79·130
34	35	36·82	− 0·005	− 0·008	− 79·721	+ 0·057	− 79·664
35	36	37·82	− 0·009	− 0·017	− 71·558	+ 0·051	− 71·507
36	37	38·82	− 0·005	− 0·022	− 86·889	+ 0·062	− 86·827
37	38	39·14	− 0·002	− 0·024	− 88·937	+ 0·063	− 88·874
38	39	42·27	+ 0·009	− 0·015	− 82·529	+ 0·059	− 82·470
39	40	43·45	+ 0·012	− 0·003	− 83·064	+ 0·059	− 83·005
40	41	44·69	+ 0·007	+ 0·004	− 86·013	+ 0·061	− 85·952
41	42	45·64	− 0·006	− 0·002	− 93·623	+ 0·066	− 93·557
42	43	46·61	− 0·004	− 0·006	− 88·871	+ 0·063	− 88·808
43	44	47·12	+ 0·008	+ 0·002	− 91·851	+ 0·065	− 91·786
44	45	50·48	+ 0·017	+ 0·019	− 88·819	+ 0·063	− 88·756
45	46	55·28	+ 0·001	+ 0·020	− 90·930	+ 0·064	− 90·866
46	47	57·50	+ 0·004	+ 0·024	− 89·622	+ 0·063	− 89·559
47	48	59·14	+ 0·006	+ 0·030	− 89·497	+ 0·063	− 89·434
48	49	65·04	− 0·030	0·000	− 92·480	+ 0·065	− 92·415
49	50	65·72	+ 0·010	+ 0·010	− 91·967	+ 0·065	− 91·902
50	51†	65·74	+ 0·002	+ 0·012	− 90·826	+ 0·064	− 90·762

Difference of dynamic height, Shoranur to Cochin = − 90·762 feet.

Length of line in mile = M = 65·74. $\Sigma d^2 = 0{\cdot}007232$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\dfrac{\Sigma d^2}{4M}} = \pm\, 0{\cdot}0035.$

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\dfrac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0287.$

* Bench-mark No. 1 is the mark at Shoranur described on page 135. † Bench-mark No. 51 is the mark at Cochin described on page 133.

Line No. 14. Gooty to Arkonam.

Bench-marks		Distance from Gooty	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Gooty (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Gooty
From	To		From mark to mark (= *d*)	Total from Gooty		Total from Gooty	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·83	+ 0·004	+ 0·004	+ 26·623	– 0·014	+ 26·609
2	3	2·66	– 0·005	– 0·001	– 5·294	+ 0·003	– 5·291
3	4	4·23	– 0·001	– 0·002	– 45·299	+ 0·024	– 45·275
4	5	5·34	– 0·002	– 0·004	– 81·294	+ 0·043	– 81·251
5	6	7·28	– 0·007	– 0·011	– 108·326	+ 0·057	– 108·269
6	7	8·45	– 0·005	– 0·016	– 148·121	+ 0·078	– 148·043
7	8	10·03	– 0·005	– 0·021	– 183·200	+ 0·096	– 183·104
8	9	12·89	+ 0·009	– 0·012	– 225·200	+ 0·118	– 225·082
9	10	14·49	– 0·002	– 0·014	– 258·573	+ 0·135	– 258·438
10	11	14·53	+ 0·002	– 0·012	– 257·817	+ 0·135	– 257·682
11	12	15·57	+ 0·008	– 0·004	– 283·246	+ 0·148	– 283·098
12	13	16·63	+ 0·002	– 0·002	– 304·238	+ 0·159	– 304·079
13	14	19·74	– 0·006	– 0·008	– 345·340	+ 0·180	– 345·160
14	15	20·11	– 0·002	– 0·010	– 346·022	+ 0·180	– 345·842
15	16	21·90	– 0·003	– 0·013	– 353·065	+ 0·184	– 352·881
16	17	23·63	– 0·002	– 0·015	– 385·078	+ 0·201	– 384·877
17	18	24·82	– 0·013	– 0·028	– 389·405	+ 0·203	– 389·202
18	19	25·23	– 0·004	– 0·032	– 391·666	+ 0·204	– 391·462
19	20	27·70	+ 0·014	– 0·018	– 416·010	+ 0·217	– 415·793
20	21	28·93	– 0·011	– 0·029	– 425·348	+ 0·222	– 425·126
21	22	30·97	– 0·005	– 0·034	– 429·674	+ 0·224	– 429·450
22	23	31·81	+ 0·003	– 0·031	– 436·543	+ 0·228	– 436·315
23	24	35·03	– 0·012	– 0·043	– 461·539	+ 0·241	– 461·298
24	25	36·35	+ 0·017	– 0·026	– 464·762	+ 0·243	– 464·519
25	26	36·83	+ 0·004	– 0·022	– 471·636	+ 0·247	– 471·389
26	27	38·53	+ 0·004	– 0·018	– 466·976	+ 0·245	– 466·731
27	28	39·77	– 0·002	– 0·020	– 463·575	+ 0·243	– 463·332
28	29	41·17	+ 0·003	– 0·017	– 483·229	+ 0·253	– 482·976
29	30	42·30	+ 0·009	– 0·008	– 491·793	+ 0·257	– 491·536
30	31	44·10	+ 0·003	– 0·005	– 499·742	+ 0·261	– 499·481
31	32	46·22	– 0·007	– 0·012	– 491·595	+ 0·257	– 491·338
32	33	46·98	+ 0·011	– 0·001	– 477·824	+ 0·250	– 477·574
33	34	47·75	+ 0·002	+ 0·001	– 491·494	+ 0·257	– 491·237
34	35	48·39	+ 0·005	+ 0·006	– 500·536	+ 0·262	– 500·274
35	36	49·43	– 0·003	+ 0·003	– 512·516	+ 0·268	– 512·248
36	37	50·72	– 0·005	– 0·002	– 514·269	+ 0·269	– 514·000
37	38	53·19	+ 0·005	+ 0·003	– 495·262	+ 0·264	– 494·998
38	39	53·79	+ 0·008	+ 0·011	– 480·981	+ 0·257	– 480·724
39	40	54·54	+ 0·010	+ 0·021	– 459·679	+ 0·246	– 459·433
40	41	57·37	– 0·022	– 0·001	– 504·745	+ 0·270	– 504·475
41	42	58·54	– 0·004	– 0·005	– 526·324	+ 0·281	– 526·043
42	43	59·87	– 0·011	– 0·016	– 550·312	+ 0·294	– 550·018
43	44	61·01	– 0·003	– 0·019	– 572·942	+ 0·306	– 572·636
44	45	61·67	– 0·007	– 0·026	– 580·636	+ 0·310	– 580·326
45	46	63·16	+ 0·016	– 0·010	– 597·403	+ 0·319	– 597·084
46	47	64·13	+ 0·001	– 0·009	– 614·248	+ 0·328	– 613·920
47	48	66·17	– 0·016	– 0·025	– 616·482	+ 0·329	– 616·153
48	49	67·52	+ 0·008	– 0·017	– 627·699	+ 0·335	– 627·364
49	50	69·56	+ 0·015	– 0·002	– 648·838	+ 0·346	– 648·492
50	51	70·97	– 0·023	– 0·025	– 656·002	+ 0·350	– 655·652
51	52	72·63	+ 0·013	– 0·012	– 658·576	+ 0·351	– 658·225
52	53	73·95	– 0·002	– 0·014	– 683·370	+ 0·364	– 683·006
53	54	75·35	– 0·007	– 0·021	– 708·233	+ 0·378	– 707·855
54	55	77·41	+ 0·007	– 0·014	– 725·085	+ 0·387	– 724·698
55	56	78·42	+ 0·001	– 0·013	– 729·710	+ 0·389	– 729·321
56	57	79·42	– 0·002	– 0·015	– 733·139	+ 0·391	– 732·748
57	58	81·23	– 0·005	– 0·020	– 736·953	+ 0·393	– 736·560
58	59	83·23	– 0·003	– 0·023	– 741·920	+ 0·396	– 741·524
59	60	84·42	– 0·013	– 0·036	– 749·336	+ 0·400	– 748·936
60	61	85·65	– 0·002	– 0·038	– 751·011	+ 0·401	– 750·610

* Bench-mark No. 1 is the mark at Gooty described on page 134.

Line No. 14. Gooty to Arkonam.—(Continued).

Bench-marks		Distance from Gooty	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Gooty (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Gooty
From	To		From mark to mark (= *d*)	Total from Gooty		Total from Gooty	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	86·55	+ 0·001	– 0·037	– 756·433	+ 0·404	– 756·029
62	63	88·21	– 0·001	– 0·038	– 751·471	+ 0·401	– 751·070
63	64	91·30	+ 0·009	– 0·029	– 765·101	+ 0·408	– 764·693
64	65	92·00	+ 0·005	– 0·024	– 769·557	+ 0·410	– 769·147
65	66	92·72	+ 0·007	– 0·017	– 767·591	+ 0·409	– 767·182
66	67	95·91	– 0·010	– 0·027	– 748·124	+ 0·398	– 747·726
67	68	96·01	+ 0·002	– 0·025	– 741·638	+ 0·395	– 741·243
68	69	97·70	– 0·003	– 0·028	– 736·041	+ 0·392	– 735·649
69	70	98·79	– 0·011	– 0·039	– 680·508	+ 0·361	– 680·147
70	71	101·25	+ 0·007	– 0·032	– 538·152	+ 0·283	– 537·869
71	72	102·29	+ 0·011	– 0·021	– 565·873	+ 0·298	– 565·575
72	73	107·53	– 0·014	– 0·035	– 751·708	+ 0·400	– 751·308
73	74	108·88	+ 0·004	– 0·031	– 765·835	+ 0·408	– 765·427
74	75	109·69	– 0·008	– 0·039	– 776·170	+ 0·414	– 775·756
75	76	110·86	– 0·004	– 0·043	– 799·365	+ 0·427	– 798·938
76	77	112·18	– 0·002	– 0·045	– 783·397	+ 0·418	– 782.979
77	78	114·36	– 0·005	– 0·050	– 730·743	+ 0·389	– 730·354
78	79	115·66	+ 0·007	– 0·043	– 730·240	+ 0·389	– 729·851
79	80	119·98	– 0·004	– 0·047	– 728·800	+ 0·388	– 728·412
80	81	120·29	+ 0·004	– 0·043	– 731·420	+ 0·389	– 731·031
81	82	121·28	0·000	– 0·043	– 713·881	+ 0·379	– 713·502
82	83	121·33	– 0·001	– 0·044	– 716·922	+ 0·381	– 716·541
83	84	121·99	+ 0·003	– 0·041	– 716·968	+ 0·381	– 716·587
84	85	122·79	+ 0·003	– 0·038	– 731·606	+ 0·389	– 731·217
85	86	124·29	– 0·016	– 0·054	– 738·802	+ 0·393	– 738·409
86	87	125·86	– 0·003	– 0·057	– 754·483	+ 0·402	– 754·081
87	88	126·30	+ 0·005	– 0·052	– 745·129	+ 0·397	– 744·732
88	89	128·89	+ 0·004	– 0·048	– 732·070	+ 0·390	– 731·680
89	90	131·60	– 0·005	– 0·053	– 699·192	+ 0·371	– 698·821
90	91	133·68	– 0·001	– 0·054	– 674·014	+ 0·357	– 673·657
91	92	135·06	0·000	– 0·054	– 655·299	+ 0·346	– 654·953
92	93	135·69	– 0·006	– 0·060	– 638·845	+ 0·337	– 638·508
93	94	136·63	– 0·005	– 0·065	– 620·295	+ 0·326	– 619·969
94	95	138·08	– 0·010	– 0·075	– 611·522	+ 0·321	– 611·201
95	96	140·28	0·000	– 0·075	– 581·115	+ 0·304	– 580·811
96	97	141·80	+ 0·001	– 0·074	– 559·887	+ 0·292	– 559·595
97	98	142.97	– 0·001	– 0·075	– 553·917	+ 0·289	– 553·628
98	99	144·18	– 0·007	– 0·082	– 568·771	+ 0·298	– 568·473
99	100	144·47	+ 0·001	– 0·081	– 565·036	+ 0·296	– 564·740
100	101	145·47	– 0·007	– 0·088	– 582·823	+ 0·306	– 582·517
101	102	145·82	– 0·001	– 0·089	– 585·718	+ 0·308	– 585·410
102	103	147·65	+ 0·023	– 0·066	– 569·951	+ 0·299	– 569·652
103	104	148·34	+ 0·002	– 0·064	– 560·218	+ 0·293	– 559·925
104	105	148·47	+ 0·004	– 0·060	– 556·602	+ 0·291	– 556·311
105	106	149·06	+ 0·002	– 0·058	– 564·686	+ 0·296	– 564·390
106	107	150·99	– 0·007	– 0·065	– 534·769	+ 0·279	– 534·490
107	108	151·69	– 0·008	– 0·073	– 529·916	+ 0·276	– 529·640
108	109	153·27	+ 0·012	– 0·061	– 511·771	+ 0·266	– 511·505
109	110	154·49	– 0·007	– 0·068	– 489·524	+ 0·253	– 489·271
110	111	155·13	– 0·003	– 0·071	– 482·895	+ 0·249	– 482·646
111	112	158·49	+ 0·002	– 0·069	– 407·204	+ 0·205	– 406·999
112	113	161·84	+ 0·010	– 0·059	– 539·876	+ 0·281	– 539·595
113	114	163·63	+ 0·006	– 0·053	– 599·284	+ 0·315	– 598·969
114	115	166·31	+ 0·001	– 0·052	– 643·383	+ 0·341	– 643·042
115	116	167·30	– 0·005	– 0·057	– 668·423	+ 0·356	– 668·067
116	117	170·19	+ 0·001	– 0·056	– 767·026	+ 0·413	– 766·613
117	118	171·69	– 0·002	– 0·058	– 826·037	+ 0·447	– 825·590
118	119	173·22	+ 0·004	– 0·054	– 840·395	+ 0·455	– 839·940
119	120	174·17	– 0·003	– 0·057	– 830·157	+ 0·449	– 829·708
120	121	177·37	+ 0·002	– 0·055	– 799·033	+ 0·431	– 798·602

Line No. 14. Gooty to Arkonam.—(Continued).

Bench-marks		Distance from Gooty	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Gooty (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Gooty
From	To		From mark to mark (= d)	Total from Gooty		Total from Gooty	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
121	122	179·17	+ 0·019	– 0·036	– 783·048	+ 0·422	– 782·626
122	123	180·07	– 0·009	– 0·045	– 769·753	+ 0·414	– 769·339
123	124	180·91	+ 0·006	– 0·039	– 738·203	+ 0·395	– 737·808
124	125	181·80	+ 0·001	– 0·038	– 696·363	+ 0·370	– 695·993
125	126	182·99	– 0·002	– 0·040	– 659·934	+ 0·349	– 659·585
126	127	184·93	0·000	– 0·040	– 640·100	+ 0·337	– 639·763
127	128	186·62	+ 0·005	– 0·035	– 689·855	+ 0·366	– 689·489
128	129	186·86	+ 0·003	– 0·032	– 701·329	+ 0·373	– 700·956
129	130	188·38	– 0·011	– 0·043	– 707·922	+ 0·377	– 707·545
130	131	189·49	+ 0·005	– 0·038	– 722·632	+ 0·386	– 722·246
131	132	192·72	+ 0·006	– 0·032	– 731·983	+ 0·391	– 731·592
132	133	193·10	0·000	– 0·032	– 726·438	+ 0·388	– 726·050
133	134	194·40	– 0·002	– 0·034	– 711·425	+ 0·379	– 711·046
134	135	196·00	+ 0·010	– 0·024	– 797·510	+ 0·430	– 797·080
135	136	197·89	+ 0·004	– 0·020	– 804·882	+ 0·434	– 804·448
136	137	198·14	– 0·005	– 0·025	– 806·038	+ 0·435	– 805·603
137	138	199·13	+ 0·020	– 0·005	– 801·820	+ 0·433	– 801·387
138	139	204·17	– 0·005	– 0·010	– 890·778	+ 0·486	– 890·292
139	140	206·48	+ 0·006	– 0·004	– 918·200	+ 0·502	– 917·698
140	141	207·29	– 0·007	– 0·011	– 918·259	+ 0·502	– 917·757
141	142	207·33	+ 0·002	– 0·009	– 916·434	+ 0·501	– 915·933
142	143	210·33	+ 0·009	0·000	– 918·607	+ 0·502	– 918·105
143	144	211·84	– 0·008	– 0·008	– 935·150	+ 0·512	– 934·638
144	145	213·89	+ 0·004	– 0·004	– 917·034	+ 0·501	– 916·533
145	146	214·60	– 0·005	– 0·009	– 905·204	+ 0·494	– 904·710
146	147	215·33	0·000	– 0·009	– 903·203	+ 0·493	– 902·710
147	148*	215·38	– 0·002	– 0·011	– 905·890	+ 0·495	– 905·395

Difference of dynamic height, Gooty to Arkonam = – 905·395 feet.

Length of line in miles = M = 215·38. $\Sigma d^2 = 0\cdot008571$.

Probable error of the mean result per mile of double-levelling $= 0\cdot6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm\, 0\cdot0021$.

Probable error of the difference of elevation between the terminal bench-marks $= 0\cdot6745 \sqrt{\frac{\Sigma d^2}{4}} = \pm\, 0\cdot0312$.

* Bench-mark No. 148 is the mark at Arkonam described on page 133.

Line No. 15. Gooty to Bellary.

Bench-marks		Distance from Gooty	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Gooty (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Gooty
From	To		From mark to mark (=d)	Total from Gooty		Total from Gooty	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·08	– 0·012	– 0·012	– 40·718	+ 0·021	– 40·697
2	3	0·66	+ 0·019	+ 0·007	– 26·926	+ 0·014	– 26·912
3	4	2·33	– 0·012	– 0·005	– 39·184	+ 0·020	– 39·164
4	5	2·83	– 0·006	– 0·011	– 39·984	+ 0·020	– 39·964
5	6	4·23	– 0·010	– 0·021	– 40·049	+ 0·020	– 40·029
6	7	4·42	+ 0·001	– 0·020	– 45·389	+ 0·023	– 45·366
7	8	5·38	– 0·002	– 0·022	– 32·948	+ 0·017	– 32·931
8	9	6·38	– 0·015	– 0·037	– 8·502	+ 0·005	– 8·497
9	10	7·38	– 0·002	– 0·039	+ 41·940	– 0·021	+ 41·919
10	11	8·38	– 0·001	– 0·040	+ 45·269	– 0·023	+ 45·046
11	12	8·74	– 0·006	– 0·046	+ 65·435	– 0·033	+ 65·402
12	13	9·39	– 0·001	– 0·047	+ 56·942	– 0·029	+ 56·913
13	14	10·43	– 0·008	– 0·055	+ 66·681	– 0·034	+ 66·647
14	15	11·57	– 0·010	– 0·065	+ 77·189	– 0·039	+ 77·150
15	16	13·58	+ 0·014	– 0·051	+ 116·993	– 0·060	+ 116·933
16	17	14·23	+ 0·001	– 0·050	+ 114·230	– 0·058	+ 114·172
17	18	14·61	– 0·003	– 0·053	+ 123·415	– 0·063	+ 123·352
18	19	15·65	– 0·005	– 0·058	+ 152·745	– 0·078	+ 152·667
19	20	15·74	0·000	– 0·058	+ 155·187	– 0·079	+ 155·108
20	21	16·64	– 0·004	– 0·062	+ 184·013	– 0·094	+ 183·919
21	22	18·64	– 0·009	– 0·071	+ 259·032	– 0·133	+ 258·899
22	23	19·64	– 0·005	– 0·076	+ 290·393	– 0·149	+ 290·244
23	24	20·67	– 0·008	– 0·084	+ 294·821	– 0·151	+ 294·670
24	25	21·68	+ 0·008	– 0·076	+ 264·817	– 0·135	+ 264·682
25	26	22·69	– 0·001	– 0·077	+ 288·223	– 0·147	+ 288·076
26	27	23·70	– 0·006	– 0·083	+ 277·846	– 0·142	+ 277·704
27	28	24·14	+ 0·003	– 0·080	+ 263·947	– 0·135	+ 263·812
28	29	24·69	– 0·016	– 0·096	+ 235·295	– 0·120	+ 235·175
29	30	25·12	+ 0·003	– 0·093	+ 214·849	– 0·110	+ 214·739
30	31	25·53	– 0·002	– 0·095	+ 209·147	– 0·107	+ 209·040
31	32	26·54	– 0·008	– 0·103	+ 215·657	– 0·110	+ 215·547
32	33	26·68	+ 0·001	– 0·102	+ 225·950	– 0·115	+ 225·835
33	34	27·39	0·000	– 0·102	+ 232·676	– 0·118	+ 232·558
34	35	27·80	– 0·005	– 0·107	+ 237·822	– 0·121	+ 237·701
35	36	28·35	+ 0·007	– 0·100	+ 251·485	– 0·128	+ 251·357
36	37	29·05	– 0·004	– 0·104	+ 261·759	– 0·133	+ 261·626
37	38	29·39	+ 0·007	– 0·097	+ 257·702	– 0·131	+ 257·571
38	39	30·39	0·000	– 0·097	+ 225·488	– 0·114	+ 225·374
39	40	31·39	– 0·001	– 0·098	+ 188·736	– 0·095	+ 188·641
40	41	31·54	– 0·004	– 0·102	+ 182·832	– 0·092	+ 182·740
41	42	32·48	+ 0·005	– 0·097	+ 217·252	– 0·110	+ 217·142
42	43	33·38	– 0·003	– 0·100	+ 226·074	– 0·115	+ 225·959
43	44	34·38	– 0·010	– 0·110	+ 220·992	– 0·112	+ 220·880
44	45	35·38	+ 0·007	– 0·103	+ 250·951	– 0·128	+ 250·823
45	46	36·38	+ 0·015	– 0·088	+ 240·842	– 0·123	+ 240·719
46	47	37·38	– 0·006	– 0·094	+ 244·338	– 0·125	+ 244·213
47	48	37·72	+ 0·009	– 0·085	+ 202·105	– 0·103	+ 202·002
48	49	38·38	+ 0·008	– 0·077	+ 191·749	– 0·098	+ 191·651
49	50	39·51	+ 0·005	– 0·072	+ 166·691	– 0·085	+ 166·606
50	51	39·61	– 0·001	– 0·073	+ 165·077	– 0·084	+ 164·993
51	52	40·39	+ 0·007	– 0·066	+ 151·897	– 0·077	+ 151·820
52	53	40·88	– 0·005	– 0·071	+ 147·235	– 0·075	+ 147·160
53	54	41·39	– 0·006	– 0·077	+ 145·610	– 0·074	+ 145·536
54	55	42·39	+ 0·050	– 0·027	+ 140·371	– 0·071	+ 140·300
55	56	42·84	– 0·055	– 0·082	+ 150·456	– 0·076	+ 150·380
56	57	43·39	+ 0·003	– 0·079	+ 160·101	– 0·081	+ 160·020
57	58	44·49	+ 0·008	– 0·071	+ 167·660	– 0·085	+ 167·575
58	59	45·39	+ 0·001	– 0·070	+ 187·258	– 0·095	+ 187·163
59	60	46·39	+ 0·006	– 0·064	+ 202·788	– 0·103	+ 202·685
60	61	47·40	– 0·006	– 0·070	+ 219·615	– 0·112	+ 219·503

* Bench-mark No. 1 is the mark at Gooty described on page 134.

Line No. 15. Gooty to Bellary.—(Continued).

Bench-marks		Distance from Gooty	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Gooty (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Gooty
From	To		From mark to mark (= d)	Total from Gooty		Total from Gooty	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	48·41	+ 0·003	– 0·067	+ 242·847	– 0·124	+ 242·723
62	63	49·40	+ 0·068	+ 0·001	+ 266·139	– 0·136	+ 266·003
63	64	49·59	– 0·059	– 0·058	+ 277·331	– 0·142	+ 277·189
64	65	50·23	+ 0·007	– 0·051	+ 282·529	– 0·145	+ 282·384
65	66*	50·68	0·000	– 0·051	+ 281·236	– 0·144	+ 281·092

Difference of dynamic height, Gooty to Bellary = + 281·092 feet.

Length of line in miles = M = 50·68. $\Sigma d^2 = 0{\cdot}016797$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm\, 0{\cdot}0061$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745 \sqrt{\frac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0437$.

* Bench-mark No. 66 is the mark at Bellary described on page 133.

Line No. 16. Hubli to Bellary.

Bench-marks		Distance from Hubli	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Hubli (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Hubli
From	To		From mark to mark (= d)	Total from Hubli		Total from Hubli	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	1·51	− 0·014	− 0·014	+ 58·102	− 0·030	+ 58·072
2	3	3·90	+ 0·013	− 0·001	+ 28·535	− 0·015	+ 28·520
3	4	7·65	− 0·027	− 0·028	− 57·537	+ 0·028	− 57·509
4	5	15·74	+ 0·001	− 0·027	− 73·645	+ 0·036	− 73·609
5	6	33·45	+ 0·024	− 0·051	+ 111·266	− 0·057	+ 111·209
6	7	34·31	− 0·002	− 0·053	+ 107·052	− 0·055	+ 106·997
7	8	40·02	− 0·019	− 0·072	+ 227·552	− 0·116	+ 227·436
8	9	40·83	− 0·002	− 0·074	+ 177·774	− 0·091	+ 177·683
9	10	44·61	− 0·021	− 0·095	− 29·086	+ 0·015	− 29·071
10	11	57·10	− 0·028	− 0·123	− 327·238	+ 0·167	− 327·071
11	12	67·66	− 0·015	− 0·138	− 420·962	+ 0·215	− 420·747
12	13	69·67	+ 0·031	− 0·107	− 427·889	+ 0·219	− 427·670
13	14	70·49	− 0·003	− 0·110	− 438·801	+ 0·225	− 438·576
14	15	72·12	+ 0·016	− 0·094	− 429·487	+ 0·220	− 429·267
15	16	76·76	+ 0·004	− 0·090	− 412·113	+ 0·211	− 411·902
16	17	79·71	− 0·012	− 0·102	− 412·746	+ 0·211	− 412·535
17	18	81·71	+ 0·004	− 0·098	− 420·654	+ 0·215	− 420·439
18	19	83·72	+ 0·011	− 0·087	− 449·056	+ 0·229	− 448·827
19	20	86·75	+ 0·016	− 0·071	− 456·357	+ 0·233	− 456·124
20	21	89·75	− 0·016	− 0·087	− 464·870	+ 0·237	− 464·633
21	22	92·74	+ 0·003	− 0·084	− 455·841	+ 0·232	− 455·609
22	23	94·38	+ 0·015	− 0·069	− 488·816	+ 0·249	− 488·567
23	24	95·47	+ 0·036	− 0·033	− 358·886	+ 0·183	− 358·703
24	25	96·80	− 0·002	− 0·035	− 454·034	+ 0·232	− 453·802
25	26	97·80	+ 0·003	− 0·032	− 480·146	+ 0·245	− 479·901
26	27	98·60	+ 0·018	− 0·014	− 484·633	+ 0·247	− 484·386
27	28	99·60	+ 0·005	− 0·009	− 465·364	+ 0·237	− 465·127
28	29	102·60	− 0·006	− 0·015	− 319·441	+ 0·162	− 319·279
29	30	105·52	+ 0·011	− 0·004	− 239·349	+ 0·121	− 239·228
30	31	105·87	+ 0·002	− 0·002	− 232·940	+ 0·118	− 232·822
31	32	109·87	− 0·065	− 0·067	− 378·198	+ 0·192	− 378·006
32	33	110·88	− 0·015	− 0·082	− 390·967	+ 0·198	− 390·769
33	34	111·89	− 0·002	− 0·084	− 431·048	+ 0·218	− 430·830
34	35	112·90	− 0·003	− 0·087	− 457·924	+ 0·232	− 457·692
35	36	113·90	− 0·004	− 0·091	− 486·767	+ 0·247	− 486·520
36	37	115·31	− 0·012	− 0·103	− 512·076	+ 0·260	− 511·816
37	38	116·91	+ 0·005	− 0·098	− 520·299	+ 0·264	− 520·035
38	39	117·17	− 0·006	− 0·104	− 518·022	+ 0·263	− 517·759
39	40	117·91	− 0·003	− 0·107	− 515·703	+ 0·262	− 515·441
40	41	118·97	− 0·006	− 0·113	− 519·843	+ 0·264	− 519·579
41	42	120·93	− 0·010	− 0·123	− 498·501	+ 0·253	− 498·248
42	43	124·96	− 0·012	− 0·135	− 485·162	+ 0·246	− 484·916
43	44	125·16	+ 0·001	− 0·134	− 483·072	+ 0·245	− 482·827
44	45	125·96	− 0·009	− 0·143	− 469·457	+ 0·238	− 469·219
45	46	126·40	− 0·006	− 0·149	− 468·665	+ 0·238	− 468·427
46	47	128·36	+ 0·002	− 0·147	− 476·870	+ 0·242	− 476·628
47	48	128·99	0·000	− 0·147	− 481·554	+ 0·244	− 481·310
48	49	130·39	+ 0·002	− 0·145	− 499·995	+ 0·253	− 499·742
49	50	131·02	+ 0·008	− 0·137	− 501·665	+ 0·254	− 501·411
50	51	133·56	+ 0·006	− 0·131	− 531·399	+ 0·269	− 531·130
51	52	134·32	+ 0·001	− 0·130	− 548·906	+ 0·278	− 548·628
52	53	135·37	+ 0·007	− 0·123	− 538·507	+ 0·273	− 538·234
53	54†	137·25	+ 0·022	− 0·101	− 578·890	+ 0·294	− 578·596

Difference of dynamic height, Hubli to Bellary = − 578·596 feet.

Length of line in miles = M = 137·25. $\Sigma d^2 = 0{\cdot}013311$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm\, 0{\cdot}0033$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745 \sqrt{\frac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0389$.

* Bench-mark No. 1 is the mark at Hubli described on page 134. † Bench-mark No. 54 is the mark at Bellary described on page 133.

Line No. 17. Karwar to Hubli.

Bench-marks		Distance from Karwar	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Karwar (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Karwar
From	To		From mark to mark (= d)	Total from Karwar		Total from Karwar	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·89	+ 0·019	+ 0·019	+ 85·152	− 0·045	+ 85·107
2	3	1·90	− 0·006	+ 0·013	+ 3·521	− 0·002	+ 3·519
3	4	3·24	− 0·028	− 0·015	+ 137·538	− 0·074	+ 137·464
4	5	10·63	− 0·018	− 0·033	+ 2·575	− 0·002	+ 2·573
5	6	27·56	+ 0·003	− 0·030	+ 30·275	− 0·017	+ 30·258
6	7	29·41	− 0·013	− 0·043	+ 80·058	− 0·044	+ 80·014
7	8	30·59	+ 0·004	− 0·039	+ 60·044	− 0·033	+ 60·011
8	9	31·74	+ 0·021	− 0·018	+ 67·671	− 0·037	+ 67·634
9	10	33·48	+ 0·019	+ 0·001	+ 161·114	− 0·086	+ 161·028
10	11	35·20	+ 0·005	+ 0·006	+ 150·821	− 0·081	+ 150·740
11	12	40·66	− 0·027	− 0·021	+ 161·310	− 0·087	+ 161·223
12	13	44·04	0·000	− 0·021	+ 167·922	− 0·090	+ 167·832
13	14	51·67	− 0·012	− 0·033	+ 1096·384	− 0·581	+ 1095·803
14	15	53·62	+ 0·042	+ 0·009	+ 1439·993	− 0·763	+ 1439·230
15	16	54·32	+ 0·011	+ 0·020	+ 1464·459	− 0·776	+ 1463·683
16	17	56·21	+ 0·013	+ 0·033	+ 1563·133	− 0·828	+ 1562·305
17	18	59·74	+ 0·043	+ 0·076	+ 1798·086	− 0·952	+ 1797·134
18	19	59·88	+ 0·001	+ 0·077	+ 1777·079	− 0·941	+ 1776·138
19	20	63·10	+ 0·013	+ 0·090	+ 1815·700	− 0·961	+ 1814·739
20	21	64·79	− 0·004	+ 0·086	+ 1757·099	− 0·930	+ 1756·169
21	22	66·78	+ 0·002	+ 0·088	+ 1722·850	− 0·912	+ 1721·938
22	23	70·79	− 0·030	+ 0·058	+ 1775·139	− 0·939	+ 1774·200
23	24	73·23	+ 0·026	+ 0·084	+ 1711·726	− 0·907	+ 1710·819
24	25	80·77	+ 0·024	+ 0·108	+ 1749·708	− 0·926	+ 1748·782
25	26	84·07	+ 0·013	+ 0·121	+ 1689·169	− 0·895	+ 1688·274
26	27	90·41	+ 0·056	+ 0·177	+ 1847·468	− 0·975	+ 1846·493
27	28†	102·74	+ 0·001	+ 0·178	+ 2048·893	− 1·077	+ 2047·816

Difference of dynamic height, Karwar to Hubli = + 2047·816 feet.

Length of line in miles = M = 102·74. $\Sigma d^2 = 0·012950$.

Probable error of the mean result per mile of double-levelling $= 0·6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm 0·0038.$

Probable error of the difference of elevation between the terminal bench-marks $= 0·6745 \sqrt{\frac{\Sigma d^2}{4}} = \pm 0·0384.$

* Bench-mark No. 1 is the mark at Karwar described on page 134. † Bench-mark No. 28 is the mark at Hubli described on page 134.

Line No. 18. Jalarpet to Bangalore.

Bench-marks		Distance from Jalarpet	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Jalarpet (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Jalarpet
From	To		From mark to mark (= d)	Total from Jalarpet		Total from Jalarpet	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·05	+ 0·004	+ 0·004	+ 2·385	– 0·001	+ 2·384
2	3	2·59	– 0·029	– 0·025	+ 50·487	– 0·031	+ 50·456
3	4	4·93	– 0·019	– 0·044	+ 126·899	– 0·079	+ 126·820
4	5	7·93	– 0·025	– 0·069	+ 287·864	– 0·180	+ 287·684
5	6	8·54	– 0·013	– 0·082	+ 318·695	– 0·200	+ 318·495
6	7	9·54	– 0·029	– 0·111	+ 379·797	– 0·238	+ 379·559
7	8	11·37	– 0·036	– 0·147	+ 496·545	– 0·311	+ 496·234
8	9	12·40	– 0·002	– 0·149	+ 560·856	– 0·351	+ 560·505
9	10	12·96	0·000	– 0·149	+ 606·692	– 0·380	+ 606·312
10	11	13·87	– 0·011	– 0·160	+ 675·759	– 0·423	+ 675·336
11	12	14·55	– 0·001	– 0·161	+ 715·553	– 0·448	+ 715·105
12	13	14·66	+ 0·009	– 0·152	+ 708·792	– 0·444	+ 708·348
13	14	15·32	– 0·004	– 0·156	+ 729·346	– 0·457	+ 728·889
14	15	18·16	– 0·040	– 0·196	+ 817·367	– 0·512	+ 816·855
15	16	18·87	– 0·003	– 0·199	+ 820·291	– 0·514	+ 819·777
16	17	19·98	+ 0·001	– 0·198	+ 852·052	– 0·534	+ 851·518
17	18	21·49	– 0·015	– 0·213	+ 884·027	– 0·554	+ 883·473
18	19	22·07	– 0·007	– 0·220	+ 919·604	– 0·576	+ 919·028
19	20	22·10	+ 0·003	– 0·217	+ 920·174	– 0·576	+ 919·598
20	21	22·11	0·000	– 0·217	+ 920·092	– 0·576	+ 919·516
21	22	23·49	– 0·009	– 0·226	+ 963·445	– 0·603	+ 962·842
22	23	25·87	– 0·020	– 0·246	+ 1039·743	– 0·650	+ 1039·093
23	24	28·02	– 0·019	– 0·265	+ 1099·415	– 0·687	+ 1098·728
24	25	29·08	– 0·005	– 0·270	+ 1158·451	– 0·724	+ 1157·727
25	26	30·52	+ 0·002	– 0·268	+ 1185·782	– 0·741	+ 1185·041
26	27	30·92	+ 0·006	– 0·262	+ 1168·786	– 0·731	+ 1168·055
27	28	32·75	– 0·012	– 0·274	+ 1245·778	– 0·778	+ 1245·000
28	29	34·01	+ 0·006	– 0·268	+ 1275·489	– 0·796	+ 1274·693
29	30	35·06	– 0·010	– 0·278	+ 1260·710	– 0·787	+ 1259·923
30	31	35·80	– 0·017	– 0·295	+ 1258·312	– 0·786	+ 1257·526
31	32	35·81	– 0·002	– 0·297	+ 1259·046	– 0·786	+ 1258·260
32	33	36·91	+ 0·014	– 0·283	+ 1260·479	– 0·787	+ 1259·692
33	34	37·39	– 0·015	– 0·298	+ 1270·073	– 0·793	+ 1269·280
34	35	37·98	– 0·001	– 0·299	+ 1287·802	– 0·804	+ 1286·998
35	36	38·95	+ 0·007	– 0·292	+ 1282·323	– 0·801	+ 1281·522
36	37	39·90	– 0·018	– 0·310	+ 1307·966	– 0·817	+ 1307·149
37	38	41·21	+ 0·011	– 0·299	+ 1322·736	– 0·826	+ 1321·910
38	39	42·17	+ 0·010	– 0·289	+ 1339·077	– 0·836	+ 1338·241
39	40	43·29	– 0·002	– 0·291	+ 1339·935	– 0·837	+ 1339·098
40	41	43·33	+ 0·002	– 0·289	+ 1335·564	– 0·835	+ 1334·729
41	42	43·67	– 0·013	– 0·302	+ 1340·305	– 0·838	+ 1339·467
42	43	44·20	0·000	– 0·302	+ 1360·309	– 0·850	+ 1359·459
43	44	45·85	– 0·013	– 0·315	+ 1431·517	– 0·893	+ 1430·624
44	45	47·28	– 0·028	– 0·343	+ 1475·310	– 0·920	+ 1474·390
45	46	48·84	– 0·006	– 0·349	+ 1530·620	– 0·954	+ 1529·666
46	47	50·67	– 0·009	– 0·358	+ 1506·781	– 0·939	+ 1505·842
47	48	51·73	+ 0·009	– 0·349	+ 1469·811	– 0·916	+ 1468·895
48	49	52·83	– 0·011	– 0·360	+ 1514·126	– 0·943	+ 1513·183
49	50	54·72	– 0·016	– 0·376	+ 1584·729	– 0·986	+ 1583·743
50	51	55·85	+ 0·028	– 0·348	+ 1523·867	– 0·949	+ 1522·918
51	52	57·76	– 0·018	– 0·366	+ 1598·010	– 0·994	+ 1597·016
52	53	58·57	– 0·032	– 0·398	+ 1642·024	– 1·021	+ 1641·003
53	54	59·95	– 0·016	– 0·414	+ 1641·476	– 1·021	+ 1640·455
54	55	60·01	– 0·002	– 0·416	+ 1637·087	– 1·019	+ 1636·068
55	56	62·20	– 0·002	– 0·418	+ 1602·037	– 0·998	+ 1601·039
56	57	63·23	– 0·001	– 0·419	+ 1620·428	– 1·009	+ 1619·419
57	58	64·13	+ 0·001	– 0·418	+ 1654·028	– 1·030	+ 1652·998
58	59	65·78	+ 0·001	– 0·417	+ 1626·060	– 1·013	+ 1625·047
59	60	67·83	+ 0·013	– 0·404	+ 1601·883	– 0·998	+ 1600·885
60	61	69·79	– 0·011	– 0·415	+ 1565·185	– 0·976	+ 1564·209

* Bench-mark No. 1 is the mark at Jalarpet described on page 134.

Line No. 18. Jalarpet to Bangalore.—(Continued).

Bench-marks		Distance from Jalarpet	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Jalarpet (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Jalarpet
From	To		From mark to mark (= d)	Total from Jalarpet		Total from Jalarpet	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	70·46	+ 0·003	– 0·412	+ 1542·212	– 0·962	+ 1541·250
62	63	71·31	– 0·005	– 0·417	+ 1500·942	– 0·937	+ 1500·005
63	64	72·20	+ 0·013	– 0·404	+ 1527·614	– 0·953	+ 1526·661
64	65	72·21	– 0·003	– 0·407	+ 1527·870	– 0·953	+ 1526·917
65	66	73·90	– 0·003	– 0·410	+ 1572·437	– 0·980	+ 1571·457
66	67	74·26	+ 0·001	– 0·409	+ 1555·121	– 0·970	+ 1554·151
67	68	75·84	+ 0·012	– 0·397	+ 1600·357	– 0·998	+ 1599·359
68	69	76·80	+ 0·003	– 0·394	+ 1603·244	– 1·000	+ 1602·244
69	70	77·95	– 0·001	– 0·395	+ 1651·625	– 1·029	+ 1650·596
70	71	77·98	– 0·004	– 0·399	+ 1651·734	– 1·029	+ 1650·705
71	72	78·43	– 0·009	– 0·408	+ 1630·588	– 1·016	+ 1629·572
72	73	81·28	– 0·008	– 0·416	+ 1649·037	– 1·027	+ 1648·010
73	74	82·04	+ 0·007	– 0·409	+ 1653·748	– 1·030	+ 1652·718
74	75	83·82	– 0·014	– 0·423	+ 1700·418	– 1·059	+ 1699·359
75	76	83·83	0·000	– 0·423	+ 1704·414	– 1·061	+ 1703·353
76	77	83·98	+ 0·009	– 0·414	+ 1700·970	– 1·059	+ 1699·911
77	78*	85·76	+ 0·026	– 0·388	+ 1793·138	– 1·115	+ 1792·023

Difference of dynamic height, Jalarpet to Bangalore = + 1792·023 feet.

Length of line in miles = M = 85·76. $\Sigma d^2 = 0{\cdot}014694$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745 \sqrt{\dfrac{\Sigma d^2}{4M}} = \pm\ 0{\cdot}0044$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745 \sqrt{\dfrac{\Sigma d^2}{4}} = \pm\ 0{\cdot}0409$.

* Bench-mark No. 78 is the mark at Bangalore described on page 133.

Line No. 19. Bangalore to Bellary.

Bench-marks From	Bench-marks To	Distance from Bangalore	Discrepancy between levellers (First – Second leveller) From mark to mark (= *d*)	Discrepancy between levellers (First – Second leveller) Total from Bangalore	Observed elevation above (+) or below (–) Bangalore (mean result by two levellers)	Dynamic correction deduced from mark to mark Total from Bangalore	Dynamic height above (+) or below (–) Bangalore
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	1·65	+ 0·019	+ 0·019	– 62·085	+ 0·038	– 62·047
2	3	2·65	+ 0·038	+ 0·057	– 122·401	+ 0·075	– 122·326
3	4	3·65	– 0·016	+ 0·041	– 99·319	+ 0·061	– 99·258
4	5	4·39	+ 0·015	+ 0·056	– 111·872	+ 0·069	– 111·803
5	6	4·65	+ 0·012	+ 0·068	– 156·276	+ 0·096	– 156·180
6	7	5·65	+ 0·007	+ 0·075	– 196·141	+ 0·120	– 196·021
7	8	7·65	+ 0·027	+ 0·102	– 281·982	+ 0·173	– 281·809
8	9	8·65	+ 0·007	+ 0·109	– 311·496	+ 0·191	– 311·305
9	10	8·69	– 0·005	+ 0·104	– 305·755	+ 0·188	– 305·567
10	11	9·41	+ 0·001	+ 0·105	– 359·795	+ 0·221	– 359·574
11	12	9·55	– 0·003	+ 0·102	– 351·641	+ 0·216	– 351·425
12	13	9·65	– 0·002	+ 0·100	– 334·767	+ 0·206	– 334·561
13	14	11·65	+ 0·014	+ 0·114	– 285·372	+ 0·176	– 285·196
14	15	11·90	+ 0·008	+ 0·122	– 272·272	+ 0·168	– 272·104
15	16	13·64	– 0·034	+ 0·088	– 241·661	+ 0·149	– 241·512
16	17	13·67	0·000	+ 0·088	– 238·047	+ 0·147	– 237·900
17	18	13·85	– 0·004	+ 0·084	– 212·977	+ 0·132	– 212·845
18	19	14·62	– 0·016	+ 0·068	– 193·962	+ 0·121	– 193·841
19	20	15·63	– 0·010	+ 0·058	– 158·443	+ 0·100	– 158·343
20	21	16·63	+ 0·013	+ 0·071	– 197·562	+ 0·123	– 197·439
21	22	17·62	– 0·007	+ 0·064	– 257·010	+ 0·158	– 256·852
22	23	18·62	– 0·003	+ 0·061	– 294·756	+ 0·181	– 294·575
23	24	19·18	– 0·007	+ 0·054	– 298·775	+ 0·183	– 298·592
24	25	19·61	– 0·009	+ 0·045	– 273·768	+ 0·168	– 273·600
25	26	20·60	– 0·018	+ 0·027	– 196·341	+ 0·122	– 196·219
26	27	21·58	– 0·005	+ 0·022	– 226·948	+ 0·140	– 226·808
27	28	22·58	+ 0·001	+ 0·023	– 236·245	+ 0·145	– 236·100
28	29	22·93	– 0·013	+ 0·010	– 179·444	+ 0·111	– 179·333
29	30	23·56	+ 0·003	+ 0·013	– 135·458	+ 0·085	– 135·373
30	31	24·24	+ 0·001	+ 0·014	– 178·154	+ 0·111	– 178·043
31	32	25·54	– 0·014	0·000	– 134·915	+ 0·085	– 134·830
32	33	26·53	+ 0·024	+ 0·024	– 112·236	+ 0·071	– 112·165
33	34	27·93	– 0·036	– 0·012	– 72·370	+ 0·047	– 72·323
34	35	30·56	+ 0·003	– 0·009	– 252·761	+ 0·155	– 252·606
35	36	31·01	– 0·002	– 0·011	– 275·409	+ 0·169	– 275·240
36	37	31·61	– 0·010	– 0·021	– 286·483	+ 0·176	– 286·307
37	88	32·51	– 0·014	– 0·035	– 311·719	+ 0·191	– 311·528
38	39	33·51	– 0·016	– 0·051	– 300·822	+ 0·184	– 300·638
39	40	33·60	+ 0·002	– 0·049	– 313·340	+ 0·192	– 313·148
40	41	34·04	– 0·008	– 0·057	– 309·790	+ 0·190	– 309·600
41	42	34·53	+ 0·009	– 0·048	– 346·251	+ 0·212	– 346·039
42	43	35·53	+ 0·006	– 0·042	– 399·052	+ 0·244	– 398·808
43	44	36·53	+ 0·003	– 0·039	– 396·416	+ 0·242	– 396·174
44	45	37·23	– 0·003	– 0·042	– 386·160	+ 0·236	– 385·924
45	46	38·53	– 0·002	– 0·044	– 374·107	+ 0·229	– 373·878
46	47	39·83	+ 0·005	– 0·039	– 434·762	+ 0·265	– 434·497
47	48	41·58	0·000	– 0·039	– 460·969	+ 0·280	– 460·689
48	49	42·23	– 0·016	– 0·055	– 416·327	+ 0·254	– 416·073
49	50	42·78	+ 0·013	– 0·042	– 457·326	+ 0·278	– 457·048
50	51	44·68	– 0·016	– 0·058	– 485·144	+ 0·295	– 484·849
51	52	45·73	– 0·004	– 0·062	– 494·561	+ 0·300	– 494·261
52	53	46·74	0·000	– 0·062	– 493·579	+ 0·299	– 493·280
53	54	48·74	– 0·016	– 0·078	– 458·062	+ 0·278	– 457·784
54	55	49·75	– 0·014	– 0·092	– 402·928	+ 0·245	– 402·683
55	56	51·02	– 0·010	– 0·102	– 367·484	+ 0·224	– 367·260
56	57	51·75	+ 0·003	– 0·099	– 432·250	+ 0·262	– 431·988
57	58	53·28	– 0·005	– 0·104	– 433·027	+ 0·263	– 432·764
58	59	57·76	+ 0·044	– 0·060	– 713·183	+ 0·428	– 712·755
59	60	59·64	+ 0·018	– 0·042	– 749·763	+ 0·450	– 749·313
60	61	60·46	– 0·006	– 0·048	– 757·475	+ 0·455	– 757·020

* Bench-mark No. 1 is the mark at Bangalore described on page 133.

Line No. 19. Bangalore to Bellary.—(Continued).

Bench-marks		Distance from Bangalore	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Bangalore (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Bangalore
From	To		From mark to mark (= d)	Total from Bangalore		Total from Bangalore	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	61·77	0·000	– 0·048	– 824·135	+ 0·494	– 823·641
62	63	62·78	– 0·003	– 0·051	– 833·310	+ 0·499	– 832·811
63	64	68·76	+ 0·008	– 0·043	– 931·735	+ 0·556	– 931·179
64	65	69·07	+ 0·004	– 0·039	– 953·496	+ 0·569	– 952·927
65	66	70·47	+ 0·009	– 0·030	– 959·945	+ 0·573	– 959·372
66	67	71·73	0·000	– 0·030	– 950·584	+ 0·568	– 950·016
67	68	71·97	+ 0·008	– 0·022	– 982·860	+ 0·587	– 982·273
68	69	73·50	– 0·015	– 0·037	– 986·035	+ 0·589	– 985·446
69	70	73·75	– 0·007	– 0·044	– 961·797	+ 0·575	– 961·222
70	71	75·75	+ 0·017	– 0·027	–1055·263	+ 0·629	–1054·634
71	72	76·31	+ 0·006	– 0·021	–1064·890	+ 0·635	–1064·255
72	73	77·95	– 0·002	– 0·023	–1078·159	+ 0·643	–1077·516
73	74	79·80	– 0·004	– 0·027	–1113·137	+ 0·663	–1112·474
74	75	81·01	+ 0·003	– 0·024	–1115·958	+ 0·665	–1115·293
75	76	81·72	– 0·003	– 0·027	–1104·819	+ 0·659	–1104·160
76	77	82·92	+ 0·002	– 0·025	–1099·893	+ 0·656	–1099·237
77	78	83·75	– 0·017	– 0·042	–1072·403	+ 0·640	–1071·763
78	79	84·41	– 0·005	– 0·047	–1126·982	+ 0·672	–1126·310
79	80	85·75	– 0·017	– 0·064	–1078·900	+ 0·645	–1078·255
80	81	87·76	– 0·001	– 0·065	– 984·981	+ 0·591	– 984·390
81	82	89·76	+ 0·025	– 0·040	–1082·604	+ 0·647	–1081·957
82	83	90·15	0·000	– 0·040	–1078·021	+ 0·644	–1077·377
83	84	92·64	– 0·005	– 0·045	–1147·180	+ 0·683	–1146·497
84	85	93·75	– 0·003	– 0·048	–1122·894	+ 0·669	–1122·225
85	86	96·66	– 0·007	– 0·055	–1162·272	+ 0·691	–1161·581
86	87	97·29	– 0·013	– 0·068	–1147·220	+ 0·682	–1146·538
87	88	97·82	0·000	– 0·068	–1091·139	+ 0·650	–1090·489
88	89	98·70	– 0·006	– 0·074	–1109·306	+ 0·660	–1108·646
89	90	99·59	– 0·010	– 0·084	–1047·788	+ 0·625	–1047·163
90	91	101·82	+ 0·038	– 0·046	–1077·307	+ 0·642	–1076·665
91	92	104·21	– 0·020	– 0·066	–1127·083	+ 0·670	–1126·413
92	93	104·81	– 0·017	– 0·083	–1118·388	+ 0·665	–1117·723
93	94	105·90	– 0·002	– 0·085	–1149·302	+ 0·682	–1148·620
94	95	107·80	+ 0·006	– 0·079	–1146·194	+ 0·680	–1145·514
95	96	111·21	– 0·032	– 0·111	–1041·186	+ 0·621	–1040·565
96	97	112·51	– 0·007	– 0·118	–1105·760	+ 0·657	–1105·103
97	98	112·91	+ 0·006	– 0·112	–1147·930	+ 0·681	–1147·249
98	99	113·77	+ 0·009	– 0·103	–1136·032	+ 0·674	–1135·358
99	100	114·71	+ 0·007	– 0·096	–1174·800	+ 0·696	–1174·104
100	101	116·76	+ 0·009	– 0·087	–1235·179	+ 0·730	–1234·449
101	102	118·76	– 0·007	– 0·094	–1234·602	+ 0·730	–1233·872
102	103	119·76	+ 0·010	– 0·084	–1231·941	+ 0·728	–1231·213
103	104	120·40	– 0·009	– 0·093	–1219·279	+ 0·721	–1218·558
104	105	122·70	– 0·011	– 0·104	–1203·936	+ 0·713	–1203·223
105	106	122·85	+ 0·003	– 0·101	–1212·103	+ 0·717	–1211·386
106	107	123·84	– 0·005	– 0·106	–1190·138	+ 0·705	–1189·433
107	108	124·84	– 0·007	– 0·113	–1188·527	+ 0·704	–1187·823
108	109	126·83	+ 0·003	– 0·110	–1196·281	+ 0·708	–1195·573
109	110	128·19	– 0·001	– 0·111	–1225·681	+ 0·724	–1224·957
110	111	129·47	+ 0·020	– 0·091	–1277·242	+ 0·752	–1276·490
111	112	132·08	+ 0·020	– 0·071	–1319·094	+ 0·775	–1318·319
112	113	132·82	+ 0·008	– 0·063	–1322·711	+ 0·777	–1321·934
113	114	133·91	+ 0·002	– 0·061	–1305·673	+ 0·768	–1304·905
114	115	136·80	+ 0·013	– 0·048	–1272·974	+ 0·750	–1272·224
115	116	137·84	+ 0·003	– 0·045	–1250·003	+ 0·737	–1249·266
116	117	137·93	– 0·003	– 0·048	–1238·274	+ 0·731	–1237·543
117	118	138·81	– 0·007	– 0·055	–1246·407	+ 0·735	–1245·672
118	119	140·23	– 0·029	– 0·084	–1189·014	+ 0·704	–1188·310
119	120	141·79	+ 0·004	– 0·080	–1190·891	+ 0·705	–1190·186
120	121	142·79	+ 0·018	– 0·062	–1245·210	+ 0·734	–1244·476

Line No. 19. Bangalore to Bellary.—(Continued).

Bench-marks		Distance from Bangalore	Discrepancy between levellers (First — Second leveller)		Observed elevation above (+) or below (−) Bangalore (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Bangalore
From	To		From mark to mark (= d)	Total from Bangalore		Total from Bangalore	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
121	122	144·74	− 0·018	− 0·080	−1197·587	+ 0·708	−1196·879
122	123	144·79	0·000	− 0·080	−1198·163	+ 0·708	−1197·455
123	124	145·65	+ 0·004	− 0·076	−1128·195	+ 0·670	−1127·525
124	125	147·25	− 0·022	− 0·098	−1128·514	+ 0·670	−1127·844
125	126	147·78	− 0·013	− 0·111	−1087·556	+ 0·648	−1086·908
126	127	150·33	+ 0·010	− 0·101	−1189·094	+ 0·702	−1188·392
127	128	153·91	− 0·005	− 0·106	−1277·259	+ 0·749	−1276·510
128	129	154·64	0·000	− 0·106	−1281·309	+ 0·751	−1280·558
129	130	157·87	+ 0·058	− 0·048	−1423·877	+ 0·827	−1423·050
130	131	159·86	+ 0·001	− 0·047	−1438·764	+ 0·835	−1437·929
131	132	160·24	− 0·011	− 0·058	−1431·431	+ 0·831	−1430·600
132	133	163·84	+ 0·014	− 0·044	−1424·260	+ 0·827	−1423·433
133	134	164·79	+ 0·001	− 0·043	−1394·789	+ 0·812	−1393·977
134	135	165·36	+ 0·004	− 0·039	−1426·400	+ 0·829	−1425·571
135	136	166·86	+ 0·009	− 0·030	−1427·579	+ 0·830	−1426·749
136	137	173·17	+ 0·045	+ 0·015	−1564·070	+ 0·901	−1563·169
137	138	174·02	+ 0·005	+ 0·020	−1567·123	+ 0·903	−1566·220
138	139	192·81	− 0·060	− 0·040	−1660·013	+ 0·951	−1659·062
139	140	201·04	+ 0·025	− 0·015	−1638·980	+ 0·940	−1638·040
140	141	201·44	+ 0·007	− 0·008	−1630·896	+ 0·936	−1629·960
141	142*	201·89	0·000	− 0·008	−1632·189	+ 0·937	−1631·252

Difference of dynamic height, Bangalore to Bellary = − 1631·252 feet.

Length of line in miles = M = 201·89. $\Sigma d^2 = 0{\cdot}032350$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\dfrac{\Sigma d^2}{4M}} = \pm\, 0{\cdot}0043.$

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\dfrac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0607.$

* Bench-mark No. 142 is the mark at Bellary described on page 133.

Line No. 20. Bezwada to Madras.

Bench-marks		Distance from Bezwada	Discrepancy between levellers (First—Second leveller)		Observed elevation above (+) or below (−) Bezwada (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Bezwada
From	To		From mark to mark (=d)	Total from Bezwada		Total from Bezwada	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·14	− 0·001	− 0·001	+ 0·044	0·000	+ 0·044
2	3	0·56	− 0·012	− 0·013	− 4·142	+ 0·002	− 4·140
3	4	1·39	− 0·029	− 0·042	+ 3·494	− 0·001	+ 3·493
4	5	2·12	+ 0·005	− 0·037	+ 4·387	− 0·001	+ 4·386
5	6	2·56	− 0·004	− 0·041	+ 2·224	0·000	+ 2·224
6	7	4·23	+ 0·031	− 0·010	+ 4·018	− 0·001	+ 4·017
7	8	5·13	+ 0·007	− 0·003	+ 25·366	− 0·011	+ 25·355
8	9	6·23	− 0·002	− 0·005	+ 40·753	− 0·018	+ 40·735
9	10	6·73	− 0·018	− 0·023	+ 34·289	− 0·015	+ 34·274
10	11	6·95	− 0·012	− 0·035	+ 31·001	− 0·014	+ 30·987
11	12	7·31	+ 0·004	− 0·031	+ 31·044	− 0·014	+ 31·030
12	13	8·61	− 0·007	− 0·038	+ 0·795	0·000	+ 0·795
13	14	10·56	+ 0·003	− 0·035	+ 4·034	− 0·001	+ 4·033
14	15	10·65	− 0·006	− 0·041	+ 7·929	− 0·003	+ 7·926
15	16	11·27	+ 0·001	− 0·040	− 3·561	+ 0·002	− 3·559
16	17	12·54	− 0·004	− 0·044	+ 27·563	− 0·012	+ 27·551
17	18	13·54	+ 0·005	− 0·039	+ 35·841	− 0·016	+ 35·825
18	19	14·54	− 0·007	− 0·046	+ 48·282	− 0·022	+ 48·260
19	20	16·49	+ 0·011	− 0·035	+ 12·713	− 0·006	+ 12·707
20	21	17·52	+ 0·017	− 0·018	+ 8·469	− 0·004	+ 8·465
21	22	18·50	0·000	− 0·018	+ 7·143	− 0·003	+ 7·140
22	23	19·49	+ 0·001	− 0·017	+ 11·491	− 0·005	+ 11·486
23	24	20·34	− 0·014	− 0·031	+ 24·161	− 0·011	+ 24·150
24	25	21·33	− 0·001	− 0·032	+ 20·417	− 0·009	+ 20·408
25	26	21·98	− 0·014	− 0·046	+ 28·501	− 0·013	+ 28·488
26	27	22·29	− 0·016	− 0·062	+ 25·396	− 0·012	+ 25·384
27	28	24·03	+ 0·012	− 0·050	+ 38·690	− 0·018	+ 38·672
28	29	24·97	+ 0·010	− 0·040	+ 35·839	− 0·017	+ 35·822
29	30	25·87	+ 0·002	− 0·038	+ 44·888	− 0·021	+ 44·867
30	31	26·95	− 0·023	− 0·061	+ 56·818	− 0·027	+ 56·791
31	32	28·17	− 0·019	− 0·080	+ 79·300	− 0·037	+ 79·263
32	33	28·76	− 0·004	− 0·084	+ 82·520	− 0·038	+ 82·482
33	34	29·27	+ 0·004	− 0·080	+ 76·360	− 0·035	+ 76·325
34	35	31·92	− 0·047	− 0·127	+ 77·693	− 0·036	+ 77·657
35	36	32·90	+ 0·015	− 0·112	+ 98·879	− 0·046	+ 98·833
36	37	33·29	0·000	− 0·112	+ 103·258	− 0·048	+ 103·210
37	38	33·93	+ 0·002	− 0·110	+ 97·965	− 0·046	+ 97·919
38	39	34·93	+ 0·007	− 0·103	+ 94·898	− 0·045	+ 94·853
39	40	35·91	− 0·017	− 0·120	+ 77·544	− 0·037	+ 77·507
40	41	36·27	− 0·003	− 0·123	+ 70·506	− 0·034	+ 70·472
41	42	36·91	− 0·012	− 0·135	+ 65·417	− 0·032	+ 65·385
42	43	37·91	− 0·008	− 0·143	+ 45·873	− 0·023	+ 45·850
43	44	38·91	+ 0·005	− 0·138	+ 16·406	− 0·009	+ 16·397
44	45	39·91	− 0·005	− 0·143	+ 18·368	− 0·010	+ 18·358
45	46	40·91	+ 0·001	− 0·142	+ 49·429	− 0·025	+ 49·404
46	47	41·77	+ 0·004	− 0·138	+ 59·066	− 0·030	+ 59·036
47	48	41·91	− 0·005	− 0·143	+ 59·567	− 0·030	+ 59·537
48	49	42·91	+ 0·011	− 0·132	+ 53·637	− 0·027	+ 53·610
49	50	43·92	+ 0·003	− 0·129	+ 21·387	− 0·012	+ 21·375
50	51	44·88	+ 0·002	− 0·127	+ 33·893	− 0·018	+ 33·875
51	52	45·89	− 0·026	− 0·153	+ 27·544	− 0·015	+ 27·529
52	53	46·89	− 0·026	− 0·179	+ 37·280	− 0·020	+ 37·260
53	54	47·88	− 0·018	− 0·197	+ 52·173	− 0·027	+ 52·146
54	55	48·85	+ 0·001	− 0·196	+ 53·270	− 0·028	+ 53·242
55	56	49·85	− 0·012	− 0·208	+ 29·152	− 0·017	+ 29·135
56	57	50·88	+ 0·011	− 0·197	+ 17·102	− 0·011	+ 17·091
57	58	51·86	− 0·009	− 0·206	+ 24·528	− 0·015	+ 24·513
58	59	52·85	+ 0·006	− 0·200	+ 42·295	− 0·024	+ 42·271
59	60	54·15	0·000	− 0·200	+ 69·543	− 0·037	+ 69·506
60	61	55·15	+ 0·008	− 0·192	+ 83·697	− 0·044	+ 83·653

* Bench-mark No. 1 is the mark at Bezwada described on page 133.

Line No. 20. Bezwada to Madras.—(Continued).

Bench-marks From	Bench-marks To	Distance from Bezwada	Discrepancy between levellers (First – Second leveller): From mark to mark (= *d*)	Discrepancy between levellers (First – Second leveller): Total from Bezwada	Observed elevation above (+) or below (–) Bezwada (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Bezwada	Dynamic height above (+) or below (–) Bezwada
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	56·15	+ 0·012	– 0·180	+115·901	– 0·059	+115·842
62	63	57·01	– 0·007	– 0·187	+ 92·330	– 0·048	+ 92·282
63	64	57·14	+ 0·001	– 0·186	+ 96·207	– 0·050	+ 96·157
64	65	58·14	+ 0·001	– 0·185	+113·970	– 0·059	+113·911
65	66	58·40	– 0·009	– 0·194	+113·696	– 0·059	+113·637
66	67	59·14	– 0·018	– 0·212	+110·730	– 0·057	+110·673
67	68	60·13	– 0·003	– 0·215	+135·508	– 0·069	+135·439
68	69	61·04	+ 0·014	– 0·201	+152·507	– 0·077	+152·430
69	70	62·05	– 0·016	– 0·217	+114·672	– 0·059	+114·613
70	71	63·06	– 0·029	– 0·246	+ 72·241	– 0·039	+ 72·202
71	72	64·07	– 0·011	– 0·257	+ 87·144	– 0·046	+ 87·098
72	73	64·35	+ 0·003	– 0·254	+ 66·171	– 0·036	+ 66·135
73	74	65·10	+ 0·013	– 0·241	+ 95·356	– 0·050	+ 95·306
74	75	66·10	– 0·007	– 0·248	+ 94·777	– 0·050	+ 94·727
75	76	67·11	0·000	– 0·248	+ 96·747	– 0·051	+ 96·696
76	77	68·12	0·000	– 0·248	+ 81·688	– 0·044	+ 81·644
77	78	69·13	+ 0·008	– 0·240	+ 97·577	– 0·052	+ 97·525
78	79	70·13	– 0·002	– 0·242	+ 87·359	– 0·047	+ 87·312
79	80	71·13	– 0·003	– 0·245	+ 66·578	– 0·037	+ 66·541
80	81	72·14	– 0·012	– 0·257	+ 70·274	– 0·039	+ 70·235
81	82	73·15	– 0·011	– 0·268	+ 73·668	– 0·041	+ 73·627
82	83	74·16	– 0·011	– 0·279	+ 45·666	– 0·027	+ 45·639
83	84	75·16	– 0·011	– 0·290	+ 20·064	– 0·014	+ 20·050
84	85	76·12	+ 0·016	– 0·274	+ 18·270	– 0·013	+ 18·257
85	86	77·17	– 0·002	– 0·276	+ 22·370	– 0·015	+ 22·355
86	87	78·17	– 0·001	– 0·277	– 3·793	– 0·002	– 3·795
87	88	78·83	+ 0·010	– 0·267	– 11·299	+ 0·002	– 11·297
88	89	79·17	– 0·006	– 0·273	– 14·323	+ 0·004	– 14·319
89	90	80·16	– 0·015	– 0·288	– 18·456	+ 0·006	– 18·450
90	91	81·16	– 0·018	– 0·306	– 18·788	+ 0·006	– 18·782
91	92	82·16	+ 0·007	– 0·299	– 21·267	+ 0·007	– 21·260
92	93	83·16	+ 0·005	– 0·294	– 29·559	+ 0·011	– 29·548
93	94	84·16	– 0·002	– 0·296	– 33·561	+ 0·013	– 33·548
94	95	85·16	+ 0·011	– 0·285	– 35·037	+ 0·014	– 35·023
95	96	86·16	+ 0·015	– 0·270	– 35·142	+ 0·014	– 35·128
96	97	87·16	– 0·011	– 0·281	– 38·091	+ 0·016	– 38·075
97	98	88·16	0·000	– 0·281	– 38·838	+ 0·016	– 38·822
98	99	89·17	+ 0·005	– 0·276	– 16·204	+ 0·005	– 16·199
99	100	90·17	– 0·025	– 0·301	– 35·456	+ 0·015	– 35·441
100	101	91·17	– 0·003	– 0·304	– 38·150	+ 0·016	– 38·134
101	102	92·17	– 0·014	– 0·318	– 32·225	+ 0·013	– 32·212
102	103	93·17	+ 0·019	– 0·299	– 41·184	+ 0·018	– 41·166
103	104	94·20	+ 0·013	– 0·286	– 39·104	+ 0·017	– 39·087
104	105	94·42	+ 0·006	– 0·280	– 35·769	+ 0·015	– 35·754
105	106	95·22	+ 0·002	– 0·278	– 41·998	+ 0·018	– 41·980
106	107	96·22	+ 0·007	– 0·271	– 39·795	+ 0·017	– 39·778
107	108	97·20	– 0·005	– 0·274	– 44·534	+ 0·019	– 44·515
108	109	98·31	– 0·011	– 0·287	– 44·537	+ 0·019	– 44·518
109	110	99·21	+ 0·007	– 0·280	– 47·996	+ 0·021	– 47·975
110	111	100·21	– 0·001	– 0·281	– 45·628	+ 0·020	– 45·608
111	112	101·21	0·000	– 0·281	– 47·739	+ 0·021	– 47·718
112	113	102·22	– 0·011	– 0·292	– 46·391	+ 0·020	– 46·371
113	114	103·24	+ 0·007	– 0·285	– 48·203	+ 0·021	– 48·182
114	115	104·23	+ 0·005	– 0·280	– 42·832	+ 0·018	– 42·814
115	116	105·23	+ 0·001	– 0·279	– 13·766	+ 0·003	– 13·763
116	117	106·23	+ 0·012	– 0·267	+ 15·206	– 0·012	+ 15·194
117	118	107·23	– 0·006	– 0·273	+ 1·251	– 0·005	+ 1·246
118	119	107·26	– 0·003	– 0·276	+ 3·773	– 0·006	+ 3·767
119	120	108·26	– 0·006	– 0·282	– 37·297	+ 0·015	– 37·282
120	121	110·26	– 0·035	– 0·317	– 45·117	+ 0·019	– 45·098

Line No. 20. Bezwada to Madras.—(Continued).

Bench-marks From	Bench-marks To	Distance from Bezwada	Discrepancy between levellers (First – Second leveller): From mark to mark (= *d*)	Discrepancy between levellers (First – Second leveller): Total from Bezwada	Observed elevation above (+) or below (–) Bezwada (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Bezwada	Dynamic height above (+) or below (–) Bezwada
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
121	122	111·26	– 0·006	– 0·323	– 47·461	+ 0·020	– 47·441
122	123	112·28	– 0·001	– 0·324	– 40·729	+ 0·017	– 40·712
123	124	113·28	– 0·005	– 0·329	– 34·805	+ 0·014	– 34·791
124	125	114·27	– 0·001	– 0·330	– 39·333	+ 0·016	– 39·317
125	126	115·28	+ 0·008	– 0·322	– 29·875	+ 0·011	– 29·864
126	127	116·28	– 0·018	– 0·340	– 37·629	+ 0·015	– 37·614
127	128	117·33	+ 0·006	– 0·334	– 49·068	+ 0·021	– 49·047
128	129	118·33	– 0·001	– 0·335	– 38·217	+ 0·015	– 38·202
129	130	119·33	+ 0·008	– 0·327	– 27·607	+ 0·010	– 27·597
130	131	120·33	+ 0·008	– 0·319	– 15·643	+ 0·004	– 15·639
131	132	120·56	+ 0·008	– 0·311	– 6·367	0·000	– 6·367
132	133	121·35	+ 0·003	– 0·308	+ 12·867	– 0·010	+ 12·857
133	134	122·35	– 0·001	– 0·309	– 7·009	0·000	– 7·009
134	135	123·35	+ 0·003	– 0·306	– 7·850	+ 0·001	– 7·849
135	136	124·35	+ 0·004	– 0·302	+ 1·962	– 0·004	+ 1·958
136	137	125·36	+ 0·006	– 0·296	– 7·566	+ 0·001	– 7·565
137	138	126·37	+ 0·005	– 0·291	– 32·297	+ 0·014	– 32·283
138	139	127·37	+ 0·003	– 0·288	– 28·122	+ 0·012	– 28·110
139	140	128·41	+ 0·009	– 0·279	– 32·062	+ 0·014	– 32·048
140	141	129·42	+ 0·018	– 0·261	– 25·216	+ 0·010	– 25·206
141	142	129·85	+ 0·011	– 0·250	– 22·856	+ 0·009	– 22·847
142	143	130·45	+ 0·003	– 0·247	– 21·772	+ 0·008	– 21·764
143	144	131·46	+ 0·010	– 0·237	– 25·726	+ 0·010	– 25·716
144	145	132·47	– 0·011	– 0·248	– 16·343	+ 0·005	– 16·338
145	146	133·49	– 0·012	– 0·260	– 38·518	+ 0·017	– 38·501
146	147	134·44	+ 0·008	– 0·252	– 40·391	+ 0·018	– 40·373
147	148	135·52	– 0·003	– 0·255	– 40·019	+ 0·018	– 40·001
148	149	136·53	– 0·006	– 0·261	– 40·901	+ 0·019	– 40·882
149	150	137·54	+ 0·007	– 0·254	– 39·639	+ 0·018	– 39·621
150	151	138·55	+ 0·005	– 0·249	– 42·200	+ 0·019	– 42·181
151	152	139·55	+ 0·016	– 0·233	– 47·028	+ 0·022	– 47·006
152	153	139·58	– 0·006	– 0·239	– 46·085	+ 0·021	– 46·064
153	154	140·59	+ 0·004	– 0·235	– 29·263	+ 0·012	– 29·251
154	155	141·60	+ 0·002	– 0·233	– 49·257	+ 0·023	– 49·234
155	156	142·65	+ 0·025	– 0·208	– 20·696	+ 0·008	– 20·688
156	157	143·65	– 0·010	– 0·218	– 44·805	+ 0·021	– 44·784
157	158	144·65	+ 0·004	– 0·214	– 42·314	+ 0·020	– 42·294
158	159	145·65	+ 0·032	– 0·182	– 32·132	+ 0·015	– 32·117
159	160	146·66	+ 0·005	– 0·177	– 13·398	+ 0·005	– 13·393
160	161	147·66	+ 0·007	– 0·170	+ 1·756	– 0·003	+ 1·753
161	162	148·67	– 0·012	– 0·182	+ 9·706	– 0·007	+ 9·699
162	163	149·67	+ 0·017	– 0·165	– 13·785	+ 0·006	– 13·779
163	164	150·67	+ 0·004	– 0·161	– 6·121	+ 0·002	– 6·119
164	165	151·67	+ 0·002	– 0·159	– 19·310	+ 0·009	– 19·301
165	166	152·56	+ 0·004	– 0·155	– 23·729	+ 0·011	– 23·718
166	167	152·70	0·000	– 0·155	– 18·940	+ 0·009	– 18·931
167	168	153·71	+ 0·013	– 0·142	– 14·629	+ 0·007	– 14·622
168	169	154·72	+ 0·001	– 0·141	– 16·151	+ 0·008	– 16·143
169	170	155·72	– 0·009	– 0·150	– 15·743	+ 0·008	– 15·735
170	171	156·71	– 0·009	– 0·159	– 17·308	+ 0·009	– 17·299
171	172	157·69	– 0·016	– 0·175	– 15·610	+ 0·008	– 15·602
172	173	158·68	– 0·005	– 0·180	– 10·911	+ 0·005	– 10·906
173	174	159·68	0·000	– 0·180	– 10·602	+ 0·005	– 10·597
174	175	160·05	+ 0·008	– 0·172	– 4·862	+ 0·002	– 4·860
175	176	160·66	– 0·010	– 0·182	– 13·416	+ 0·007	– 13·409
176	177	161·86	– 0·001	– 0·183	– 4·273	+ 0·002	– 4·271
177	178	162·21	+ 0·009	– 0·174	– 8·713	+ 0·004	– 8·709
178	179	162·57	– 0·008	– 0·182	– 8·617	+ 0·004	– 8·613
179	180	162·88	+ 0·004	– 0·178	– 9·766	+ 0·005	– 9·761
180	181	164·21	– 0·003	– 0·181	– 10·801	+ 0·006	– 10·795

Line No. 20. Bezwada to Madras.—(Continued).

Bench-marks From	Bench-marks To	Distance from Bezwada	Discrepancy between levellers (First – Second leveller). From mark to mark (= *d*)	Discrepancy between levellers (First – Second leveller). Total from Bezwada	Observed elevation above (+) or below (–) Bezwada (mean result by two levellers)	Dynamic correction deduced from mark to mark. Total from Bezwada	Dynamic height above (+) or below (–) Bezwada
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
181	182	165·20	– 0·001	– 0·182	+ 2·831	– 0·002	+ 2·829
182	183	166·19	+ 0·022	– 0·160	+ 25·232	– 0·003	+ 25·229
183	184	167·18	+ 0·005	– 0·155	+ 38·123	– 0·010	+ 38·113
184	185	168·17	+ 0·013	– 0·142	+ 5·157	+ 0·008	+ 5·165
185	186	169·16	+ 0·031	– 0·111	+ 5·747	+ 0·008	+ 5·755
186	187	170·15	+ 0·004	– 0·107	– 2·736	+ 0·012	– 2·724
187	188	171·14	+ 0·004	– 0·103	+ 5·988	+ 0·007	+ 5·995
188	189	172·13	+ 0·001	– 0·102	+ 9·449	+ 0·005	+ 9·454
189	190	173·12	+ 0·004	– 0·098	+ 0·971	+ 0·009	+ 0·980
190	191	174·12	+ 0·010	– 0·088	– 7·392	+ 0·013	– 7·379
191	192	175·11	+ 0·004	– 0·084	– 2·703	+ 0·010	– 2·693
192	193	176·12	+ 0·006	– 0·078	– 30·078	+ 0·025	– 30·053
193	194	177·11	– 0·010	– 0·088	– 38·340	+ 0·029	– 38·311
194	195	178·07	– 0·002	– 0·090	– 40·261	+ 0·030	– 40·231
195	196	179·09	– 0·004	– 0·094	– 40·851	+ 0·030	– 40·821
196	197	180·08	– 0·011	– 0·105	– 22·330	+ 0·020	– 22·310
197	198	181·07	– 0·001	– 0·106	– 6·765	+ 0·011	– 6·754
198	199	182·05	+ 0·013	– 0·093	– 8·275	+ 0·012	– 8·263
199	200	183·01	+ 0·027	– 0·066	– 30·744	+ 0·025	– 30·719
200	201	183·95	– 0·003	– 0·069	– 30·051	+ 0·025	– 30·026
201	202	184·90	+ 0·003	– 0·066	– 30·610	+ 0·025	– 30·585
202	203	185·90	0·000	– 0·066	– 31·070	+ 0·025	– 31·045
203	204	186·46	+ 0·006	– 0·060	– 28·870	+ 0·024	– 28·846
204	205	186·97	+ 0·003	– 0·057	– 30·480	+ 0·025	– 30·455
205	206	187·97	+ 0·001	– 0·056	– 30·185	+ 0·025	– 30·160
206	207	188·92	+ 0·011	– 0·045	– 34·672	+ 0·027	– 34·645
207	208	189·97	– 0·016	– 0·061	– 17·040	+ 0·017	– 17·023
208	209	190·97	– 0·010	– 0·071	– 31·667	+ 0·025	– 31·642
209	210	191·97	+ 0·013	– 0·058	– 20·963	+ 0·019	– 20·944
210	211	192·97	– 0·004	– 0·062	+ 13·386	0·000	+ 13·386
211	212	193·26	– 0·005	– 0·067	+ 17·823	– 0·002	+ 17·821
212	213	193·99	+ 0·005	– 0·062	+ 25·767	– 0·007	+ 25·760
213	214	195·00	+ 0·008	– 0·054	+ 41·267	– 0·016	+ 41·251
214	215	196·01	+ 0·014	– 0·040	+ 34·503	– 0·012	+ 34·491
215	216	197·01	+ 0·015	– 0·025	+ 45·003	– 0·018	+ 44·985
216	217	198·01	+ 0·021	– 0·004	+ 22·719	– 0·005	+ 22·714
217	218	199·01	+ 0·024	+ 0·020	+ 9·077	+ 0·003	+ 9·080
218	219	200·01	+ 0·002	+ 0·022	+ 10·648	+ 0·002	+ 10·650
219	220	201·01	+ 0·017	+ 0·039	+ 12·724	+ 0·001	+ 12·725
220	221	202·02	– 0·006	+ 0·033	+ 18·875	– 0·003	+ 18·872
221	222	203·02	– 0·007	+ 0·026	+ 24·943	– 0·007	+ 24·936
222	223	204·03	– 0·013	+ 0·013	+ 27·808	– 0·009	+ 27·799
223	224	205·02	+ 0·001	+ 0·014	+ 26·856	– 0·008	+ 26·848
224	225	206·02	– 0·005	+ 0·009	+ 39·703	– 0·015	+ 39·688
225	226	207·03	+ 0·011	+ 0·020	+ 47·759	– 0·020	+ 47·739
226	227	208·03	+ 0·006	+ 0·026	+ 47·235	– 0·020	+ 47·215
227	228	208·56	+ 0·002	+ 0·028	+ 58·506	– 0·026	+ 58·480
228	229	209·12	+ 0·015	+ 0·043	+ 42·837	– 0·017	+ 42·820
229	230	210·12	+ 0·001	+ 0·044	+ 44·643	– 0·018	+ 44·625
230	231	211·12	+ 0·003	+ 0·047	+ 33·538	– 0·012	+ 33·526
231	232	212·13	+ 0·020	+ 0·067	+ 18·490	– 0·003	+ 18·487
232	233	213·13	+ 0·010	+ 0·077	+ 5·608	+ 0·004	+ 5·612
233	234	214·14	+ 0·001	+ 0·078	– 21·056	+ 0·019	– 21·037
234	235	215·15	– 0·005	+ 0·073	– 23·653	+ 0·021	– 23·632
235	236	216·15	+ 0·023	+ 0·096	– 29·274	+ 0·024	– 29·250
236	237	217·15	+ 0·024	+ 0·120	– 31·243	+ 0·025	– 31·218
237	238	218·15	– 0·001	+ 0·119	– 35·730	+ 0·027	– 35·703
238	239	219·15	– 0·012	+ 0·107	– 42·745	+ 0·031	– 42·714
239	240	220·16	– 0·018	+ 0·089	– 42·051	+ 0·031	– 42·020
240	241	221·16	+ 0·022	+ 0·111	– 44·137	+ 0·032	– 44·105

Line No. 20. Bezwada to Madras.—(Continued).

Bench-marks From	Bench-marks To	Distance from Bezwada	Discrepancy between levellers (First − Second leveller): From mark to mark (= d)	Discrepancy between levellers (First − Second leveller): Total from Bezwada	Observed elevation above (+) or below (−) Bezwada (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Bezwada	Dynamic height above (+) or below (−) Bezwada
		miles	foot	foot	feet	foot	feet
241	242	221·88	+ 0·016	+ 0·127	− 42·220	+ 0·031	− 42·189
242	243	223·14	+ 0·005	+ 0·132	− 52·510	+ 0·037	− 52·473
243	244	224·15	− 0·001	+ 0·131	− 39·885	+ 0·030	− 39·855
244	245	225·16	+ 0·002	+ 0·133	− 47·087	+ 0·034	− 47·053
245	246	226·16	− 0·005	+ 0·128	− 43·623	+ 0·032	− 43·591
246	247	227·16	+ 0·019	+ 0·147	− 51·567	+ 0·037	− 51·530
247	248	228·17	+ 0·006	+ 0·153	− 53·405	+ 0·038	− 53·367
248	249	229·18	+ 0·002	+ 0·155	− 25·680	+ 0·022	− 25·658
249	250	230·19	0·000	+ 0·155	− 36·209	+ 0·028	− 36·181
250	251	231·20	− 0·019	+ 0·136	− 34·034	+ 0·027	− 34·007
251	252	232·21	− 0·024	+ 0·112	− 23·136	+ 0·020	− 23·116
252	253	234·22	+ 0·009	+ 0·121	− 41·906	+ 0·031	− 41·875
253	254	235·22	− 0·016	+ 0·105	− 33·782	+ 0·026	− 33·756
254	255	236·16	0·000	+ 0·105	− 42·323	+ 0·031	− 42·292
255	256	237·16	− 0·003	+ 0·102	− 50·910	+ 0·036	− 50·874
256	257	238·16	− 0·003	+ 0·099	− 54·597	+ 0·038	− 54·559
257	258	239·16	+ 0·007	+ 0·106	− 51·882	+ 0·036	− 51·846
258	259	240·16	− 0·005	+ 0·101	− 20·931	+ 0·018	− 20·913
259	260	241·16	+ 0·020	+ 0·121	− 18·049	+ 0·016	− 18·033
260	261	242·16	− 0·007	+ 0·114	− 15·359	+ 0·014	− 15·345
261	262	243·16	− 0·012	+ 0·102	− 13·201	+ 0·013	− 13·188
262	263	244·16	− 0·008	+ 0·094	− 18·651	+ 0·016	− 18·635
263	264	244·36	− 0·002	+ 0·092	− 21·097	+ 0·017	− 21·080
264	265	245·26	+ 0·016	+ 0·108	− 20·445	+ 0·017	− 20·428
265	266	246·26	− 0·008	+ 0·100	− 18·477	+ 0·016	− 18·461
266	267	247·26	− 0·001	+ 0·099	− 18·876	+ 0·016	− 18·860
267	268	248·26	+ 0·018	+ 0·117	− 20·152	+ 0·017	− 20·135
268	269	249·26	− 0·008	+ 0·109	− 18·318	+ 0·016	− 18·302
269	270	249·44	+ 0·009	+ 0·118	− 12·468	+ 0·012	− 12·456
270	271	250·27	− 0·004	+ 0·114	− 22·845	+ 0·018	− 22·827
271	272	251·27	− 0·013	+ 0·101	− 21·120	+ 0·017	− 21·103
272	273	252·27	+ 0·016	+ 0·117	− 17·882	+ 0·015	− 17·867
273	274	253·28	+ 0·027	+ 0·144	− 18·405	+ 0·015	− 18·390
274	275	255·27	+ 0·042	+ 0·186	− 17·250	+ 0·014	− 17·236
275	276	256·25	+ 0·003	+ 0·189	− 13·191	+ 0·012	− 13·179
276	277	257·25	− 0·003	+ 0·186	− 21·910	+ 0·017	− 21·893
277	278	258·24	+ 0·002	+ 0·188	− 25·865	+ 0·019	− 25·846
278	279	260·35	+ 0·014	+ 0·202	− 26·710	+ 0·020	− 26·690
279	280	261·24	− 0·021	+ 0·181	− 38·740	+ 0·027	− 38·713
280	281	262·24	+ 0·009	+ 0·190	− 17·305	+ 0·014	− 17·291
281	282	263·24	− 0·023	+ 0·167	− 36·072	+ 0·025	− 36·047
282	283	264·23	− 0·032	+ 0·135	− 42·250	+ 0·029	− 42·221
283	284	265·22	+ 0·009	+ 0·144	− 45·604	+ 0·031	− 45·573
284	285	266·67	− 0·007	+ 0·137	− 46·127	+ 0·031	− 46·096
285	286	270·25	− 0·004	+ 0·133	− 32·867	+ 0·023	− 32·844
286	287	273·45	+ 0·007	+ 0·140	− 49·178	+ 0·033	− 49·145
287	288	275·95	− 0·010	+ 0·130	− 51·443	+ 0·034	− 51·409
288	289	276·78	+ 0·006	+ 0·136	− 50·651	+ 0·033	− 50·618
289	290	277·03	− 0·001	+ 0·135	− 51·088	+ 0·033	− 51·055
290	291*	277·07	+ 0·003	+ 0·138	− 50·006	+ 0·032	− 49·974

Difference of dynamic height, Bezwada to Madras = − 49·974 feet.

Length of line in miles = M = 277·07. $\Sigma d^2 = 0 \cdot 041268$.

Probable error of the mean result per mile of double-levelling $= 0 \cdot 6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0 \cdot 0040$.

Probable error of the difference of elevation between the terminal bench-marks $= 0 \cdot 6745 \sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0 \cdot 0685$.

* Bench-mark No. 291 is the mark at Madras described on page 135.

Line No. 21. Raichur to Gooty.

Bench-marks		Distance from Raichur	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Raichur (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Raichur
From	To		From mark to mark (=*d*)	Total from Raichur		Total from Raichur	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	1·55	− 0·012	− 0·012	− 23·402	+ 0·011	− 23·391
2	3	3·23	+ 0·010	− 0·002	+ 4·350	− 0·002	+ 4·348
3	4	4·26	− 0·004	− 0·006	− 9·498	+ 0·005	− 9·493
4	5	5·01	+ 0·014	+ 0·008	− 13·166	+ 0·007	− 13·159
5	6	6·85	− 0·032	− 0·024	− 47·232	+ 0·023	− 47·209
6	7	11·22	+ 0·023	− 0·001	− 84·828	+ 0·041	− 84·787
7	8	17·66	− 0·031	− 0·032	− 180·669	+ 0·087	− 180·582
8	9	20·81	− 0·005	− 0·037	− 225·948	+ 0·109	− 225·839
9	10	21·33	0·000	− 0·037	− 228·320	+ 0·110	− 228·210
10	11	23·48	− 0·011	− 0·048	− 195·155	+ 0·094	− 195·061
11	12	25·13	+ 0·007	− 0·041	− 141·462	+ 0·068	− 141·394
12	13	26·48	+ 0·006	− 0·035	− 129·768	+ 0·062	− 129·706
13	14	28·99	+ 0·035	0·000	− 72·172	+ 0·034	− 72·138
14	15	30·44	+ 0·019	+ 0·019	− 36·299	+ 0·017	− 36·282
15	16	32·14	+ 0·010	+ 0·029	− 29·070	+ 0·013	− 29·057
16	17	33·28	+ 0·009	+ 0·038	− 6·561	+ 0·002	− 6·559
17	18	34·86	− 0·025	+ 0·013	− 11·553	+ 0·005	− 11·547
18	19	37·39	+ 0·006	+ 0·019	+ 40·943	− 0·021	+ 40·922
19	20	37·51	0·000	+ 0·019	+ 37·784	− 0·019	+ 37·765
20	21	37·87	− 0·006	+ 0·013	+ 35·171	− 0·018	+ 35·153
21	22	42·67	+ 0·007	+ 0·020	+ 51·117	− 0·026	+ 51·091
22	23	46·05	+ 0·027	+ 0·047	+ 53·168	− 0·027	+ 53·141
23	24	46·34	+ 0·002	+ 0·049	+ 56·462	− 0·029	+ 56·433
24	25	46·43	+ 0·004	+ 0·053	+ 51·781	− 0·027	+ 51·754
25	26	48·78	− 0·015	+ 0·038	+ 57·727	− 0·030	+ 57·697
26	27	50·29	+ 0·010	+ 0·048	+ 91·556	− 0·047	+ 91·509
27	28	52·02	− 0·005	+ 0·043	+ 90·778	− 0·047	+ 90·731
28	29	55·16	+ 0·016	+ 0·059	+ 136·270	− 0·070	+ 136·200
29	30	56·12	+ 0·009	+ 0·068	+ 159·872	− 0·082	+ 159·790
30	31	58·65	+ 0·021	+ 0·089	+ 183·680	− 0·094	+ 183·586
31	32	59·89	− 0·001	+ 0·088	+ 173·766	− 0·089	+ 173·677
32	33	61·14	0·000	+ 0·088	+ 209·232	− 0·107	+ 209·125
33	34	65·78	− 0·007	+ 0·081	+ 223·131	− 0·114	+ 223·017
34	35	69·36	− 0·015	+ 0·066	+ 213·631	− 0·109	+ 213·522
35	36	70·16	+ 0·008	+ 0·074	+ 234·145	− 0·120	+ 234·025
36	37	70·97	+ 0·006	+ 0·080	+ 232·109	− 0·119	+ 231·990
37	38	72·76	− 0·006	+ 0·074	+ 243·551	− 0·125	+ 243·426
38	39	74·03	− 0·002	+ 0·072	+ 221·265	− 0·114	+ 221·151
39	40	75·74	− 0·003	+ 0·069	+ 230·171	− 0·119	+ 230·052
40	41	78·59	− 0·003	+ 0·066	+ 162·601	− 0·084	+ 162·517
41	42	80·27	+ 0·004	+ 0·070	+ 109·160	− 0·057	+ 109·103
42	43	80·59	− 0·002	+ 0·068	+ 101·912	− 0·053	+ 101·859
43	44	80·67	− 0·004	+ 0·064	+ 101·340	− 0·053	+ 101·287
44	45	81·99	− 0·002	+ 0·062	+ 46·591	− 0·025	+ 46·566
45	46	82·69	− 0·005	+ 0·057	+ 31·774	− 0·017	+ 31·757
46	47	83·90	− 0·004	+ 0·053	+ 4·910	− 0·003	+ 4·907
47	48	84·15	− 0·004	+ 0·049	− 1·256	0·000	− 1·256
48	49	85·04	0·000	+ 0·049	− 19·733	+ 0·009	− 19·724
49	50	85·38	+ 0·005	+ 0·054	− 24·785	+ 0·012	− 24·773
50	51	86·30	− 0·001	+ 0·053	− 34·226	+ 0·017	− 34·209
51	52	87·51	+ 0·009	+ 0·062	− 48·042	+ 0·024	− 48·018
52	53	89·11	0·000	+ 0·062	− 76·872	+ 0·039	− 76·833
53	54	89·85	− 0·005	+ 0·057	− 91·503	+ 0·047	− 91·456
54	55	90·89	− 0·014	+ 0·043	− 90·938	+ 0·047	− 90·891
55	56	92·59	− 0·010	+ 0·033	− 72·536	+ 0·038	− 72·498

* Bench-mark No. 1 is the mark at Raichur described on page 135.

Line No. 21. Raichur to Gooty.—(Continued).

Bench-marks		Distance from Raichur	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Raichur (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Raichur
From	To		From mark to mark (=d)	Total from Raichur		Total from Raichur	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
56	57	94·97	– 0·003	+ 0·030	– 109·330	+ 0·057	– 109·273
57	58	95·95	– 0·004	+ 0·026	– 108·567	+ 0·057	– 108·510
58	59	96·27	– 0·003	+ 0·023	– 105·843	+ 0·056	– 105·787
59	60*	96·45	– 0·007	+ 0·016	– 110·433	+ 0·058	– 110·375

Difference of dynamic height, Raichur to Gooty = – 110·375 feet.

Length of line in miles = M = 96·45. Σd^2 = 0·008632.

Probable error of the mean result per mile of double-levelling $= 0 \cdot 6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm 0 \cdot 0032$.

Probable error of the difference of elevation between the terminal bench-marks $= 0 \cdot 6745 \sqrt{\frac{\Sigma d^2}{4}} = \pm 0 \cdot 0313$.

* Bench-mark No. 60 is the mark at Gooty described on page 134.

Line No. 22. Gulbarga to Raichur.

Bench-marks		Distance from Gulbarga	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Gulbarga (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Gulbarga
From	To		From mark to mark (= d)	Total from Gulbarga		Total from Gulbarga	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·15	– 0·001	– 0·001	+ 0·349	0·000	+ 0·349
2	3	0·65	– 0·004	– 0·005	– 12·877	+ 0·005	– 12·872
3	4	2·34	– 0·003	– 0·008	– 27·797	+ 0·011	– 27·786
4	5	4·17	– 0·013	– 0·021	+ 38·109	– 0·016	+ 38·093
5	6	6·33	– 0·007	– 0·028	– 3·275	+ 0·001	– 3·274
6	7	8·47	– 0·028	– 0·056	– 68·091	+ 0·028	– 68·063
7	8	9·57	– 0·022	– 0·078	– 104·405	+ 0·043	– 104·362
8	9	11·07	+ 0·003	– 0·075	– 122·999	+ 0·051	– 122·948
9	10	12·22	+ 0·010	– 0·065	– 146·461	+ 0·060	– 146·401
10	11	16·51	+ 0·026	– 0·039	– 180·444	+ 0·074	– 180·370
11	12	16·59	– 0·002	– 0·041	– 180·868	+ 0·074	– 180·794
12	13	17·23	– 0·018	– 0·059	– 186·505	+ 0·076	– 186·429
13	14	20·57	– 0·013	– 0·072	– 189·140	+ 0·077	– 189·063
14	15	22·96	+ 0·010	– 0·062	– 84·234	+ 0·033	– 84·201
15	16	23·07	+ 0·002	– 0·060	– 84·237	+ 0·033	– 84·204
16	17	24·46	– 0·037	– 0·097	– 114·092	+ 0·046	– 114·046
17	18	27·37	– 0·005	– 0·102	– 183·327	+ 0·075	– 183·252
18	19	28·28	+ 0·019	– 0·083	– 147·994	+ 0·060	– 147·934
19	20	28·84	+ 0·007	– 0·076	– 137·843	+ 0·056	– 137·787
20	21	29·89	– 0·007	– 0·083	– 163·933	+ 0·067	– 163·866
21	22	31·37	+ 0·016	– 0·067	– 164·600	+ 0·067	– 164·533
22	23	31·43	+ 0·002	– 0·065	– 168·306	+ 0·069	– 168·237
23	24	37·41	+ 0·018	– 0·047	– 191·163	+ 0·079	– 191·084
24	25	39·14	– 0·044	– 0·091	– 235·724	+ 0·098	– 235·626
25	26	42·45	+ 0·003	– 0·088	– 243·167	+ 0·101	– 243·066
26	27	43·79	+ 0·012	– 0·076	– 255·756	+ 0·106	– 255·650
27	28	45·92	+ 0·039	– 0·037	– 294·519	+ 0·123	– 294·396
28	29	46·07	– 0·001	– 0·038	– 299·054	+ 0·125	– 298·929
29	30	47·06	+ 0·004	– 0·034	– 294·455	+ 0·123	– 294·332
30	31	47·10	+ 0·004	– 0·030	– 291·271	+ 0·122	– 291·149
31	32	47·20	– 0·004	– 0·034	– 291·360	+ 0·122	– 291·238
32	33	54·09	– 0·005	– 0·039	– 281·266	+ 0·118	– 281·148
33	34	55·84	+ 0·024	– 0·015	– 284·738	+ 0·119	– 284·619
34	35	57·55	– 0·002	– 0·017	– 284·175	+ 0·119	– 284·056
35	36	60·30	+ 0·017	0·000	– 270·396	+ 0·113	– 270·283
36	37	61·54	+ 0·014	+ 0·014	– 260·928	+ 0·109	– 260·819
37	38	61·64	+ 0·001	+ 0·015	– 261·032	+ 0·109	– 260·923
38	39	66·80	– 0·012	+ 0·003	– 317·464	+ 0·134	– 317·330
39	40	68·74	0·000	+ 0·003	– 279·503	+ 0·117	– 279·386
40	41	70·88	+ 0·010	+ 0·013	– 312·725	+ 0·132	– 312·593
41	42	74·32	+ 0·042	+ 0·055	– 351·481	+ 0·150	– 351·331
42	43	74·55	+ 0·001	+ 0·056	– 350·429	+ 0·149	– 350·280
43	44	76·46	– 0·017	+ 0·039	– 357·447	+ 0·152	– 357·295
44	45	78·55	– 0·016	+ 0·023	– 308·438	+ 0·129	– 308·309
45	46	79·80	+ 0·006	+ 0·029	– 317·230	+ 0·133	– 317·097
46	47	80·85	– 0·014	+ 0·015	– 348·326	+ 0·147	– 348·179
47	48	83·96	+ 0·012	+ 0·027	– 268·680	+ 0·110	– 268·570
48	49	84·41	+ 0·001	+ 0·028	– 258·478	+ 0·105	– 258·373
49	50	88·31	+ 0·013	+ 0·041	– 202·852	+ 0·079	– 202·773
50	51†	89·86	+ 0·012	+ 0·053	– 179·450	+ 0·068	– 179·382

Difference of dynamic height, Gulbarga to Raichur = – 179·382 feet.

Length of line in mile = M = 89·86. $\Sigma d^2 = 0{\cdot}013329$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\dfrac{\Sigma d^2}{4\mathrm{M}}} = \pm\, 0{\cdot}0041$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\dfrac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0389$.

* Bench-mark No. 1 is the mark at Gulbarga described on page 134. † Bench-mark No. 51 is the mark at Raichur described on page 135.

Line No. 23. Bellary to Raichur.

Bench-marks		Distance from Bellary	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Bellary (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Bellary
From	To		From mark to mark (= d)	Total from Bellary		Total from Bellary	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·45	0·000	0·000	+ 1·293	– 0·001	+ 1·292
2	3	2·39	0·000	0·000	– 24·464	+ 0·012	– 24·452
3	4	4·44	– 0·020	– 0·020	– 25·320	+ 0·013	– 25·307
4	5	6·60	– 0·015	– 0·035	– 75·351	+ 0·039	– 75·312
5	6	7·60	– 0·013	– 0·048	– 79·346	+ 0·041	– 79·305
6	7	10·38	+ 0·012	– 0·036	– 165·076	+ 0·085	– 164·991
7	8	11·47	+ 0·021	– 0·015	– 170·324	+ 0·088	– 170·236
8	9	16·58	– 0·004	– 0·019	– 161·184	+ 0·083	– 161·101
9	10	18·53	– 0·004	– 0·023	– 131·683	+ 0·068	– 131·615
10	11	19·54	– 0·010	– 0·033	– 105·172	+ 0·054	– 105·118
11	12	21·63	– 0·002	– 0·035	– 138·176	+ 0·071	– 138·105
12	13	22·63	– 0·006	– 0·041	– 119·182	+ 0·061	– 119·121
13	14	24·64	– 0·011	– 0·052	– 73·562	+ 0·038	– 73·524
14	15	25·50	+ 0·011	– 0·041	– 42·859	+ 0·023	– 42·836
15	16	26·50	– 0·002	– 0·043	– 33·367	+ 0·018	– 33·349
16	17	28·63	+ 0·001	– 0·042	+ 24·612	– 0·011	+ 24·601
17	18	29·54	– 0·019	– 0·061	+ 41·060	– 0·019	+ 41·041
18	19	31·33	– 0·019	– 0·080	+ 40·518	– 0·019	+ 40·499
19	20	33·53	+ 0·018	– 0·062	– 74·971	+ 0·039	– 74·932
20	21	35·58	+ 0·027	– 0·035	– 77·462	+ 0·040	– 77·422
21	22	36·86	+ 0·012	– 0·023	– 139·530	+ 0·071	– 139·459
22	23	38·69	– 0·002	– 0·025	– 158·812	+ 0·081	– 158·731
23	24	39·01	– 0·001	– 0·026	– 141·302	+ 0·072	– 141·230
24	25	39·69	– 0·012	– 0·038	– 119·159	+ 0·061	– 119·098
25	26	40·18	+ 0·002	– 0·036	– 150·272	+ 0·077	– 150·195
26	27	40·70	– 0·001	– 0·037	– 166·929	+ 0·085	– 166·844
27	28	41·14	+ 0·005	– 0·032	– 155·926	+ 0·079	– 155·847
28	29	41·70	+ 0·009	– 0·023	– 146·141	+ 0·074	– 146·067
29	30	43·77	– 0·013	– 0·036	– 125·356	+ 0·064	– 125·292
30	31	44·48	+ 0·011	– 0·025	– 115·270	+ 0·059	– 115·211
31	32	44·83	– 0·015	– 0·040	– 128·311	+ 0·065	– 128·246
32	33	46·49	+ 0·006	– 0·034	– 133·269	+ 0·068	– 133·201
33	34	47·32	– 0·006	– 0·040	– 119·922	+ 0·062	– 119·860
34	35	48·07	+ 0·008	– 0·032	– 119·628	+ 0·062	– 119·566
35	36	48·45	– 0·003	– 0·035	– 106·529	+ 0·056	– 106·473
36	37	48·51	– 0·004	– 0·039	– 104·702	+ 0·055	– 104·647
37	38	49·09	– 0·007	– 0·046	– 84·087	+ 0·045	– 84·042
38	39	50·52	– 0·006	– 0·052	– 81·909	+ 0·044	– 81·865
39	40	50·82	+ 0·004	– 0·048	– 76·252	+ 0·041	– 76·211
40	41	53·68	+ 0·005	– 0·043	– 175·711	+ 0·090	– 175·621
41	42	54·68	+ 0·012	– 0·031	– 201·072	+ 0·102	– 200·970
42	43	55·69	+ 0·001	– 0·030	– 226·040	+ 0·114	– 225·926
43	44	57·57	+ 0·017	– 0·013	– 257·229	+ 0·129	– 257·100
44	45	58·70	+ 0·025	+ 0·012	– 262·545	+ 0·132	– 262·413
45	46	59·11	+ 0·006	+ 0·018	– 260·627	+ 0·131	– 260·496
46	47	59·70	+ 0·004	+ 0·022	– 265·791	+ 0·134	– 265·657
47	48	60·71	– 0·002	+ 0·020	– 273·603	+ 0·138	– 273·465
48	49	61·96	+ 0·004	+ 0·024	– 313·809	+ 0·157	– 313·652
49	50	62·72	+ 0·001	+ 0·025	– 328·434	+ 0·164	– 328·270
50	51	63·01	0·000	+ 0·025	– 324·826	+ 0·162	– 324·664
51	52	64·41	+ 0·009	+ 0·034	– 338·958	+ 0·169	– 338·789
52	53	64·73	– 0·002	+ 0·032	– 352·195	+ 0·175	– 352·020
53	54	65·88	+ 0·011	+ 0·043	– 366·741	+ 0·182	– 366·559
54	55	67·74	+ 0·002	+ 0·045	– 379·760	+ 0·188	– 379·572
55	56	68·40	– 0·002	+ 0·043	– 372·296	+ 0·184	– 372·112
56	57	69·89	+ 0·003	+ 0·046	– 402·874	+ 0·199	– 402·675
57	58	70·26	– 0·007	+ 0·039	– 409·848	+ 0·203	– 409·645
58	59	70·67	+ 0·003	+ 0·042	– 435·011	+ 0·215	– 434·796
59	60	71·95	– 0·012	+ 0·030	– 425·157	+ 0·210	– 424·947
60	61	72·96	– 0·005	+ 0·025	– 402·281	+ 0·199	– 402·082

* Bench-mark No. 1 is the mark at Bellary described on page 133.

Line No. 23. Bellary to Raichur.—(Continued).

Bench-marks From	Bench-marks To	Distance from Bellary	Discrepancy between levellers (First – Second leveller) From mark to mark (= d)	Discrepancy between levellers (First – Second leveller) Total from Bellary	Observed elevation above (+) or below (–) Bellary (mean result by two levellers)	Dynamic correction deduced from mark to mark Total from Bellary	Dynamic height above (+) or below (–) Bellary
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	73·97	+ 0·029	+ 0·054	–378·864	+ 0·188	–378·676
62	63	75·15	– 0·004	+ 0·050	–377·360	+ 0·187	–377·173
63	64	75·99	+ 0·007	+ 0·057	–369·084	+ 0·183	–368·901
64	65	78·00	+ 0·019	+ 0·076	–355·137	+ 0·176	–354·961
65	66	79·01	0·000	+ 0·076	–328·207	+ 0·163	–328·044
66	67	80·02	– 0·013	+ 0·063	–305·415	+ 0·152	–305·263
67	68	80·17	– 0·004	+ 0·059	–300·002	+ 0·150	–299·852
68	69	82·04	+ 0·003	+ 0·062	–283·296	+ 0·142	–283·154
69	70	88·10	+ 0·009	+ 0·071	–126·307	+ 0·068	–126·239
70	71	89·11	+ 0·003	+ 0·074	–129·822	+ 0·070	–129·752
71	72	90·89	– 0·017	+ 0·057	–155·609	+ 0·082	–155·527
72	73	91·05	+ 0·004	+ 0·061	–170·070	+ 0·089	–169·981
73	74*	91·19	+ 0·005	+ 0·066	–170·893	+ 0·090	–170·803

Difference of dynamic height, Bellary to Raichur = – 170·803 feet.

Length of line in miles = M = 91·19. $\Sigma d^2 = 0\cdot008242$.

Probable error of the mean result per mile of double-levelling $= 0\cdot6745\sqrt{\frac{\Sigma d^2}{M}} = \pm\ 0\cdot0032$.

Probable error of the difference of elevation between the terminal bench-marks $= 0\cdot6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0\cdot0306$.

* Bench-mark No. 74 is the mark at Raichur described on page 135.

Line No. 24. Gulbarga to Bezwada.

Bench-marks		Distance from Gulbarga	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Gulbarga (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Gulbarga
From	To		From mark to mark (= d)	Total from Gulbarga		Total from Gulbarga	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	1·55	0·000	0·000	+ 17·732	− 0·007	+ 17·725
2	3	1·88	+ 0·001	+ 0·001	+ 59·391	− 0·024	+ 59·367
3	4	2·09	− 0·010	− 0·009	+ 61·044	− 0·025	+ 61·019
4	5	13·75	0·000	− 0·009	− 32·941	+ 0·013	− 32·928
5	6	20·23	+ 0·026	+ 0·017	+ 73·689	− 0·029	+ 73·660
6	7	21·92	+ 0·002	+ 0·019	+ 85·552	− 0·034	+ 85·518
7	8	22·35	+ 0·011	+ 0·030	+ 117·743	− 0·047	+ 117·696
8	9	23·35	− 0·001	+ 0·029	+ 133·423	− 0·053	+ 133·370
9	10	26·51	+ 0·058	+ 0·087	+ 585·247	− 0·230	+ 585·017
10	11	28·57	− 0·006	+ 0·081	+ 424·593	− 0·167	+ 424·426
11	12	31·04	− 0·024	+ 0·057	+ 359·066	− 0·141	+ 358·925
12	13	31·69	+ 0·022	+ 0·079	+ 424·729	− 0·167	+ 424·562
13	14	32·70	+ 0·005	+ 0·084	+ 424·356	− 0·167	+ 424·189
14	15	35·73	+ 0·096	+ 0·180	+ 675·663	− 0·265	+ 675·398
15	16	36·73	+ 0·005	+ 0·185	+ 619·105	− 0·243	+ 618·862
16	17	38·34	− 0·010	+ 0·175	+ 595·893	− 0·234	+ 595·659
17	18	38·74	− 0·019	+ 0·156	+ 565·573	− 0·222	+ 565·351
18	19	39·40	− 0·017	+ 0·139	+ 551·547	− 0·216	+ 551·331
19	20	39·72	− 0·007	+ 0·132	+ 560·201	− 0·220	+ 559·981
20	21	40·14	− 0·001	+ 0·131	+ 596·509	− 0·234	+ 596·275
21	22	41·58	− 0·003	+ 0·128	+ 534·948	− 0·211	+ 534·737
22	23	41·80	− 0·004	+ 0·124	+ 531·798	− 0·210	+ 531·588
23	24	43·93	− 0·023	+ 0·101	+ 497·576	− 0·197	+ 497·379
24	25	45·61	− 0·029	+ 0·072	+ 480·760	− 0·190	+ 480·570
25	26	46·91	+ 0·001	+ 0·073	+ 479·111	− 0·189	+ 479·022
26	27	47·61	+ 0·025	+ 0·098	+ 543·916	− 0·214	+ 543·802
27	28	48·61	+ 0·017	+ 0·115	+ 533·599	− 0·210	+ 533·389
28	29	48·84	− 0·016	+ 0·099	+ 516·186	− 0·203	+ 515·983
29	30	49·55	− 0·017	+ 0·082	+ 472·227	− 0·186	+ 472·041
30	31	50·94	− 0·013	+ 0·069	+ 438·176	− 0·173	+ 438·003
31	32	51·96	− 0·015	+ 0·054	+ 470·097	− 0·185	+ 469·912
32	33	56·98	+ 0·041	+ 0·095	+ 437·037	− 0·172	+ 436·865
33	34	60·21	+ 0·036	+ 0·131	+ 554·257	− 0·217	+ 554·040
34	35	62·34	+ 0·003	+ 0·134	+ 558·274	− 0·219	+ 558·055
35	36	64·10	+ 0·003	+ 0·137	+ 551·605	− 0·216	+ 551·389
36	37	66·00	− 0·019	+ 0·118	+ 542·384	− 0·212	+ 542·172
37	38	67·75	− 0·025	+ 0·093	+ 635·533	− 0·247	+ 635·286
38	39	71·39	+ 0·022	+ 0·115	+ 715·421	− 0·277	+ 715·144
39	40	71·89	+ 0·009	+ 0·124	+ 713·711	− 0·276	+ 713·435
40	41	75·09	+ 0·003	+ 0·127	+ 657·809	− 0·255	+ 657·554
41	42	81·92	+ 0·003	+ 0·130	+ 560·648	− 0·218	+ 560·430
42	43	83·98	+ 0·015	+ 0·145	+ 543·427	− 0·211	+ 543·216
43	44	86·06	+ 0·011	+ 0·156	+ 529·772	− 0·206	+ 529·566
44	45	89·79	− 0·006	+ 0·150	+ 464·972	− 0·181	+ 464·791
45	46	97·17	+ 0·004	+ 0·154	+ 350·635	− 0·137	+ 350·498
46	47	97·18	0·000	+ 0·154	+ 346·986	− 0·136	+ 346·850
47	48	100·79	+ 0·012	+ 0·166	+ 415·523	− 0·163	+ 415·360
48	49	103·84	− 0·017	+ 0·149	+ 369·023	− 0·145	+ 368·878
49	50	104·10	− 0·001	+ 0·148	+ 345·385	− 0·136	+ 345·249
50	51	105·10	+ 0·007	+ 0·155	+ 285·557	− 0·113	+ 285·444
51	52	106·10	+ 0·017	+ 0·172	+ 258·381	− 0·102	+ 258·279
52	53	106·51	+ 0·011	+ 0·183	+ 270·898	− 0·107	+ 270·791
53	54	107·54	+ 0·019	+ 0·202	+ 315·201	− 0·124	+ 315·077
54	55	108·10	+ 0·004	+ 0·206	+ 274·212	− 0·108	+ 274·104
55	56	109·10	− 0·004	+ 0·202	+ 278·665	− 0·110	+ 278·555
56	57	110·45	− 0·001	+ 0·201	+ 268·945	− 0·106	+ 268·839
57	58	111·13	+ 0·001	+ 0·202	+ 248·695	− 0·098	+ 248·597
58	59	114·13	− 0·006	+ 0·196	+ 201·832	− 0·080	+ 201·752
59	60	115·13	+ 0·014	+ 0·210	+ 232·001	− 0·092	+ 231·909
60	61	116·41	+ 0·007	+ 0·217	+ 198·808	− 0·079	+ 198·729

* Bench-mark No. 1 is the mark at Gulbarga described on page 134.

Line No. 24. Gulbarga to Bezwada.—(Continued).

Bench-marks		Distance from Gulbarga	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Gulbarga (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Gulbarga
From	To		From mark to mark (= *d*)	Total from Gulbarga		Total from Gulbarga	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	117·64	– 0·012	+ 0·205	+ 261·882	– 0·104	+ 261·778
62	63	120·10	+ 0·020	+ 0·225	+ 217·691	– 0·087	+ 217·604
63	64	120·38	+ 0·004	+ 0·229	+ 250·129	– 0·100	+ 250·029
64	65	121·13	– 0·006	+ 0·223	+ 232·379	– 0·093	+ 232·286
65	66	122·13	+ 0·004	+ 0·227	+ 250·713	– 0·102	+ 255·611
66	67	123·13	+ 0·010	+ 0·237	+ 249·567	– 0·100	+ 249·467
67	68	125·13	– 0·011	+ 0·226	+ 241·192	– 0·097	+ 241·095
68	69	127·10	+ 0·016	+ 0·242	+ 244·734	– 0·098	+ 244·636
69	70	127·53	+ 0·004	+ 0·246	+ 255·681	– 0·102	+ 255·579
70	71	128·11	+ 0·006	+ 0·252	+ 254·526	– 0·102	+ 254·424
71	72	129·76	+ 0·010	+ 0·262	+ 224·654	– 0·090	+ 224·764
72	73	131·14	– 0·006	+ 0·256	+ 249·413	– 0·100	+ 249·313
73	74	131·73	+ 0·003	+ 0·259	+ 275·238	– 0·110	+ 275·128
74	75	133·15	– 0·011	+ 0·248	+ 309·399	– 0·124	+ 309·275
75	76	136·66	+ 0·047	+ 0·295	+ 348·172	– 0·140	+ 348·032
76	77	136·71	0·000	+ 0·295	+ 344·231	– 0·138	+ 344·093
77	78	138·13	0·000	+ 0·295	+ 342·659	– 0·137	+ 342·522
78	79	139·38	+ 0·005	+ 0·300	+ 381·291	– 0·152	+ 381·139
79	80	140·38	– 0·002	+ 0·298	+ 446·201	– 0·178	+ 446·023
80	81	141·38	0·000	+ 0.298	+ 491·857	– 0·196	+ 491·661
81	82	142·38	– 0·007	+ 0·291	+ 458·912	– 0·183	+ 458·729
82	83	143·38	+ 0·012	+ 0·303	+ 388·574	– 0·155	+ 388·419
83	84	144·37	+ 0·022	+ 0·325	+ 321·365	– 0·128	+ 321·237
84	85	146·37	+ 0·063	+ 0·388	+ 278·116	– 0·111	+ 278·005
85	86	147·36	+ 0·020	+ 0·408	+ 255·826	– 0·102	+ 255·724
86	87	148·36	0·000	+ 0·408	+ 237·901	– 0·095	+ 237·806
87	88	149·57	+ 0·024	+ 0·432	+ 243·511	– 0·097	+ 243·414
88	89	149·58	+ 0·005	+ 0·437	+ 243·424	– 0·097	+ 243·327
89	90	150·00	– 0·004	+ 0·433	+ 215·718	– 0·086	+ 215·632
90	91	150·21	+ 0·004	+ 0·437	+ 226·609	– 0·090	+ 226·519
91	92	150·58	+ 0·011	+ 0·448	+ 218·032	– 0·087	+ 217·945
92	93	150·59	– 0·005	+ 0·443	+ 221·125	– 0·088	+ 221·037
93	94	151·26	– 0·006	+ 0·437	+ 206·791	– 0·082	+ 206·709
94	95	151·71	– 0·011	+ 0·426	+ 206·695	– 0·082	+ 206·613
95	96	152·52	– 0·021	+ 0·405	+ 211·872	– 0·084	+ 211·788
96	97	152·70	– 0·005	+ 0·400	+ 208·925	– 0·083	+ 208·842
97	98	154·80	– 0·010	+ 0·390	+ 133·786	– 0·053	+ 133·733
98	99	154·88	– 0·001	+ 0·389	+ 142·009	– 0·056	+ 141·953
99	100	155·67	+ 0·004	+ 0·393	+ 120·446	– 0·047	+ 120·399
100	101	157·49	+ 0·041	+ 0·434	+ 138·862	– 0·054	+ 138·808
101	102	157·82	+ 0·003	+ 0·437	+ 148·851	– 0·058	+ 148·793
102	103	159·22	– 0·001	+ 0·436	+ 138·556	– 0·054	+ 138·502
103	104	160·22	– 0·006	+ 0·430	+ 171·713	– 0·068	+ 171·645
104	105	161·22	+ 0·008	+ 0·438	+ 198·484	– 0·079	+ 198·405
105	106	162·22	+ 0·005	+ 0·443	+ 230·567	– 0·092	+ 230·475
106	107	163·22	– 0·002	+ 0·441	+ 216·342	– 0·086	+ 216·256
107	108	164·22	– 0·008	+ 0·433	+ 198·422	– 0·079	+ 198·343
108	109	165·22	+ 0·015	+ 0·448	+ 182·760	– 0·073	+ 182·687
109	110	166·23	+ 0·002	+ 0·450	+ 142·589	– 0·057	+ 142·532
110	111	167·08	+ 0·004	+ 0·454	+ 124·432	– 0·050	+ 124·382
111	112	167·09	0·000	+ 0·454	+ 126·466	– 0·051	+ 126·415
112	113	167·27	– 0·007	+ 0·447	+ 114·764	– 0·046	+ 114·718
113	114	168·27	– 0·011	+ 0·436	+ 140·464	– 0·057	+ 140·407
114	115	170·28	– 0·007	+ 0·429	+ 22·061	– 0·009	+ 22·052
115	116	171·28	+ 0·037	+ 0·466	– 43·364	+ 0·018	– 43·346
116	117	172·28	– 0·009	+ 0·457	– 52·685	+ 0·022	– 52·663
117	118	173·29	+ 0·036	+ 0·493	– 119·052	+ 0·049	– 119·003
118	119	174·02	+ 0·012	+ 0·505	– 152·344	+ 0·063	– 152·281
119	120	174·31	– 0·010	+ 0·495	– 135·378	+ 0·056	– 135·322
120	121	175·32	+ 0·010	+ 0·505	– 122·366	+ 0·051	– 122·315

Line No. 24. Gulbarga to Bezwada.—(Continued).

Bench-marks		Distance from Gulbarga	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Gulbarga (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Gulbarga
From	To		From mark to mark (=*d*)	Total from Gulbarga		Total from Gulbarga	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
121	122	175·54	– 0·001	+ 0·504	– 98·012	+ 0·041	– 97·971
122	123	176·33	– 0·012	+ 0·492	– 46·419	+ 0·020	– 46·399
123	124	177·34	– 0·021	+ 0·471	+ 20·192	– 0·007	+ 20·185
124	125	178·34	+ 0·017	+ 0·488	+ 0·933	+ 0·001	+ 0·934
125	126	179·34	+ 0·019	+ 0·507	– 22·707	+ 0·011	– 22·696
126	127	179·85	+ 0·010	+ 0·517	– 54·362	+ 0·024	– 54·338
127	128	180·34	– 0·019	+ 0·498	– 75·188	+ 0·033	– 75·155
128	129	181·33	+ 0·006	+ 0·504	– 127·462	+ 0·054	– 127·408
129	130	182·03	– 0·003	+ 0·501	– 138·659	+ 0·059	– 138·600
130	131	182·36	– 0·001	+ 0·500	– 133·706	+ 0·057	– 133·649
131	132	183·36	+ 0·011	+ 0·511	– 211·430	+ 0·089	– 211·341
132	133	184·36	+ 0·016	+ 0·527	– 259·157	+ 0·109	– 259·048
133	134	185·36	– 0·007	+ 0·520	– 306·064	+ 0·128	– 305·936
134	135	186·36	+ 0·004	+ 0·524	– 331·253	+ 0·138	– 331·115
135	136	187·36	+ 0·022	+ 0·546	– 358·633	+ 0·149	– 358·484
136	137	188·36	+ 0·017	+ 0·563	– 387·188	+ 0·161	– 387·027
137	138	189·36	+ 0·006	+ 0·569	– 422·962	+ 0·176	– 422·786
138	139	190·36	– 0·005	+ 0·564	– 437·741	+ 0·182	– 437·559
139	140	191·36	– 0·012	+ 0·552	– 438·729	+ 0·182	– 438·547
140	141	191·80	+ 0·002	+ 0·554	– 447·421	+ 0·186	– 447·235
141	142	191·81	+ 0·002	+ 0·556	– 446·822	+ 0·186	– 446·636
142	143	192·37	– 0·021	+ 0·535	– 425·632	+ 0·177	– 425·455
143	144	193·37	+ 0·002	+ 0·537	– 447·978	+ 0·186	– 447·792
144	145	194·37	+ 0·012	+ 0·549	– 409·383	+ 0·170	– 409·213
145	146	195·37	– 0·010	+ 0·539	– 390·260	+ 0·162	– 390·098
146	147	197·38	+ 0·004	+ 0·543	– 443·111	+ 0·184	– 442·927
147	148	198·38	+ 0·004	+ 0·547	– 426·288	+ 0·177	– 426·111
148	149	199·38	+ 0·005	+ 0·552	– 416·443	+ 0·173	– 416·270
149	150	200·38	+ 0·005	+ 0·557	– 458·882	+ 0·190	– 458·692
150	151	201·38	+ 0·013	+ 0·570	– 483·073	+ 0·200	– 482·873
151	152	202·38	+ 0·017	+ 0·587	– 509·570	+ 0·211	– 509·359
152	153	203·38	+ 0·015	+ 0·602	– 522·990	+ 0·216	– 522·774
153	154	204·38	+ 0·002	+ 0·604	– 551·182	+ 0·228	– 550·954
154	155	205·38	+ 0·004	+ 0·608	– 569·740	+ 0·236	– 569·504
155	156	206·38	– 0·007	+ 0·601	– 600·497	+ 0·249	– 600·248
156	157	207·38	– 0·007	+ 0·594	– 590·143	+ 0·245	– 589·898
157	158	208·38	– 0·009	+ 0·585	– 648·224	+ 0·269	– 647·955
158	159	209·39	+ 0·002	+ 0·587	– 674·762	+ 0·280	– 674·482
159	160	210·39	+ 0·010	+ 0·597	– 687·888	+ 0·285	– 687·603
160	161	211·39	– 0·001	+ 0·596	– 714·144	+ 0·296	– 713·848
161	162	212·39	+ 0·007	+ 0·603	– 729·877	+ 0·302	– 729·575
162	163	213·39	+ 0·006	+ 0·609	– 752·937	+ 0·311	– 752·626
163	164	214·39	– 0·007	+ 0·602	– 763·971	+ 0·316	– 763·655
164	165	215·40	+ 0·002	+ 0·604	– 757·676	+ 0·314	– 757·362
165	166	216·40	+ 0·020	+ 0·624	– 787·320	+ 0·326	– 786·994
166	167	217·43	+ 0·043	+ 0·667	– 793·349	+ 0·328	– 793·021
167	168	217·43	+ 0·003	+ 0·670	– 794·165	+ 0·328	– 793·837
168	169	217·47	0·000	+ 0·670	– 791·814	+ 0·327	– 791·487
169	170	218·47	+ 0·015	+ 0·685	– 804·790	+ 0·333	– 804·457
170	171	219·47	+ 0·009	+ 0·694	– 790·639	+ 0·327	– 790·312
171	172	220·48	+ 0·006	+ 0·700	– 781·901	+ 0·323	– 781·578
172	173	221·48	+ 0·007	+ 0·707	– 812·816	+ 0·336	– 812·480
173	174	222·48	+ 0·003	+ 0·710	– 829·536	+ 0·343	– 829·193
174	175	223·48	– 0·003	+ 0·707	– 824·839	+ 0·341	– 824·498
175	176	224·48	+ 0·012	+ 0·719	– 809·624	+ 0·335	– 809·289
176	177	225·48	+ 0·005	+ 0·724	– 820·304	+ 0·340	– 819·964
177	178	226·47	– 0·001	+ 0·723	– 854·584	+ 0·354	– 854·230
178	179	227·47	+ 0·010	+ 0·733	– 867·724	+ 0·360	– 867·364
179	180	227·62	+ 0·010	+ 0·743	– 879·520	+ 0·365	– 879·155
180	181	228·52	+ 0·005	+ 0·748	– 904·145	+ 0·375	– 903·770

Line No. 24. Gulbarga to Bezwada.—(Continued).

Bench-marks From	Bench-marks To	Distance from Gulbarga	Discrepancy between levellers (First – Second leveller) From mark to mark (=d)	Discrepancy between levellers (First – Second leveller) Total from Gulbarga	Observed elevation above (+) or below (–) Gulbarga (mean result by two levellers)	Dynamic correction deduced from mark to mark Total from Gulbarga	Dynamic height above (+) or below (–) Gulbarga
		miles	*foot*	*feet*	*feet*	*foot*	*feet*
181	182	229·55	+ 0·020	+ 0·768	– 942·548	+ 0·391	– 942·157
182	183	230·55	+ 0·023	+ 0·791	– 925·862	+ 0·384	– 925·478
183	184	231·55	+ 0·022	+ 0·813	– 945·220	+ 0·392	– 944·828
184	185	232·55	+ 0·011	+ 0·824	– 934·262	+ 0·387	– 933·875
185	186	233·55	– 0·007	+ 0·817	– 902·931	+ 0·374	– 902·557
186	187	234·55	+ 0·005	+ 0·822	– 935·537	+ 0·388	– 935·149
187	188	235·55	– 0·006	+ 0·816	– 919·352	+ 0·381	– 918·971
188	189	235·71	+ 0·002	+ 0·818	– 916·451	+ 0·380	– 916·071
189	190	236·00	– 0·008	+ 0·810	– 923·635	+ 0·383	– 923·252
190	191	236·58	+ 0·003	+ 0·813	– 927·027	+ 0·384	– 926·643
191	192	237·58	+ 0·007	+ 0·820	– 896·706	+ 0·371	– 896·335
192	193	238·58	+ 0·009	+ 0·829	– 875·728	+ 0·362	– 875·366
193	194	239·60	+ 0·008	+ 0·837	– 886·749	+ 0·367	– 886·382
194	195	240·58	0·000	+ 0·837	– 845·299	+ 0·350	– 844·949
195	196	241·59	– 0·007	+ 0·830	– 874·713	+ 0·362	– 874·351
196	197	242·59	+ 0·007	+ 0·837	– 890·840	+ 0·369	– 890·471
197	198	243·59	+ 0·010	+ 0·847	– 917·013	+ 0·380	– 916·633
198	199	244·56	0·000	+ 0·847	– 939·253	+ 0·389	– 938·864
199	200	245·54	+ 0·025	+ 0·872	– 949·405	+ 0·393	– 949·012
200	201	246·76	+ 0·017	+ 0·889	– 970·144	+ 0·402	– 970·342
201	202	247·76	+ 0·011	+ 0·900	– 987·482	+ 0·409	– 987·073
202	203	248·76	– 0·015	+ 0·885	–1002·642	+ 0·415	–1002·227
203	204	249·76	+ 0·021	+ 0·906	–1002·005	+ 0·415	–1001·590
204	205	250·75	– 0·006	+ 0·900	–1021·124	+ 0·423	–1020·701
205	206	251·93	+ 0·033	+ 0·933	–1004·543	+ 0·416	–1004·127
206	207	252·00	+ 0·005	+ 0·938	–1008·316	+ 0·418	–1007·898
207	208	253·00	– 0·005	+ 0·933	–1036·099	+ 0·430	–1035·669
208	209	254·00	+ 0·027	+ 0·960	–1042·719	+ 0·433	–1042·286
209	210	255·00	+ 0·009	+ 0·969	–1044·843	+ 0·434	–1044·409
210	211	256·00	+ 0·002	+ 0·971	–1034·581	+ 0·430	–1034·151
211	212	257·00	+ 0·002	+ 0·973	–1027·952	+ 0·427	–1027·525
212	213	258·00	+ 0·012	+ 0·985	–1055·435	+ 0·438	–1054·997
213	214	259·00	+ 0·019	+ 1·004	–1064·461	+ 0·442	–1064·019
214	215	260·00	+ 0·008	+ 1·012	–1094·506	+ 0·455	–1094·051
215	216	260·35	+ 0·002	+ 1·014	–1093·258	+ 0·455	–1092·803
216	217	262·15	– 0·026	+ 0·988	–1125·342	+ 0·468	–1124·874
217	218	263·15	+ 0·008	+ 0·996	–1143·163	+ 0·476	–1142·687
218	219	264·15	+ 0·007	+ 1·003	–1143·110	+ 0·476	–1142·634
219	220	265·15	– 0·007	+ 0·996	–1144·992	+ 0·477	–1144·515
220	221	266·15	+ 0·019	+ 1·015	–1165·099	+ 0·485	–1164·614
221	222	267·15	+ 0·009	+ 1·024	–1186·931	+ 0·494	–1186·437
222	223	268·15	+ 0·017	+ 1·041	–1229·475	+ 0·512	–1228·963
223	224	269·10	+ 0·008	+ 1·049	–1230·675	+ 0·512	–1230·163
224	225	270·09	+ 0·021	+ 1·070	–1216·147	+ 0·506	–1215·641
225	226	271·09	+ 0·011	+ 1·081	–1249·141	+ 0·520	–1248·621
226	227	272·08	+ 0·004	+ 1·085	–1288·826	+ 0·537	–1288·289
227	228	272·56	+ 0·006	+ 1·091	–1293·447	+ 0·539	–1292·908
228	229	272·64	+ 0·002	+ 1·093	–1294·665	+ 0·539	–1294·126
229	230	273·15	– 0·001	+ 1·092	–1309·009	+ 0·545	–1308·464
230	231	274·14	+ 0·008	+ 1·100	–1266·641	+ 0·527	–1266·114
231	232	275·14	+ 0·012	+ 1·112	–1270·748	+ 0·529	–1270·219
232	233	276·14	+ 0·013	+ 1·125	–1230·093	+ 0·511	–1229·582
233	234	277·14	0·000	+ 1·125	–1243·460	+ 0·517	–1242·943
234	235	279·12	– 0·005	+ 1·120	–1180·289	+ 0·490	–1179·799
235	236	280·10	+ 0·010	+ 1·130	–1209·522	+ 0·503	–1209·019
236	237	280·95	+ 0·005	+ 1·135	–1239·439	+ 0·516	–1238·923
237	238	281·17	– 0·004	+ 1·131	–1244·177	+ 0·518	–1243·659
238	239	282·17	– 0·003	+ 1·128	–1256·867	+ 0·524	–1256·343
239	240	283·16	+ 0·023	+ 1·151	–1286·902	+ 0·537	–1286·365
240	241	284·15	0·000	+ 1·151	–1293·713	+ 0·540	–1293·173

Line No. 24. Gulbarga to Bezwada.—(Continued).

Bench-marks		Distance from Gulbarga	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Gulbarga (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Gulbarga
From	To		From mark to mark (= d)	Total from Gulbarga		Total from Gulbarga	
		miles	*foot*	*feet*	*feet*	*foot*	*feet*
241	242	285·16	+ 0·017	+ 1·168	– 1290·311	+ 0·539	– 1289·772
242	243	286·17	+ 0·005	+ 1·173	– 1310·555	+ 0·548	– 1310·007
243	244	287·18	+ 0·010	+ 1·183	– 1340·164	+ 0·561	– 1339·603
244	245	288·18	+ 0·006	+ 1·189	– 1331·442	+ 0·557	– 1330·885
245	246	289·18	0·000	+ 1·189	– 1348·346	+ 0·565	– 1347·781
246	247	289·51	+ 0·003	+ 1·192	– 1350·690	+ 0·566	– 1350·124
247	248	290·21	– 0·003	+ 1·189	– 1334·637	+ 0·559	– 1334·078
248	249	291·22	+ 0·008	+ 1·197	– 1355·768	+ 0·568	– 1355·200
249	250	292·23	– 0·006	+ 1·191	– 1350·177	+ 0·566	– 1349·611
250	251	293·24	+ 0·015	+ 1·206	– 1372·610	+ 0·576	– 1372·034
251	252	294·26	+ 0·009	+ 1·215	– 1381·421	+ 0·580	– 1380·841
252	253	295·28	+ 0·013	+ 1·228	– 1339·801	+ 0·562	– 1339·239
253	254	296·28	– 0·003	+ 1·225	– 1316·558	+ 0·552	– 1316·006
254	255	297·29	+ 0·013	+ 1·238	– 1336·847	+ 0·561	– 1336·286
255	256	298·29	+ 0·025	+ 1·263	– 1363·917	+ 0·573	– 1363·344
256	257	299·29	– 0·004	+ 1·259	– 1369·625	+ 0·575	– 1369·050
257	258	299·53	+ 0·002	+ 1·261	– 1363·871	+ 0·573	– 1363·298
258	259	300·37	+ 0·006	+ 1·267	– 1383·003	+ 0·581	– 1382·422
259	260	301·37	+ 0·028	+ 1·295	– 1376·437	+ 0·578	– 1375·859
260	261	302·37	– 0·008	+ 1·287	– 1398·511	+ 0·588	– 1397·823
261	262	303·37	– 0·016	+ 1·271	– 1396·018	+ 0·587	– 1395·431
262	263	304·38	+ 0·002	+ 1·273	– 1384·250	+ 0·582	– 1383·668
263	264	305·38	+ 0·011	+ 1·284	– 1398·666	+ 0·588	– 1398·078
264	265	306·38	+ 0·001	+ 1·285	– 1402·461	+ 0·590	– 1401·871
265	266	307·38	+ 0·028	+ 1·313	– 1411·110	+ 0·593	– 1410·517
266	267	308·36	+ 0·015	+ 1·328	– 1404·719	+ 0·590	– 1404·129
267	268	309·35	+ 0·009	+ 1·337	– 1407·515	+ 0·591	– 1406·924
268	269	310·34	+ 0·009	+ 1·346	– 1409·438	+ 0·592	– 1408·846
269	270	311·37	+ 0·015	+ 1·361	– 1415·259	+ 0·595	– 1414·664
270	271	312·36	+ 0·003	+ 1·364	– 1418·527	+ 0·596	– 1417·931
271	272	313·36	– 0·001	+ 1·363	– 1421·757	+ 0·597	– 1421·160
272	273	314·37	+ 0·017	+ 1·380	– 1422·339	+ 0·597	– 1421·742
273	274	315·36	– 0·003	+ 1·377	– 1424·091	+ 0·598	– 1423·493
274	275	316·37	– 0·010	+ 1·367	– 1425·138	+ 0·599	– 1424·539
275	276	317·36	+ 0·002	+ 1·369	– 1423·707	+ 0·598	– 1423·109
276	277	318·35	+ 0·009	+ 1·378	– 1422·709	+ 0·597	– 1422·112
277	278	319·74	+ 0·009	+ 1·387	– 1422·934	+ 0·597	– 1422·337
278	279	319·88	+ 0·001	+ 1·388	– 1422·972	+ 0·597	– 1422·375
279	280*	319·89	+ 0·003	+ 1·391	– 1422·980	+ 0·597	– 1422·383

Difference of dynamic height, Gulbarga to Bezwada = – 1422·383 feet.

Length of line in miles = M = 319·89. $\Sigma d^2 = 0{\cdot}063811$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745 \sqrt{\frac{\Sigma d^2}{4\mathrm{M}}} = \pm\, 0{\cdot}0048$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745 \sqrt{\frac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0852$.

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* Bench-mark No. 280 is the mark at Bezwada described on page 138.

Line No. 25. Kedgaon to Diksal.

Bench-marks		Distance from Kedgaon	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Kedgaon (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Kedgaon
From	To		From mark to mark (= d)	Total from Kedgaon		Total from Kedgaon	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·65	− 0·008	− 0·008	− 11·601	+ 0·004	− 11·597
2	3	2·01	− 0·023	− 0·031	− 36·358	+ 0·013	− 36·345
3	4	7·86	− 0·004	− 0·035	− 64·766	+ 0·023	− 64·743
4	5	9·21	− 0·008	− 0·043	− 78·996	+ 0·028	− 78·968
5	6	10·71	− 0·011	− 0·054	− 64·403	+ 0·023	− 64·380
6	7	12·83	− 0·031	− 0·085	− 91·838	+ 0·033	− 91·805
7	8	12·96	0·000	− 0·085	− 90·339	+ 0·033	− 90·306
8	9	13·56	+ 0·002	− 0·083	− 83·666	+ 0·031	− 83·635
9	10	14·49	+ 0·006	− 0·077	− 98·306	+ 0·036	− 98·270
10	11	17·46	− 0·030	− 0·107	− 104·936	+ 0·038	− 104·898
11	12	19·02	+ 0·008	− 0·099	− 62·389	+ 0·023	− 62·366
12	13	20·37	+ 0·009	− 0·090	− 44·514	+ 0·017	− 44·497
13	14	21·65	+ 0·016	− 0·074	− 64·721	+ 0·024	− 64·697
14	15	24·40	− 0·021	− 0·095	− 89·642	+ 0·033	− 89·609
15	16	26·35	+ 0·002	− 0·093	− 64·584	+ 0·024	− 64·560
16	17	26·74	+ 0·002	− 0·091	− 67·779	+ 0·025	− 67·754
17	18	28·18	+ 0·003	− 0·088	− 88·293	+ 0·032	− 88·261
18	19	29·81	− 0·010	− 0·098	− 110·352	+ 0·040	− 110·312
19	20†	30·64	− 0·005	− 0·103	− 118·267	+ 0·043	− 118·224

Difference of dynamic height, Kedgaon to Diksal = − 118·224 feet.

Length of line in miles = M = 30·64. $\Sigma d^2 = 0 \cdot 003679$.

Probable error of the mean result per mile of double-levelling $= 0 \cdot 6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm 0 \cdot 0037$.

Probable error of the difference of elevation between the terminal bench-marks $= 0 \cdot 6745 \sqrt{\frac{\Sigma d^2}{4}} = \pm 0 \cdot 0205$.

* Bench-mark No. 1 is the mark at Kedgaon described on page 134. † Bench-mark No. 20 is the mark at Diksal described on page 133.

Line No. 26. Diksal to Gulbarga.

Bench-marks		Distance from Diksal	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Diksal (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Diksal
From	To		From mark to mark (=d)	Total from Diksal		Total from Diksal	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	2·99	+ 0·005	+ 0·005	− 24·089	+ 0·008	− 24·081
2	3	4·16	− 0·014	− 0·009	− 23·585	+ 0·008	− 23·577
3	4	6·26	+ 0·009	0·000	+ 7·999	− 0·003	+ 7·996
4	5	7·27	+ 0·009	+ 0·009	+ 0·882	0·000	+ 0·882
5	6	7·64	− 0·003	+ 0·006	− 8·643	+ 0·003	− 8·640
6	7	11·35	− 0·022	− 0·016	− 28·011	+ 0·010	− 28·001
7	8	11·51	+ 0·002	− 0·014	− 31·579	+ 0·011	− 31·568
8	9	12·39	+ 0·009	− 0·005	− 41·149	+ 0·014	− 41·135
9	10	14·32	− 0·008	− 0·013	− 37·445	+ 0·013	− 37·432
10	11	18·87	− 0·012	− 0·025	− 52·969	+ 0·018	− 52·951
11	12	19·02	0·000	− 0·025	− 53·230	+ 0·018	− 53·212
12	13	19·62	− 0·008	− 0·033	− 57·341	+ 0·019	− 57·322
13	14	20·85	− 0·006	− 0·039	− 34·692	+ 0·011	− 34·681
14	15	21·74	+ 0·002	− 0·037	− 3·332	0·000	− 3·332
15	16	23·92	+ 0·012	− 0·025	+ 71·366	− 0·027	+ 71·339
16	17	24·80	0·000	− 0·025	+ 101·226	− 0·038	+ 101·188
17	18	25·09	+ 0·001	− 0·024	+ 111·060	− 0·042	+ 111·018
18	19	28·85	− 0·010	− 0·034	+ 60·832	− 0·024	+ 60·808
19	20	29·55	+ 0·005	− 0·029	+ 45·213	− 0·018	+ 45·195
20	21	29·94	0·000	− 0·029	+ 40·980	− 0·017	+ 40·963
21	22	31·32	− 0·008	− 0·037	+ 32·166	− 0·014	+ 32·152
22	23	31·96	− 0·006	− 0·043	+ 42·128	− 0·018	+ 42·110
23	24	33·71	− 0·013	− 0·056	+ 39·519	− 0·017	+ 39·502
24	25	35·94	+ 0·019	− 0·037	+ 96·965	− 0·038	+ 96·927
25	26	39·20	+ 0·011	− 0·026	+ 125·573	− 0·048	+ 125·525
26	27	39·41	− 0·005	− 0·031	+ 129·598	− 0·049	+ 129·549
27	28	40·26	− 0·003	− 0·034	+ 157·986	− 0·059	+ 157·927
28	29	41·87	0·000	− 0·034	+ 166·306	− 0·062	+ 166·244
29	30	43·87	− 0·026	− 0·060	+ 128·660	− 0·048	+ 128·612
30	31	44·33	+ 0·002	− 0·058	+ 117·412	− 0·044	+ 117·368
31	32	45·57	− 0·010	− 0·068	+ 89·185	− 0·034	+ 89·151
32	33	47·38	+ 0·006	− 0·062	+ 55·632	− 0·022	+ 55·610
33	34	47·62	− 0·001	− 0·063	+ 55·237	− 0·022	+ 55·215
34	35	50·35	− 0·007	− 0·070	+ 24·825	− 0·011	+ 24·814
35	36	50·48	+ 0·001	− 0·069	+ 23·353	− 0·011	+ 23·342
36	37	51·00	+ 0·006	− 0·063	+ 17·180	− 0·009	+ 17·171
37	38	51·85	+ 0·004	− 0·059	+ 3·569	− 0·004	+ 3·565
38	39	53·52	− 0·005	− 0·064	− 29·478	+ 0·008	− 29·470
39	40	54·43	− 0·014	− 0·078	− 37·918	+ 0·011	− 37·907
40	41	57·62	+ 0·028	− 0·050	− 67·778	+ 0·022	− 67·756
41	42	68·88	− 0·008	− 0·058	− 130·063	+ 0·046	− 130·017
42	43	69·89	− 0·013	− 0·071	− 144·948	+ 0·052	− 144·896
43	44	78·08	− 0·023	− 0·094	− 175·575	+ 0·064	− 175·511
44	45	88·39	+ 0·014	− 0·080	− 198·536	+ 0·073	− 198·463
45	46	89·55	− 0·012	− 0·092	− 191·639	+ 0·076	− 191·563
46	47	90·31	− 0·009	− 0·101	− 198·602	+ 0·079	− 198·523
47	48	92·76	− 0·005	− 0·106	− 143·120	+ 0·057	− 143·063
48	49	94·24	− 0·014	− 0·120	− 142·635	+ 0·057	− 142·578
49	50	95·15	− 0·004	− 0·124	− 172·731	+ 0·069	− 172·662
50	51	96·05	+ 0·006	− 0·118	− 189·143	+ 0·075	− 189·068
51	52	98·64	+ 0·004	− 0·114	− 189·307	+ 0·075	− 189·232
52	53	99·33	+ 0·012	− 0·102	− 176·684	+ 0·070	− 176·614
53	54	99·91	0·000	− 0·102	− 165·981	+ 0·066	− 165·915
54	55	100·17	− 0·002	− 0·104	− 162·385	+ 0·065	− 162·320
55	56	101·10	+ 0·008	− 0·096	− 108·890	+ 0·044	− 108·846
56	57	101·28	+ 0·002	− 0·094	− 127·953	+ 0·051	− 127·902
57	58	101·97	+ 0·022	− 0·072	− 104·590	+ 0·042	− 104·548
58	59	103·07	− 0·001	− 0·073	− 93·230	+ 0·038	− 93·192
59	60	103·85	+ 0·021	− 0·052	− 119·049	+ 0·048	− 119·001
60	61	104·06	0·000	− 0·052	− 117·878	+ 0·048	− 117·830

* Bench-mark No. 1 is the mark at Diksal described on page 133.

Line No. 26. Diksal to Gulbarga.—(Continued).

Bench-marks		Distance from Diksal	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Diksal (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Diksal
From	To		From mark to mark (= d)	Total from Diksal		Total from Diksal	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	105·08	+ 0·009	– 0·043	– 127·790	+ 0·052	– 127·738
62	63	106·70	– 0·023	– 0·066	– 193·352	+ 0·078	– 193·274
63	64	107·39	+ 0·004	– 0·062	– 175·706	+ 0·071	– 175·635
64	65	107·83	– 0·007	– 0·069	– 180·833	+ 0·073	– 180·760
65	66	107·97	0·000	– 0·069	– 178·648	+ 0·072	– 178·576
66	67	108·37	– 0·003	– 0·072	– 165·560	+ 0·067	– 165·493
67	68	109·53	+ 0·001	– 0·071	– 128·832	+ 0·053	– 128·779
68	69	109·61	– 0·004	– 0·075	– 124·283	+ 0·051	– 124·232
69	70	109·72	– 0·005	– 0·080	– 124·228	+ 0·051	– 124·177
70	71	111·83	– 0·017	– 0·097	– 154·681	+ 0·063	– 154·618
71	72	115·44	+ 0·006	– 0·091	– 190·012	+ 0·077	– 189·935
72	73	115·53	+ 0·001	– 0·090	– 190·059	+ 0·077	– 189·982
73	74	122·24	– 0·002	– 0·092	– 182·904	+ 0·074	– 182·830
74	75	122·29	+ 0·001	– 0·091	– 177·823	+ 0·072	– 177·751
75	76	122·80	– 0·010	– 0·101	– 166·875	+ 0·068	– 166·807
76	77	129·55	– 0·023	– 0·124	– 123·714	+ 0·051	– 123·663
77	78	130·96	+ 0·008	– 0·116	– 140·170	+ 0·057	– 140·113
78	79	134·66	– 0·038	– 0·154	– 256·458	+ 0·104	– 256·354
79	80	136·42	+ 0·029	– 0·125	– 221·372	+ 0·090	– 221·282
80	81	139·17	+ 0·021	– 0·104	– 184·321	+ 0·075	– 184·246
81	82	139·58	+ 0·004	– 0·100	– 181·327	+ 0·074	– 181·253
82	83	139·88	0·000	– 0·100	– 170·096	+ 0·069	– 170·027
83	84	140·67	– 0·004	– 0·104	– 128·274	+ 0·052	– 128·222
84	85	141·40	+ 0·001	– 0·103	– 96·805	+ 0·039	– 96·766
85	86	143·58	– 0·034	– 0·137	– 153·578	+ 0·062	– 153·516
86	87	145·49	+ 0·002	– 0·135	– 185·111	+ 0·075	– 185·036
87	88	145·60	0·000	– 0·135	– 185·236	+ 0·075	– 185·161
88	89	149·76	– 0·015	– 0·150	– 206·043	+ 0·084	– 205·959
89	90	153·91	– 0·008	– 0·158	– 219·890	+ 0·090	– 219·800
90	91	155·34	– 0·002	– 0·160	– 209·464	+ 0·086	– 209·378
91	92	156·51	+ 0·006	– 0·154	– 148·247	+ 0·061	– 148·186
92	93	157·85	+ 0·001	– 0·153	– 90·467	+ 0·037	– 90·430
93	94	162·97	– 0·050	– 0·203	– 161·040	+ 0·066	– 160·974
94	95	164·65	+ 0·004	– 0·199	– 100·937	+ 0·041	– 100·896
95	96	170·41	+ 0·021	– 0·178	– 168·520	+ 0·069	– 168·451
96	97*	170·56	+ 0·001	– 0·177	– 168·869	+ 0·069	– 168·800

Difference of dynamic height, Diksal to Gulbarga = – 168·800 feet.

Length of line in miles = M = 170·56. $\Sigma d^2 = 0{\cdot}015823$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm\, 0{\cdot}0033$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745 \sqrt{\frac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0424$.

* Bench-mark No. 97 is the mark at Gulbarga described on page 134.

Line No. 27. Diksal to Nira.

Bench-marks		Distance from Diksal	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Diksal (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Diksal
From	To		From mark to mark (= d)	Total from Diksal		Total from Diksal	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	1·69	– 0·004	– 0·004	– 39·052	+ 0·014	– 39·038
2	3	2·00	– 0·002	– 0·006	– 44·996	+ 0·016	– 44·980
3	4	2·69	– 0·010	– 0·016	– 42·762	+ 0·015	– 42·747
4	5	3·72	– 0·001	– 0·017	– 45·140	+ 0·016	– 45·124
5	6	4·54	+ 0·020	+ 0·003	– 27·860	+ 0·010	– 27·850
6	7	11·19	– 0·076	– 0.073	+ 168·423	– 0·061	+ 168·362
7	8	18·53	– 0·030	– 0·103	+ 79·410	– 0·029	+ 79·381
8	9	18·59	– 0·003	– 0·106	+ 82·264	– 0·030	+ 82·234
9	10	19·58	– 0·014	– 0·120	+ 121·460	– 0·044	+ 121·416
10	11	20·57	+ 0·005	– 0·115	+ 95·910	– 0·035	+ 95·875
11	12	21·56	– 0·004	– 0·119	+ 108·871	– 0·040	+ 108·831
12	13	22·09	+ 0·001	– 0·118	+ 78·040	– 0·029	+ 78·011
13	14	22·56	– 0·005	– 0·123	+ 84·586	– 0·031	+ 84·555
14	15	23·56	– 0·007	– 0·130	+ 100·649	– 0·037	+ 100·612
15	16	24·54	– 0·006	– 0·136	+ 138·475	– 0·051	+ 138·424
16	17	25·55	+ 0·018	– 0·118	+ 135·796	– 0·050	+ 135·746
17	18	26·55	+ 0·004	– 0·114	+ 103·589	– 0·038	+ 103·551
18	19	26·80	+ 0·004	– 0·110	+ 111·230	– 0·041	+ 111·189
19	20	27·55	+ 0·003	– 0·107	+ 120·115	– 0·044	+ 120·071
20	21	27·63	+ 0·009	– 0·098	+ 108·293	– 0·040	+ 108·253
21	22	27·83	+ 0·011	– 0·087	+ 100·622	– 0·037	+ 100·585
22	23	30·37	– 0·017	– 0·104	+ 145·665	– 0·053	+ 145·612
23	24	31·92	– 0·011	– 0·115	+ 141·193	– 0·052	+ 141·141
24	25	32·69	+ 0·007	– 0·108	+ 186·288	– 0·068	+ 186·220
25	26	33·14	+ 0·010	– 0·098	+ 144·706	– 0·053	+ 144·653
26	27	35·19	– 0·021	– 0·119	+ 139·652	– 0·051	+ 139·601
27	28	39·90	+ 0·020	– 0·099	+ 153·973	– 0·056	+ 153·917
28	29	42·50	– 0·012	– 0·111	+ 141·818	– 0·052	+ 141·766
29	30	43·49	+ 0·003	– 0·108	+ 160·037	– 0·059	+ 159·978
30	31	50·23	– 0·007	– 0·115	+ 142·914	– 0·053	+ 142·861
31	32†	52·94	– 0·026	– 0·141	+ 135·962	– 0·050	+ 135·912

Difference of dynamic height, Diksal to Nira = + 135·912 feet.

Length of line in miles = M = 52·94. $\Sigma d^2 = 0{\cdot}010399$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4M}} = \pm\, 0{\cdot}0047$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0344$.

* Bench-mark No. 1 is the mark at Diksal described on page 133. † Bench-mark No. 32 is the mark at Nira described on page 135.

Line No. 28. Kedgaon to Nira.

Bench-marks From	Bench-marks To	Distance from Kedgaon	Discrepancy between levellers (First – Second leveller): From mark to mark (= d)	Discrepancy between levellers (First – Second leveller): Total from Kedgaon	Observed elevation above (+) or below (–) Kedgaon (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Kedgaon	Dynamic height above (+) or below (–) Kedgaon
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·48	0·000	0·000	+ 4·505	– 0·001	+ 4·504
2	3	1·21	+ 0·009	+ 0·009	+ 25·717	– 0·008	+ 25·709
3	4	1·49	+ 0·008	+ 0·017	+ 25·330	– 0·008	+ 25·322
4	5	2·49	– 0·034	– 0·017	+ 103·679	– 0·035	+ 103·644
5	6	3·50	– 0·007	– 0·024	+ 121·316	– 0·041	+ 121·275
6	7	4·50	+ 0·003	– 0·021	+ 76·918	– 0·026	+ 76·892
7	8	5·50	+ 0·002	– 0·019	+ 135·216	– 0·046	+ 135·170
8	9	6·51	– 0·001	– 0·020	+ 142·300	– 0·049	+ 142·251
9	10	7·51	– 0·025	– 0·045	+ 184·849	– 0·064	+ 184·785
10	11	8·52	– 0·010	– 0·055	+ 293·926	– 0·102	+ 293·824
11	12	9·53	– 0·006	– 0·061	+ 333·313	– 0·116	+ 333·197
12	13	10·25	– 0·012	– 0·073	+ 300·200	– 0·104	+ 300·096
13	14	10·65	+ 0·012	– 0·061	+ 302·736	– 0·105	+ 302·631
14	15	11·65	+ 0·007	– 0·054	+ 290·736	– 0·101	+ 290·635
15	16	12·65	0·000	– 0·054	+ 271·716	– 0·094	+ 271·622
16	17	13·65	+ 0·016	– 0·038	+ 275·861	– 0·095	+ 275·766
17	18	14·65	+ 0·007	– 0·031	+ 238·874	– 0·082	+ 238·792
18	19	15·65	+ 0·010	– 0·021	+ 236·613	– 0·081	+ 236·532
19	20	16·20	+ 0·010	– 0·011	+ 244·925	– 0·084	+ 244·841
20	21	16·71	– 0·017	– 0·028	+ 250·489	– 0·086	+ 250·403
21	22	17·72	– 0·015	– 0·043	+ 267·437	– 0·092	+ 267·345
22	23	18·73	– 0·013	– 0·056	+ 294·724	– 0·102	+ 294·622
23	24	19·74	+ 0·003	– 0·053	+ 248·457	– 0·085	+ 248·372
24	25	20·74	+ 0·026	– 0·027	+ 211·502	– 0·072	+ 211·430
25	26	21·76	+ 0·013	– 0·014	+ 213·853	– 0·073	+ 213·780
26	27	22·76	0·000	– 0·014	+ 254·185	– 0·087	+ 254·098
27	28	23·77	– 0·004	– 0·018	+ 198·857	– 0·067	+ 198·790
28	29	24·77	– 0·016	– 0·034	+ 252·282	– 0·086	+ 252·196
29	30	25·77	+ 0·001	– 0·033	+ 226·181	– 0·077	+ 226·104
30	31	29·41	+ 0·048	+ 0·015	+ 24·757	– 0·004	+ 24·753
31	32	32·31	– 0·021	– 0·006	+ 16·292	– 0·001	+ 16·291
32	33†	32·33	+ 0·007	+ 0·001	+ 17·845	– 0·002	+ 17·843

Difference of dynamic height, Kedgaon to Nira = + 17·843 feet.

Length of line in miles = M = 32·33. $\Sigma d^2 = 0{\cdot}007571$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0{\cdot}0052$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745 \sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0{\cdot}0293$.

* Bench-mark No. 1 is the mark at Kedgaon described on page 134. † Bench-mark No. 33 is the mark at Nira described on page 135.

Line No. 29. Nira to Hubli.

Bench-marks		Distance from Nira	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Nira (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Nira
From	To		From mark to mark (= d)	Total from Nira		Total from Nira	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·31	− 0·004	− 0·004	+ 6·230	− 0·002	+ 6·228
2	3	1·34	− 0·017	− 0·021	+ 60·719	− 0·022	+ 60·697
3	4	2·49	+ 0·003	− 0·018	+ 102·196	− 0·037	+ 102·159
4	5	3·19	+ 0·016	− 0·002	+ 98·200	− 0·035	+ 98·165
5	6	4·30	− 0·019	− 0·021	+ 145·646	− 0·052	+ 145·594
6	7	5·21	− 0·004	− 0·025	+ 188·465	− 0·068	+ 188·397
7	8	6·17	− 0·011	− 0·036	+ 205·850	− 0·074	+ 205·776
8	9	6·27	− 0·004	− 0·040	+ 202·177	− 0·073	+ 202·104
9	10	7·21	− 0·013	− 0·053	+ 244·126	− 0·089	+ 244·037
10	11	8·22	− 0·008	− 0·061	+ 307·571	− 0·112	+ 307·459
11	12	9·35	− 0·016	− 0·077	+ 346·455	− 0·126	+ 346·329
12	13	10·13	− 0·002	− 0·079	+ 377·469	− 0·138	+ 377·331
13	14	10·34	+ 0·001	− 0·078	+ 399·336	− 0·146	+ 399·190
14	15	10·89	+ 0·019	− 0·059	+ 416·487	− 0·152	+ 416·335
15	16	11·33	− 0·016	− 0·075	+ 462·048	− 0·169	+ 461·879
16	17	12·36	− 0·053	− 0·128	+ 665·843	− 0·246	+ 665·597
17	18	13·35	+ 0·004	− 0·124	+ 709·496	− 0·263	+ 709·233
18	19	13·44	− 0·001	− 0·125	+ 701·387	− 0·260	+ 701·127
19	20	14·25	− 0·014	− 0·139	+ 753·889	− 0·280	+ 753·609
20	21	14·91	− 0·011	− 0·150	+ 836·795	− 0·312	+ 836·483
21	22	15·37	− 0·001	− 0·151	+ 855·670	− 0·319	+ 855·351
22	23	16·38	+ 0·011	− 0·140	+ 831·155	− 0·310	+ 830·845
23	24	17·39	+ 0·025	− 0·115	+ 781·467	− 0·291	+ 781·176
24	25	17·78	+ 0·004	− 0·111	+ 734·095	− 0·273	+ 733·822
25	26	18·39	− 0·017	− 0·128	+ 756·283	− 0·281	+ 756·002
26	27	19·39	− 0·012	− 0·140	+ 680·271	− 0·252	+ 680·019
27	28	21·36	+ 0·024	− 0·116	+ 663·805	− 0·246	+ 663·559
28	29	21·70	− 0·005	− 0·121	+ 661·963	− 0·245	+ 661·718
29	30	22·34	− 0·008	− 0·129	+ 641·530	− 0·237	+ 641·293
30	31	23·34	+ 0·004	− 0·125	+ 626·275	− 0·231	+ 626·044
31	32	23·53	+ 0·003	− 0·122	+ 596·340	− 0·220	+ 596·120
32	33	25·36	0·000	− 0·122	+ 448·433	− 0·202	+ 448·231
33	34	26·36	+ 0·030	− 0·092	+ 367·230	− 0·171	+ 367·059
34	35	27·36	+ 0·010	− 0·082	+ 312·444	− 0·150	+ 312·294
35	36	27·55	+ 0·001	− 0·081	+ 299·067	− 0·145	+ 298·922
36	37	28·35	+ 0·005	− 0·076	+ 326·771	− 0·156	+ 326·615
37	38	29·35	− 0·005	− 0·081	+ 387·938	− 0·179	+ 387·759
38	39	30·35	+ 0·026	− 0·055	+ 320·604	− 0·153	+ 320·451
39	40	30·88	+ 0·015	− 0·040	+ 271·138	− 0·134	+ 271·004
40	41	31·35	− 0·007	− 0·047	+ 311·289	− 0·149	+ 311·140
41	42	32·11	+ 0·011	− 0·036	+ 344·680	− 0·162	+ 344·518
42	43	32·41	+ 0·003	− 0·033	+ 363·784	− 0·169	+ 363·615
43	44	32·75	+ 0·004	− 0·029	+ 381·953	− 0·176	+ 381·777
44	45	32·84	− 0·003	− 0·032	+ 393·826	− 0·181	+ 393·645
45	46	32·85	+ 0·003	− 0·029	+ 389·383	− 0·179	+ 389·204
46	47	33·56	− 0·031	− 0·060	+ 519·953	− 0·230	+ 519·723
47	48	33·60	0·000	− 0·060	+ 517·580	− 0·229	+ 517·351
48	49	34·33	+ 0·012	− 0·048	+ 491·285	− 0·219	+ 491·066
49	50	34·49	+ 0·003	− 0·045	+ 478·705	− 0·214	+ 478·491
50	51	34·65	+ 0·002	− 0·043	+ 470·930	− 0·211	+ 470·719
51	52	35·65	+ 0·014	− 0·029	+ 409·855	− 0·187	+ 409·668
52	53	36·65	− 0·012	− 0·041	+ 345·462	− 0·162	+ 345·300
53	54	37·86	+ 0·021	− 0·020	+ 288·103	− 0·140	+ 287·963
54	55	38·65	+ 0·008	− 0·012	+ 279·889	− 0·137	+ 279·752
55	56	38·93	− 0·003	− 0·015	+ 272·053	− 0·134	+ 271·919
56	57	39·63	− 0·003	− 0·018	+ 268·003	− 0·132	+ 267·871
57	58	39·78	− 0·005	− 0·023	+ 272·720	− 0·134	+ 272·586
58	59	40·66	+ 0·017	− 0·006	+ 277·059	− 0·136	+ 276·923
59	60	41·65	− 0·006	− 0·012	+ 311·957	− 0·150	+ 311·807
60	61	42·39	+ 0·016	+ 0·004	+ 252·194	− 0·127	+ 252·067

* Bench-mark No. 1 is the mark at Nira described on page 135.

Line No. 29. Nira to Hubli.—(Continued).

Bench-marks		Distance from Nira	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Nira (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Nira
From	To		From mark to mark (= *d*)	Total from Nira		Total from Nira	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	43·70	– 0·017	– 0·013	+ 279·614	– 0·138	+ 279·476
62	63	44·09	+ 0·004	– 0·009	+ 265·962	– 0·133	+ 265·829
63	64	46·77	– 0·003	– 0·012	+ 314·073	– 0·152	+ 313·921
64	65	48·72	– 0·006	– 0·018	+ 331·827	– 0·159	+ 331·668
65	66	48·77	– 0·004	– 0·022	+ 330·738	– 0·159	+ 330·579
66	67	49·87	– 0·004	– 0·026	+ 406·985	– 0·189	+ 406·796
67	68	50·78	– 0·004	– 0·030	+ 433·349	– 0·199	+ 433·150
68	69	51·45	+ 0·018	– 0·012	+ 441·430	– 0·202	+ 441·228
69	70	51·84	– 0·004	– 0·016	+ 471·051	– 0·214	+ 470·837
70	71	52·36	+ 0·015	– 0·001	+ 451·998	– 0·207	+ 451·791
71	72	52·86	0·000	– 0·001	+ 456·502	– 0·209	+ 456·293
72	73	53·74	– 0·016	– 0·017	+ 516·949	– 0·232	+ 516·717
73	74	53·83	+ 0·004	– 0·013	+ 522·430	– 0·234	+ 522·196
74	75	55·00	+ 0·018	+ 0·005	+ 561·737	– 0·249	+ 561·488
75	76	55·31	0·000	+ 0·005	+ 566·546	– 0·251	+ 566·295
76	77	55·96	– 0·062	– 0·057	+ 772·128	– 0·332	+ 771·796
77	78	56·25	– 0·010	– 0·067	+ 804·518	– 0·345	+ 804·173
78	79	56·99	+ 0·018	– 0·049	+ 765·540	– 0·329	+ 765·211
79	80	57·59	+ 0·010	– 0·039	+ 745·243	– 0·321	+ 744·922
80	81	58·00	+ 0·007	– 0·032	+ 716·453	– 0·309	+ 716·144
81	82	59·02	+ 0·031	– 0·001	+ 665·161	– 0·289	+ 664·872
82	83	59·40	– 0·003	– 0·004	+ 657·081	– 0·286	+ 656·795
83	84	60·04	+ 0·034	+ 0·030	+ 625·986	– 0·274	+ 625·712
84	85	61·05	+ 0·004	+ 0·034	+ 597·598	– 0·263	+ 597·335
85	86	61·49	+ 0·008	+ 0·042	+ 586·657	– 0·259	+ 586·398
86	87	61·61	– 0·004	+ 0·038	+ 586·064	– 0·259	+ 585·805
87	88	63·59	– 0·033	+ 0·005	+ 563·905	– 0·250	+ 563·655
88	89	63·77	+ 0·011	+ 0·016	+ 554·299	– 0·246	+ 554·053
89	90	66·15	– 0·007	+ 0·009	+ 585·696	– 0·258	+ 585·438
90	91	71·40	– 0·003	+ 0·006	+ 512·821	– 0·229	+ 512·592
91	92	72·54	+ 0·017	+ 0·023	+ 468·783	– 0·211	+ 468·572
92	93	74·58	+ 0·032	+ 0·055	+ 373·380	– 0·172	+ 373·208
93	94	78·18	– 0·016	+ 0·039	+ 329·877	– 0·154	+ 329·723
94	95	84·61	– 0·006	+ 0·033	+ 259·874	– 0·125	+ 259·749
95	96	87·48	+ 0·004	+ 0·037	+ 251·612	– 0·122	+ 251·490
96	97	90·04	– 0·025	+ 0·012	+ 286·732	– 0·136	+ 286·596
97	98	90·50	+ 0·001	+ 0·013	+ 285·596	– 0·136	+ 285·460
98	99	91·51	+ 0·002	+ 0·015	+ 279·884	– 0·134	+ 279·750
99	100	92·51	– 0·004	+ 0·011	+ 247·044	– 0·120	+ 246·924
100	101	94·58	+ 0·005	+ 0·016	+ 199·625	– 0·100	+ 199·525
101	102	98·90	– 0·022	– 0·006	+ 130·897	– 0·071	+ 130·826
102	103	99·28	– 0·009	– 0·015	+ 142·359	– 0·076	+ 142·283
103	104	103·55	+ 0·034	+ 0·019	+ 53·714	– 0·039	+ 53·675
104	105	104·43	– 0·013	+ 0·006	+ 34·734	– 0·031	+ 34·703
105	106	105·99	– 0·008	– 0·002	+ 46·797	– 0·036	+ 46·761
106	107	108·41	– 0·022	– 0·024	+ 18·156	– 0·024	+ 18·132
107	108	109·59	– 0·011	– 0·035	+ 16·054	– 0·023	+ 16·031
108	109	114·06	+ 0·003	– 0·032	+ 104·622	– 0·060	+ 104·562
109	110	114·48	– 0·011	– 0·043	+ 81·662	– 0·050	+ 81·612
110	111	115·26	+ 0·018	– 0·025	+ 82·264	– 0·050	+ 82·214
111	112	116·22	+ 0·003	– 0·022	+ 92·169	– 0·054	+ 92·115
112	113	116·30	– 0·002	– 0·024	+ 94·475	– 0·055	+ 94·420
113	114	117·48	– 0·010	– 0·034	+ 140·382	– 0·074	+ 140·308
114	115	118·48	– 0·001	– 0·035	+ 181·741	– 0·091	+ 181·650
115	116	119·00	– 0·015	– 0·050	+ 192·158	– 0·095	+ 192·063
116	117	119·48	– 0·009	– 0·059	+ 190·785	– 0·095	+ 190·690
117	118	120·47	– 0·020	– 0·079	+ 185·552	– 0·093	+ 185·459
118	119	120·55	– 0·007	– 0·086	+ 186·380	– 0·093	+ 186·287
119	120	121·46	– 0·021	– 0·107	+ 193·398	– 0·096	+ 193·302
120	121	122·46	– 0·009	– 0·116	+ 207·317	– 0·102	+ 207·215

Line No. 29. Nira to Hubli.—(Continued).

Bench-marks From	Bench-marks To	Distance from Nira	Discrepancy between levellers (First − Second leveller) From mark to mark (= d)	Discrepancy between levellers (First − Second leveller) Total from Nira	Observed elevation above (+) or below (−) Nira (mean result by two levellers)	Dynamic correction deduced from mark to mark Total from Nira	Dynamic height above (+) or below (−) Nira
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
121	122	123·05	+ 0·001	− 0·115	+ 184·767	− 0·092	+ 184·675
122	123	123·45	+ 0·004	− 0·111	+ 168·993	− 0·085	+ 168·908
123	124	124·45	− 0·017	− 0·128	+ 116·470	− 0·062	+ 116·408
124	125	124·54	− 0·003	− 0·131	+ 110·063	− 0·060	+ 110·003
125	126	125·43	+ 0·017	− 0·114	+ 49·447	− 0·034	+ 49·413
126	127	125·82	− 0·001	− 0·115	+ 42·649	− 0·031	+ 42·618
127	128	126·80	+ 0·011	− 0·104	+ 14·625	− 0·019	+ 14·606
128	129	128·79	− 0·034	− 0·138	+ 2·194	− 0·014	+ 2·180
129	130	130·11	+ 0·003	− 0·135	+ 20·457	− 0·022	+ 20·435
130	131	130·53	+ 0·006	− 0·129	+ 40·146	− 0·031	+ 40·115
131	132	130·70	+ 0·006	− 0·123	+ 52·104	− 0·036	+ 52·068
132	133	131·15	+ 0·003	− 0·120	+ 53·201	− 0·036	+ 53·165
133	134	132·16	+ 0·002	− 0·118	+ 83·488	− 0·049	+ 83·439
134	135	133·16	− 0·025	− 0·143	+ 153·342	− 0·079	+ 153·263
135	136	133·80	− 0·011	− 0·154	+ 166·058	− 0·085	+ 165·973
136	137	134·16	− 0·008	− 0·162	+ 206·049	− 0·102	+ 205·947
137	138	134·36	− 0·004	− 0·166	+ 217·037	− 0·107	+ 216·930
138	139	134·54	+ 0·004	− 0·162	+ 213·892	− 0·106	+ 213·786
139	140	135·18	− 0·011	− 0·173	+ 222·759	− 0·110	+ 222·649
140	141	136·19	+ 0·010	− 0·163	+ 126·038	− 0·067	+ 125·971
141	142	136·90	− 0·007	− 0·170	+ 120·512	− 0·065	+ 120·447
142	143	137·84	+ 0·006	− 0·164	+ 37·844	− 0·029	+ 37·815
143	144	139·45	+ 0·012	− 0·152	− 15·980	− 0·005	− 15·985
144	145	140·46	− 0·001	− 0·153	+ 3·217	− 0·013	+ 3·204
145	146	141·44	− 0·018	− 0·171	− 8·222	− 0·008	− 8·230
146	147	141·46	0·000	− 0·171	− 8·070	− 0·008	− 8·078
147	148	142·09	− 0·009	− 0·180	+ 53·764	− 0·035	+ 53·729
148	149	142·94	+ 0·001	− 0·179	+ 55·381	− 0·036	+ 55·345
149	150	143·24	+ 0·006	− 0·173	+ 63·531	− 0·039	+ 63·492
150	151	144·24	− 0·018	− 0·191	+ 109·342	− 0·059	+ 109·283
151	152	145·24	− 0·028	− 0·219	+ 177·622	− 0·089	+ 177·533
152	153	146·24	− 0·013	− 0·232	+ 223·868	− 0·109	+ 223·759
153	154	146·92	− 0·028	− 0·260	+ 247·361	− 0·119	+ 247·242
154	155	147·24	− 0·007	− 0·267	+ 226·709	− 0·110	+ 226·599
155	156	148·10	− 0·001	− 0·268	+ 149·224	− 0·076	+ 149·148
156	157	148·25	− 0·006	− 0·274	+ 166·947	− 0·084	+ 166·863
157	158	148·89	− 0·024	− 0·298	+ 183·758	− 0·092	+ 183·666
158	159	149·25	+ 0·004	− 0·294	+ 156·471	− 0·080	+ 156·391
159	160	149·40	+ 0·009	− 0·285	+ 130·185	− 0·069	+ 130·116
160	161	150·01	− 0·006	− 0·291	+ 147·121	− 0·077	+ 147·044
161	162	150·25	− 0·016	− 0·307	+ 188·323	− 0·095	+ 188·228
162	163	151·26	− 0·001	− 0·308	+ 252·902	− 0·123	+ 252·779
163	164	151·44	− 0·001	− 0·309	+ 239·008	− 0·117	+ 238·891
164	165	152·03	+ 0·029	− 0·280	+ 150·201	− 0·078	+ 150·123
165	166	152·27	+ 0·003	− 0·277	+ 122·110	− 0·066	+ 122·044
166	167	153·27	− 0·008	− 0·285	+ 62·169	− 0·040	+ 62·129
167	168	153·41	+ 0·003	− 0·282	+ 38·680	− 0·029	+ 38·651
168	169	153·43	+ 0·002	− 0·280	+ 37·469	− 0·028	+ 37·441
169	170	153·74	− 0·001	− 0·281	+ 11·348	− 0·016	+ 11·332
170	171	154·14	− 0·002	− 0·283	+ 33·199	− 0·026	+ 33·173
171	172	154·33	+ 0·001	− 0·282	+ 23·248	− 0·021	+ 23·227
172	173	155·34	+ 0·033	− 0·249	− 21·395	− 0·001	− 21·396
173	174	155·61	+ 0·008	− 0·241	− 14·767	− 0·004	− 14·771
174	175	156·95	+ 0·007	− 0·234	+ 44·767	− 0·031	+ 44·736
175	176	158·23	− 0·009	− 0·243	+ 52·593	− 0·035	+ 52·558
176	177	160·81	− 0·015	− 0·258	+ 68·054	− 0·042	+ 68·012
177	178	161·76	+ 0·015	− 0·243	+ 21·894	− 0·021	+ 21·873
178	179	162·63	+ 0·029	− 0·214	− 7·855	− 0·008	− 7·863
179	180	163·11	+ 0·013	− 0·201	− 1·463	− 0·011	− 1·474
180	181	165·16	− 0·011	− 0·212	+ 35·865	− 0·028	+ 35·837

Line No. 29. Nira to Hubli.—(Continued).

Bench-marks From	Bench-marks To	Distance from Nira	Discrepancy between levellers (First − Second leveller): From mark to mark (= d)	Discrepancy between levellers: Total from Nira	Observed elevation above (+) or below (−) Nira (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Nira	Dynamic height above (+) or below (−) Nira
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
181	182	166·70	− 0·018	− 0·230	+ 128·761	− 0·070	+ 128·691
182	183	167·29	− 0·015	− 0·245	+ 181·570	− 0·094	+ 181·476
183	184	167·51	+ 0·001	− 0·244	+ 183·810	− 0·095	+ 183·715
184	185	171·16	− 0·045	− 0·289	+ 658·211	− 0·310	+ 657·901
185	186	172·30	+ 0·001	− 0·288	+ 765·674	− 0·359	+ 765·315
186	187	173·48	+ 0·052	− 0·236	+ 541·709	− 0·257	+ 541·452
187	188	174·29	+ 0·017	− 0·219	+ 471·058	− 0·224	+ 470·834
188	189	174·60	+ 0·001	− 0·218	+ 436·560	− 0·208	+ 436·352
189	190	175·01	− 0·015	− 0·233	+ 445·098	− 0·212	+ 444·886
190	191	176·15	+ 0·013	− 0·220	+ 387·471	− 0·185	+ 387·286
191	192	177·36	+ 0·002	− 0·218	+ 439·239	− 0·209	+ 439·030
192	193	177·61	+ 0·006	− 0·212	+ 427·130	− 0·203	+ 426·927
193	194	179·67	+ 0·035	− 0·177	+ 318·325	− 0·153	+ 318·172
194	195	180·36	− 0·008	− 0·185	+ 292·145	− 0·141	+ 292·004
195	196	180·75	− 0·007	− 0·192	+ 308·377	− 0·148	+ 308·229
196	197	181·71	+ 0·004	− 0·188	+ 286·111	− 0·138	+ 285·973
197	198	182·79	+ 0·004	− 0·184	+ 279·229	− 0·135	+ 279·094
198	199	183·25	− 0·013	− 0·197	+ 325·809	− 0·156	+ 325·653
199	200	183·73	+ 0·004	− 0·193	+ 274·308	− 0·132	+ 274·176
200	201	185·08	− 0·010	− 0·203	+ 261·791	− 0·126	+ 261·665
201	202	190·29	− 0·001	− 0·204	+ 411·542	− 0·196	+ 411·346
202	203	190·38	− 0·001	− 0·205	+ 411·092	− 0·196	+ 410·896
203	204	191·52	− 0·029	− 0·234	+ 500·838	− 0·238	+ 500·600
204	205	194·63	+ 0·027	− 0·207	+ 366·888	− 0·175	+ 366·713
205	206	195·26	− 0·013	− 0·220	+ 429·138	− 0·204	+ 428·934
206	207	196·29	− 0·012	− 0·232	+ 464·439	− 0·221	+ 464·218
207	208	197·49	− 0·016	− 0·248	+ 622·326	− 0·296	+ 622·030
208	209	201·00	− 0·035	− 0·283	+ 824·171	− 0·392	+ 823·779
209	210	206·29	− 0·021	− 0·304	+ 638·792	− 0·303	+ 638·489
210	211	209·48	− 0·030	− 0·334	+ 786·905	− 0·374	+ 786·531
211	212	211·13	+ 0·022	− 0·312	+ 679·083	− 0·322	+ 678·761
212	213	211·44	− 0·007	− 0·319	+ 684·493	− 0·325	+ 684·168
213	214	217·61	+ 0·028	− 0·291	+ 822·028	− 0·392	+ 821·636
214	215	223·17	+ 0·051	− 0·240	+ 415·722	− 0·372	+ 415·350
215	216	223·19	− 0·001	− 0·241	+ 407·073	− 0·368	+ 406·705
216	217	228·05	+ 0·012	− 0·229	+ 369·995	− 0·350	+ 369·645
217	218	228·84	+ 0·023	− 0·206	+ 311·852	− 0·322	+ 311·530
218	219	229·35	+ 0·003	− 0·203	+ 290·833	− 0·312	+ 290·521
219	220	231·61	− 0·017	− 0·220	+ 395·662	− 0·363	+ 395·299
220	221	234·58	+ 0·018	− 0·202	+ 464·600	− 0·397	+ 464·203
221	222	236·55	− 0·011	− 0·213	+ 544·326	− 0·436	+ 543·890
222	223	238·93	+ 0·005	− 0·208	+ 587·077	− 0·457	+ 586·620
223	224	239·25	+ 0·005	− 0·203	+ 617·645	− 0·472	+ 617·173
224	225	243·99	+ 0·017	− 0·186	+ 467·036	− 0·398	+ 466·638
225	226	244·99	− 0·004	− 0·190	+ 583·018	− 0·456	+ 582·562
226	227	248·80	+ 0·040	− 0·150	+ 459·524	− 0·395	+ 459·129
227	228	250·83	− 0·001	− 0·151	+ 477·518	− 0·404	+ 477·114
228	229	252·98	− 0·017	− 0·168	+ 507·576	− 0·419	+ 507·157
229	230	254·74	− 0·006	− 0·174	+ 516·638	− 0·424	+ 516·214
230	231	258·24	− 0·022	− 0·196	+ 590·897	− 0·461	+ 590·436
231	232	264·59	+ 0·030	− 0·166	+ 508·120	− 0·420	+ 507·700
232	233	269·47	+ 0·014	− 0·152	+ 263·754	− 0·297	+ 263·457
233	234	271·09	+ 0·011	− 0·141	+ 244·800	− 0·287	+ 244·513
234	235*	271·33	− 0·005	− 0·146	+ 266·019	− 0·298	+ 265·721

Difference of dynamic height, Nira to Hubli = + 265·721 feet.

Length of line in miles = M = 271·33. $\Sigma d^2 = 0{\cdot}060468$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745 \sqrt{\dfrac{\Sigma d^2}{4M}} = \pm\, 0{\cdot}0051$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745 \sqrt{\dfrac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0829$.

* Bench-mark No. 235 is the mark at Hubli described on page 134.

Line No. 30. Bezwada to Vizagapatam.

Bench-marks		Distance from Bezwada	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Bezwada (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Bezwada
From	To		From mark to mark (= d)	Total from Bezwada		Total from Bezwada	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·24	− 0·011	− 0·011	− 0·576	0·000	− 0·576
2	3	1·42	+ 0·004	− 0·007	− 3·943	+ 0·001	− 3·942
3	4	3·36	0·000	− 0·007	− 5·610	+ 0·002	− 5·608
4	5	4·35	− 0·008	− 0·015	− 10·002	+ 0·004	− 9·998
5	6	5·34	− 0·014	− 0·029	− 12·733	+ 0·005	− 12·728
6	7	6·34	+ 0·005	− 0·024	− 14·852	+ 0·006	− 14·846
7	8	7·91	+ 0·015	− 0·009	− 6·656	+ 0·002	− 6·654
8	9	8·31	− 0·004	− 0·013	− 18·035	+ 0·007	− 18·028
9	10	9·30	− 0·006	− 0·019	− 19·362	+ 0·008	− 19·354
10	11	10·30	+ 0·008	− 0·011	− 22·747	+ 0·009	− 22·738
11	12	11·36	+ 0·010	− 0·001	− 14·756	+ 0·005	− 14·751
12	13	12·41	− 0·008	− 0·009	+ 13·804	− 0·008	+ 13·796
13	14	14·43	− 0·022	− 0·031	− 0·362	− 0·002	− 0·364
14	15	15·42	− 0·012	− 0·043	+ 8·249	− 0·006	+ 8·243
15	16	16·41	+ 0·011	− 0·032	+ 2·346	− 0·003	+ 2·343
16	17	17·39	+ 0·013	− 0·019	− 7·498	+ 0·002	− 7·496
17	18	18·38	+ 0·007	− 0·012	− 17·715	+ 0·007	− 17·708
18	19	19·36	+ 0·006	− 0·006	− 15·919	+ 0·006	− 15·913
19	20	20·35	+ 0·007	+ 0·001	− 13·897	+ 0·005	− 13·892
20	21	21·34	− 0·004	− 0·003	− 13·055	+ 0·005	− 13·050
21	22	22·32	+ 0·004	+ 0·001	− 11·035	+ 0·004	− 11·031
22	23	22·89	0·000	+ 0·001	+ 3·444	− 0·002	+ 3·442
23	24	23·31	− 0·008	− 0·007	− 10·971	+ 0·004	− 10·967
24	25	24·31	+ 0·018	+ 0·011	− 9·466	+ 0·003	− 9·463
25	26	25·30	+ 0·023	+ 0·034	− 6·013	+ 0·002	− 6·011
26	27	26·29	+ 0·019	+ 0·053	− 0·375	0·000	− 0·375
27	28	26·85	0·000	+ 0·053	− 3·107	+ 0·001	− 3·106
28	29	34·19	− 0·030	+ 0·023	− 11·839	+ 0·005	− 11·834
29	30	35·57	− 0·013	+ 0·010	− 22·635	+ 0·010	− 22·625
30	31	36·66	− 0·003	+ 0·007	− 23·622	+ 0·010	− 23·612
31	32	38·86	− 0·002	+ 0·005	− 21·783	+ 0·009	− 21·774
32	33	39·75	+ 0·002	+ 0·007	− 23·921	+ 0·010	− 23·911
33	34	41·14	− 0·016	− 0·009	− 31·267	+ 0·013	− 31·254
34	35	42·00	+ 0·005	− 0·004	− 32·860	+ 0·014	− 32·846
35	36	42·40	+ 0·011	+ 0·007	− 30·780	+ 0·013	− 30·767
36	37	42·87	+ 0·002	+ 0·009	− 33·221	+ 0·014	− 33·207
37	38	43·89	− 0·016	− 0·007	− 31·016	+ 0·013	− 31·003
38	39	44·97	+ 0·008	+ 0·001	− 32·166	+ 0·013	− 32·153
39	40	45·97	− 0·005	− 0·004	− 33·853	+ 0·014	− 33·839
40	41	47·17	− 0·029	− 0·033	− 32·387	+ 0·013	− 32·374
41	42	48·59	− 0·006	− 0·039	− 30·712	+ 0·012	− 30·700
42	43	49·34	+ 0·014	− 0·025	− 30·628	+ 0·012	− 30·616
43	44	50·55	+ 0·018	− 0·007	− 33·883	+ 0·013	− 33·870
44	45	51·84	− 0·004	− 0·011	− 22·067	+ 0·008	− 22·059
45	46	53·10	− 0·010	− 0·021	− 34·419	+ 0·013	− 34·406
46	47	54·09	+ 0·001	− 0·020	− 33·063	+ 0·013	− 33·050
47	48	55·08	− 0·002	− 0·022	− 31·530	+ 0·012	− 31·518
48	49	56·07	+ 0·005	− 0·017	− 34·167	+ 0·013	− 34·154
49	50	57·06	− 0·020	− 0·037	− 32·878	+ 0·013	− 32·865
50	51	57·58	− 0·007	− 0·044	− 31·342	+ 0·012	− 31·330
51	52	59·05	+ 0·010	− 0·034	− 33·227	+ 0·013	− 33·214
52	53	60·04	− 0·009	− 0·043	− 33·207	+ 0·013	− 33·194
53	54	61·05	− 0·001	− 0·044	− 29·852	+ 0·012	− 29·840
54	55	61·98	− 0·005	− 0·049	− 29·003	+ 0·012	− 28·991
55	56	63·41	+ 0·013	− 0·036	− 28·825	+ 0·012	− 28·813
56	57	64·02	− 0·003	− 0·039	− 31·877	+ 0·013	− 31·864
57	58	65·01	− 0·018	− 0·057	− 31·878	+ 0·013	− 31·865
58	59	65·80	+ 0·015	− 0·042	− 29·877	+ 0·012	− 29·865
59	60	66·00	+ 0·005	− 0·037	− 30·406	+ 0·012	− 30·394
60	61	67·00	+ 0·009	− 0·028	− 27·749	+ 0·011	− 27·738

* Bench-mark No. 1 is the mark at Bezwada described on page 133.

Line No. 30. Bezwada to Vizagapatam.—(Continued).

Bench-marks From	Bench-marks To	Distance from Bezwada	Discrepancy between levellers (First – Second leveller) From mark to mark (= d)	Discrepancy between levellers (First – Second leveller) Total from Bezwada	Observed elevation above (+) or below (–) Bezwada (mean result by two levellers)	Dynamic correction deduced from mark to mark Total from Bezwada	Dynamic height above (+) or below (–) Bezwada
		miles	foot	foot	feet	foot	feet
61	62	68·00	+ 0·009	– 0·019	– 30·543	+ 0·012	– 30·531
62	63	68·49	+ 0·005	– 0·014	– 29·141	+ 0·011	– 29·130
63	64	68·96	+ 0·012	– 0·002	– 29·859	+ 0·011	– 29·848
64	65	69·81	– 0·007	– 0·009	– 23·616	+ 0·009	– 23·607
65	66	69·95	+ 0·003	– 0·006	– 29·095	+ 0·011	– 29·084
66	67	70·87	– 0·004	– 0·010	– 28·384	+ 0·011	– 28·373
67	68	71·95	+ 0·018	+ 0·008	– 29·031	+ 0·011	– 29·020
68	69	72·95	+ 0·001	+ 0·009	– 27·050	+ 0·010	– 27·040
69	70	73·95	+ 0·006	+ 0·015	– 29·595	+ 0·011	– 29·584
70	71	74·94	– 0·007	+ 0·008	– 29·118	+ 0·011	– 29·107
71	72	75·92	– 0·009	– 0·001	– 28·273	+ 0·011	– 28·262
72	73	76·89	– 0·002	– 0·003	– 27·840	+ 0·011	– 27·829
73	74	77·89	+ 0·022	+ 0·019	– 26·448	+ 0·010	– 26·438
74	75	78·87	+ 0·003	+ 0·022	– 23·431	+ 0·009	– 23·422
75	76	79·87	– 0·008	+ 0·014	– 27·263	+ 0·011	– 27·252
76	77	80·73	– 0·010	+ 0·004	– 25·890	+ 0·011	– 25·879
77	78	80·86	– 0·006	– 0·002	– 28·592	+ 0·012	– 28·580
78	79	81·47	– 0·006	– 0·008	– 27·221	+ 0·012	– 27·209
79	80	82·92	– 0·007	– 0·015	– 25·335	+ 0·011	– 25·324
80	81	83·90	+ 0·003	– 0·012	– 24·632	+ 0·011	– 24·621
81	82	84·88	+ 0·019	+ 0·007	– 22·405	+ 0·010	– 22·395
82	83	85·86	+ 0·001	+ 0·008	– 17·099	+ 0·008	– 17·091
83	84	86·85	+ 0·026	+ 0·034	– 9·076	+ 0·005	– 9·071
84	85	87·22	+ 0·001	+ 0·035	– 25·230	+ 0·012	– 25·218
85	86	88·08	– 0·014	+ 0·021	– 24·971	+ 0·012	– 24·959
86	87	88·54	– 0·003	+ 0·018	– 6·903	+ 0·004	– 6·899
87	88	88·60	+ 0·002	+ 0·020	– 11·820	+ 0·006	– 11·814
88	89	90·71	– 0·019	+ 0·001	– 9·659	+ 0·005	– 9·654
89	90	90·81	+ 0·016	+ 0·017	– 12·708	+ 0·006	– 12·702
90	91	91·76	– 0·010	+ 0·007	– 18·940	+ 0·008	– 18·932
91	92	92·73	– 0·006	+ 0·001	– 19·744	+ 0·008	– 19·736
92	93	93·71	– 0·008	– 0·007	– 20·355	+ 0·008	– 20·347
93	94	94·70	– 0·006	– 0·013	– 25·741	+ 0·010	– 25·731
94	95	94·87	+ 0·001	– 0·012	– 22·691	+ 0·009	– 22·682
95	96	95·70	– 0·001	– 0·013	– 23·113	+ 0·009	– 23·104
96	97	96·70	+ 0·009	– 0·004	– 24·131	+ 0·009	– 24·122
97	98	97·70	+ 0·005	+ 0·001	– 26·060	+ 0·010	– 26·050
98	99	98·69	+ 0·010	+ 0·011	– 25·875	+ 0·010	– 25·865
99	100	99·68	– 0·003	+ 0·008	– 25·572	+ 0·010	– 25·562
100	101	100·18	– 0·009	– 0·001	– 27·915	+ 0·011	– 27·904
101	102	100·70	+ 0·002	+ 0·001	– 34·141	+ 0·013	– 34·128
102	103	101·69	– 0·007	– 0·006	– 33·506	+ 0·013	– 33·493
103	104	102·69	+ 0·029	+ 0·023	– 36·039	+ 0·014	– 36·025
104	105	103·68	+ 0·010	+ 0·033	– 35·592	+ 0·014	– 35·578
105	106	104·66	+ 0·014	+ 0·047	– 36·818	+ 0·014	– 36·804
106	107	105·67	– 0·003	+ 0·044	– 36·106	+ 0·014	– 36·092
107	108	106·66	– 0·027	+ 0·017	– 40·351	+ 0·016	– 40·335
108	109	107·65	– 0·010	+ 0·007	– 42·082	+ 0·017	– 42·065
109	110	108·65	+ 0·033	+ 0·040	– 42·191	+ 0·017	– 42·174
110	111	109·64	+ 0·013	+ 0·053	– 42·007	+ 0·017	– 41·990
111	112	110·63	+ 0·003	+ 0·056	– 45·104	+ 0·018	– 45·086
112	113	111·12	+ 0·004	+ 0·060	– 46·674	+ 0·019	– 46·655
113	114	111·65	– 0·002	+ 0·058	– 49·930	+ 0·020	– 49·910
114	115	112·65	0·000	+ 0·058	– 50·003	+ 0·020	– 49·983
115	116	113·64	+ 0·004	+ 0·062	– 51·920	+ 0·021	– 51·899
116	117	114·64	– 0·009	+ 0·053	– 51·246	+ 0·021	– 51·225
117	118	115·63	+ 0·006	+ 0·059	– 51·973	+ 0·021	– 51·952
118	119	116·64	+ 0·015	+ 0·074	– 55·110	+ 0·022	– 55·088
119	120	117·56	+ 0·006	+ 0·080	– 54·162	+ 0·022	– 54·140
120	121	118·55	+ 0·007	+ 0·087	– 56·041	+ 0·023	– 56·018

Line No. 30. Bezwada to Vizagapatam.—(Continued).

Bench-marks From	Bench-marks To	Distance from Bezwada	Discrepancy between levellers (First – Second leveller) From mark to mark (= d)	Discrepancy between levellers (First – Second leveller) Total from Bezwada	Observed elevation above (+) or below (–) Bezwada (mean result by two levellers)	Dynamic correction deduced from mark to mark Total from Bezwada	Dynamic height above (+) or below (–) Bezwada
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
121	122	119·90	+ 0·024	+ 0·111	– 54·631	+ 0·022	– 54·609
122	123	120·52	+ 0·005	+ 0·116	– 55·818	+ 0·022	– 55·796
123	124	121·51	+ 0·002	+ 0·118	– 58·103	+ 0·023	– 58·080
124	125	123·53	+ 0·022	+ 0·140	– 59·304	+ 0·023	– 59·281
125	126	123·93	0·000	+ 0·140	– 59·564	+ 0·023	– 59·541
126	127	124·01	– 0·002	+ 0·138	– 59·514	+ 0·023	– 59·491
127	128	126·40	– 0·017	+ 0·121	– 50·309	+ 0·019	– 50·290
128	129	127·39	– 0·023	+ 0·098	– 51·647	+ 0·019	– 51·628
129	130	128·39	– 0·001	+ 0·097	– 44·623	+ 0·016	– 44·607
130	131	129·39	+ 0·011	+ 0·108	– 51·573	+ 0·019	– 51·554
131	132	130·37	+ 0·014	+ 0·122	– 49·109	+ 0·018	– 49·091
132	133	130·54	+ 0·002	+ 0·124	– 46·518	+ 0·017	– 46·501
133	134	131·35	+ 0·005	+ 0·129	– 42·946	+ 0·016	– 42·930
134	135	132·35	– 0·005	+ 0·124	– 39·060	+ 0·014	– 39·046
135	136	133·35	– 0·002	+ 0·122	– 25·747	+ 0·008	– 25·739
136	137	135·55	+ 0·016	+ 0·138	– 24·433	+ 0·008	– 24·425
137	138	135·56	+ 0·003	+ 0·141	– 19·870	+ 0·006	– 19·864
138	139	136·52	+ 0·011	+ 0·152	– 20·508	+ 0·006	– 20·502
139	140	137·32	– 0·001	+ 0·151	– 21·842	+ 0·006	– 21·836
140	141	138·50	– 0·001	+ 0·150	– 20·228	+ 0·005	– 20·223
141	142	139·56	– 0·019	+ 0·131	– 21·701	+ 0·006	– 21·695
142	143	141·95	– 0·004	+ 0·127	– 19·221	+ 0·005	– 19·216
143	144	142·49	+ 0·015	+ 0·142	– 16·082	+ 0·004	– 16·078
144	145	143·49	+ 0·001	+ 0·143	– 29·402	+ 0·010	– 29·392
145	146	144·49	+ 0·004	+ 0·147	– 36·859	+ 0·013	– 36·846
146	147	147·47	– 0·006	+ 0·141	– 29·089	+ 0·010	– 29·079
147	148	148·47	+ 0·001	+ 0·142	– 20·377	+ 0·006	– 20·371
148	149	149·46	+ 0·017	+ 0·159	+ 6·850	– 0·005	+ 6·845
149	150	150·46	– 0·004	+ 0·155	+ 15·360	– 0·008	+ 15·352
150	151	151·46	+ 0·025	+ 0·180	+ 41·226	– 0·019	+ 41·207
151	152	152·74	+ 0·002	+ 0·182	+ 85·859	– 0·037	+ 85·822
152	153	153·75	+ 0·011	+ 0·193	+ 68·857	– 0·030	+ 68·827
153	154	154·75	+ 0·005	+ 0·198	+ 52·093	– 0·023	+ 52·070
154	155	155·76	– 0·006	+ 0·192	+ 70·698	– 0·031	+ 70·667
155	156	156·76	– 0·004	+ 0·188	+ 27·541	– 0·013	+ 27·528
156	157	157·75	+ 0·012	+ 0·200	+ 29·316	– 0·014	+ 29·302
157	158	158·75	– 0·008	+ 0·192	+ 30·046	– 0·014	+ 30·032
158	159	159·76	– 0·022	+ 0·170	+ 28·113	– 0·013	+ 28·100
159	160	160·76	+ 0·025	+ 0·195	+ 85·752	– 0·037	+ 85·715
160	161	161·76	– 0·006	+ 0·189	+ 74·111	– 0·032	+ 74·079
161	162	162·76	+ 0·003	+ 0·192	+ 60·075	– 0·026	+ 60·049
162	163	163·76	– 0·007	+ 0·185	+ 122·431	– 0·051	+ 122·380
163	164	164·76	+ 0·032	+ 0·217	+ 180·454	– 0·075	+ 180·379
164	165	165·76	+ 0·002	+ 0·219	+ 109·462	– 0·046	+ 109·416
165	166	166·41	– 0·014	+ 0·205	+ 35·528	– 0·016	+ 35·512
166	167	166·76	+ 0·001	+ 0·206	+ 32·136	– 0·015	+ 32·121
167	168	167·76	+ 0·008	+ 0·214	+ 7·827	– 0·005	+ 7·822
168	169	169·61	+ 0·012	+ 0·226	– 8·479	+ 0·002	– 8·477
169	170	169·81	– 0·008	+ 0·218	– 7·237	+ 0·002	– 7·235
170	171	171·02	– 0·010	+ 0·208	– 9·936	+ 0·003	– 9·933
171	172	172·03	– 0·011	+ 0·197	– 12·424	+ 0·004	– 12·420
172	173	174·36	+ 0·024	+ 0·221	– 34·173	+ 0·013	– 34·160
173	174	175·50	+ 0·007	+ 0·228	– 32·763	+ 0·012	– 32·751
174	175	178·00	+ 0·019	+ 0·247	+ 0·827	– 0·001	+ 0·826
175	176	179·13	– 0·002	+ 0·245	– 0·914	0·000	– 0·914
176	177	180·02	+ 0·003	+ 0·248	+ 1·542	– 0·001	+ 1·541
177	178	181·02	+ 0·014	+ 0·262	+ 1·026	– 0·001	+ 1·025
178	179	181·70	+ 0·007	+ 0·269	– 4·464	+ 0·001	– 4·463
179	180	182·09	+ 0·007	+ 0·276	– 20·600	+ 0·007	– 20·593
180	181	183·10	+ 0·005	+ 0·281	+ 1·005	– 0·002	+ 1·003

Line No. 30. Bezwada to Vizagapatam.—(Continued).

Bench-marks From	Bench-marks To	Distance from Bezwada	Discrepancy between levellers (First – Second leveller) From mark to mark (= d)	Discrepancy between levellers (First – Second leveller) Total from Bezwada	Observed elevation above (+) or below (–) Bezwada (mean result by two levellers)	Dynamic correction deduced from mark to mark Total from Bezwada	Dynamic height above (+) or below (–) Bezwada
		miles	*foot*	*feet*	*feet*	*foot*	*feet*
181	182	184·11	– 0·003	+ 0·278	– 13·029	+ 0·004	– 13·025
182	183	185·11	– 0·009	+ 0·269	– 37·177	+ 0·014	– 37·163
183	184	186·12	+ 0·008	+ 0·277	– 30·214	+ 0·011	– 30·203
184	185	187·13	+ 0·006	+ 0·283	– 21·669	+ 0·008	– 21·661
185	186	188·14	– 0·014	+ 0·269	– 24·274	+ 0·009	– 24·265
186	187	190·28	+ 0·041	+ 0·310	– 23·838	+ 0·009	– 23·829
187	188	191·15	– 0·020	+ 0·290	– 19·061	+ 0·007	– 19·054
188	189	192·16	+ 0·018	+ 0·308	+ 14·476	– 0·006	+ 14·470
189	190	193·17	– 0·007	+ 0·301	+ 21·106	– 0·009	+ 21·097
190	191	194·18	– 0·008	+ 0·293	– 27·209	+ 0·010	– 27·199
191	192	195·36	+ 0·007	+ 0·300	– 19·808	+ 0·007	– 19·801
192	193	196·23	+ 0·003	+ 0·303	– 31·896	+ 0·012	– 31·884
193	194	197·24	+ 0·006	+ 0·309	– 32·891	+ 0·012	– 32·879
194	195	198·25	+ 0·010	+ 0·319	– 20·386	+ 0·007	– 20·379
195	196	199·26	+ 0·005	+ 0·324	– 8·584	+ 0·002	– 8·582
196	197	200·26	– 0·005	+ 0·319	+ 2·458	– 0·002	+ 2·456
197	198	201·26	– 0·001	+ 0·318	+ 5·771	– 0·003	+ 5·768
198	199	202·27	+ 0·009	+ 0·327	+ 0·789	– 0·001	+ 0·788
199	200	203·28	+ 0·004	+ 0·331	+ 23·608	– 0·010	+ 23·598
200	201	204·29	+ 0·002	+ 0·333	+ 49·001	– 0·020	+ 48·981
201	202	205·29	– 0·009	+ 0·324	+ 27·673	– 0·012	+ 27·661
202	203	206·30	+ 0·002	+ 0·326	+ 22·616	– 0·010	+ 22·606
203	204	207·30	0·000	+ 0·326	+ 23·740	– 0·010	+ 23·730
204	205	208·32	+ 0·009	+ 0·335	+ 18·350	– 0·008	+ 18·342
205	206	209·32	+ 0·016	+ 0·351	+ 19·231	– 0·008	+ 19·223
206	207	210·32	+ 0·002	+ 0·353	+ 23·585	– 0·010	+ 23·575
207	208	211·33	+ 0·004	+ 0·357	+ 11·775	– 0·005	+ 11·770
208	209	212·15	– 0·013	+ 0·344	+ 7·819	– 0·003	+ 7·816
209	210	213·15	– 0·003	+ 0·341	+ 16·557	– 0·007	+ 16·550
210	211	214·15	+ 0·012	+ 0·353	+ 41·104	– 0·017	+ 41·087
211	212	215·15	+ 0·017	+ 0·370	+ 42·321	– 0·017	+ 42·304
212	213	216·16	– 0·009	+ 0·361	+ 63·942	– 0·025	+ 63·917
213	214	217·16	+ 0·021	+ 0·382	+ 158·003	– 0·062	+ 157·941
214	215	218·06	+ 0·004	+ 0·386	+ 101·727	– 0·040	+ 101·687
215	216	218·16	– 0·006	+ 0·380	+ 96·522	– 0·038	+ 96·484
216	217	218·17	+ 0·005	+ 0·385	+ 101·377	– 0·040	+ 101·337
217	218	219·18	– 0·001	+ 0·384	+ 69·578	– 0·028	+ 69·550
218	219	219·22	– 0·003	+ 0·381	+ 70·045	– 0·028	+ 70·017
219	220	220·27	– 0·022	+ 0·359	+ 21·888	– 0·009	+ 21·879
220	221	220·28	0·000	+ 0·359	+ 19·928	– 0·008	+ 19·920
221	222	221·28	– 0·001	+ 0·358	– 6·778	+ 0·002	– 6·776
222	223	222·27	– 0·016	+ 0·342	– 12·576	+ 0·004	– 12·572
223	224	223·58	– 0·011	+ 0·331	+ 1·477	– 0·002	+ 1·475
224	225	224·26	+ 0·003	+ 0·334	+ 6·546	– 0·004	+ 6·543
225	226	225·23	+ 0·017	+ 0·351	+ 44·883	– 0·019	+ 44·864
226	227	226·25	+ 0·004	+ 0·355	– 18·860	+ 0·006	– 18·854
227	228	226·75	– 0·008	+ 0·347	– 9·547	+ 0·002	– 9·545
228	229	227·25	– 0·008	+ 0·339	– 27·233	+ 0·009	– 27·224
229	230	228·24	– 0·028	+ 0·311	– 33·136	+ 0·011	– 33·125
230	231	229·22	– 0·006	+ 0·305	– 60·205	+ 0·022	– 60·183
231	232	229·71	+ 0·006	+ 0·311	– 63·293	+ 0·023	– 63·270
232	233	229·76	– 0·002	+ 0·309	– 59·846	+ 0·022	– 59·824
233	234*	229·87	+ 0·004	+ 0·313	– 51·530	+ 0·019	– 51·511

Difference of dynamic height, Bezwada to Vizagapatam = – 51·511 feet.

Length of line in miles = M = 229·87. $\Sigma d^2 = 0\cdot031923$.

Probable error of the mean result per mile of double-levelling $= 0\cdot6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0\cdot0039.$

Line No. 31. Kalyan to Kedgaon.

Bench-marks From	Bench-marks To	Distance from Kalyan *	Discrepancy between levellers (First − Second leveller): From mark to mark (= d)	Discrepancy between levellers (First − Second leveller): Total from Kalyan	Observed elevation above (+) or below (−) Kalyan (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Kalyan	Dynamic height above (+) or below (−) Kalyan
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·05	− 0·001	− 0·001	+ 1·709	− 0·001	+ 1·708
2	3	1·04	+ 0·003	− 0·002	+ 13·999	− 0·005	+ 13·994
3	4	6·34	− 0·020	− 0·018	+ 98·387	− 0·030	+ 98·357
4	5	7·70	− 0·012	− 0·030	+ 67·148	− 0·020	+ 67·128
5	6	8·15	+ 0·001	− 0·029	+ 56·463	− 0·017	+ 56·446
6	7	8·69	+ 0·006	− 0·023	+ 44·657	− 0·013	+ 44·644
7	8	12·17	− 0·016	− 0·039	+ 43·416	− 0·013	+ 43·403
8	9	13·10	− 0·004	− 0·043	+ 46·624	− 0·014	+ 46·610
9	10	14·29	+ 0·004	− 0·039	+ 81·307	− 0·025	+ 81·282
10	11	14·69	+ 0·006	− 0·033	+ 96·245	− 0·030	+ 96·215
11	12	15·09	+ 0·005	− 0·028	+ 105·616	− 0·033	+ 105·583
12	13	18·05	+ 0·007	− 0·021	+ 103·329	− 0·032	+ 103·297
13	14	18·73	− 0·001	− 0·022	+ 93·098	− 0·029	+ 93·069
14	15	19·36	+ 0·005	− 0·017	+ 92·322	− 0·029	+ 92·293
15	16	20·29	+ 0·003	− 0·014	+ 103·499	− 0·032	+ 103·467
16	17	20·86	+ 0·004	− 0·010	+ 121·323	− 0·038	+ 121·285
17	18	21·91	+ 0·001	− 0·009	+ 143·625	− 0·045	+ 143·580
18	19	23·87	+ 0·004	− 0·005	+ 131·552	− 0·041	+ 131·511
19	20	25·96	+ 0·015	+ 0·010	+ 129·747	− 0·040	+ 129·707
20	21	28·05	+ 0·003	+ 0·013	+ 135·381	− 0·042	+ 135·339
21	22	28·94	− 0·004	+ 0·009	+ 144·628	− 0·045	+ 144·583
22	23	30·88	+ 0·009	+ 0·018	+ 169·215	− 0·053	+ 169·162
23	24	35·94	− 0·002	+ 0·016	+ 183·008	− 0·057	+ 182·951
24	25	37·45	+ 0·013	+ 0·029	+ 204·965	− 0·064	+ 204·901
25	26	37·66	+ 0·001	+ 0·030	+ 210·144	− 0·066	+ 210·078
26	27	37·72	+ 0·001	+ 0·031	+ 207·071	− 0·065	+ 207·006
27	28	42·99	+ 0·067	+ 0·098	+ 1754·506	− 0·576	+ 1753·930
28	29	43·72	+ 0·003	+ 0·101	+ 1765·513	− 0·580	+ 1764·933
29	30	45·92	+ 0·023	+ 0·124	+ 2012·665	− 0·662	+ 2012·003
30	31	48·22	− 0·025	+ 0·099	+ 1999·154	− 0·657	+ 1998·497
31	32	50·27	− 0·009	+ 0·090	+ 1997·789	− 0·657	+ 1997·132
32	33	52·01	− 0·009	+ 0·081	+ 1994·058	− 0·656	+ 1993·402
33	34	53·25	+ 0·002	+ 0·083	+ 1984·754	− 0·653	+ 1984·101
34	35	54·52	+ 0·008	+ 0·091	+ 1978·482	− 0·651	+ 1977·831
35	36	55·88	− 0·007	+ 0·084	+ 1975·952	− 0·650	+ 1975·302
36	37	55·93	− 0·001	+ 0·083	+ 1974·387	− 0·649	+ 1973·738
37	38	57·58	− 0·011	+ 0·072	+ 1992·977	− 0·655	+ 1992·322
38	39	58·90	+ 0·012	+ 0·084	+ 2034·989	− 0·669	+ 2034·320
39	40	61·15	+ 0·002	+ 0·086	+ 2012·630	− 0·662	+ 2011·968
40	41	62·95	+ 0·004	+ 0·090	+ 1991·901	− 0·655	+ 1991·246
41	42	65·42	− 0·022	+ 0·068	+ 1957·046	− 0·643	+ 1956·403
42	43	67·35	+ 0·005	+ 0·073	+ 1894·721	− 0·622	+ 1894·099
43	44	69·72	+ 0·018	+ 0·091	+ 1957·261	− 0·643	+ 1956·618
44	45	70·37	+ 0·002	+ 0·093	+ 1970·434	− 0·647	+ 1969·787
45	46	71·18	+ 0·004	+ 0·097	+ 1951·022	− 0·641	+ 1950·381
46	47	71·78	+ 0·001	+ 0·098	+ 1931·946	− 0·635	+ 1931·311
47	48	72·29	− 0·002	+ 0·096	+ 1911·628	− 0·628	+ 1911·000
48	49	75·40	− 0·011	+ 0·085	+ 1850·694	− 0·607	+ 1850·087
49	50	76·28	+ 0·003	+ 0·088	+ 1819·693	− 0·596	+ 1819·097
50	51	78·08	− 0·012	+ 0·076	+ 1810·042	− 0·593	+ 1809·449
51	52	80·34	− 0·025	+ 0·051	+ 1803·920	− 0·591	+ 1803·329
52	53	82·35	+ 0·003	+ 0·054	+ 1808·875	− 0·593	+ 1808·282
53	54	83·43	− 0·007	+ 0·047	+ 1780·050	− 0·583	+ 1779·467
54	55	84·72	+ 0·008	+ 0·055	+ 1781·756	− 0·584	+ 1781·172
55	56	85·43	− 0·008	+ 0·047	+ 1795·984	− 0·589	+ 1795·395
56	57	86·14	− 0·003	+ 0·044	+ 1817·922	− 0·597	+ 1817·325
57	58	86·77	− 0·005	+ 0·039	+ 1857·351	− 0·610	+ 1856·741
58	59	87·66	+ 0·017	+ 0·056	+ 1884·288	− 0·619	+ 1883·669
59	60	90·67	− 0·016	+ 0·040	+ 1836·626	− 0·603	+ 1836·023
60	61	92·36	+ 0·005	+ 0·045	+ 1841·194	− 0·604	+ 1840·590

* Bench-mark No. 1 is the mark at Kalyan described on page 134.

Line No. 31. Kalyan to Kedgaon.—(Continued).

Bench-marks From	Bench-marks To	Distance from Kalyan	Discrepancy between levellers (First – Second leveller) From mark to mark (= d)	Discrepancy between levellers (First – Second leveller) Total from Kalyan	Observed elevation above (+) or below (–) Kalyan (mean result by two levellers)	Dynamic correction deduced from mark to mark Total from Kalyan	Dynamic height above (+) or below (–) Kalyan
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	94·85	– 0·009	+ 0·036	+ 1784·235	– 0·585	+ 1783·650
62	63	97·16	– 0·016	+ 0·020	+ 1739·303	– 0·570	+ 1738·733
63	64	98·38	– 0·003	+ 0·017	+ 1778·579	– 0·583	+ 1777·996
64	65	100·36	– 0·001	+ 0·016	+ 1776·954	– 0·582	+ 1776·372
65	66	102·41	+ 0·002	+ 0·018	+ 1771·609	– 0·580	+ 1771·029
66	67	104·31	+ 0·013	+ 0·031	+ 1775·818	– 0·581	+ 1775·237
67	68	104·51	+ 0·001	+ 0·032	+ 1778·541	– 0·582	+ 1777·959
68	69	105·59	– 0·005	+ 0·027	+ 1779·422	– 0·582	+ 1778·840
69	70	106·75	– 0·012	+ 0·015	+ 1784·559	– 0·584	+ 1783·975
70	71	108·51	– 0·020	– 0·005	+ 1780·293	– 0·583	+ 1779·710
71	72	110·67	+ 0·005	0·000	+ 1800·955	– 0·590	+ 1800·365
72	73	111·01	– 0·004	– 0·004	+ 1796·227	– 0·589	+ 1795·638
73	74	112·34	+ 0·005	+ 0·001	+ 1797·141	– 0·589	+ 1796·552
74	75	112·87	– 0·005	– 0·004	+ 1785·410	– 0·585	+ 1784·825
75	76	113·53	– 0·001	– 0·005	+ 1793·488	– 0·588	+ 1792·900
76	77	115·29	– 0·007	– 0·012	+ 1812·458	– 0·595	+ 1811·863
77	78	115·49	+ 0·001	– 0·011	+ 1812·160	– 0·595	+ 1811·565
78	79	119·63	– 0·014	– 0·025	+ 1761·584	– 0·578	+ 1761·006
79	80*	119·98	– 0·004	– 0·029	+ 1751·532	– 0·575	+ 1750·957

Difference of dynamic height, Kalyan to Kedgaon = + 1750·957 feet.

Length of line in miles = M = 119·98. $\Sigma d^2 = 0{\cdot}011771$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0{\cdot}0033$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0{\cdot}0366$.

* Bench-mark No. 80 is the mark at Kedgaon described on page 134.

Line No. 32. Bombay to Kalyan.

Bench-marks		Distance from Bombay	Discrepancy between levellers (First—Second leveller)		Observed elevation above (+) or below (−) Bombay (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Bombay
From	To		From mark to mark (= d)	Total from Bombay		Total from Bombay	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	3·90	+ 0·003	+ 0·003	− 5·321	+ 0·002	− 5·319
2	3	5·14	− 0·008	− 0·005	− 11·060	+ 0·004	− 11·056
3	4	6·86	− 0·002	− 0·007	− 5·208	+ 0·002	− 5·206
4	5	7·09	− 0·003	− 0·010	− 8·143	+ 0·003	− 8·140
5	6	7·20	0·000	− 0·010	− 7·249	+ 0·003	− 7·246
6	7	10·56	− 0·017	− 0·027	− 9·874	+ 0·004	− 9·870
7	8	11·06	− 0·001	− 0·028	− 3·736	+ 0·002	− 3·734
8	9	11·85	+ 0·006	− 0·022	− 7·852	+ 0·003	− 7·849
9	10	14·34	− 0·009	− 0·031	− 0·307	+ 0·001	− 0·306
10	11	16·80	0·000	− 0·031	− 4·391	+ 0·002	− 4·389
11	12	17·13	+ 0·001	− 0·030	+ 1·483	0·000	+ 1·483
12	13	22·00	+ 0·008	− 0·022	+ 6·182	− 0·001	+ 6·181
13	14	22·64	+ 0·007	− 0·015	+ 19·798	− 0·005	+ 19·793
14	15	23·34	− 0·002	− 0·017	− 2·459	+ 0·002	− 2·457
15	16	24·73	− 0·005	− 0·022	+ 18·022	− 0·004	+ 18·018
16	17	25·33	− 0·003	− 0·025	+ 1·426	+ 0·001	+ 1·427
17	18	26·60	+ 0·003	− 0·022	+ 3·980	0·000	+ 3·980
18	19	27·73	− 0·003	− 0·025	− 1·692	+ 0·002	− 1·690
19	20	31·43	0·000	− 0·025	+ 16·211	− 0·003	+ 16·208
20	21†	34·54	− 0·007	− 0·032	+ 5·399	0·000	+ 5·399

Difference of dynamic height, Bombay to Kalyan = + 5·399 feet.

Length of line in miles = M = 34·54. $\Sigma d^2 = 0{\cdot}000712$.

$$\text{Probable error of the mean result per mile of double-levelling} = 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4\text{M}}} = \pm\ 0{\cdot}0015.$$

$$\text{Probable error of the difference of elevation between the terminal bench-marks} = 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0{\cdot}0090.$$

* Bench-mark No. 1 is the mark at Bombay described on page 133. † Bench-mark No. 21 is the mark at Kalyan described on page 134.

Line No. 33. Kalyan to Nandgaon.

Bench-marks		Distance from Kalyan	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Kalyan (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Kalyan
From	To		From mark to mark (=d)	Total from Kalyan		Total from Kalyan	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·02	– 0·002	– 0·002	– 1·557	+ 0·001	– 1·556
2	3	1·30	– 0·004	– 0·006	+ 11·999	– 0·003	+ 11·996
3	4	1·70	– 0·002	– 0·008	+ 12·238	– 0·003	+ 12·235
4	5	2·30	– 0·003	– 0·011	+ 14·262	– 0·004	+ 14·258
5	6	2·90	– 0·005	– 0·016	+ 28·036	– 0·008	+ 28·028
6	7	4·00	– 0·009	– 0·025	+ 18·962	– 0·005	+ 18·957
7	8	5·50	+ 0·008	– 0·017	+ 12·374	– 0·003	+ 12·371
8	9	6·80	– 0·002	– 0·019	+ 26·742	– 0·007	+ 26·735
9	10	6·80	+ 0·001	– 0·018	+ 27·994	– 0·007	+ 27·987
10	11	7·30	– 0·006	– 0·024	+ 30·011	– 0·008	+ 30·003
11	12	10·10	– 0·016	– 0·040	+ 33·887	– 0·009	+ 33·878
12	13	12·40	+ 0·002	– 0·038	+ 36·704	– 0·010	+ 36·694
13	14	13·01	+ 0·001	– 0·037	+ 43·580	– 0·012	+ 43·568
14	15	14·40	– 0·002	– 0·039	+ 66·415	– 0·019	+ 66·396
15	16	15·70	– 0·014	– 0·053	+ 53·202	– 0·015	+ 53·187
16	17	16·40	+ 0·001	– 0·052	+ 76·195	– 0·022	+ 76·173
17	18	16·40	+ 0·001	– 0·051	+ 74·285	– 0·021	+ 74·264
18	19	16·60	+ 0·004	– 0·047	+ 74·264	– 0·021	+ 74·243
19	20	17·70	– 0·010	– 0·057	+ 109·344	– 0·031	+ 109·313
20	21	18·70	+ 0·007	– 0·050	+ 162·608	– 0·046	+ 162·562
21	22	20·10	– 0·013	– 0·063	+ 221·279	– 0·063	+ 221·216
22	23	20·20	+ 0·003	– 0·060	+ 217·530	– 0·062	+ 217·468
23	24	20·70	+ 0·002	– 0·058	+ 214·144	– 0·061	+ 214·083
24	25	22·90	0·000	– 0·058	+ 322·722	– 0·092	+ 322·630
25	26	23·30	– 0·008	– 0·066	+ 344·535	– 0·098	+ 344·437
26	27	23·80	+ 0·012	– 0·054	+ 364·402	– 0·104	+ 364·298
27	28	26·10	+ 0·026	– 0·028	+ 452·137	– 0·129	+ 452·008
28	29	26·10	– 0·002	– 0·030	+ 449·901	– 0·128	+ 449·773
29	30	26·80	– 0·016	– 0·046	+ 457·684	– 0·130	+ 457·554
30	31	28·30	– 0·006	– 0·052	+ 499·915	– 0·142	+ 499·773
31	32	29·80	– 0·008	– 0·060	+ 541·347	– 0·154	+ 541·193
32	33	30·10	+ 0·007	– 0·053	+ 578·929	– 0·165	+ 578·764
33	34	32·70	– 0·009	– 0·062	+ 679·827	– 0·194	+ 679·633
34	35	32·84	– 0·004	– 0·066	+ 688·814	– 0·197	+ 688·617
35	36	33·68	+ 0·005	– 0·061	+ 724·619	– 0·207	+ 724·412
36	37	33·69	0·000*	– 0·061	+ 723·216	– 0·207	+ 723·009
37	38	34·17	– 0·002	– 0·063	+ 711·410	– 0·204	+ 711·206
38	39	34·57	– 0·002	– 0·065	+ 693·413	– 0·199	+ 693·214
39	40	36·25	+ 0·025	– 0·040	+ 714·238	– 0·205	+ 714·033
40	41	38·15	– 0·023	– 0·063	+ 804·013	– 0·230	+ 803·783
41	42	38·77	0·000	– 0·063	+ 830·209	– 0·237	+ 829·972
42	43	40·35	+ 0·018	– 0·045	+ 854·708	– 0·244	+ 854·464
43	44	41·34	+ 0·003	– 0·042	+ 899·635	– 0·257	+ 899·378
44	45	42·04	– 0·013	– 0·055	+ 924·770	– 0·264	+ 924·506
45	46	42·51	+ 0·001	– 0·054	+ 915·242	– 0·261	+ 914·981
46	47	43·35	+ 0·010	– 0·044	+ 739·238	– 0·212	+ 739·026
47	48	43·60	– 0·005	– 0·049	+ 800·518	– 0·229	+ 800·289
48	49	43·76	– 0·005	– 0·054	+ 839·855	– 0·240	+ 839·615
49	50	44·26	– 0·019	– 0·073	+ 947·410	– 0·270	+ 947·140
50	51	45·30	– 0·002	– 0·075	+ 942·436	– 0·268	+ 942·168
51	52	47·36	– 0·015	– 0·090	+ 1088·627	– 0·308	+ 1088·319
52	53	47·90	– 0·036	– 0·126	+ 1215·124	– 0·343	+ 1214·781
53	54	48·20	– 0·019	– 0·145	+ 1286·209	– 0·363	+ 1285·846
54	55	48·40	– 0·013	– 0·158	+ 1341·082	– 0·378	+ 1340·704
55	56	49·35	– 0·005	– 0·163	+ 1580·530	– 0·444	+ 1580·086
56	57	50·20	– 0·009	– 0·172	+ 1673·978	– 0·470	+ 1673·508
57	58	50·96	+ 0·014	– 0·158	+ 1737·965	– 0·488	+ 1737·477
58	59	51·20	– 0·003	– 0·161	+ 1769·710	– 0·497	+ 1769·213
59	60	51·66	– 0·025	– 0·186	+ 1852·369	– 0·520	+ 1851·849
60	61	53·02	– 0·024	– 0·210	+ 1896·810	– 0·532	+ 1896·278

* Bench-mark No. 1 is the mark at Kalyan described on page 134.

Line No. 33. Kalyan to Nandgaon.—(Continued).

Bench-marks		Distance from Kalyan	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Kalyan (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Kalyan
From	To		From mark to mark (= d)	Total from Kalyan		Total from Kalyan	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	53·20	+ 0·003	– 0·207	+ 1893·928	– 0·531	+ 1893·397
62	63	54·18	– 0·007	– 0·214	+ 1894·631	– 0·531	+ 1894·100
63	64	54·24	+ 0·003	– 0·211	+ 1897·695	– 0·532	+ 1897·163
64	65	55·28	– 0·020	– 0·231	+ 1880·201	– 0·527	+ 1879·674
65	66	57·26	0·000	– 0·231	+ 1873·369	– 0·525	+ 1872·844
66	67	57·65	+ 0·010	– 0·221	+ 1879·646	– 0·527	+ 1879·119
67	68	59·95	+ 0·039	– 0·182	+ 1870·146	– 0·524	+ 1869·622
68	69	59·96	+ 0·002	– 0·180	+ 1871·612	– 0·524	+ 1871·088
69	70	61·77	+ 0·015	– 0·165	+ 1861·037	– 0·521	+ 1860·516
70	71	62·57	+ 0·001	– 0·164	+ 1862·096	– 0·521	+ 1861·575
71	72	63·47	+ 0·011	– 0·153	+ 1864·575	– 0·522	+ 1864·053
72	73	66·17	+ 0·004	– 0·149	+ 1944·737	– 0·544	+ 1944·193
73	74	67·86	+ 0·012	– 0·137	+ 1862·968	– 0·522	+ 1862·446
74	75	68·65	+ 0·009	– 0·128	+ 1863·908	– 0·522	+ 1863·386
75	76	69·69	+ 0·002	– 0·126	+ 1863·860	– 0·522	+ 1863·338
76	77	69·70	– 0·006	– 0·132	+ 1865·664	– 0·523	+ 1865·141
77	78	71·45	+ 0·017	– 0·115	+ 1837·138	– 0·515	+ 1836·623
78	79	73·25	– 0·014	– 0·129	+ 1811·328	– 0·508	+ 1810·820
79	80	74·30	+ 0·001	– 0·128	+ 1827·339	– 0·512	+ 1826·827
80	81	75·50	– 0·006	– 0·134	+ 1833·388	– 0·514	+ 1832·874
81	82	76·92	+ 0·020	– 0·114	+ 1880·402	– 0·527	+ 1879·875
82	83	78·78	– 0·008	– 0·122	+ 1858·284	– 0·521	+ 1857·763
83	84	80·06	+ 0·002	– 0·120	+ 1818·905	– 0·510	+ 1818·395
84	85	82·07	+ 0·014	– 0·106	+ 1804·129	– 0·506	+ 1803·623
85	86	82·08	0·000	– 0·106	+ 1802·158	– 0·505	+ 1801·653
86	87	83·57	– 0·024	– 0·130	+ 1803·900	– 0·506	+ 1803·394
87	88	84·72	– 0·016	– 0·146	+ 1813·519	– 0·509	+ 1813·010
88	89	85·60	– 0·017	– 0·163	+ 1815·458	– 0·510	+ 1814·948
89	90	85·62	+ 0·001	– 0·162	+ 1816·714	– 0·510	+ 1816·204
90	91	85·76	– 0·003	– 0·165	+ 1815·643	– 0·510	+ 1815·133
91	92	86·11	+ 0·002	– 0·163	+ 1825·587	– 0·513	+ 1825·074
92	93	87·66	+ 0·012	– 0·151	+ 1855·837	– 0·521	+ 1855·316
93	94	89·45	– 0·010	– 0·161	+ 1812·461	– 0·510	+ 1811·951
94	95	90·20	– 0·004	– 0·165	+ 1836·695	– 0·516	+ 1836·179
95	96	92·60	– 0·001	– 0·166	+ 1843·383	– 0·518	+ 1842·865
96	97	93·48	– 0·012	– 0·178	+ 1834·767	– 0·516	+ 1834·251
97	98	96·58	+ 0·007	– 0·171	+ 1786·938	– 0·503	+ 1786·435
98	99	97·26	+ 0·006	– 0·165	+ 1785·079	– 0·502	+ 1784·577
99	100	97·27	+ 0·002	– 0·163	+ 1782·520	– 0·501	+ 1782·019
100	101	98·20	+ 0·007	– 0·156	+ 1782·976	– 0·501	+ 1782·475
101	102	100·20	– 0·001	– 0·157	+ 1777·914	– 0·500	+ 1777·414
102	103	101·10	– 0·003	– 0·160	+ 1773·032	– 0·499	+ 1772·533
103	104	101·55	– 0·002	– 0·162	+ 1764·478	– 0·497	+ 1763·981
104	105	102·57	– 0·008	– 0·170	+ 1782·796	– 0·502	+ 1782·294
105	106	104·71	0·000	– 0·170	+ 1783·558	– 0·502	+ 1783·056
106	107	105·09	+ 0·002	– 0·168	+ 1778·546	– 0·501	+ 1778·045
107	108	105·12	– 0·001	– 0·169	+ 1779·925	– 0·501	+ 1779·424
108	109	107·68	+ 0·010	– 0·159	+ 1807·235	– 0·508	+ 1806·727
109	110	108·60	– 0·004	– 0·163	+ 1828·192	– 0·513	+ 1827·679
110	111	109·64	– 0·014	– 0·177	+ 1838·112	– 0·516	+ 1837·596
111	112	111·31	+ 0·008	– 0·169	+ 1887·802	– 0·528	+ 1887·274
112	113	113·97	+ 0·020	– 0·149	+ 1919·082	– 0·536	+ 1918·546
113	114	115·52	+ 0·002	– 0·147	+ 1917·351	– 0·536	+ 1916·815
114	115	115·54	– 0·001	– 0·148	+ 1915·079	– 0·535	+ 1914·544
115	116	116·03	– 0·013	– 0·161	+ 1914·794	– 0·535	+ 1914·259
116	117	118·45	– 0·015	– 0·176	+ 1918·385	– 0·536	+ 1917·849
117	118	121·85	+ 0·023	– 0·153	+ 1999·130	– 0·556	+ 1998·574
118	119	124·25	– 0·022	– 0·175	+ 2079·843	– 0·576	+ 2079·267
119	120	126·54	+ 0·003	– 0·172	+ 1993·704	– 0·554	+ 1993·150
120	121	128·64	+ 0·002	– 0·170	+ 1931·874	– 0·538	+ 1931·336

Line No. 33. Kalyan to Nandgaon.—(Continued).

Bench-marks		Distance from Kalyan	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (−) Kalyan (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Kalyan
From	To		From mark to mark (= d)	Total from Kalyan		Total from Kalyan	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
121	122	130·93	+ 0·006	− 0·164	+ 1872·973	− 0·524	+ 1872·44
122	123	130·95	− 0·006	− 0·170	+ 1874·630	− 0·524	+ 1874·10
123	124	134·20	− 0·013	− 0·183	+ 1810·481	− 0·509	+ 1809·97$_5$
124	125	136·31	+ 0·013	− 0·170	+ 1775·817	− 0·501	+ 1775·31
125	126	136·60	0·000	− 0·170	+ 1769·134	− 0·499	+ 1768·635
126	127	139·36	+ 0·008	− 0·162	+ 1738·607	− 0·492	+ 1738·115
127	128	140·18	0·000	− 0·162	+ 1724·281	− 0·489	+ 1723·792
128	129	142·41	− 0·013	− 0·175	+ 1659·369	− 0·473	+ 1658·896
129	130	143·31	− 0·001	− 0·176	+ 1634·340	− 0·467	+ 1633·873
130	131	144·67	+ 0·026	− 0·150	+ 1586·842	− 0·456	+ 1586·386
131	132	146·29	+ 0·001	− 0·149	+ 1533·892	− 0·443	+ 1533·449
132	133	146·57	+ 0·004	− 0·145	+ 1528·154	− 0·442	+ 1527·712
133	134*	146·60	+ 0·004	− 0·141	+ 1529·696	− 0·442	+ 1529·254

Difference of dynamic height, Kalyan to Nandgaon = + 1529·254 feet.

Length of line in miles = M = 146·60. $\Sigma d^2 = 0{\cdot}017433$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745 \sqrt{\dfrac{\Sigma d^2}{4M}} = \pm\, 0{\cdot}0037.$

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745 \sqrt{\dfrac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0445.$

* Bench-mark No. 134 is the mark at Nandgaon described on page 135.

Line No. 34. Nandgaon to Sironj.

Bench-marks		Distance from Nandgaon	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Nandgaon (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Nandgaon
From	To		From mark to mark (= *d*)	Total from Nandgaon		Total from Nandgaon	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·30	− 0·008	− 0·008	+ 4·196	− 0·001	+ 4·195
2	3	2·56	+ 0·035	+ 0·027	+ 78·586	− 0·019	+ 78·567
3	4	8·51	+ 0·048	+ 0·075	− 86·354	+ 0·019	− 86·335
4	5	9·94	− 0·008	+ 0·067	− 82·154	+ 0·018	− 82·136
5	6	18·32	− 0·001	+ 0·066	− 208·230	+ 0·047	− 208·183
6	7	19·73	+ 0·022	+ 0·088	− 167·850	+ 0·038	− 167·812
7	8	21·91	+ 0·022	+ 0·110	− 149·939	+ 0·034	− 149·905
8	9	22·91	− 0·013	+ 0·097	− 71·372	+ 0·017	− 71·355
9	10	25·11	− 0·005	+ 0·092	− 34·870	+ 0·009	− 34·861
10	11	27·19	+ 0·021	+ 0·113	− 96·199	+ 0·022	− 96·177
11	12	27·72	+ 0·004	+ 0·117	− 113·557	+ 0·026	− 113·531
12	13	28·33	− 0·009	+ 0·108	− 151·606	+ 0·034	− 151·572
13	14	29·26	− 0·006	+ 0·102	− 140·326	+ 0·032	− 140·294
14	15	30·26	+ 0·010	+ 0·112	− 154·700	+ 0·035	− 154·665
15	16	31·27	+ 0·008	+ 0·120	− 156·138	+ 0·035	− 156·103
16	17	33·26	+ 0·018	+ 0·138	− 162·900	+ 0·036	− 162·864
17	18	34·26	− 0·009	+ 0·129	− 173·516	+ 0·038	− 173·478
18	19	35·26	− 0·013	+ 0·116	− 258·591	+ 0·056	− 258·535
19	20	36·25	− 0·005	+ 0·111	− 286·890	+ 0·062	− 286·828
20	21	37·28	− 0·015	+ 0·096	− 300·657	+ 0·065	− 300·592
21	22	38·29	− 0·003	+ 0·093	− 283·826	+ 0·061	− 283·765
22	23	38·89	− 0·007	+ 0·086	− 261·896	+ 0·056	− 261·840
23	24	38·90	+ 0·005	+ 0·091	− 260·813	+ 0·056	− 260·757
24	25	40·43	− 0·003	+ 0·088	− 211·962	+ 0·046	− 211·916
25	26	42·46	+ 0·016	+ 0·104	− 193·204	+ 0·042	− 193·162
26	27	43·47	− 0·015	+ 0·089	− 355·717	+ 0·076	− 355·641
27	28	44·69	− 0·001	+ 0·088	− 403·969	+ 0·086	− 403·883
28	29	45·48	− 0·018	+ 0·070	− 455·411	+ 0·097	− 455·314
29	30	46·48	+ 0·008	+ 0·078	− 493·518	+ 0·105	− 493·413
30	31	47·48	− 0·018	+ 0·060	− 526·085	+ 0·112	− 525·973
31	32	49·64	+ 0·005	+ 0·065	− 655·054	+ 0·139	− 654·915
32	33	50·49	− 0·010	+ 0·055	− 684·331	+ 0·145	− 684·186
33	34	50·69	− 0·003	+ 0·052	− 688·673	+ 0·146	− 688·527
34	35	50·94	0·000	+ 0·052	− 692·672	+ 0·147	− 692·525
35	36	51·63	− 0·011	+ 0·041	− 708·135	+ 0·150	− 707·985
36	37	52·23	+ 0·004	+ 0·045	− 708·667	+ 0·150	− 708·517
37	38	54·24	+ 0·051	+ 0·096	− 621·414	+ 0·133	− 621·281
38	39	55·22	+ 0·003	+ 0·099	− 650·332	+ 0·139	− 650·193
39	40	56·22	− 0·001	+ 0·098	− 676·892	+ 0·144	− 676·748
40	41	57·68	+ 0·010	+ 0·108	− 700·443	+ 0·149	− 700·294
41	42	59·21	+ 0·012	+ 0·120	− 736·718	+ 0·156	− 736·562
42	43	60·19	+ 0·015	+ 0·135	− 757·818	+ 0·160	− 757·658
43	44	61·24	− 0·018	+ 0·117	− 778·990	+ 0·164	− 778·826
44	45	62·14	0·000	+ 0·117	− 781·545	+ 0·165	− 781·380
45	46	63·13	− 0·021	+ 0·096	− 742·742	+ 0·158	− 742·584
46	47	63·32	0·000	+ 0·096	− 763·748	+ 0·162	− 763·586
47	48	64·36	− 0·002	+ 0·094	− 737·281	+ 0·157	− 737·124
48	49	65·34	+ 0·008	+ 0·102	− 786·150	+ 0·166	− 785·984
49	50	66·32	− 0·003	+ 0·099	− 821·984	+ 0·173	− 821·811
50	51	67·33	+ 0·007	+ 0·106	− 864·928	+ 0·181	− 864·747
51	52	68·33	+ 0·006	+ 0·112	− 887·940	+ 0·185	− 887·755
52	53	69·33	− 0·009	+ 0·103	− 913·693	+ 0·190	− 913·503
53	54	70·46	− 0·007	+ 0·096	− 938·956	+ 0·195	− 938·761
54	55	71·31	− 0·006	+ 0·090	− 961·277	+ 0·199	− 961·078
55	56	72·31	+ 0·003	+ 0·093	− 983·187	+ 0·203	− 982·984
56	57	72·41	− 0·004	+ 0·089	− 986·991	+ 0·204	− 986·787
57	58	74·31	+ 0·009	+ 0·098	− 1034·043	+ 0·213	− 1033·830
58	59	75·31	+ 0·014	+ 0·112	− 1052·233	+ 0·216	− 1052·017
59	60	76·31	− 0·002	+ 0·110	− 1053·333	+ 0·216	− 1053·117
60	61	77·40	− 0·003	+ 0·107	− 1065·401	+ 0·218	− 1065·183

* Bench-mark No. 1 is the mark at Nandgaon described on page 135.

Line No. 34. Nandgaon to Sironj.—(Continued).

Bench-marks		Distance from Nandgaon	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Nandgaon (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Nandgaon
From	To		From mark to mark (= d)	Total from Nandgaon		Total from Nandgaon	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	79·38	– 0·018	+ 0·125	– 1056·559	+ 0·216	– 1056·343
62	63	85·69	– 0·011	+ 0·114	– 1030·606	+ 0·211	– 1030·395
63	64	86·69	+ 0·010	+ 0·124	– 1018·312	+ 0·209	– 1018·103
64	65	87·69	+ 0·025	+ 0·149	– 994·813	+ 0·205	– 994·608
65	66	88·69	+ 0·007	+ 0·156	– 947·341	+ 0·197	– 947·144
66	67	89·68	+ 0·019	+ 0·175	– 890·492	+ 0·187	– 890·305
67	68	90·68	+ 0·003	+ 0·178	– 852·190	+ 0·180	– 852·010
68	69	91·39	+ 0·006	+ 0·184	– 877·439	+ 0·184	– 877·255
69	70	92·11	+ 0·015	+ 0·199	– 824·556	+ 0·175	– 824·381
70	71	93·63	– 0·031	+ 0·168	– 874·897	+ 0·184	– 874·713
71	72	93·97	– 0·011	+ 0·157	– 882·440	+ 0·185	– 882·255
72	73	96·66	+ 0·013	+ 0·170	– 774·511	+ 0·166	– 774·345
73	74	97·31	+ 0·012	+ 0·182	– 733·524	+ 0·159	– 733·365
74	75	98·65	– 0·029	+ 0·153	– 817·354	+ 0·173	– 817·181
75	76	99·06	+ 0·003	+ 0·156	– 814·444	+ 0·172	– 814·272
76	77	100·07	+ 0·006	+ 0·162	– 769·337	+ 0·164	– 769·173
77	78	101·50	– 0·002	+ 0·160	– 724·020	+ 0·156	– 723·864
78	79	101·65	+ 0·001	+ 0·161	– 711·123	+ 0·154	– 710·969
79	80	102·65	– 0·001	+ 0·160	– 681·045	+ 0·149	– 680·896
80	81	104·21	+ 0·033	+ 0·193	– 609·376	+ 0·137	– 609·239
81	82	104·68	+ 0·005	+ 0·198	– 575·448	+ 0·131	– 575·317
82	83	105·63	– 0·003	+ 0·195	– 475·549	+ 0·114	– 475·435
83	84	106·63	+ 0·010	+ 0·205	– 322·921	+ 0·089	– 322·832
84	85	107·63	+ 0·018	+ 0·223	– 87·671	+ 0·051	– 87·620
85	86	107·63	+ 0·022	+ 0·245	+ 216·427	+ 0·002	+ 216·429
86	87	111·04	– 0·050	+ 0·195	+ 115·813	+ 0·018	+ 115·831
87	88	112·01	– 0·020	+ 0·175	+ 57·402	+ 0·027	+ 57·429
88	89	113·50	– 0·010	+ 0·165	– 20·935	+ 0·040	– 20·895
89	90	114·04	– 0·004	+ 0·161	– 72·315	+ 0·048	– 72·267
90	91	115·79	– 0·031	+ 0·130	– 179·549	+ 0·065	– 179·484
91	92	116·83	– 0·007	+ 0·123	– 227·086	+ 0·073	– 227·013
92	93	118·09	– 0·006	+ 0·117	– 263·969	+ 0·079	– 263·890
93	94	120·15	+ 0·035	+ 0·152	– 294·380	+ 0·084	– 294·296
94	95	121·14	– 0·038	+ 0·114	– 342·825	+ 0·091	– 342·734
95	96	122·13	+ 0·009	+ 0·123	– 390·122	+ 0·098	– 390·024
96	97	123·12	– 0·008	+ 0·115	– 437·833	+ 0·105	– 437·728
97	98	124·12	– 0·008	+ 0·107	– 471·984	+ 0·110	– 471·874
98	99	125·09	+ 0·012	+ 0·119	– 530·599	+ 0·119	– 530·480
99	100	126·08	+ 0·005	+ 0·124	– 520·704	+ 0·117	– 520·587
100	101	127·10	– 0·006	+ 0·118	– 544·553	+ 0·121	– 544·432
101	102	128·07	+ 0·012	+ 0·130	– 555·537	+ 0·123	– 555·414
102	103	130·03	– 0·008	+ 0·122	– 671·777	+ 0·140	– 671·637
103	104	131·01	– 0·012	+ 0·110	– 710·571	+ 0·145	– 710·426
104	105	133·52	+ 0·020	+ 0·130	– 752·103	+ 0·151	– 751·952
105	106	134·48	+ 0·017	+ 0·147	– 772·812	+ 0·154	– 772·658
106	107	135·47	– 0·003	+ 0·144	– 815·210	+ 0·160	– 815·050
107	108	135·96	– 0·010	+ 0·134	– 836·650	+ 0·163	– 836·487
108	109	137·09	– 0·019	+ 0·115	– 853·216	+ 0·165	– 853·051
109	110	138·02	+ 0·006	+ 0·121	– 847·013	+ 0·164	– 846·849
110	111	139·02	+ 0·001	+ 0·122	– 875·898	+ 0·168	– 875·730
111	112	140·91	– 0·001	+ 0·121	– 855·737	+ 0·165	– 855·572
112	113	142·02	+ 0·012	+ 0·133	– 834·033	+ 0·162	– 833·871
113	114	143·89	+ 0·022	+ 0·155	– 822·764	+ 0·160	– 822·604
114	115	145·30	– 0·003	+ 0·152	– 894·606	+ 0·170	– 894·436
115	116	145·98	+ 0·014	+ 0·166	– 921·976	+ 0·174	– 921·802
116	117	146·35	– 0·002	+ 0·164	– 926·745	+ 0·175	– 926·570
117	118	147·03	+ 0·003	+ 0·167	– 946·087	+ 0·178	– 945·909
118	119	148·01	+ 0·011	+ 0·178	– 959·487	+ 0·180	– 959·307
119	120	148·39	– 0·012	+ 0·166	– 979·667	+ 0·183	– 979·484
120	121	149·50	+ 0·005	+ 0·171	– 987·784	+ 0·184	– 987·600

Line No. 34. Nandgaon to Sironj.—(Continued).

Bench-marks		Distance from Nandgaon	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Nandgaon (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Nandgaon
From	To		From mark to mark (= d)	Total from Nandgaon		Total from Nandgaon	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
121	122	150·99	+ 0·009	+ 0·180	− 987·648	+ 0·184	− 987·464
122	123	152·03	+ 0·007	+ 0·187	− 986·729	+ 0·184	− 986·545
123	124	152·88	+ 0·017	+ 0·204	− 969·500	+ 0·182	− 969·318
124	125	153·99	− 0·016	+ 0·188	− 985·776	+ 0·184	− 985·592
125	126	155·47	+ 0·017	+ 0·205	− 1016·348	+ 0·188	− 1016·160
126	127	157·03	+ 0·010	+ 0·215	− 1036·107	+ 0·191	− 1035·916
127	128	158·95	+ 0·014	+ 0·229	− 1028·661	+ 0·190	− 1028·471
128	129	159·94	+ 0·009	+ 0·238	− 1025·749	+ 0·190	− 1025·559
129	130	161·93	0·000	+ 0·238	− 1002·645	+ 0·187	− 1002·458
130	131	162·92	− 0·017	+ 0·221	− 984·030	+ 0·185	− 983·845
131	132	163·91	+ 0·012	+ 0·233	− 966·907	+ 0·183	− 966·724
132	133	164·90	+ 0·002	+ 0·235	− 945·321	+ 0·180	− 945·141
133	134	166·63	− 0·004	+ 0·231	− 868·425	+ 0·171	− 868·254
134	135	167·88	+ 0·013	+ 0·244	− 834·675	+ 0·167	− 834·508
135	136	169·73	− 0·008	+ 0·236	− 813·670	+ 0·164	− 813·506
136	137	170·85	− 0·009	+ 0·227	− 790·181	+ 0·161	− 790·020
137	138	171·85	− 0·013	+ 0·214	− 744·575	+ 0·156	− 744·419
138	139	172·85	0·000	+ 0·214	− 669·583	+ 0·148	− 669·435
139	140	174·29	+ 0·011	+ 0·225	− 590·070	+ 0·139	− 589·931
140	141	176·80	− 0·009	+ 0·216	− 110·683	+ 0·086	− 110·597
141	142	177·79	− 0·018	+ 0·198	− 105·232	+ 0·085	− 105·147
142	143	178·79	+ 0·028	+ 0·226	− 64·427	+ 0·080	− 64·347
143	144	179·11	− 0·002	+ 0·224	− 108·693	+ 0·085	− 108·608
144	145	179·79	+ 0·015	+ 0·239	+ 2·375	+ 0·073	+ 2·448
145	146	181·43	− 0·015	+ 0·224	+ 247·054	+ 0·047	+ 247·101
146	147	181·78	+ 0·009	+ 0·233	+ 261·010	+ 0·045	+ 261·055
147	148	183·23	+ 0·030	+ 0·203	+ 288·705	+ 0·042	+ 288·747
148	149	183·97	+ 0·002	+ 0·205	+ 330·543	+ 0·037	+ 330·580
149	150	185·89	− 0·017	+ 0·188	+ 392·120	+ 0·031	+ 392·151
150	151	186·89	− 0·041	+ 0·147	+ 359·222	+ 0·034	+ 359·256
151	152	188·87	+ 0·007	+ 0·154	+ 385·249	+ 0·031	+ 385·280
152	153	190·84	+ 0·005	+ 0·159	+ 504·137	+ 0·019	+ 504·156
153	154	191·78	− 0·021	+ 0·138	+ 447·744	+ 0·025	+ 447·769
154	155	192·83	+ 0·002	+ 0·140	+ 469·202	+ 0·023	+ 469·225
155	156	193·82	+ 0·002	+ 0·142	+ 427·815	+ 0·027	+ 427·842
156	157	194·81	+ 0·001	+ 0·141	+ 433·841	+ 0·026	+ 433·867
157	158	195·79	− 0·014	+ 0·127	+ 360·384	+ 0·033	+ 360·417
158	159	196·64	− 0·016	+ 0·111	+ 350·494	+ 0·034	+ 350·528
159	160	197·28	− 0·002	+ 0·109	+ 348·503	+ 0·034	+ 348·537
160	161	198·17	− 0·007	+ 0·102	+ 307·965	+ 0·038	+ 308·003
161	162	198·67	− 0·002	+ 0·100	+ 303·026	+ 0·039	+ 303·065
162	163	199·23	− 0·001	+ 0·099	+ 302·793	+ 0·039	+ 302·832
163	164	200·57	− 0·028	+ 0·071	+ 310·663	+ 0·038	+ 310·701
164	165	201·74	− 0·009	+ 0·062	+ 343·192	+ 0·035	+ 343·227
165	166	203·11	+ 0·017	+ 0·079	+ 361·997	+ 0·033	+ 362·030
166	167	203·54	+ 0·010	+ 0·089	+ 350·618	+ 0·034	+ 350·652
167	168	205·14	− 0·008	+ 0·081	+ 314·923	+ 0·037	+ 314·960
168	169	206·94	+ 0·011	+ 0·092	+ 289·607	+ 0·039	+ 289·646
169	170	207·70	+ 0·004	+ 0·096	+ 271·750	+ 0·041	+ 271·791
170	171	208·65	+ 0·017	+ 0·113	+ 259·031	+ 0·042	+ 259·073
171	172	209·89	+ 0·001	+ 0·114	+ 251·389	+ 0·043	+ 251·432
172	173	210·15	0·000	+ 0·114	+ 252·356	+ 0·043	+ 252·399
173	174	210·31	+ 0·006	+ 0·120	+ 251·357	+ 0·043	+ 251·400
174	175	211·45	− 0·012	+ 0·108	+ 253·197	+ 0·043	+ 253·240
175	176	213·23	− 0·014	+ 0·094	+ 232·676	+ 0·045	+ 232·721
176	177	214·23	+ 0·014	+ 0·108	+ 248·305	+ 0·044	+ 248·349
177	178	216·19	− 0·014	+ 0·094	+ 218·488	+ 0·047	+ 218·535
178	179	216·78	0·000	+ 0·094	+ 208·088	+ 0·048	+ 208·136
179	180	218·16	+ 0·022	+ 0·116	+ 193·385	+ 0·049	+ 193·434
180	181	219·15	− 0·003	+ 0·113	+ 219·849	+ 0·047	+ 219·896

Line No. 34. Nandgaon to Sironj.—(Continued).

Bench-marks		Distance from Nandgaon	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Nandgaon (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Nandgaon
From	To		From mark to mark (=*d*)	Total from Nandgaon		Total from Nandgaon	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
181	182	221·13	+ 0·009	+ 0·122	+ 172·359	+ 0·051	+ 172·410
182	183	222·14	+ 0·019	+ 0·141	+ 169·484	+ 0·051	+ 169·535
183	184	223·28	+ 0·020	+ 0·161	+ 147·890	+ 0·049	+ 147·939
184	185	224·08	+ 0·012	+ 0·173	+ 138·944	+ 0·050	+ 138·994
185	186	225·25	+ 0·004	+ 0·177	+ 111·048	+ 0·052	+ 111·100
186	187	226·08	– 0·015	+ 0·162	+ 147·896	+ 0·049	+ 146·945
187	188	228·16	+ 0·015	+ 0·177	+ 172·207	+ 0·047	+ 172·254
188	189	229·04	– 0·001	+ 0·176	+ 187·905	+ 0·046	+ 187·951
189	190	230·03	– 0·002	+ 0·174	+ 172·786	+ 0·047	+ 172·833
190	191	231·39	– 0·002	+ 0·172	+ 202·380	+ 0·045	+ 202·425
191	192	232·78	– 0·023	+ 0·149	+ 230·450	+ 0·043	+ 230·493
192	193	234·71	– 0·020	+ 0·129	+ 219·357	+ 0·044	+ 219·401
193	194	235·60	– 0·034	+ 0·095	+ 216·554	+ 0·044	+ 216·598
194	195	236·43	+ 0·006	+ 0·101	+ 182·845	+ 0·046	+ 182·891
195	196	237·47	– 0·004	+ 0·097	+ 172·902	+ 0·047	+ 172·949
196	197	238·98	+ 0·019	+ 0·116	+ 128·826	+ 0·050	+ 128·876
197	198	239·49	– 0·005	+ 0·111	+ 120·296	+ 0·051	+ 120·347
198	199	241·78	+ 0·013	+ 0·124	+ 61·670	+ 0·055	+ 61·725
199	200	242·34	– 0·007	+ 0·117	+ 48·670	+ 0·056	+ 48·726
200	201	243·34	– 0·002	+ 0·115	+ 36·065	+ 0·057	+ 36·122
201	202	245·44	– 0·022	+ 0·093	+ 15·747	+ 0·058	+ 15·805
202	203	247·09	+ 0·022	+ 0·115	+ 15·917	+ 0·058	+ 15·975
203	204	248·73	+ 0·016	+ 0·131	+ 37·318	+ 0·056	+ 37·374
204	205	250·27	– 0·010	+ 0·121	– 4·891	+ 0·059	– 4·832
205	206	251·26	– 0·019	+ 0·102	+ 2·995	+ 0·058	+ 3·053
206	207	252·69	+ 0·012	+ 0·114	– 0·119	+ 0·058	– 0·061
207	208	253·24	0·000	+ 0·114	+ 29·894	+ 0·056	+ 29·950
208	209	254·59	+ 0·013	+ 0·127	+ 44·135	+ 0·055	+ 44·190
209	210	255·34	– 0·007	+ 0·120	+ 59·570	+ 0·054	+ 59·624
210	211	256·25	– 0·007	+ 0·113	+ 61·431	+ 0·054	+ 61·485
211	212	267·43	+ 0·045	+ 0·158	+ 90·201	+ 0·052	+ 90·253
212	213	277·61	– 0·040	+ 0·118	+ 52·105	+ 0·055	+ 52·160
213	214	290·72	+ 0·010	+ 0·128	+ 55·307	+ 0·055	+ 55·362
214	215	290·74	+ 0·004	+ 0·132	+ 57·798	+ 0·055	+ 57·853
215	216	303·54	– 0·075	+ 0·057	+ 62·479	+ 0·055	+ 62·534
216	217	314·56	+ 0·032	+ 0·089	+ 135·408	+ 0·051	+ 135·459
217	218	325·26	+ 0·057	+ 0·146	+ 143·842	+ 0·051	+ 143·893
218	219	330·91	+ 0·002	+ 0·148	+ 59·269	+ 0·055	+ 59·324
219	220	335·04	– 0·004	+ 0·144	+ 53·105	+ 0·055	+ 53·160
220	221	341·57	– 0·028	+ 0·116	– 56·124	+ 0·060	– 56·064
221	222	349·17	– 0·014	+ 0·102	– 111·830	+ 0·062	– 111·768
222	223	350·90	+ 0·028	+ 0·130	– 124·509	+ 0·063	– 124·446
223	224	357·03	+ 0·028	+ 0·158	– 171·690	+ 0·065	– 171·625
224	225	359·66	+ 0·013	+ 0·171	– 169·819	+ 0·065	– 169·754
225	226	361·16	– 0·037	+ 0·134	– 189·461	+ 0·066	– 189·395
226	227	361·36	0·000	+ 0·134	– 194·841	+ 0·066	– 194·775
227	228	364·32	– 0·004	+ 0·130	– 174·779	+ 0·065	– 174·714
228	229	367·52	– 0·015	+ 0·115	– 184·550	+ 0·065	– 184·485
229	230	369·36	+ 0·018	+ 0·133	– 176·450	+ 0·065	– 176·385
230	231	377·64	+ 0·058	+ 0·191	– 196·303	+ 0·065	– 196·238
231	232	395·70	– 0·053	+ 0·138	– 38·011	+ 0·062	– 37·949
232	233	395·71	+ 0·004	+ 0·142	– 39·082	+ 0·062	– 39·020
233	234	400·50	+ 0·046	+ 0·188	– 39·591	+ 0·062	– 39·529
234	235	401·61	– 0·008	+ 0·180	– 25·253	+ 0·062	– 25·191
235	236	405·79	– 0·025	+ 0·155	– 76·456	+ 0·061	– 76·395
236	237*	408·83	– 0·022	+ 0·133	– 75·346	+ 0·061	– 75·285

Difference of dynamic height, Nandgaon to Sironj = – 75·285 feet.

Length of line in miles = M = 408·83. $\Sigma d^2 = 0{\cdot}073551$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\dfrac{\Sigma d^2}{4M}} = \pm\, 0{\cdot}0046.$

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\dfrac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0915.$

* Bench-mark No. 237 is the mark at Sironj described on page 135.

Line No. 35. Nandgaon to Raipur.

Bench-marks		Distance from Nandgaon	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Nandgaon (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Nandgaon
From	To		From mark to mark (= d)	Total from Nandgaon		Total from Nandgaon	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	2·27	+ 0·031	+ 0·031	− 2·367	+ 0·001	− 2·366
2	3	3·73	+ 0·026	+ 0·057	− 40·506	+ 0·010	− 40·496
3	4	5·44	+ 0·017	+ 0·074	− 53·881	+ 0·013	− 53·868
4	5	7·74	+ 0·017	+ 0·091	− 67·811	+ 0·016	− 67·795
5	6	8·34	+ 0·006	+ 0·097	− 88·241	+ 0·021	− 88·220
6	7	8·75	− 0·003	+ 0·094	− 96·216	+ 0·023	− 96·193
7	8	10·83	+ 0·009	+ 0·103	− 125·650	+ 0·030	− 125·620
8	9	11·51	− 0·001	+ 0·102	− 142·206	+ 0·034	− 142·172
9	10	12·72	+ 0·008	+ 0·110	− 164·194	+ 0·039	− 164·155
10	11	12·74	+ 0·001	+ 0·111	− 161·922	+ 0·038	− 161·884
11	12	14·03	+ 0·002	+ 0·113	− 180·814	+ 0·043	− 180·771
12	13	15·13	+ 0·014	+ 0·127	− 186·318	+ 0·044	− 186·274
13	14	15·69	+ 0·007	+ 0·134	− 177·768	+ 0·042	− 177·726
14	15	16·84	− 0·016	+ 0·118	− 212·919	+ 0·050	− 212·869
15	16	18·84	− 0·033	+ 0·085	− 282·090	+ 0·066	− 282·024
16	17	20·48	− 0·011	+ 0·074	− 333·320	+ 0·078	− 333·242
17	18	21·13	− 0·004	+ 0·070	− 338·942	+ 0·079	− 338·863
18	19	22·38	− 0·007	+ 0·063	− 346·530	+ 0·081	− 346·449
19	20	23·71	− 0·013	+ 0·050	− 373·122	+ 0·087	− 373·035
20	21	24·27	− 0·005	+ 0·045	− 379·738	+ 0·088	− 379·650
21	22	26·06	− 0·002	+ 0·043	− 411·713	+ 0·095	− 411·618
22	23	26·07	+ 0·001	+ 0·044	− 411·711	+ 0·095	− 411·616
23	24	26·08	− 0·001	+ 0·043	− 414·436	+ 0·096	− 414·340
24	25	27·68	− 0·042	+ 0·001	− 453·740	+ 0·105	− 453·635
25	26	28·58	− 0·005	− 0·004	− 468·861	+ 0·109	− 468·752
26	27	29·38	+ 0·005	+ 0·001	− 477·710	+ 0·111	− 477·599
27	28	30·65	+ 0·015	+ 0·016	− 473·585	+ 0·110	− 473·475
28	29	31·82	+ 0·002	+ 0·018	− 477·368	+ 0·111	− 477·257
29	30	31·83	− 0·002	+ 0·016	− 479·257	+ 0·112	− 479·145
30	31	32·55	− 0·004	+ 0·012	− 500·004	+ 0·117	− 499·887
31	32	33·55	− 0·008	+ 0·004	− 525·383	+ 0·123	− 525·260
32	33	34·60	− 0·002	+ 0·002	− 552·876	+ 0·129	− 552·747
33	34	35·60	− 0·003	− 0·001	− 557·544	+ 0·130	− 557·414
34	35	36·51	− 0·004	− 0·005	− 570·426	+ 0·133	− 570·293
35	36	37·54	+ 0·013	+ 0·008	− 587·522	+ 0·137	− 587·385
36	37	37·89	− 0·009	− 0·001	− 584·016	+ 0·136	− 583·880
37	38	37·90	+ 0·002	+ 0·001	− 584·016	+ 0·136	− 583·880
38	39	39·75	− 0·031	− 0·030	− 615·131	+ 0·143	− 614·988
39	40	41·11	− 0·020	− 0·050	− 626·814	+ 0·146	− 626·668
40	41	43·05	− 0·025	− 0·075	− 644·813	+ 0·150	− 644·663
41	42	45·51	+ 0·013	− 0·062	− 661·755	+ 0·154	− 661·601
42	43	46·85	+ 0·009	− 0·053	− 641·737	+ 0·150	− 641·587
43	44	47·32	− 0·003	− 0·056	− 641·076	+ 0·150	− 640·926
44	45	47·34	0·000	− 0·056	− 637·410	+ 0·149	− 637·261
45	46	47·35	0·000	− 0·056	− 640·184	+ 0·150	− 640·034
46	47	49·69	+ 0·028	− 0·028	− 667·124	+ 0·156	− 666·968
47	48	53·32	− 0·003	− 0·031	− 694·813	+ 0·162	− 694·651
48	49	53·93	− 0·007	− 0·038	− 697·948	+ 0·163	− 697·785
49	50	53·94	+ 0·001	− 0·037	− 697·921	+ 0·163	− 697·758
50	51	55·22	− 0·030	− 0·067	− 726·142	+ 0·169	− 725·973
51	52	57·63	− 0·018	− 0·085	− 759·542	+ 0·176	− 759·366
52	53	59·39	− 0·018	− 0·103	− 755·282	+ 0·175	− 755·107
53	54	61·74	+ 0·009	− 0·094	− 757·549	+ 0·175	− 757·374
54	55	63·06	− 0·014	− 0·108	− 758·895	+ 0·175	− 758·720
55	56	63·07	− 0·001	− 0·109	− 759·120	+ 0·175	− 758·945
56	57	65·37	− 0·034	− 0·143	− 796·002	+ 0·183	− 795·819
57	58	70·36	− 0·028	− 0·171	− 834·124	+ 0·191	− 833·933
58	59	70·37	0·000	− 0·171	− 834·135	+ 0·191	− 833·944
59	60	73·20	− 0·019	− 0·190	− 871·727	+ 0·199	− 871·528
60	61	75·29	− 0·007	− 0·197	− 870·680	+ 0·199	− 870·481

* Bench-mark No. 1 is the mark at Nandgaon described on page 135.

Line No. 35. Nandgaon to Raipur.—(Continued).

Bench-marks From	Bench-marks To	Distance from Nandgaon	Discrepancy between levellers (First – Second leveller): From mark to mark (= d)	Discrepancy between levellers (First – Second leveller): Total from Nandgaon	Observed elevation above (+) or below (–) Nandgaon (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Nandgaon	Dynamic height above (+) or below (–) Nandgaon
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	76·50	– 0·001	– 0·198	– 861·583	+ 0·197	– 861·386
62	63	78·00	– 0·029	– 0·227	– 893·410	+ 0·203	– 893·207
63	64	78·95	– 0·003	– 0·230	– 880·739	+ 0·200	– 880·539
64	65	80·60	+ 0·021	– 0·209	– 889·888	+ 0·202	– 889·686
65	66	82·55	– 0·024	– 0·233	– 868·524	+ 0·198	– 868·326
66	67	83·49	+ 0·017	– 0·216	– 863·778	+ 0·197	– 863·581
67	68	83·50	+ 0·004	– 0·212	– 863·446	+ 0·197	– 863·249
68	69	84·06	– 0·008	– 0·220	– 871·129	+ 0·199	– 870·930
69	70	85·26	+ 0·014	– 0·206	– 879·012	+ 0·201	– 878·811
70	71	87·42	– 0·008	– 0·214	– 865·457	+ 0·198	– 865·259
71	72	89·15	+ 0·020	– 0·194	– 868·181	+ 0·199	– 867·982
72	73	90·65	– 0·041	– 0·235	– 869·443	+ 0·199	– 869·244
73	74	91·88	– 0·004	– 0·239	– 877·023	+ 0·201	– 876·822
74	75	93·98	+ 0·003	– 0·236	– 893·512	+ 0·204	– 893·308
75	76	96·94	+ 0·008	– 0·228	– 865·300	+ 0·199	– 865·101
76	77	97·38	+ 0·002	– 0·226	– 873·428	+ 0·201	– 873·227
77	78	98·43	+ 0·008	– 0·218	– 874·773	+ 0·201	– 874·572
78	79	98·46	– 0·002	– 0·220	– 875·218	+ 0·201	– 875·017
79	80	99·20	– 0·015	– 0·235	– 876·355	+ 0·201	– 876·154
80	81	101·58	+ 0·009	– 0·226	– 861·873	+ 0·198	– 861·675
81	82	102·86	– 0·008	– 0·234	– 838·309	+ 0·193	– 838·116
82	83	103·93	0·000	– 0·234	– 844·595	+ 0·194	– 844·401
83	84	105·48	+ 0·038	– 0·196	– 819·595	+ 0·189	– 819·406
84	85	106·37	+ 0·013	– 0·183	– 829·125	+ 0·191	– 828·934
85	86	106·38	0·000	– 0·183	– 829·007	+ 0·191	– 828·816
86	87	107·08	– 0·002	– 0·185	– 822·054	+ 0·190	– 821·864
87	88	108·12	– 0·008	– 0·193	– 818·085	+ 0·189	– 817·896
88	89	109·07	+ 0·003	– 0·190	– 809·408	+ 0·187	– 809·221
89	90	110·37	+ 0·011	– 0·179	– 776·247	+ 0·180	– 776·067
90	91	111·26	+ 0·026	– 0·153	– 745·307	+ 0·174	– 745·133
91	92	112·16	+ 0·009	– 0·144	– 713·156	+ 0·168	– 712·988
92	93	113·37	+ 0·036	– 0·108	– 665·347	+ 0·158	– 665·189
93	94	114·43	+ 0·013	– 0·095	– 622·544	+ 0·149	– 622·395
94	95	115·27	+ 0·022	– 0·073	– 588·315	+ 0·142	– 588·173
95	96	116·50	– 0·003	– 0·076	– 575·323	+ 0·139	– 575·184
96	97	117·29	– 0·004	– 0·080	– 593·694	+ 0·143	– 593·551
97	98	117·30	0·000	– 0·080	– 593·976	+ 0·143	– 593·833
98	99	118·45	– 0·006	– 0·086	– 623·041	+ 0·149	– 622·892
99	100	119·59	+ 0·003	– 0·083	– 630·245	+ 0·150	– 630·095
100	101	120·47	– 0·019	– 0·102	– 647·809	+ 0·154	– 647·655
101	102	121·26	– 0·004	– 0·106	– 668·154	+ 0·158	– 667·996
102	103	122·46	– 0·002	– 0·108	– 681·258	+ 0·161	– 681·097
103	104	123·86	– 0·023	– 0·131	– 721·392	+ 0·169	– 721·223
104	105	124·01	– 0·008	– 0·139	– 724·284	+ 0·170	– 724·114
105	106	124·51	+ 0·002	– 0·137	– 723·282	+ 0·170	– 723·112
106	107	126·02	0·000	– 0·137	– 738·267	+ 0·173	– 738·094
107	108	126·65	+ 0·016	– 0·121	– 733·883	+ 0·172	– 733·711
108	109	127·92	– 0·001	– 0·122	– 724·046	+ 0·170	– 723·876
109	110	129·10	– 0·010	– 0·132	– 730·883	+ 0·171	– 730·712
110	111	129·56	+ 0·002	– 0·130	– 736·164	+ 0·172	– 735·992
111	112	129·57	– 0·002	– 0·132	– 735·809	+ 0·172	– 735·637
112	113	130·40	– 0·004	– 0·136	– 745·249	+ 0·174	– 745·075
113	114	131·93	+ 0·015	– 0·121	– 747·845	+ 0·175	– 747·670
114	115	133·27	– 0·018	– 0·139	– 744·455	+ 0·174	– 744·281
115	116	133·94	+ 0·023	– 0·116	– 733·654	+ 0·172	– 733·482
116	117	135·13	0·000	– 0·116	– 725·810	+ 0·170	– 725·640
117	118	136·01	– 0·022	– 0·138	– 740·298	+ 0·173	– 740·125
118	119	136·61	+ 0·001	– 0·137	– 743·940	+ 0·174	– 743·766
119	120	137·88	– 0·006	– 0·143	– 739·619	+ 0·173	– 739·446
120	121	138·24	+ 0·006	– 0·137	– 736·410	+ 0·172	– 736·238

Line No. 35. Nandgaon to Raipur.—(Continued).

Bench-marks		Distance from Nandgaon	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Nandgaon (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Nandgaon
From	To		From mark to mark (= d)	Total from Nandgaon		Total from Nandgaon	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
121	122	138·55	− 0·002	− 0·139	− 735·019	+ 0·172	− 734·847
122	123	139·29	− 0·005	− 0·144	− 737·681	+ 0·173	− 737·508
123	124	139·87	+ 0·006	− 0·138	− 737·537	+ 0·173	− 737·364
124	125	141·13	+ 0·001	− 0·137	− 752·442	+ 0·176	− 752·266
125	126	142·28	+ 0·015	− 0·122	− 732·831	+ 0·172	− 732·659
126	127	143·63	− 0·003	− 0·125	− 713·343	+ 0·168	− 713·175
127	128	144·37	+ 0·005	− 0·120	− 705·933	+ 0·167	− 705·766
128	129	145·47	− 0·005	− 0·125	− 696·607	+ 0·165	− 696·442
129	130	146·30	− 0·004	− 0·129	− 689·361	+ 0·164	− 689·197
130	131	146·81	− 0·016	− 0·145	− 686·191	+ 0·163	− 686·028
131	132	146·82	+ 0·002	− 0·143	− 686·546	+ 0·163	− 686·383
132	133	147·38	− 0·010	− 0·153	− 688·447	+ 0·163	− 688·284
133	134	147·73	− 0·003	− 0·156	− 690·000	+ 0·163	− 689·837
134	135	148·88	+ 0·002	− 0·154	− 709·310	+ 0·167	− 709·143
135	136	149·87	− 0·008	− 0·162	− 716·609	+ 0·168	− 716·441
136	137	150·78	+ 0·014	− 0·148	− 713·468	+ 0·167	− 713·301
137	138	151·99	+ 0·006	− 0·142	− 703·142	+ 0·165	− 702·977
138	139	152·84	− 0·006	− 0·148	− 689·905	+ 0·162	− 689·743
139	140	153·55	+ 0·001	− 0·147	− 686·328	+ 0·161	− 686·167
140	141	154·38	− 0·009	− 0·156	− 665·730	+ 0·157	− 665·573
141	142	154·39	0·000	− 0·156	− 665·510	+ 0·157	− 665·353
142	143	155·59	+ 0·004	− 0·152	− 694·434	+ 0·163	− 694·271
143	144	156·94	− 0·016	− 0·168	− 676·529	+ 0·159	− 676·370
144	145	158·02	+ 0·022	− 0·146	− 691·579	+ 0·162	− 691·417
145	146	159·46	+ 0·004	− 0·142	− 708·477	+ 0·166	− 708·311
146	147	160·41	− 0·013	− 0·155	− 696·766	+ 0·163	− 696·603
147	148	160·69	− 0·008	− 0·163	− 682·937	+ 0·160	− 682·777
148	149	162·06	− 0·007	− 0·170	− 642·012	+ 0·151	− 641·861
149	150	162·07	+ 0·002	− 0·168	− 642·303	+ 0·151	− 642·152
150	151	163·12	0·000	− 0·168	− 664·534	+ 0·156	− 664·378
151	152	164·43	+ 0·007	− 0·161	− 630·502	+ 0·149	− 630·353
152	153	165·18	+ 0·009	− 0·152	− 635·269	+ 0·150	− 635·119
153	154	166·52	+ 0·001	− 0·151	− 656·686	+ 0·154	− 656·532
154	155	167·20	− 0·002	− 0·153	− 668·852	+ 0·157	− 668·695
155	156	168·56	− 0·001	− 0·154	− 666·985	+ 0·157	− 666·828
156	157	169·29	− 0·002	− 0·156	− 659·384	+ 0·155	− 659·229
157	158	170·25	+ 0·006	− 0·150	− 650·967	+ 0·153	− 650·814
158	159	171·29	+ 0·006	− 0·144	− 635·265	+ 0·150	− 635·115
159	160	172·24	+ 0·021	− 0·123	− 640·949	+ 0·151	− 640·798
160	161	172·82	+ 0·009	− 0·114	− 636·028	+ 0·150	− 635·878
161	162	172·83	− 0·003	− 0·117	− 636·674	+ 0·150	− 636·524
162	163	173·13	+ 0·007	− 0·110	− 639·300	+ 0·151	− 639·149
163	164	174·16	− 0·001	− 0·111	− 631·350	+ 0·149	− 631·201
164	165	175·07	+ 0·026	− 0·085	− 604·333	+ 0·143	− 604·190
165	166	176·30	+ 0·022	− 0·063	− 580·511	+ 0·138	− 580·373
166	167	177·31	− 0·013	− 0·076	− 575·420	+ 0·137	− 575·283
167	168	178·47	+ 0·006	− 0·070	− 591·231	+ 0·140	− 591·091
168	169	178·62	+ 0·007	− 0·063	− 595·337	+ 0·141	− 595·196
169	170	179·33	− 0·008	− 0·071	− 606·824	+ 0·143	− 606·681
170	171	180·12	− 0·013	− 0·084	− 627·151	+ 0·147	− 627·004
171	172	181·53	− 0·005	− 0·089	− 650·416	+ 0·152	− 650·264
172	173	181·94	+ 0·010	− 0·079	− 648·902	+ 0·152	− 648·750
173	174	182·92	− 0·001	− 0·080	− 648·689	+ 0·152	− 648·537
174	175	183·86	+ 0·029	− 0·051	− 647·384	+ 0·152	− 647·232
175	176	185·16	+ 0·021	− 0·030	− 634·535	+ 0·149	− 634·386
176	177	185·17	+ 0·003	− 0·027	− 634·257	+ 0·149	− 634·108
177	178	185·61	+ 0·013	− 0·014	− 631·281	+ 0·148	− 631·133
178	179	186·47	+ 0·013	− 0·001	− 640·643	+ 0·150	− 640·493
179	180	188·01	+ 0·048	+ 0·047	− 614·805	+ 0·144	− 614·661
180	181	189·01	+ 0·018	+ 0·065	− 597·873	+ 0·140	− 597·733

Line No. 35. Nandgaon to Raipur.—(Continued).

Bench-marks		Distance from Nandgaon	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Nandgaon (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Nandgaon
From	To		From mark to mark (= d)	Total from Nandgaon		Total from Nandgaon	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
181	182	189·87	+ 0·017	+ 0·082	– 586·754	+ 0·138	– 586·616
182	183	189·88	+ 0·002	+ 0·084	– 589·081	+ 0·138	– 588·943
183	184	191·23	– 0·012	+ 0·072	– 628·148	+ 0·146	– 628·002
184	185	192·17	– 0·022	+ 0·050	– 625·609	+ 0·145	– 625·464
185	186	193·48	– 0·002	+ 0·048	– 628·595	+ 0·146	– 628·449
186	187	194·54	+ 0·022	+ 0·070	– 598·540	+ 0·140	– 598·400
187	188	196·00	+ 0·001	+ 0·071	– 578·029	+ 0·136	– 577·893
188	189	196·54	+ 0·003	+ 0·074	– 564·138	+ 0·133	– 564·005
189	190	197·48	– 0·006	+ 0·068	– 591·492	+ 0·139	– 591·353
190	191	197·88	– 0·001	+ 0·067	– 585·332	+ 0·138	– 585·194
191	192	200·49	+ 0·007	+ 0·074	– 593·565	+ 0·140	– 593·425
192	193	201·43	+ 0·010	+ 0·084	– 605·851	+ 0·143	– 605·708
193	194	201·71	– 0·011	+ 0·073	– 601·996	+ 0·142	– 601·854
194	195	203·59	– 0·040	+ 0·033	– 608·768	+ 0·143	– 608·625
195	196	204·18	– 0·018	+ 0·015	– 613·941	+ 0·144	– 613·797
196	197	205·19	– 0·005	+ 0·010	– 611·811	+ 0·144	– 611·667
197	198	206·07	– 0·005	+ 0·005	– 611·185	+ 0·144	– 611·041
198	199	206·57	+ 0·004	+ 0·009	– 604·732	+ 0·143	– 604·589
199	200	208·31	+ 0·007	+ 0·016	– 564·810	+ 0·135	– 564·675
200	201	208·32	– 0·001	+ 0·015	– 564·799	+ 0·135	– 564·664
201	202	208·60	– 0·018	– 0·003	– 571·375	+ 0·136	– 571·239
202	203	209·18	– 0·018	– 0·021	– 580·881	+ 0·138	– 580·743
203	204	210·56	+ 0·016	– 0·005	– 565·753	+ 0·135	– 565·618
204	205	211·51	+ 0·003	– 0·002	– 555·613	+ 0·133	– 555·480
205	206	213·06	– 0·024	– 0·026	– 591·675	+ 0·141	– 591·534
206	207	213·34	– 0·009	– 0·035	– 591·736	+ 0·141	– 591·595
207	208	214·09	+ 0·006	– 0·029	– 568·530	+ 0·136	– 568·394
208	209	214·85	+ 0·008	– 0·021	– 567·339	+ 0·136	– 567·203
209	210	215·84	+ 0·012	– 0·009	– 592·956	+ 0·141	– 592·815
210	211	216·09	– 0·005	– 0·014	– 595·763	+ 0·142	– 595·621
211	212	216·73	+ 0·004	– 0·010	– 601·371	+ 0·143	– 601·228
212	313	218·13	– 0·008	– 0·018	– 582·820	+ 0·139	– 582·681
213	214	218·41	– 0·008	– 0·026	– 585·266	+ 0·139	– 585·127
214	215	219·07	– 0·007	– 0·033	– 573·765	+ 0·137	– 573·628
215	216	220·11	– 0·011	– 0·044	– 580·314	+ 0·138	– 580·176
216	217	220·69	– 0·009	– 0·053	– 594·298	+ 0·141	– 594·157
217	218	221·05	+ 0·002	– 0·051	– 593·781	+ 0·141	– 593·640
218	219	221·49	– 0·001	– 0·052	– 590·685	+ 0·140	– 590·545
219	220	222·60	– 0·003	– 0·055	– 586·201	+ 0·139	– 586·062
220	221	223·32	– 0·001	– 0·056	– 567·734	+ 0·135	– 567·599
221	222	223·99	+ 0·007	– 0·049	– 544·985	+ 0·130	– 544·855
222	223	224·38	– 0·010	– 0·059	– 546·407	+ 0·130	– 546·277
223	224	225·23	+ 0·007	– 0·052	– 558·898	+ 0·133	– 558·765
224	225	225·55	– 0·013	– 0·065	– 561·781	+ 0·134	– 561·647
225	226	226·81	+ 0·019	– 0·046	– 537·588	+ 0·129	– 537·459
226	227	227·80	+ 0·019	– 0·027	– 512·367	+ 0·124	– 512·243
227	228	228·04	+ 0·015	– 0·012	– 504·780	+ 0·122	– 504·658
228	229	228·94	– 0·021	– 0·033	– 471·166	+ 0·115	– 471·051
229	230	228·95	+ 0·004	– 0·029	– 468·036	+ 0·114	– 467·922
230	231	229·48	– 0·004	– 0·033	– 481·849	+ 0·117	– 481·732
231	232	230·00	– 0·003	– 0·036	– 500·232	+ 0·121	– 500·111
232	233	231·03	– 0·001	– 0·037	– 510·251	+ 0·123	– 510·128
233	234	231·78	– 0·003	– 0·040	– 489·357	+ 0·119	– 489·238
234	235	233·23	+ 0·019	– 0·021	– 464·645	+ 0·114	– 464·531
235	236	234·41	– 0·033	– 0·054	– 456·355	+ 0·112	– 456·243
236	237	234·42	+ 0·003	– 0·051	– 456·153	+ 0·112	– 456·041
237	238	235·52	+ 0·006	– 0·045	– 428·599	+ 0·106	– 428·493
238	239	236·21	+ 0·012	– 0·033	– 411·466	+ 0·102	– 411·364
239	240	237·17	+ 0·030	– 0·003	– 408·383	+ 0·101	– 408·282
240	241	238·30	– 0·037	– 0·040	– 429·983	+ 0·106	– 429·877

Line No. 35. Nandgaon to Raipur.—(Continued).

Bench-marks		Distance from Nandgaon	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Nandgaon (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Nandgaon
From	To		From mark to mark (=d)	Total from Nandgaon		Total from Nandgaon	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
241	242	238·78	– 0·005	– 0·045	– 433·788	+ 0·107	– 433·681
242	243	240·28	+ 0·019	– 0·026	– 400·730	+ 0·100	– 400·630
243	244	242·02	+ 0·023	– 0·003	– 441·417	+ 0·109	– 441·308
244	245	242·67	– 0·004	– 0·007	– 452·164	+ 0·111	– 452·053
245	246	243·70	+ 0·026	+ 0·019	– 438·655	+ 0·108	– 438·547
246	247	244·08	– 0·007	+ 0·012	– 431·618	+ 0·107	– 431·511
247	248	244·09	0·000	+ 0·012	– 429·842	+ 0·107	– 429·735
248	249	244·10	+ 0·001	+ 0·013	– 429·519	+ 0·107	– 429·412
249	250	245·16	– 0·004	+ 0·009	– 455·442	+ 0·113	– 455·329
250	251	246·34	+ 0·006	+ 0·015	– 431·873	+ 0·108	– 431·765
251	252	247·80	– 0·023	– 0·008	– 463·472	+ 0·115	– 463·357
252	253	248·30	– 0·022	– 0·030	– 480·200	+ 0·119	– 480·081
253	254	248·66	– 0·010	– 0·040	– 492·532	+ 0·122	– 492·410
254	255	248·99	+ 0·002	– 0·038	– 495·429	+ 0·123	– 495·306
255	256	251·23	+ 0·007	– 0·031	– 499·088	+ 0·124	– 498·964
256	257	252·17	+ 0·005	– 0·026	– 471·027	+ 0·118	– 470·909
257	258	252·19	+ 0·002	– 0·024	– 470·768	+ 0·118	– 470·650
258	259	253·67	+ 0·017	– 0·007	– 504·932	+ 0·125	– 504·807
259	260	254·71	+ 0·015	+ 0·008	– 498·198	+ 0·124	– 498·074
260	261	255·28	– 0·015	– 0·007	– 509·032	+ 0·126	– 508·906
261	262	255·84	+ 0·006	– 0·001	– 502·476	+ 0·125	– 502·351
262	263	256·11	+ 0·017	+ 0·016	– 498·229	+ 0·124	– 498·105
263	264	257·89	+ 0·006	+ 0·022	– 545·672	+ 0·134	– 545·538
264	265	259·05	+ 0·020	+ 0·042	– 527·152	+ 0·130	– 527·022
265	266	259·54	+ 0·003	+ 0·045	– 522·703	+ 0·129	– 522·574
266	267	260·05	– 0·010	+ 0·035	– 539·404	+ 0·133	– 539·271
267	268	261·38	– 0·012	+ 0·023	– 576·384	+ 0·141	– 576·243
268	269	262·48	+ 0·006	+ 0·029	– 576·627	+ 0·141	– 576·486
269	270	262·49	+ 0·003	+ 0·032	– 576·501	+ 0·141	– 576·360
270	271	263·01	+ 0·012	+ 0·044	– 592·730	+ 0·144	– 592·586
271	272	263·90	– 0·002	+ 0·042	– 611·635	+ 0·148	– 611·487
272	273	264·81	– 0·011	+ 0·031	– 624·333	+ 0·151	– 624·182
273	274	265·54	+ 0·013	+ 0·044	– 633·115	+ 0·153	– 632·962
274	275	266·64	+ 0·013	+ 0·057	– 621·177	+ 0·150	– 621·027
275	276	266·87	+ 0·001	+ 0·058	– 618·127	+ 0·149	– 617·978
276	277	268·47	– 0·012	+ 0·046	– 651·243	+ 0·156	– 651·087
277	278	268·83	– 0·004	+ 0·042	– 647·603	+ 0·155	– 647·448
278	279	270·20	– 0·031	+ 0·011	– 664·508	+ 0·159	– 664·349
279	280	271·05	+ 0·010	+ 0·021	– 681·740	+ 0·163	– 681·577
280	281	271·79	– 0·003	+ 0·018	– 675·924	+ 0·162	– 675·762
281	282	272·33	+ 0·009	+ 0·027	– 690·017	+ 0·165	– 689·852
282	283	273·81	+ 0·020	+ 0·047	– 677·580	+ 0·162	– 677·418
283	284	274·22	+ 0·013	+ 0·060	– 677·082	+ 0·162	– 676·920
284	285	274·37	– 0·006	+ 0·054	– 676·924	+ 0·162	– 676·762
285	286	274·88	– 0·005	+ 0·049	– 667·976	+ 0·160	– 667·816
286	287	274·89	– 0·001	+ 0·048	– 668·308	+ 0·160	– 668·148
287	288	275·74	+ 0·016	+ 0·064	– 651·681	+ 0·156	– 651·525
288	289	276·79	+ 0·010	+ 0·074	– 620·897	+ 0·149	– 620·748
289	290	277·29	+ 0·009	+ 0·083	– 612·005	+ 0·147	– 611·858
290	291	277·49	– 0·002	+ 0·081	– 607·349	+ 0·146	– 607·203
291	292	278·33	– 0·018	+ 0·063	– 619·532	+ 0·149	– 619·383
292	293	279·35	– 0·029	+ 0·034	– 637·588	+ 0·153	– 637·435
293	294	280·19	+ 0·006	+ 0·040	– 646·917	+ 0·155	– 646·762
294	295	281·43	+ 0·025	+ 0·065	– 626·883	+ 0·151	– 626·732
295	296	282·37	+ 0·004	+ 0·069	– 645·185	+ 0·155	– 645·030
296	297	282·89	– 0·023	+ 0·046	– 658·328	+ 0·158	– 658·170
297	298	283·19	+ 0·001	+ 0·047	– 665·536	+ 0·159	– 665·377
298	299	283·94	– 0·002	+ 0·045	– 683·216	+ 0·163	– 683·053
299	300	284·67	+ 0·010	+ 0·055	– 664·270	+ 0·159	– 664·111
300	301	284·68	+ 0·001	+ 0·056	– 664·240	+ 0·159	– 664·081

Line No. 35. Nandgaon to Raipur.—(Continued).

Bench-marks		Distance from Nandgaon	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Nandgaon (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Nandgaon
From	To		From mark to mark (= d)	Total from Nandgaon		Total from Nandgaon	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
301	302	285·88	– 0·014	+ 0·042	– 701·219	+ 0·167	– 701·052
302	303	287·03	+ 0·008	+ 0·050	– 677·391	+ 0·162	– 677·229
303	304	287·71	– 0·004	+ 0·046	– 676·246	+ 0·162	– 676·084
304	305	288·26	– 0·009	+ 0·037	– 684·342	+ 0·164	– 684·178
305	306	288·71	0·000	+ 0·037	– 693·749	+ 0·166	– 693·583
306	307	289·86	– 0·018	+ 0·019	– 712·371	+ 0·170	– 712·201
307	308	290·98	– 0·002	+ 0·017	– 697·288	+ 0·167	– 697·121
308	309	291·84	+ 0·007	+ 0·024	– 668·256	+ 0·161	– 668·095
309	310	292·68	+ 0·022	+ 0·046	– 630·622	+ 0·153	– 630·469
310	311	293·31	+ 0·004	+ 0·050	– 618·689	+ 0·150	– 618·539
311	312	293·35	+ 0·005	+ 0·055	– 619·328	+ 0·150	– 619·178
312	313	294·25	– 0·014	+ 0·041	– 649·666	+ 0·156	– 649·510
313	314	295·01	+ 0·016	+ 0·057	– 649·559	+ 0·156	– 649·403
314	315	296·35	– 0·012	+ 0·045	– 683·750	+ 0·163	– 683·587
315	316	297·15	+ 0·002	+ 0·047	– 710·461	+ 0·169	– 710·292
316	317	298·31	– 0·011	+ 0·036	– 730·002	+ 0·173	– 729·829
317	318	299·25	– 0·005	+ 0·031	– 756·520	+ 0·179	– 756·341
318	319	299·83	+ 0·011	+ 0·042	– 749·311	+ 0·178	– 749·133
319	320	300·61	– 0·009	+ 0·033	– 745·390	+ 0·177	– 745·213
320	321	301·50	– 0·008	+ 0·025	– 736·209	+ 0·175	– 736·034
321	322	301·96	+ 0·004	+ 0·029	– 723·979	+ 0·172	– 723·807
322	323	301·97	– 0·001	+ 0·028	– 725·970	+ 0·172	– 725·798
323	324	301·98	0·000	+ 0·028	– 724·101	+ 0·172	– 723·929
324	325	302·54	– 0·003	+ 0·025	– 733·238	+ 0·174	– 733·064
325	326	303·38	+ 0·002	+ 0·027	– 734·076	+ 0·174	– 733·902
326	327	304·22	+ 0·013	+ 0·040	– 711·842	+ 0·169	– 711·673
327	328	304·87	+ 0·002	+ 0·042	– 707·385	+ 0·168	– 707·217
328	329	305·98	+ 0·001	+ 0·043	– 702·158	+ 0·167	– 701·991
329	330	306·89	– 0·016	+ 0·027	– 710·954	+ 0·169	– 710·785
330	331	308·17	– 0·045	– 0·018	– 711·433	+ 0·169	– 711·264
331	332	309·12	– 0·020	– 0·038	– 739·129	+ 0·175	– 738·954
332	333	309·41	+ 0·004	– 0·034	– 742·801	+ 0·176	– 742·625
332	334	310·56	+ 0·004	– 0·030	– 757·722	+ 0·179	– 757·543
334	335	310·70	– 0·001	– 0·031	– 757·639	+ 0·179	– 757·460
335	336	311·69	– 0·005	– 0·036	– 754·260	+ 0·178	– 754·082
336	337	312·43	+ 0·001	– 0·035	– 759·087	+ 0·179	– 758·908
337	338	313·14	+ 0·010	– 0·025	– 745·318	+ 0·176	– 745·142
338	339	313·85	– 0·003	– 0·028	– 745·713	+ 0·176	– 745·537
339	340	315·56	+ 0·001	– 0·027	– 724·480	+ 0·176	– 724·304
340	341	316·67	– 0·010	– 0·037	– 708·643	+ 0·173	– 708·470
341	342	317·56	+ 0·016	– 0·021	– 691·862	+ 0·169	– 691·693
342	343	318·69	+ 0·003	– 0·018	– 690·741	+ 0·169	– 690·572
343	344	319·13	+ 0·003	– 0·015	– 697·806	+ 0·170	– 697·636
344	345	320·05	+ 0·014	– 0·001	– 683·582	+ 0·167	– 683·415
345	346	320·51	+ 0·008	+ 0·007	– 677·372	+ 0·166	– 677·206
346	347	321·61	+ 0·007	+ 0·014	– 649·696	+ 0·160	– 649·536
347	348	322·16	+ 0·002	+ 0·016	– 664·222	+ 0·163	– 664·059
348	349	323·10	– 0·024	– 0·008	– 681·523	+ 0·166	– 681·357
349	350	323·88	– 0·008	– 0·016	– 698·385	+ 0·169	– 698·216
350	351	325·13	+ 0·005	– 0·011	– 680·687	+ 0·165	– 680·522
351	352	325·68	+ 0·006	– 0·005	– 674·846	+ 0·164	– 674·682
352	353	326·18	+ 0·007	+ 0·002	– 664·550	+ 0·162	– 664·388
353	354	327·21	– 0·012	– 0·010	– 641·538	+ 0·157	– 641·381
354	355	328·33	– 0·015	– 0·025	– 609·354	+ 0·151	– 609·203
355	356	329·18	– 0·001	– 0·026	– 596·340	+ 0·148	– 596·192
356	357	330·14	– 0·015	– 0·041	– 583·101	+ 0·145	– 582·956
357	358	331·29	– 0·020	– 0·061	– 588·318	+ 0·146	– 588·172
358	359	332·15	– 0·015	– 0·076	– 603·369	+ 0·149	– 603·220
369	360	332·65	– 0·003	– 0·079	– 586·503	+ 0·146	– 586·357
360	361	333·36	– 0·011	– 0·090	– 584·251	+ 0·146	– 584·105

Line No. 35. Nandgaon to Raipur.—(Continued).

Bench-marks		Distance from Nandgaon	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Nandgaon (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Nandgaon
From	To		From mark to mark (= *d*)	Total from Nandgaon		Total from Nandgaon	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
361	362	334·60	+ 0·023	– 0·067	– 539·951	+ 0·138	– 539·813
362	363	334·63	+ 0·001	– 0·066	– 541·272	+ 0·138	– 541·134
363	364	334·94	– 0·001	– 0·067	– 546·007	+ 0·139	– 545·868
364	365	336·21	– 0·059	– 0·126	– 581·574	+ 0·146	– 581·428
365	366	337·65	– 0·007	– 0·133	– 577·027	+ 0·145	– 576·882
366	367	339·13	– 0·001	– 0·134	– 572·612	+ 0·144	– 572·468
367	368	339·86	+ 0·013	– 0·121	– 548·323	+ 0·139	– 548·184
368	369	341·16	– 0·004	– 0·125	– 569·293	+ 0·143	– 569·150
369	370	341·98	+ 0·014	– 0·111	– 541·182	+ 0·138	– 541·044
370	371	342·04	+ 0·004	– 0·107	– 541·276	+ 0·138	– 541·138
371	372	342·05	0·000	– 0·107	– 541·289	+ 0·138	– 541·151
372	373	342·74	– 0·005	– 0·112	– 546·113	+ 0·139	– 545·974
373	374	343·77	+ 0·006	– 0·106	– 571·026	+ 0·144	– 570·882
374	375	344·32	+ 0·005	– 0·101	– 575·134	+ 0·145	– 574·989
375	376	345·20	+ 0·020	– 0·081	– 586·218	+ 0·147	– 586·071
376	377	345·35	+ 0·005	– 0·076	– 585·308	+ 0·147	– 585·161
377	378	346·51	– 0·005	– 0·081	– 601·888	+ 0·150	– 601·738
378	379	347·28	– 0·003	– 0·084	– 614·235	+ 0·152	– 614·083
379	380	349·18	+ 0·015	– 0·069	– 606·251	+ 0·150	– 606·101
380	381	349·85	+ 0·008	– 0·061	– 617·631	+ 0·152	– 617·479
381	382	350·24	– 0·012	– 0·073	– 624·426	+ 0·153	– 624·273
382	383	350·73	+ 0·005	– 0·068	– 614·002	+ 0·151	– 613·851
383	384	351·44	– 0·006	– 0·074	– 633·925	+ 0·155	– 633·770
384	385	351·98	+ 0·009	– 0·065	– 637·389	+ 0·156	– 637·233
385	386	352·97	– 0·009	– 0·074	– 620·326	+ 0·153	– 620·173
386	387	353·19	+ 0·001	– 0·073	– 620·147	+ 0·153	– 619·994
387	388	353·97	– 0·013	– 0·086	– 626·050	+ 0·154	– 625·896
388	389	354·52	– 0·004	– 0·090	– 628·848	+ 0·155	– 628·693
389	390	355·88	+ 0·025	– 0·065	– 633·626	+ 0·156	– 633·470
390	391	356·93	+ 0·008	– 0·057	– 608·070	+ 0·151	– 607·919
391	392	357·24	+ 0·010	– 0·047	– 607·454	+ 0·151	– 607·303
392	393	357·25	+ 0·001	– 0·046	– 605·743	+ 0·151	– 605·592
393	394	357·26	+ 0·001	– 0·045	– 607·505	+ 0·151	– 607·354
394	395	357·71	– 0·003	– 0·048	– 612·741	+ 0·152	– 612·589
395	396	359·67	– 0·009	– 0·057	– 638·861	+ 0·157	– 638·704
396	397	360·92	– 0·021	– 0·078	– 639·970	+ 0·157	– 639·813
397	398	362·05	+ 0·010	– 0·068	– 650·055	+ 0·159	– 649·896
398	399	362·96	+ 0·002	– 0·066	– 649·856	+ 0·159	– 649·697
399	400	363·55	– 0·002	– 0·068	– 646·037	+ 0·158	– 645·879
400	401	364·18	+ 0·001	– 0·067	– 638·466	+ 0·156	– 638·310
401	402	365·31	– 0·002	– 0·069	– 606·564	+ 0·150	– 606·414
402	403	366·45	– 0·010	– 0·079	– 599·445	+ 0·149	– 599·296
403	404	367·63	+ 0·006	– 0·073	– 608·383	+ 0·151	– 608·232
404	405	369·68	+ 0·022	– 0·051	– 608·476	+ 0·151	– 608·325
405	406	370·96	+ 0·007	– 0·044	– 624·775	+ 0·154	– 624·621
406	407	372·05	– 0·009	– 0·053	– 635·094	+ 0·156	– 634·938
407	408	373·22	+ 0·008	– 0·045	– 638·346	+ 0·157	– 638·189
408	409	373·88	+ 0·006	– 0·039	– 633·773	+ 0·156	– 633·617
409	410	374·35	+ 0·002	– 0·037	– 628·971	+ 0·155	– 628·816
410	411	374·36	+ 0·001	– 0·036	– 630·540	+ 0·155	– 630·385
411	412	374·94	– 0·011	– 0·047	– 639·125	+ 0·157	– 638·968
412	413	375·93	+ 0·008	– 0·039	– 647·300	+ 0·159	– 647·141
413	414	376·33	+ 0·010	– 0·029	– 652·490	+ 0·160	– 652·330
414	415	377·51	+ 0·005	– 0·024	– 640·212	+ 0·158	– 640·054
415	416	378·62	+ 0·007	– 0·017	– 664·675	+ 0·162	– 664·513
416	417	380·62	+ 0·002	– 0·015	– 692·679	+ 0·167	– 692·512
417	418	380·63	0·000	– 0·015	– 691·730	+ 0·167	– 691·563
418	419	381·61	+ 0·004	– 0·011	– 716·456	+ 0·171	– 716·285
419	420	382·42	– 0·008	– 0·019	– 714·414	+ 0·171	– 714·243
420	421	384·45	– 0·015	– 0·034	– 719·326	+ 0·172	– 719·154

Line No. 35. Nandgaon to Raipur.—(Continued).

Bench-marks		Distance from Nandgaon	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Nandgaon (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Nandgaon
From	To		From mark to mark (=*d*)	Total from *Nandgaon*		Total from *Nandgaon*	
		miles	*foot*	*feet*	*feet*	*foot*	*feet*
421	422	385·53	– 0·013	– 0·047	– 710·951	+ 0·170	– 710·781
422	423	385·54	– 0·002	– 0·049	– 710·379	+ 0·170	– 710·209
423	424	387·27	+ 0·014	– 0·035	– 696·810	+ 0·168	– 696·642
424	425	388·02	– 0·013	– 0·048	– 695·798	+ 0·168	– 695·630
425	426	388·77	– 0·002	– 0·050	– 684·623	+ 0·166	– 684·457
426	427	389·54	– 0·009	– 0·059	– 687·774	+ 0·167	– 687·607
427	428	390·05	– 0·018	– 0·077	– 691·766	+ 0·168	– 691·598
428	429	391·10	– 0·003	– 0·080	– 690·753	+ 0·168	– 690·585
429	430	391·83	+ 0·013	– 0·067	– 691·405	+ 0·168	– 691·237
430	431	391·84	– 0·002	– 0·069	– 692·120	+ 0·168	– 691·952
431	432	391·85	– 0·003	– 0·072	– 691·334	+ 0·168	– 691·166
432	433	392·39	– 0·001	– 0·073	– 694·543	+ 0·169	– 694·374
433	434	394·28	+ 0·005	– 0·068	– 688·641	+ 0·168	– 688·473
434	435	394·55	+ 0·009	– 0·059	– 688·795	+ 0·168	– 688·627
435	436	396·33	– 0·003	– 0·062	– 692·690	+ 0·169	– 692·521
436	437	397·17	+ 0·002	– 0·060	– 667·427	+ 0·165	– 667·262
437	438	398·91	+ 0·007	– 0·053	– 684·723	+ 0·168	– 684·555
438	439	399·97	+ 0·002	– 0·051	– 685·065	+ 0·168	– 684·897
439	440	401·08	+ 0·001	– 0·050	– 674·471	+ 0·166	– 674·305
440	441	402·74	– 0·016	– 0·066	– 669·133	+ 0·165	– 668·968
441	442	404·18	– 0·004	– 0·070	– 646·313	+ 0·161	– 646·152
442	443	404·38	+ 0·004	– 0·066	– 644·568	+ 0·161	– 644·407
443	444	404·79	– 0·009	– 0·075	– 648·540	+ 0·162	– 648·378
444	445	406·40	– 0·046	– 0·121	– 623·641	+ 0·158	– 623·483
445	446	409·71	0·000	– 0·121	– 577·978	+ 0·150	– 577·828
446	447	410·81	+ 0·010	– 0·111	– 578·461	+ 0·150	– 578·311
447	448	412·00	+ 0·014	– 0·097	– 546·492	+ 0·145	– 546·347
448	449	413·22	+ 0·001	– 0·096	– 550·484	+ 0·146	– 550·338
449	450	413·82	– 0·007	– 0·103	– 531·541	+ 0·149	– 531·392
450	451	414·82	+ 0·006	– 0·097	– 535·577	+ 0·150	– 535·427
451	452	415·94	+ 0·011	– 0·086	– 543·428	+ 0·151	– 543·277
452	453	416·98	– 0·003	– 0·089	– 558·688	+ 0·154	– 558·534
453	454	417·98	– 0·017	– 0·106	– 528·557	+ 0·149	– 528·408
454	455	419·17	+ 0·009	– 0·097	– 527·677	+ 0·149	– 527·528
455	456	419·97	+ 0·003	– 0·094	– 532·022	+ 0·150	– 531·872
456	457	421·06	– 0·001	– 0·095	– 524·656	+ 0·149	– 524·507
457	458	421·82	– 0·012	– 0·107	– 532·768	+ 0·150	– 532·618
458	459	422·39	+ 0·006	– 0·101	– 539·899	+ 0·151	– 539·748
459	460	422·78	– 0·006	– 0·107	– 531·907	+ 0·150	– 531·757
460	461	422·80	+ 0·002	– 0·105	– 532·727	+ 0·150	– 532·577
461	462	423·49	+ 0·002	– 0·103	– 545·430	+ 0·152	– 545·278
462	463	424·84	– 0·016	– 0·119	– 552·557	+ 0·153	– 552·404
463	464	425·23	– 0·005	– 0·124	– 556·194	+ 0·154	– 556·040
464	465	426·44	– 0·008	– 0·132	– 534·981	+ 0·150	– 534·831
465	466	427·47	0·000	– 0·132	– 525·347	+ 0·148	– 525·199
466	467	428·48	+ 0·006	– 0·126	– 533·012	+ 0·149	– 532·863
467	468	429·88	+ 0·025	– 0·101	– 527·597	+ 0·148	– 527·449
468	469	430·14	– 0·003	– 0·104	– 534·332	+ 0·149	– 534·183
469	470	430·15	– 0·001	– 0·105	– 536·351	+ 0·149	– 536·202
470	471	430·39	+ 0·015	– 0·090	– 536·256	+ 0·149	– 536·107
471	472	432·61	+ 0·017	– 0·073	– 514·453	+ 0·145	– 514·308
472	473	433·86	+ 0·033	– 0·040	– 531·014	+ 0·148	– 530·866
473	474	434·91	+ 0·020	– 0·020	– 546·785	+ 0·151	– 546·634
474	475	435·71	+ 0·006	– 0·014	– 546·305	+ 0·151	– 546·154
475	476	436·76	+ 0·006	– 0·008	– 532·499	+ 0·149	– 532·350
476	477	436·79	+ 0·001	– 0·007	– 533·440	+ 0·149	– 533·291
477	478	437·18	– 0·003	– 0·010	– 530·294	+ 0·148	– 530·146
478	479	438·59	– 0·013	– 0·023	– 529·381	+ 0·148	– 529·233
479	480	439·57	– 0·012	– 0·035	– 545·852	+ 0·151	– 545·701
480	481	440·48	+ 0·015	– 0·020	– 539·928	+ 0·150	– 539·778

Line No. 35. Nandgaon to Raipur.—(Continued).

Bench-marks From	Bench-marks To	Distance from Nandgaon	Discrepancy between levellers (First – Second leveller): From mark to mark (= d)	Discrepancy between levellers (First – Second leveller): Total from Nandgaon	Observed elevation above (+) or below (–) Nandgaon (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Nandgaon	Dynamic height above (+) or below (–) Nandgaon
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
481	482	441·39	+ 0·024	+ 0·004	– 545·090	+ 0·151	– 544·939
482	483	442·51	+ 0·011	+ 0·015	– 530·597	+ 0·148	– 530·449
483	484	442·66	+ 0·004	+ 0·019	– 529·675	+ 0·148	– 529·527
484	485	444·11	+ 0·017	+ 0·036	– 518·744	+ 0·146	– 518·598
485	486	446·02	+ 0·028	+ 0·064	– 500·452	+ 0·143	– 500·309
486	487	446·03	– 0·002	+ 0·062	– 500·946	+ 0·143	– 500·803
487	488	446·73	+ 0·007	+ 0·069	– 484·862	+ 0·140	– 484·722
488	489	448·03	– 0·023	+ 0·046	– 478·609	+ 0·139	– 478·470
489	490	449·21	– 0·013	+ 0·033	– 447·979	+ 0·133	– 447·846
490	491	450·26	– 0·012	+ 0·021	– 406·666	+ 0·126	– 406·540
491	492	451·14	– 0·023	– 0·002	– 376·378	+ 0·121	– 376·257
492	493	452·38	+ 0·020	+ 0·018	– 331·107	+ 0·113	– 330·994
493	494	453·08	+ 0·004	+ 0·022	– 314·653	+ 0·110	– 314·543
494	495	453·09	+ 0·003	+ 0·025	– 314·043	+ 0·110	– 313·933
495	496	454·58	– 0·017	+ 0·008	– 274·840	+ 0·103	– 274·737
496	497	455·75	+ 0·033	+ 0·041	– 263·378	+ 0·101	– 263·277
497	498	456·30	+ 0·016	+ 0·057	– 266·586	+ 0·102	– 266·484
498	499	457·84	– 0·012	+ 0·045	– 232·385	+ 0·096	– 232·289
499	500	457·85	– 0·002	+ 0·043	– 232·656	+ 0·096	– 232·560
500	501	457·86	– 0·003	+ 0·040	– 233·994	+ 0·096	– 233·898
501	502	459·06	+ 0·021	+ 0·061	– 229·455	+ 0·095	– 229·360
502	503	459·99	+ 0·003	+ 0·064	– 265·498	+ 0·102	– 265·396
503	504	462·50	+ 0·028	+ 0·092	– 349·101	+ 0·117	– 348·984
504	505	464·49	+ 0·020	+ 0·112	– 395·996	+ 0·126	– 395·870
505	506	465·23	+ 0·002	+ 0·114	– 405·939	+ 0·128	– 405·811
506	507	466·25	+ 0·002	+ 0·116	– 393·165	+ 0·126	– 393·039
507	508	467·78	– 0·001	+ 0·115	– 411·321	+ 0·129	– 411·192
508	509	467·98	– 0·001	+ 0·114	– 415·118	+ 0·130	– 414·988
509	510	468·28	0·000	+ 0·114	– 413·459	+ 0·130	– 413·329
510	511	468·29	– 0·002	+ 0·112	– 414·447	+ 0·130	– 414·317
511	512	469·04	– 0·007	+ 0·105	– 428·883	+ 0·133	– 428·750
512	513	470·87	– 0·023	+ 0·082	– 460·964	+ 0·139	– 460·825
513	514	472·39	+ 0·004	+ 0·086	– 486·893	+ 0·144	– 486·749
514	515	473·44	+ 0·014	+ 0·100	– 488·295	+ 0·144	– 488·151
515	516	474·39	+ 0·019	+ 0·119	– 490·982	+ 0·145	– 490·837
516	517	475·69	– 0·008	+ 0·111	– 502·266	+ 0·147	– 502·119
517	518	476·23	+ 0·002	+ 0·113	– 504·222	+ 0·147	– 504·075
518	519	477·20	+ 0·009	+ 0·122	– 506·968	+ 0·148	– 506·820
519	520	478·15	– 0·015	+ 0·107	– 528·115	+ 0·152	– 527·963
520	521	479·14	– 0·004	+ 0·103	– 534·796	+ 0·153	– 534·643
521	522	480·84	+ 0·012	+ 0·115	– 519·072	+ 0·150	– 518·922
522	523	481·62	+ 0·003	+ 0·118	– 518·919	+ 0·150	– 518·769
523	524	483·01	0·000	+ 0·118	– 519·595	+ 0·150	– 519·445
524	525	483·76	– 0·007	+ 0·111	– 539·574	+ 0·154	– 539·420
525	526	484·92	+ 0·002	+ 0·113	– 543·461	+ 0·155	– 543·306
526	527	486·35	+ 0·003	+ 0·116	– 536·476	+ 0·154	– 536·322
527	528	487·65	– 0·012	+ 0·104	– 543·158	+ 0·155	– 543·003
528	529	487·66	+ 0·001	+ 0·105	– 543·540	+ 0·155	– 543·385
529	530	487·99	+ 0·004	+ 0·109	– 543·618	+ 0·155	– 543·463
530	531	488·39	+ 0·001	+ 0·110	– 557·693	+ 0·158	– 557·535
531	532	489·37	– 0·020	+ 0·090	– 575·717	+ 0·161	– 575·556
532	533	491·88	– 0·003	+ 0·087	– 572·363	+ 0·160	– 572·203
533	534	493·09	+ 0·007	+ 0·094	– 572·933	+ 0·160	– 572·773
534	535	495·35	+ 0·012	+ 0·106	– 531·590	+ 0·152	– 531·438
535	536	496·36	– 0·018	+ 0·088	– 537·728	+ 0·153	– 537·575
536	537	496·96	+ 0·007	+ 0·095	– 526·606	+ 0·151	– 526·455
537	538	496·98	+ 0·001	+ 0·096	– 526·337	+ 0·151	– 526·186
538	539	498·49	– 0·015	+ 0·081	– 568·602	+ 0·159	– 568·443
539	540	500·00	– 0·029	+ 0·052	– 583·880	+ 0·162	– 583·718
540	541	501·50	– 0·012	+ 0·040	– 610·819	+ 0·167	– 610·652

Line No. 35. Nandgaon to Raipur.—(Continued).

Bench-marks		Distance from Nandgaon	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Nandgaon (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Nandgaon
From	To		From mark to mark (= d)	Total from Nandgaon		Total from Nandgaon	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
541	542	502·81	+ 0·013	+ 0·053	– 610·343	+ 0·167	– 610·176
542	543	503·02	0·000	+ 0·053	– 610·396	+ 0·167	– 610·229
543	544	504·42	– 0·019	+ 0·034	– 615·583	+ 0·168	– 615·415
544	545	505·29	– 0·012	+ 0·022	– 615·523	+ 0·168	– 615·355
545	546	506·59	+ 0·024	+ 0·046	– 587·686	+ 0·163	– 587·523
546	547	506·62	0·000	+ 0·046	– 587·693	+ 0·163	– 587·530
547	548	507·27	+ 0·008	+ 0·054	– 582·188	+ 0·162	– 582·026
548	549	509·11	– 0·011	+ 0·043	– 594·493	+ 0·164	– 594·329
549	550	509·87	+ 0·024	+ 0·067	– 597·655	+ 0·165	– 597·490
550	551	511·94	+ 0·035	+ 0·102	– 553·486	+ 0·157	– 553·329
551	552	513·01	– 0·002	+ 0·100	– 553·707	+ 0·157	– 553·550
552	553	514·74	– 0·007	+ 0·093	– 557·734	+ 0·158	– 557·576
553	554	515·05	+ 0·002	+ 0·095	– 553·876	+ 0·157	– 553·719
554	555	515·08	– 0·002	+ 0·093	– 554·017	+ 0·157	– 553·860
555	556	516·39	– 0·008	+ 0·085	– 571·777	+ 0·160	– 571·617
556	557	517·17	+ 0·006	+ 0·091	– 567·677	+ 0·159	– 567·518
557	558	518·59	+ 0·004	+ 0·095	– 586·242	+ 0·162	– 586·080
558	559	520·21	+ 0·003	+ 0·098	– 594·530	+ 0·164	– 594·366
559	560	521·55	0·000	+ 0·098	– 616·576	+ 0·168	– 616·408
560	561	521·86	– 0·011	+ 0·087	– 617·015	+ 0·168	– 616·847
561	562	521·87	– 0·001	+ 0·086	– 617·223	+ 0·168	– 617·055
562	563	522·48	– 0·011	+ 0·075	– 628·002	+ 0·170	– 627·832
563	564	523·54	– 0·001	+ 0·074	– 637·651	+ 0·172	– 637·479
564	565	523·65	– 0·001	+ 0·073	– 637·684	+ 0·172	– 637·512
565	566	525·14	0·000	+ 0·073	– 638·275	+ 0·172	– 638·103
566	567	526·92	+ 0·017	+ 0·090	– 610·231	+ 0·167	– 610·064
567	568	528·31	– 0·020	+ 0·070	– 599·430	+ 0·165	– 599·265
568	569	529·67	– 0·008	+ 0·062	– 594·858	+ 0·164	– 594·694
569	570*	529·68	– 0·003	+ 0·059	– 594·886	+ 0·164	– 594·722

Difference of dynamic height, Nandgaon to Raipur = – 594·722 feet.

Length of line in miles = M = 529·68. $\Sigma d^2 = 0·098759$.

Probable error of the mean result per mile of double-levelling $= 0·6745\sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0·0046$.

Probable error of the difference of elevation between the terminal bench-marks $= 0·6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0·1060$.

* Bench-mark No. 570 is the mark at Raipur described on page 135.

Line No. 36. Vizagapatam to Vizianagram.

Bench-marks From	Bench-marks To	Distance from Vizagapatam	Discrepancy between levellers (First − Second leveller): From mark to mark ($=d$)	Discrepancy between levellers (First − Second leveller): Total from Vizagapatam	Observed elevation above (+) or below (−) Vizagapatam (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Vizagapatam	Dynamic height above (+) or below (−) Vizagapatam
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·76	0·000	0·000	− 5·664	+ 0·002	− 5·662
2	3	0·87	+ 0·003	+ 0·003	− 5·584	+ 0·002	− 5·582
3	4	2·13	0·000	+ 0·003	+ 3·145	− 0·002	+ 3·143
4	5	2·51	+ 0·004	+ 0·007	+ 9·333	− 0·004	+ 9·329
5	6	2·62	0·000	+ 0·007	+ 9·500	− 0·004	+ 9·496
6	7	3·04	0·000	+ 0·007	+ 5·763	− 0·002	+ 5·761
7	8	4·44	− 0·023	− 0·016	+ 41·883	− 0·016	+ 41·867
8	9	5·45	+ 0·001	− 0·015	+ 42·166	− 0·016	+ 42·150
9	10	6·61	+ 0·002	− 0·013	+ 40·620	− 0·015	+ 40·605
10	11	7·49	+ 0·020	+ 0·007	+ 54·696	− 0·021	+ 54·675
11	12	7·60	0·000	+ 0·007	+ 54·587	− 0·021	+ 54·566
12	13	8·75	− 0·017	− 0·010	+ 42·381	− 0·016	+ 42·365
13	14	9·77	+ 0·006	− 0·004	+ 50·034	− 0·019	+ 50·015
14	15	10·45	− 0·001	− 0·005	+ 49·675	− 0·019	+ 49·656
15	16	10·85	0·000	− 0·005	+ 49·547	− 0·019	+ 49·528
16	17	12·14	− 0·011	− 0·016	+ 58·068	− 0·022	+ 58·046
17	18	12·59	+ 0·007	− 0·009	+ 62·503	− 0·024	+ 62·479
18	19	13·79	− 0·010	− 0·019	+ 73·329	− 0·028	+ 73·301
19	20	15·14	− 0·008	− 0·027	+ 87·857	− 0·034	+ 87·823
20	21	16·50	+ 0·018	− 0·009	+ 111·900	− 0·043	+ 111·857
21	22	17·38	− 0·002	− 0·011	+ 131·692	− 0·051	+ 131·641
22	23	17·97	− 0·001	− 0·012	+ 148·203	− 0·057	+ 148·146
23	24	18·23	− 0·004	− 0·016	+ 155·149	− 0·060	+ 155·089
24	25	18·68	− 0·003	− 0·019	+ 159·236	− 0·062	+ 159·174
25	26	18·79	+ 0·004	− 0·015	+ 159·203	− 0·062	+ 159·141
26	27	19·05	+ 0·003	− 0·012	+ 158·379	− 0·062	+ 158·317
27	28	20·07	0·000	− 0·012	+ 191·325	− 0·075	+ 191·250
28	29	21·06	− 0·006	− 0·018	+ 225·408	− 0·088	+ 225·320
29	30	22·41	− 0·016	− 0·034	+ 236·212	− 0·092	+ 236·120
30	31	23·29	+ 0·002	− 0·032	+ 227·051	− 0·089	+ 226·962
31	32	24·59	+ 0·018	− 0·014	+ 203·887	− 0·080	+ 203·807
32	33	27·26	+ 0·003	− 0·011	+ 135·204	− 0·055	+ 135·149
33	34	28·01	+ 0·004	− 0·007	+ 112·234	− 0·046	+ 112·188
34	35	28·55	− 0·002	− 0·009	+ 114·338	− 0·047	+ 114·291
35	36	28·80	− 0·006	− 0·015	+ 119·735	− 0·049	+ 119·686
36	37	29·18	+ 0·002	− 0·013	+ 128·231	− 0·052	+ 128·179
37	38	29·29	− 0·001	− 0·014	+ 128·227	− 0·052	+ 128·175
38	39	30·03	− 0·002	− 0·016	+ 111·779	− 0·046	+ 111·733
39	40	30·94	+ 0·004	− 0·012	+ 92·451	− 0·039	+ 92·412
40	41	31·14	− 0·011	− 0·023	+ 85·382	− 0·036	+ 85·346
41	42	32·35	0·000	− 0·023	+ 90·619	− 0·038	+ 90·581
42	43	33·30	+ 0·008	− 0·015	+ 84·063	− 0·036	+ 84·027
43	44	34·40	+ 0·019	+ 0·004	+ 105·786	− 0·044	+ 105·742
44	45	35·42	− 0·006	− 0·002	+ 123·897	− 0·051	+ 123·846
45	46	36·66	+ 0·003	+ 0·001	+ 153·959	− 0·062	+ 153·897
46	47	37·26	+ 0·006	+ 0·007	+ 153·964	− 0·062	+ 153·902
47	48	38·04	+ 0·007	+ 0·014	+ 165·692	− 0·066	+ 165·626
48	49	38·30	− 0·002	+ 0·012	+ 170·016	− 0·068	+ 169·948
49	50	39·29	+ 0·013	+ 0·025	+ 179·105	− 0·071	+ 179·034
50	51†	40·16	− 0·002	+ 0·023	+ 176·667	− 0·070	+ 176·597

Difference of dynamic height, Vizagapatam to Vizianagram = + 176·597 feet.

Length of line in miles = M = 40·16, $\Sigma d^2 = 0 \cdot 003561$.

Probable error of the mean result per mile of double-levelling $= 0 \cdot 6745 \sqrt{\dfrac{\Sigma d^2}{4M}} = \pm\, 0 \cdot 0032$

Probable error of the difference of elevation between the terminal bench-marks $= 0 \cdot 6745 \sqrt{\dfrac{\Sigma d^2}{4}} = \pm\, 0 \cdot 0201'$.

* Bench-mark No. 1 is the mark at Vizagapatam described on page 136. † Bench-mark No. 51 is the mark at Vizianagram described on page 136.

Line No. 37. Vizianagram to Raipur.

Bench-marks		Distance from Vizianagram	Discrepancy between levellers (First—Second leveller)		Observed elevation above (+) or below (−) Vizianagram (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Vizianagram
From	To		From mark to mark (=d)	Total from Vizianagram		Total from Vizianagram	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·15	+ 0·004	+ 0·004	+ 5·408	− 0·002	+ 5·406
2	3	0·49	+ 0·002	+ 0·006	+ 2·975	− 0·001	+ 2·974
3	4	0·96	0·000	+ 0·006	+ 26·616	− 0·010	+ 26·606
4	5	1·69	+ 0·027	+ 0·033	+ 47·153	− 0·017	+ 47·136
5	6	2·18	+ 0·020	+ 0·053	+ 68·682	− 0·025	+ 68·657
6	7	3·18	+ 0·055	+ 0·108	+ 139·985	− 0·051	+ 139·934
7	8	4·18	+ 0·048	+ 0·156	+ 91·541	− 0·034	+ 91·507
8	9	5·18	+ 0·036	+ 0·192	+ 128·638	− 0·047	+ 128·591
9	10	6·17	+ 0·002	+ 0·194	+ 100·673	− 0·037	+ 100·636
10	11	7·17	+ 0·007	+ 0·201	+ 42·141	− 0·016	+ 42·125
11	12	7·59	+ 0·008	+ 0·209	+ 14·575	− 0·006	+ 14·569
12	13	10·16	− 0·015	+ 0·194	+ 71·465	− 0·027	+ 71·438
13	14	10·83	− 0·005	+ 0·189	+ 33·224	− 0·013	+ 33·211
14	15	11·19	− 0·004	+ 0·185	+ 27·525	− 0·011	+ 27·514
15	16	12·65	− 0·003	+ 0·182	+ 42·637	− 0·016	+ 42·621
16	17	13·38	+ 0·005	+ 0·187	+ 29·472	− 0·011	+ 29·461
17	18	15·21	+ 0·011	+ 0·198	+ 62·251	− 0·023	+ 62·228
18	19	19·05	+ 0·011	+ 0·209	+ 74·985	− 0·027	+ 74·958
19	20	19·25	− 0·004	+ 0·205	+ 81·936	− 0·029	+ 81·907
20	21	19·61	− 0·002	+ 0·203	+ 94·470	− 0·033	+ 94·437
21	22	20·81	− 0·014	+ 0·189	+ 117·641	− 0·041	+ 117·600
22	23	21·71	− 0·005	+ 0·184	+ 153·638	− 0·054	+ 153·584
23	24	23·10	+ 0·008	+ 0·192	+ 204·626	− 0·072	+ 204·554
24	25	23·76	− 0·009	+ 0·183	+ 238·506	− 0·084	+ 238·422
25	26	25·28	− 0·013	+ 0·170	+ 235·480	− 0·083	+ 235·397
26	27	25·59	− 0·002	+ 0·168	+ 225·073	− 0·079	+ 224·994
27	28	27·20	− 0·003	+ 0·165	+ 238·557	− 0·084	+ 238·473
28	29	28·31	+ 0·011	+ 0·176	+ 309·042	− 0·109	+ 308·933
29	30	28·65	+ 0·004	+ 0·180	+ 292·293	− 0·103	+ 292·190
30	31	29·32	− 0·008	+ 0·172	+ 292·876	− 0·103	+ 292·773
31	32	29·91	+ 0·006	+ 0·178	+ 256·126	− 0·090	+ 256·036
32	33	31·03	+ 0·006	+ 0·184	+ 280·958	− 0·099	+ 280·859
33	34	31·92	+ 0·007	+ 0·191	+ 295·386	− 0·104	+ 295·282
34	35	32·79	− 0·008	+ 0·183	+ 295·452	− 0·104	+ 295·348
35	36	32·86	+ 0·002	+ 0·185	+ 292·216	− 0·103	+ 292·113
36	37	34·66	+ 0·003	+ 0·188	+ 276·617	− 0·098	+ 276·519
37	38	34·76	+ 0·004	+ 0·192	+ 284·434	− 0·101	+ 284·333
38	39	35·42	+ 0·006	+ 0·198	+ 323·317	− 0·114	+ 323·203
39	40	35·75	− 0·001	+ 0·197	+ 317·130	− 0·112	+ 317·018
40	41	36·12	− 0·003	+ 0·194	+ 319·447	− 0·113	+ 319·334
41	42	36·39	− 0·002	+ 0·192	+ 329·614	− 0·116	+ 329·498
42	43	37·14	+ 0·015	+ 0·207	+ 338·583	− 0·119	+ 338·464
43	44	37·71	0·000	+ 0·207	+ 388·931	− 0·136	+ 388·795
44	45	38·15	− 0·005	+ 0·202	+ 395·236	− 0·138	+ 395·098
45	46	39·51	+ 0·011	+ 0·213	+ 415·685	− 0·145	+ 415·540
46	47	40·27	− 0·005	+ 0·208	+ 439·365	− 0·153	+ 439·212
47	48	40·90	+ 0·003	+ 0·211	+ 456·330	− 0·159	+ 456·171
48	49	41·05	− 0·003	+ 0·208	+ 504·796	− 0·176	+ 504·620
49	50	41·36	+ 0·015	+ 0·223	+ 613·962	− 0·213	+ 613·749
50	51	41·68	+ 0·019	+ 0·242	+ 710·666	− 0·246	+ 710·420
51	52	42·41	− 0·024	+ 0·218	+ 943·692	− 0·326	+ 943·366
52	53	42·87	+ 0·028	+ 0·246	+ 1092·796	− 0·377	+ 1092·419
53	54	43·25	+ 0·029	+ 0·2[illegible]5	+ 1215·379	− 0·419	+ 1214·960
54	55	43·89	+ 0·009	+ 0·284	+ 1443·656	− 0·497	+ 1443·159
55	56	44·18	+ 0·012	+ 0·296	+ 1534·793	− 0·528	+ 1534·265
56	57	44·89	+ 0·031	+ 0·327	+ 1758·976	− 0·605	+ 1758·371
57	58	45·29	+ 0·006	+ 0·333	+ 1737·500	− 0·598	+ 1736·902
58	59	45·89	+ 0·018	+ 0·351	+ 1739·977	− 0·599	+ 1739·378
59	60	46·87	− 0·023	+ 0·328	+ 1702·890	− 0·586	+ 1702·304
60	61	46·92	− 0·002	+ 0·326	+ 1697·456	− 0·584	+ 1696·872

* Bench-mark No. 1 is the mark at Vizianagram described on page 136.

Line No. 37. Vizianagram to Raipur.—(Continued).

Bench-marks		Distance from Vizianagram	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Vizianagram (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Vizianagram
From	To		From mark to mark (=*d*)	Total from Vizianagram		Total from Vizianagram	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	47·87	0·000	+ 0·326	+ 1762·517	– 0·606	+ 1761·911
62	63	48·40	+ 0·009	+ 0·335	+ 1758·709	– 0·605	+ 1758·104
63	64	49·84	+ 0·007	+ 0·342	+ 1832·418	– 0·630	+ 1831·788
64	65	49·92	+ 0·002	+ 0·344	+ 1845·626	– 0·634	+ 1844·992
65	66	50·86	+ 0·079	+ 0·423	+ 2060·690	– 0·708	+ 2059·982
66	67	51·17	+ 0·020	+ 0·443	+ 2142·572	– 0·736	+ 2141·836
67	68	52·52	+ 0·015	+ 0·458	+ 2334·568	– 0·802	+ 2333·766
68	69	52·86	– 0·005	+ 0·453	+ 2334·298	– 0·802	+ 2333·496
69	70	53·85	+ 0·009	+ 0·462	+ 2460·081	– 0·845	+ 2459·236
70	71	54·96	+ 0·028	+ 0·490	+ 2624·118	– 0·901	+ 2623·217
71	72	56·34	+ 0·063	+ 0·553	+ 2844·516	– 0·976	+ 2843·540
72	73	56·64	0·000	+ 0·553	+ 2866·811	– 0·984	+ 2865·827
73	74	56·66	0·000	+ 0·553	+ 2865·934	– 0·984	+ 2864·950
74	75	56·84	– 0·004	+ 0·549	+ 2886·995	– 0·991	+ 2886·004
75	76	57·85	+ 0·037	+ 0·586	+ 2983·405	– 1·024	+ 2982·381
76	77	58·84	+ 0·013	+ 0·599	+ 2997·615	– 1·029	+ 2996·586
77	78	59·41	+ 0·018	+ 0·617	+ 3154·054	– 1·082	+ 3152·972
78	79	59·85	+ 0·007	+ 0·624	+ 3285·593	– 1·127	+ 3284·466
79	80	61·16	+ 0·025	+ 0·649	+ 2988·597	– 1·026	+ 2987·571
80	81	61·85	+ 0·018	+ 0·667	+ 2845·427	– 0·977	+ 2844·450
81	82	62·90	– 0·013	+ 0·654	+ 2769·838	– 0·951	+ 2768·887
82	83	63·61	– 0·004	+ 0·650	+ 2786·829	– 0·957	+ 2785·872
83	84	63·86	+ 0·002	+ 0·652	+ 2788·497	– 0·958	+ 2787·539
84	85	64·91	+ 0·024	+ 0·676	+ 2762·256	– 0·949	+ 2761·307
85	86	65·94	– 0·011	+ 0·665	+ 2739·520	– 0·941	+ 2738·579
86	87	66·39	– 0·002	+ 0·663	+ 2719·677	– 0·934	+ 2718·743
87	88	66·91	– 0·009	+ 0·654	+ 2771·650	– 0·952	+ 2770·698
88	89	67·91	0·000	+ 0·654	+ 2741·871	– 0·942	+ 2740·929
89	90	68·34	+ 0·002	+ 0·656	+ 2703·768	– 0·929	+ 2702·839
90	91	68·58	– 0·001	+ 0·655	+ 2677·211	– 0·920	+ 2676·291
91	92	68·92	– 0·003	+ 0·652	+ 2688·098	– 0·924	+ 2787·174
92	93	69·94	– 0·006	+ 0·646	+ 2710·947	– 0·932	+ 2710·015
93	94	70·94	– 0·007	+ 0·639	+ 2678·231	– 0·921	+ 2677·310
94	95	71·42	+ 0·002	+ 0·641	+ 2653·117	– 0·912	+ 2652·205
95	96	71·96	+ 0·002	+ 0·643	+ 2718·379	– 0·934	+ 2717·445
96	97	72·97	+ 0·008	+ 0·651	+ 2726·775	– 0·937	+ 2725·838
97	98	73·41	– 0·005	+ 0·646	+ 2686·365	– 0·923	+ 2685·442
98	99	73·99	+ 0·003	+ 0·649	+ 2763·315	– 0·948	+ 2762·367
99	100	74·99	– 0·022	+ 0·627	+ 2798·921	– 0·960	+ 2797·961
100	101	75·41	+ 0·003	+ 0·630	+ 2698·770	– 0·927	+ 2697·843
101	102	75·99	+ 0·010	+ 0·640	+ 2786·218	– 0·956	+ 2785·262
102	103	76·57	+ 0·009	+ 0·649	+ 2712·461	– 0·932	+ 2711·529
103	104	77·00	– 0·008	+ 0·641	+ 2716·440	– 0·933	+ 2715·507
104	105	77·96	– 0·008	+ 0·633	+ 2712·289	– 0·932	+ 2711·357
105	106	78·02	+ 0·004	+ 0·637	+ 2719·457	– 0·934	+ 2718·523
106	107	79·03	– 0·006	+ 0·631	+ 2751·189	– 0·945	+ 2750·244
107	108	79·54	+ 0·003	+ 0·634	+ 2802·159	– 0·962	+ 2801·197
108	109	80·04	– 0·008	+ 0·626	+ 2741·469	– 0·942	+ 2740·527
109	110	80·85	– 0·003	+ 0·623	+ 2706·000	– 0·930	+ 2705·070
110	111	81·05	+ 0·002	+ 0·625	+ 2694·069	– 0·926	+ 2693·143
111	112	82·09	0·000	+ 0·625	+ 2604·902	– 0·897	+ 2604·005
112	113	83·06	– 0·001	+ 0·624	+ 2606·461	– 0·898	+ 2605·563
113	114	84·06	– 0·009	+ 0·615	+ 2661·788	– 0·916	+ 2660·872
114	115	85·06	+ 0·001	+ 0·616	+ 2646·693	– 0·911	+ 2645·782
115	116	87·09	– 0·008	+ 0·608	+ 2682·319	– 0·923	+ 2681·396
116	117	88·09	+ 0·010	+ 0·618	+ 2674·844	– 0·920	+ 2673·924
117	118	88·27	+ 0·002	+ 0·620	+ 2640·971	– 0·909	+ 2640·062
118	119	89·12	– 0·013	+ 0·607	+ 2663·539	– 0·917	+ 2662·622
119	120	90·96	– 0·014	+ 0·593	+ 2694·511	– 0·927	+ 2693·584
120	121	91·15	+ 0·004	+ 0·597	+ 2701·416	– 0·929	+ 2700·487

Line No. 37. Vizianagram to Raipur.—(Continued).

Bench-marks From	Bench-marks To	Distance from Vizianagram	Discrepancy between levellers (First – Second leveller): From mark to mark (= *d*)	Discrepancy between levellers (First – Second leveller): Total from Vizianagram	Observed elevation above (+) or below (–) Vizianagram (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Vizianagram	Dynamic height above (+) or below (–) Vizianagram
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
121	122	92·11	– 0·001	+ 0·596	+ 2742·978	– 0·943	+ 2742·035
122	123	92·61	+ 0·016	+ 0·612	+ 2845·717	– 0·977	+ 2844·740
123	124	93·10	– 0·001	+ 0·611	+ 2781·190	– 0·956	+ 2780·234
124	125	93·81	– 0·007	+ 0·604	+ 2742·586	– 0·943	+ 2741·643
125	126	94·11	– 0·006	+ 0·598	+ 2721·767	– 0·936	+ 2720·831
126	127	95·11	– 0·006	+ 0·592	+ 2666·240	– 0·918	+ 2665·322
127	128	96·13	– 0·031	+ 0·561	+ 2747·423	– 0·945	+ 2746·478
128	129	97·14	+ 0·009	+ 0·570	+ 2632·566	– 0·907	+ 2631·659
129	130	97·54	+ 0·004	+ 0·574	+ 2603·488	– 0·897	+ 2602·591
130	131	98·14	– 0·021	+ 0·553	+ 2601·592	– 0·896	+ 2600·696
131	132	98·72	– 0·023	+ 0·530	+ 2584·973	– 0·890	+ 2584·083
132	133	99·15	– 0·015	+ 0·515	+ 2571·918	– 0·886	+ 2571·032
133	134	101·25	– 0·057	+ 0·458	+ 2088·871	– 0·729	+ 2088·142
134	135	102·15	– 0·013	+ 0·445	+ 1856·364	– 0·653	+ 1855·711
135	136	103·15	– 0·028	+ 0·417	+ 1850·240	– 0·651	+ 1849·589
136	137	104·54	– 0·007	+ 0·410	+ 1741·882	– 0·616	+ 1741·266
137	138	105·00	– 0·002	+ 0·408	+ 1747·552	– 0·618	+ 1746·934
138	139	106·19	– 0·020	+ 0·388	+ 1757·616	– 0·621	+ 1756·995
139	140	107·73	– 0·016	+ 0·372	+ 1755·015	– 0·620	+ 1754·395
140	141	113·65	+ 0·007	+ 0·379	+ 1720·517	– 0·609	+ 1719·908
141	142	115·44	– 0·008	+ 0·371	+ 1721·229	– 0·609	+ 1720·620
142	143	131·64	+ 0·051	+ 0·422	+ 1678·229	– 0·596	+ 1677·633
143	144	135·89	+ 0·005	+ 0·427	+ 1732·953	– 0·612	+ 1732·341
144	145	142·16	+ 0·015	+ 0·442	+ 1725·229	– 0·610	+ 1724·619
145	146	160·05	– 0·021	+ 0·421	+ 1766·147	– 0·622	+ 1765·525
146	147	163·98	+ 0·010	+ 0·431	+ 1738·209	– 0·614	+ 1737·595
147	148	170·44	– 0·004	+ 0·427	+ 1801·169	– 0·632	+ 1800·537
148	149	171·16	+ 0·003	+ 0·430	+ 1801·379	– 0·632	+ 1800·747
149	150	173·24	+ 0·019	+ 0·449	+ 1824·589	– 0·638	+ 1823·951
150	151	173·86	– 0·006	+ 0·443	+ 1850·687	– 0·645	+ 1850·042
151	152	176·46	+ 0·012	+ 0·455	+ 1872·224	– 0·651	+ 1871·573
152	153	177·35	+ 0·008	+ 0·463	+ 1831·377	– 0·640	+ 1830·737
153	154	185·33	+ 0·040	+ 0·503	+ 1943·122	– 0·670	+ 1942·452
154	155	188·10	– 0·016	+ 0·487	+ 1975·931	– 0·679	+ 1975·252
155	156	188·54	– 0·003	+ 0·484	+ 1960·049	– 0·675	+ 1959·374
156	157	188·61	– 0·001	+ 0·483	+ 1960·387	– 0·675	+ 1959·712
157	158	193·09	+ 0·021	+ 0·504	+ 2004·562	– 0·686	+ 2003·876
158	159	195·91	– 0·030	+ 0·474	+ 1967·252	– 0·676	+ 1966·576
159	160	207·87	– 0·068	+ 0·406	+ 1896·298	– 0·658	+ 1895·640
160	161	210·05	– 0·006	+ 0·400	+ 1832·673	– 0·642	+ 1832·031
161	162	212·36	– 0·024	+ 0·376	+ 1669·869	– 0·602	+ 1669·267
162	163	214·79	– 0·028	+ 0·348	+ 1620·418	– 0·590	+ 1619·828
163	164	224·55	– 0·036	+ 0·312	+ 1271·393	– 0·506	+ 1270·887
164	165	226·87	– 0·037	+ 0·275	+ 1233·866	– 0·495	+ 1233·371
165	166	230·51	+ 0·002	+ 0·277	+ 1231·095	– 0·494	+ 1230·601
166	167	236·29	– 0·013	+ 0·264	+ 1247·971	– 0·498	+ 1247·473
167	168	239·65	+ 0·003	+ 0·267	+ 1134·326	– 0·471	+ 1133·855
168	169	240·57	– 0·018	+ 0·249	+ 1149·810	– 0·475	+ 1149·335
169	170	244·20	– 0·042	+ 0·207	+ 1124·007	– 0·469	+ 1123·538
170	171	245·37	+ 0·006	+ 0·213	+ 1116·490	– 0·467	+ 1116·023
171	172	247·26	– 0·007	+ 0·206	+ 1044·872	– 0·450	+ 1044·422
172	173	249·00	+ 0·008	+ 0·214	+ 1159·573	– 0·476	+ 1159·097
173	174	251·64	+ 0·044	+ 0·258	+ 1125·424	– 0·468	+ 1124·956
174	175	254·16	– 0·016	+ 0·242	+ 1077·199	– 0·457	+ 1076·742
175	176	258·26	+ 0·008	+ 0·250	+ 885·329	– 0·415	+ 884·914
176	177	260·29	– 0·004	+ 0·246	+ 894·554	– 0·417	+ 894·137
177	178	260·97	0·000	+ 0·246	+ 918·671	– 0·422	+ 918·249
178	179	262·34	+ 0·003	+ 0·249	+ 887·017	– 0·415	+ 886·602
179	180	262·95	+ 0·005	+ 0·254	+ 918·586	– 0·422	+ 918·164
180	181	265·66	– 0·018	+ 0·236	+ 870·055	– 0·411	+ 869·644

Line No. 37. Vizianagram to Raipur.—(Continued).

Bench-marks		Distance from Vizianagram	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Vizianagram (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Vizianagram
From	To		From mark to mark (= d)	Total from Vizianagram		Total from Vizianagram	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
181	182	267·96	+ 0·001	+ 0·237	+ 860·771	– 0·409	+ 860·362
182	183	269·09	+ 0·002	+ 0·239	+ 855·565	– 0·408	+ 855·157
183	184	269·17	– 0·002	+ 0·237	+ 859·686	– 0·409	+ 859·277
184	185	270·09	– 0·006	+ 0·231	+ 857·045	– 0·408	+ 856·637
185	186	271·08	– 0·009	+ 0·222	+ 852·121	– 0·407	+ 851·714
186	187	272·08	+ 0·004	+ 0·226	+ 850·895	– 0·407	+ 850·488
187	188	273·08	0·000	+ 0·226	+ 856·237	– 0·408	+ 855·829
188	189	274·07	– 0·002	+ 0·224	+ 861·489	– 0·409	+ 861·080
189	190	275·07	– 0·001	+ 0·223	+ 856·455	– 0·408	+ 856·047
190	191	276·07	– 0·006	+ 0·217	+ 852·505	– 0·407	+ 852·098
191	192	277·07	+ 0·021	+ 0·238	+ 847·212	– 0·406	+ 846·806
192	193	278·07	– 0·013	+ 0·225	+ 847·413	– 0·406	+ 847·007
193	194	279·07	– 0·001	+ 0·224	+ 839·501	– 0·404	+ 839·097
194	195	280·07	– 0·001	+ 0·223	+ 835·759	– 0·403	+ 835·356
195	196	281·06	– 0·004	+ 0·219	+ 842·161	– 0·404	+ 841·757
196	197	282·06	– 0·009	+ 0·210	+ 841·411	– 0·404	+ 841·007
197	198	283·05	+ 0·003	+ 0·213	+ 839·256	– 0·404	+ 838·852
198	199	284·07	0·000	+ 0·213	+ 834·059	– 0·403	+ 833·656
199	200	285·07	– 0·003	+ 0·210	+ 838·695	– 0·404	+ 838·291
200	201	286·06	– 0·006	+ 0·204	+ 845·607	– 0·405	+ 845·202
201	202	287·07	+ 0·014	+ 0·218	+ 839·212	– 0·404	+ 838·808
202	203	288·06	+ 0·023	+ 0·241	+ 842·883	– 0·405	+ 842·478
203	204	289·07	– 0·012	+ 0·229	+ 845·875	– 0·406	+ 845·469
204	205	290·07	– 0·003	+ 0·226	+ 837·693	– 0·404	+ 837·289
205	206	291·07	– 0·002	+ 0·224	+ 825·783	– 0·402	+ 825·381
206	207	292·07	+ 0·013	+ 0·237	+ 838·014	– 0·404	+ 837·610
207	208	293·08	– 0·001	+ 0·236	+ 818·217	– 0·400	+ 817·817
208	209	294·02	+ 0·010	+ 0·246	+ 822·186	– 0·401	+ 821·785
209	210	294·08	– 0·001	+ 0·245	+ 823·729	– 0·401	+ 823·328
210	211	295·09	– 0·004	+ 0·241	+ 822·273	– 0·401	+ 821·872
211	212	296·09	+ 0·014	+ 0·255	+ 822·737	– 0·401	+ 822·336
212	213	297·09	– 0·003	+ 0·252	+ 837·805	– 0·404	+ 837·401
213	214	298·09	– 0·008	+ 0·244	+ 849·907	– 0·406	+ 849·501
214	215	299·09	– 0·002	+ 0·242	+ 866·313	– 0·409	+ 865·904
215	216	300·08	+ 0·007	+ 0·249	+ 869·864	– 0·410	+ 869·454
216	217	301·08	+ 0·012	+ 0·261	+ 875·447	– 0·411	+ 875·036
217	218	302·08	– 0·026	+ 0·235	+ 862·210	– 0·408	+ 861·802
218	219	303·08	– 0·015	+ 0·220	+ 860·876	– 0·408	+ 860·468
219	220	304·08	– 0·020	+ 0·200	+ 839·618	– 0·404	+ 839·214
220	221	305·09	– 0·007	+ 0·193	+ 836·093	– 0·403	+ 835·690
221	222	306·09	+ 0·018	+ 0·211	+ 854·972	– 0·407	+ 854·565
222	223	307·09	+ 0·002	+ 0·213	+ 825·798	– 0·401	+ 825·397
223	224	308·10	+ 0·003	+ 0·216	+ 826·014	– 0·401	+ 825·613
224	225	308·53	– 0·009	+ 0·207	+ 817·198	– 0·399	+ 816·799
225	226	309·11	– 0·003	+ 0·204	+ 802·248	– 0·396	+ 801·852
226	227	310·11	+ 0·004	+ 0·208	+ 804·502	– 0·396	+ 804·106
227	228	311·11	– 0·011	+ 0·197	+ 783·628	– 0·392	+ 783·236
228	229	312·11	– 0·010	+ 0·187	+ 783·915	– 0·392	+ 783·523
229	230	313·11	+ 0·018	+ 0·205	+ 773·422	– 0·390	+ 773·032
230	231	314·11	+ 0·001	+ 0·206	+ 769·347	– 0·389	+ 768·958
231	232	315·90	+ 0·017	+ 0·223	+ 807·187	– 0·396	+ 806·791
232	233	316·01	+ 0·003	+ 0·226	+ 803·005	– 0·395	+ 802·610
233	234	316·34	– 0·003	+ 0·223	+ 792·096	– 0·393	+ 791·703
234	235	316·49	– 0·004	+ 0·219	+ 783·311	– 0·391	+ 782·920
235	236	316·93	– 0·008	+ 0·211	+ 775·350	– 0·389	+ 774·961
236	237	317·59	– 0·007	+ 0·204	+ 753·683	– 0·385	+ 753·298
237	238*	317·80	0·000	+ 0·204	+ 768·017	– 0·388	+ 767·629

Difference of dynamic height, Vizianagram to Raipur = + 767·629 feet.

Length of line in miles = M = 317·80. $\Sigma d^2 = 0{\cdot}066204$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745 \sqrt{\dfrac{\Sigma d^2}{4M}} = \pm\, 0{\cdot}0048$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745 \sqrt{\dfrac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0868$.

* Bench-mark No. 238 is the mark at Raipur described on page 135.

Line No. 38. Raipur to Bilaspur.

Bench-marks From	Bench-marks To	Distance from Raipur	Discrepancy between levellers (First − Second leveller) From mark to mark (= d)	Discrepancy between levellers (First − Second leveller) Total from Raipur	Observed elevation above (+) or below (−) Raipur (mean result by two levellers)	Dynamic correction deduced from mark to mark Total from Raipur	Dynamic height above (+) or below (−) Raipur
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·81	+ 0·007	+ 0·007	− 23·436	+ 0·004	− 23·432
2	3	2·15	− 0·006	+ 0·001	− 35·901	+ 0·006	− 35·895
3	4	3·40	− 0·008	− 0·007	− 60·302	+ 0·010	− 60·292
4	5	4·47	− 0·002	− 0·009	− 61·008	+ 0·010	− 60·998
5	6	5·97	+ 0·007	− 0·002	− 44·628	+ 0·007	− 44·621
6	7	7·00	+ 0·006	+ 0·004	− 34·318	+ 0·005	− 34·313
7	8	7·45	+ 0·013	+ 0·017	− 29·462	+ 0·004	− 29·458
8	9	7·46	+ 0·002	+ 0·019	− 29·418	+ 0·004	− 29·414
9	10	8·36	+ 0·002	+ 0·021	− 47·449	+ 0·007	− 47·442
10	11	10·19	+ 0·001	+ 0·022	− 63·369	+ 0·010	− 63·359
11	12	11·23	+ 0·006	+ 0·028	− 73·561	+ 0·012	− 73·549
12	13	12·36	− 0·001	+ 0·027	− 77·862	+ 0·013	− 77·849
13	14	13·46	+ 0·004	+ 0·031	− 71·945	+ 0·012	− 71·933
14	15	14·55	− 0·020	+ 0·011	− 47·650	+ 0·008	− 47·642
15	16	14·56	+ 0·002	+ 0·013	− 47·569	+ 0·008	− 47·561
16	17	15·69	− 0·005	+ 0·008	− 44·149	+ 0·007	− 44·142
17	18	17·08	− 0·009	− 0·001	− 31·949	+ 0·005	− 31·944
18	19	18·41	+ 0·011	+ 0·010	− 42·851	+ 0·007	− 42·844
19	20	19·27	− 0·007	+ 0·003	− 34·084	+ 0·005	− 34·079
20	21	20·35	+ 0·003	+ 0·006	− 42·340	+ 0·006	− 42·334
21	22	21·69	− 0·014	− 0·008	− 35·334	+ 0·005	− 35·329
22	23	22·60	+ 0·014	+ 0·006	− 35·133	+ 0·005	− 35·128
23	24	23·54	+ 0·015	+ 0·021	− 11·593	+ 0·001	− 11·592
24	25	23·55	− 0·001	+ 0·020	− 11·158	+ 0·001	− 11·157
25	26	24·61	− 0·010	+ 0·010	− 28·584	+ 0·004	− 28·580
26	27	25·30	− 0·001	+ 0·009	− 30·012	+ 0·004	− 30·008
27	28	27·27	+ 0·032	+ 0·041	− 41·415	+ 0·006	− 41·409
28	29	28·20	− 0·003	+ 0·038	− 41·691	+ 0·006	− 41·685
29	30	29·35	+ 0·013	+ 0·051	− 51·001	+ 0·007	− 50·994
30	31	30·18	0·000	+ 0·051	− 36·471	+ 0·009	− 36·462
31	32	30·21	− 0·003	+ 0·048	− 36·578	+ 0·009	− 36·569
32	33	31·58	+ 0·014	+ 0·062	− 31·126	+ 0·008	− 31·118
33	34	32·85	− 0·004	+ 0·058	− 42·052	+ 0·010	− 42·042
34	35	34·11	+ 0·010	+ 0·068	− 56·022	+ 0·012	− 56·010
35	36	35·03	+ 0·002	+ 0·070	− 44·505	+ 0·010	− 44·495
36	37	36·21	− 0·012	+ 0·058	− 64·558	+ 0·013	− 64·545
37	38	37·66	− 0·016	+ 0·042	− 66·333	+ 0·013	− 66·320
38	39	38·79	+ 0·011	+ 0·053	− 73·023	+ 0·014	− 73·009
39	40	39·73	+ 0·012	+ 0·065	− 71·331	+ 0·014	− 71·317
40	41	39·75	+ 0·001	+ 0·066	− 71·293	+ 0·014	− 71·279
41	42	40·11	+ 0·001	+ 0·067	− 68·829	+ 0·014	− 68·815
42	43	40·91	+ 0·002	+ 0·069	− 64·382	+ 0·013	− 64·369
43	44	42·44	+ 0·003	+ 0·072	− 87·440	+ 0·017	− 87·423
44	45	43·65	+ 0·009	+ 0·081	− 84·297	+ 0·016	− 84·281
45	46	44·74	+ 0·005	+ 0·086	− 88·273	+ 0·017	− 88·256
46	47	46·11	− 0·001	+ 0·085	− 85·856	+ 0·017	− 85·839
47	48	46·65	+ 0·011	+ 0·096	− 79·692	+ 0·016	− 79·676
48	49	47·90	− 0·005	+ 0·091	− 93·171	+ 0·018	− 93·153
49	50	48·88	+ 0·015	+ 0·106	− 109·949	+ 0·020	− 109·929
50	51	48·90	0·000	+ 0·106	− 109·786	+ 0·020	− 109·766
51	52	50·37	− 0·001	+ 0·105	− 134·985	+ 0·024	− 134·961
52	53	52·11	− 0·007	+ 0·098	− 139·442	+ 0·025	− 139·417
53	54	52·54	+ 0·004	+ 0·102	− 139·403	+ 0·025	− 139·378
54	55	54·34	− 0·036	+ 0·066	− 122·952	+ 0·023	− 122·929
55	56	55·98	+ 0·012	+ 0·078	− 106·795	+ 0·021	− 106·774
56	57	57·16	− 0·017	+ 0·061	− 98·870	+ 0·020	− 98·850
57	58	58·26	− 0·008	+ 0·053	− 83·729	+ 0·018	− 83·711
58	59	58·74	− 0·011	+ 0·042	− 81·183	+ 0·018	− 81·165
59	60	58·75	0·000	+ 0·042	− 81·190	+ 0·018	− 81·172
60	61	59·57	+ 0·014	+ 0·056	− 82·671	+ 0·018	− 82·653

* Bench-mark No. 1 is the mark at Raipur described on page 135.

Line No. 38. Raipur to Bilaspur.—(Continued).

Bench-marks		Distance from Raipur	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Raipur (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Raipur
From	To		From mark to mark (= d)	Total from Raipur		Total from Raipur	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	60·87	+ 0·010	+ 0·066	– 64·983	+ 0·016	– 64·967
62	63	64·21	+ 0·023	+ 0·089	– 73·020	+ 0·017	– 73·003
63	64	65·15	– 0·022	+ 0·067	– 78·555	+ 0·018	– 78·537
64	65	66·14	+ 0·021	+ 0·088	– 78·036	+ 0·018	– 78·018
65	66	66·49	+ 0·001	+ 0·089	– 78·719	+ 0·018	– 78·701
66	67	67·44	+ 0·009	+ 0·098	– 77·978	+ 0·018	– 77·960
67	68	68·87	– 0·021	+ 0·077	– 75·160	+ 0·018	– 75·142
68	69*	68·89	+ 0·001	+ 0·078	– 75·326	+ 0·018	– 75·308

Difference of dynamic height, Raipur to Bilaspur = – 75·308 feet.

Length of line in miles = M = 68·89. $\Sigma d^2 = 0{\cdot}008816$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\dfrac{\Sigma d^2}{4M}} = \pm\, 0{\cdot}0038$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\dfrac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0317$.

* Bench-mark No. 69 is the mark at Bilaspur described on page 133.

Line No. 39. Cuttack to Vizianagram.

Bench-marks		Distance from Cuttack	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Cuttack (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Cuttack
From	To		From mark to mark (= d)	Total from Cuttack		Total from Cuttack	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·88	+ 0·008	+ 0·008	+ 9·542	– 0·002	+ 9·540
2	3	1·66	– 0·007	+ 0·001	+ 7·180	– 0·002	+ 7·178
3	4	2·64	+ 0·003	+ 0·004	+ 13·474	– 0·003	+ 13·471
4	5	3·49	+ 0·004	+ 0·008	+ 12·011	– 0·003	+ 12·008
5	6	4·25	– 0·009	– 0·001	+ 10·261	– 0·003	+ 10·258
6	7	4·65	+ 0·004	+ 0·003	+ 7·932	– 0·003	+ 7·929
7	8	4·99	– 0·007	– 0·004	+ 11·913	– 0·004	+ 11·909
8	9	6·00	– 0·005	– 0·009	+ 8·805	– 0·003	+ 8·802
9	10	7·28	+ 0·012	+ 0·003	+ 24·356	– 0·007	+ 24·349
10	11	8·04	+ 0·012	+ 0·015	+ 9·633	– 0·004	+ 9·629
11	12	9·31	– 0·006	+ 0·009	+ 72·452	– 0·019	+ 72·433
12	13	9·82	+ 0·005	+ 0·014	+ 90·730	– 0·023	+ 90·707
13	14	11·09	+ 0·003	+ 0·017	+ 76·646	– 0·020	+ 76·626
14	15	11·18	0·000	+ 0·017	+ 65·698	– 0·017	+ 65·681
15	16	12·13	– 0·016	+ 0·001	+ 47·963	– 0·013	+ 47·950
16	17	13·14	+ 0·003	+ 0·004	+ 82·171	– 0·021	+ 82·150
17	18	14·15	+ 0·004	+ 0·008	+ 69·691	– 0·018	+ 69·673
18	19	14·43	– 0·004	+ 0·004	+ 69·547	– 0·018	+ 69·529
19	20	15·17	– 0·011	– 0·007	+ 105·037	– 0·027	+ 105·010
20	21	16·18	– 0·002	– 0·009	+ 102·416	– 0·026	+ 102·390
21	22	17·19	– 0·003	– 0·012	+ 108·691	– 0·027	+ 108·664
22	23	18·20	+ 0·011	– 0·001	+ 117·398	– 0·029	+ 117·369
23	24	19·22	– 0·013	– 0·014	+ 101·556	– 0·025	+ 101·531
24	25	20·23	– 0·008	– 0·022	+ 77·259	– 0·019	+ 77·240
25	26	20·74	+ 0·004	– 0·018	+ 67·821	– 0·017	+ 67·804
26	27	21·25	+ 0·005	– 0·013	+ 86·998	– 0·022	+ 86·976
27	28	22·26	– 0·010	– 0·023	+ 51·715	– 0·014	+ 51·701
28	29	23·27	+ 0·007	– 0·016	+ 61·653	– 0·016	+ 61·637
29	30	24·28	– 0·021	– 0·037	+ 73·798	– 0·019	+ 73·779
30	31	24·55	– 0·002	– 0·039	+ 83·919	– 0·022	+ 83·897
31	32	25·30	+ 0·015	– 0·024	+ 34·124	– 0·009	+ 34·115
32	33	26·31	+ 0·011	– 0·013	+ 24·018	– 0·006	+ 24·012
33	34	27·05	– 0·001	– 0·014	+ 33·447	– 0·008	+ 33·439
34	35	27·31	– 0·001	– 0·015	+ 41·352	– 0·010	+ 41·342
35	36	27·34	– 0·002	– 0·017	+ 42·994	– 0·010	+ 42·984
36	37	28·30	+ 0·019	+ 0·002	+ 64·030	– 0·015	+ 64·015
37	38	28·41	+ 0·004	+ 0·006	+ 72·519	– 0·017	+ 72·502
38	39	29·41	+ 0·001	+ 0·007	+ 105·430	– 0·025	+ 105·405
39	40	30·41	+ 0·010	+ 0·017	+ 98·005	– 0·023	+ 97·982
40	41	31·41	+ 0·009	+ 0·026	+ 72·194	– 0·016	+ 72·178
41	42	32·41	– 0·007	+ 0·019	+ 57·105	– 0·012	+ 57·093
42	43	33·41	+ 0·003	+ 0·022	+ 123·505	– 0·029	+ 123·476
43	44	34·41	– 0·009	+ 0·013	+ 137·592	– 0·033	+ 137·559
44	45	35·41	– 0·012	+ 0·001	+ 57·504	– 0·013	+ 57·491
45	46	36·41	+ 0·010	+ 0·011	+ 24·786	– 0·005	+ 24·781
46	47	37·41	+ 0·013	+ 0·024	+ 3·159	0·000	+ 3·159
47	48	38·41	– 0·003	+ 0·021	+ 9·039	– 0·002	+ 9·037
48	49	39·41	– 0·002	+ 0·019	+ 43·773	– 0·011	+ 43·762
49	50	40·41	– 0·012	+ 0·007	– 1·993	+ 0·001	– 1·992
50	51	41·41	– 0·003	+ 0·004	– 27·791	+ 0·008	– 27·783
51	52	42·41	+ 0·002	+ 0·006	+ 3·486	0·000	+ 3·486
52	53	43·41	– 0·010	– 0·004	+ 25·358	– 0·006	+ 25·352
53	54	44·41	+ 0·017	+ 0·013	+ 22·819	– 0·005	+ 22·814
54	55	45·41	+ 0·005	+ 0·018	+ 59·529	– 0·015	+ 59·514
55	56	46·41	– 0·002	+ 0·016	+ 79·745	– 0·020	+ 79·725
56	57	47·41	– 0·004	+ 0·012	+ 57·846	– 0·014	+ 57·832
57	58	48·41	– 0·001	+ 0·011	+ 35·395	– 0·008	+ 35·387
58	59	49·41	– 0·001	+ 0·010	+ 3·774	0·000	+ 3·774
59	60	50·41	+ 0·008	+ 0·018	– 7·735	+ 0·003	– 7·732
60	61	51·41	– 0·012	+ 0·006	– 11·389	+ 0·004	– 11·385

* Bench-mark No. 1 is the mark at Cuttack described on page 133.

Line No. 39. Cuttack to Vizianagram.—(Continued).

Bench-marks		Distance from Cuttack	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Cuttack (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Cuttack
From	To		From mark to mark (= d)	Total from Cuttack		Total from Cuttack	
		miles	foot	foot	feet	foot	feet
61	62	52·00	+ 0·003	+ 0·009	+ 15·412	– 0·003	+ 15·409
62	63	52·44	+ 0·006	+ 0·015	– 11·214	+ 0·004	– 11·210
63	64	53·44	+ 0·002	+ 0·017	– 28·471	0·000	– 28·471
64	65	54·44	+ 0·002	+ 0·019	– 22·351	– 0·002	– 22·353
65	66	55·44	+ 0·007	+ 0·026	– 14·252	– 0·004	– 14·256
66	67	56·44	– 0·001	+ 0·025	+ 1·888	– 0·008	+ 1·880
67	68	57·44	– 0·015	+ 0·010	+ 11·675	– 0·011	+ 11·664
68	69	58·44	– 0·009	+ 0·001	– 15·082	– 0·004	– 15·086
69	70	59·44	– 0·017	– 0·016	+ 7·693	– 0·010	+ 7·683
70	71	60·44	+ 0·005	– 0·011	+ 39·754	– 0·019	+ 39·735
71	72	61·44	+ 0·002	– 0·009	– 10·815	– 0·005	– 10·820
72	73	62·45	– 0·008	– 0·017	– 28·915	0·000	– 28·915
73	74	63·45	– 0·002	– 0·019	– 48·825	+ 0·005	– 48·820
74	75	64·45	– 0·007	– 0·026	– 43·104	+ 0·003	– 43·101
75	76	65·20	0·000	– 0·026	– 34·562	+ 0·001	– 34·561
76	77	65·44	+ 0·004	– 0·022	– 28·874	– 0·001	– 28·875
77	78	66·44	– 0·017	– 0·039	– 49·107	+ 0·004	– 49·103
78	79	67·44	– 0·008	– 0·047	– 63·526	+ 0·008	– 63·518
79	80	68·44	+ 0·006	– 0·041	– 59·255	+ 0·007	– 59·248
80	81	69·44	+ 0·007	– 0·034	– 60·933	+ 0·008	– 60·925
81	82	70·44	+ 0·011	– 0·023	– 64·830	+ 0·009	– 64·821
82	83	71·44	– 0·002	– 0·025	– 59·528	+ 0·008	– 59·520
83	84	72·44	– 0·007	– 0·032	– 48·800	+ 0·005	– 48·795
84	85	73·54	+ 0·001	– 0·031	– 55·973	+ 0·007	– 55·966
85	86	74·95	+ 0·007	– 0·024	+ 0·194	– 0·008	+ 0·186
86	87	75·45	– 0·005	– 0·029	+ 14·865	– 0·012	+ 14·853
87	88	75·84	– 0·004	– 0·033	+ 18·410	– 0·013	+ 18·397
88	89	76·93	– 0·009	– 0·042	– 49·917	+ 0·006	– 49·911
89	90	77·88	+ 0·010	– 0·032	– 62·473	+ 0·010	– 62·463
90	91	78·88	+ 0·008	– 0·024	– 37·733	+ 0·003	– 37·730
91	92	79·88	+ 0·007	– 0·017	+ 2·086	– 0·008	+ 2·078
92	93	80·88	+ 0·047	+ 0·030	+ 4·592	– 0·009	+ 4·583
93	94	82·03	– 0·011	+ 0·019	– 45·736	+ 0·005	– 45·731
94	95	83·51	– 0·008	+ 0·011	– 22·665	– 0·001	– 22·666
95	96	84·39	– 0·009	+ 0·002	+ 105·434	– 0·037	+ 105·397
96	97	85·14	– 0·012	– 0·010	+ 41·433	– 0·019	+ 41·414
97	98	87·94	+ 0·023	+ 0·013	– 9·759	– 0·005	– 9·764
98	99	88·55	+ 0·008	+ 0·021	– 41·472	+ 0·004	– 41·468
99	100	88·84	0·000	+ 0·021	– 58·964	+ 0·009	– 58·955
100	101	90·86	+ 0·006	+ 0·027	– 20·152	– 0·002	– 20·154
101	102	91·86	0·000	+ 0·027	+ 9·136	– 0·010	+ 9·126
102	103	92·86	– 0·006	+ 0·021	– 13·660	– 0·003	– 13·663
103	104	93·90	– 0·001	+ 0·020	– 11·920	– 0·004	– 11·924
104	105	94·87	– 0·002	+ 0·018	– 29·586	+ 0·001	– 29·585
105	106	95·87	– 0·005	+ 0·013	– 51·882	+ 0·007	– 51·875
106	107	96·30	– 0·004	+ 0·009	– 52·792	+ 0·007	– 52·785
107	108	98·88	+ 0·013	+ 0·022	– 60·632	+ 0·009	– 60·623
108	109	99·04	– 0·002	+ 0·020	– 63·879	+ 0·010	– 63·869
109	110	100·09	+ 0·007	+ 0·027	– 60·807	+ 0·009	– 60·798
110	111	102·48	+ 0·013	+ 0·040	– 60·564	+ 0·009	– 60·555
111	112	103·48	+ 0·013	+ 0·053	– 55·169	+ 0·007	– 55·162
112	113	104·48	+ 0·001	+ 0·054	– 23·942	– 0·002	– 23·944
113	114	105·49	+ 0·005	+ 0·059	+ 14·900	– 0·013	+ 14·887
114	115	105·86	– 0·001	+ 0·058	+ 19·533	– 0·014	+ 19·519
115	116	106·50	0·000	+ 0·058	+ 32·612	– 0·018	+ 32·594
116	117	107·51	+ 0·018	+ 0·076	+ 7·656	– 0·010	+ 7·646
117	118	108·51	– 0·019	+ 0·057	+ 93·318	– 0·036	+ 93·282
118	119	109·52	+ 0·006	+ 0·063	+ 58·745	– 0·026	+ 58·719
119	120	110·53	– 0·010	+ 0·053	– 9·819	– 0·006	– 9·825
120	121	111·53	– 0·013	+ 0·040	– 33·725	+ 0·001	– 33·724

Line No. 39. Cuttack to Vizianagram.—(Continued).

Bench-marks From	Bench-marks To	Distance from Cuttack	Discrepancy between levellers (First – Second leveller): From mark to mark (= *d*)	Discrepancy between levellers (First – Second leveller): Total from Cuttack	Observed elevation above (+) or below (–) Cuttack (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Cuttack	Dynamic height above (+) or below (–) Cuttack
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
121	122	112·53	– 0·003	+ 0·037	– 14·633	– 0·005	– 14·638
122	123	113·01	+ 0·012	+ 0·049	+ 21·950	– 0·016	+ 21·934
123	124	113·56	– 0·006	+ 0·043	+ 20·468	– 0·015	+ 20·453
124	125	114·25	– 0·007	+ 0·036	– 6·098	– 0·007	– 6·105
125	126	115·73	– 0·002	+ 0·034	– 39·151	+ 0·003	– 39·148
126	127	116·94	+ 0·018	+ 0·052	– 13·096	– 0·005	– 13·101
127	128	118·05	– 0·012	+ 0·040	+ 4·544	– 0·010	+ 4·534
128	129	118·23	– 0·001	+ 0·039	– 1·090	– 0·008	– 1·098
129	130	119·08	– 0·003	+ 0·036	– 9·510	– 0·006	– 9·516
130	131	119·19	+ 0·004	+ 0·040	– 9·402	– 0·006	– 9·408
131	132	119·20	0·000	+ 0·040	– 13·489	– 0·005	– 13·494
132	133	120·08	– 0·005	+ 0·035	– 24·990	– 0·001	– 24·991
133	134	120·77	– 0·003	+ 0·032	– 19·153	– 0·003	– 19·156
134	135	123·09	+ 0·019	+ 0·051	+ 13·095	– 0·013	+ 13·082
135	136	124·32	– 0·006	+ 0·045	– 9·993	– 0·006	– 9·999
136	137	125·37	+ 0·008	+ 0·053	+ 5·415	– 0·011	+ 5·404
137	138	126·24	+ 0·003	+ 0·056	+ 7·965	– 0·012	+ 7·953
138	139	127·69	– 0·004	+ 0·052	+ 11·309	– 0·013	+ 11·296
139	140	127·89	+ 0·002	+ 0·054	+ 0·160	– 0·010	+ 0·150
140	141	128·72	+ 0·002	+ 0·056	– 26·027	– 0·002	– 26·029
141	142	130·05	0·000	+ 0·056	– 41·840	+ 0·003	– 41·837
142	143	130·39	+ 0·005	+ 0·061	– 53·254	+ 0·006	– 53·248
143	144	130·56	– 0·008	+ 0·053	– 49·179	+ 0·005	– 49·174
144	145	131·44	– 0·006	+ 0·047	– 34·575	0·000	– 34·575
145	146	133·40	+ 0·010	+ 0·057	– 41·654	+ 0·002	– 41·652
146	147	134·36	– 0·006	+ 0·051	– 14·250	– 0·006	– 14·256
147	148	135·21	– 0·007	+ 0·044	– 34·239	0·000	– 34·239
148	149	136·15	– 0·017	+ 0·027	– 42·195	+ 0·002	– 42·193
149	150	137·10	+ 0·002	+ 0·029	– 42·147	+ 0·002	– 42·145
150	151	138·05	+ 0·005	+ 0·034	– 41·688	+ 0·002	– 41·686
151	152	138·53	– 0·009	+ 0·025	– 29·366	– 0·002	– 29·368
152	153	140·31	+ 0·024	+ 0·049	+ 6·238	– 0·013	+ 6·225
153	154	141·21	+ 0·007	+ 0·056	+ 21·480	– 0·018	+ 21·462
154	155	142·18	+ 0·005	+ 0·061	+ 29·209	– 0·020	+ 29·189
155	156	143·60	– 0·023	+ 0·038	+ 42·735	– 0·024	+ 42·711
156	157	144·22	+ 0·003	+ 0·041	+ 49·967	– 0·026	+ 49·941
157	158	144·78	+ 0·013	+ 0·054	+ 59·993	– 0·029	+ 59·964
158	159	145·40	+ 0·012	+ 0·066	+ 69·976	– 0·032	+ 69·944
159	160	145·55	0·000	+ 0·066	+ 70·412	– 0·032	+ 70·380
160	161	146·64	+ 0·016	+ 0·082	+ 39·210	– 0·022	+ 39·188
161	162	148·25	+ 0·005	+ 0·087	– 7·629	– 0·007	– 7·636
162	163	149·50	– 0·014	+ 0·073	– 39·718	+ 0·003	– 39·715
163	164	150·65	– 0·027	+ 0·046	– 45·893	+ 0·005	– 45·888
164	165	151·50	– 0·016	+ 0·030	– 37·005	+ 0·002	– 37·003
165	166	152·46	0·000	+ 0·030	– 34·804	+ 0·001	– 34·803
166	167	153·30	+ 0·005	+ 0·035	– 30·518	0·000	– 30·518
167	168	154·31	+ 0·006	+ 0·041	– 28·671	– 0·001	– 28·672
168	169	155·42	+ 0·006	+ 0·047	– 11·641	– 0·006	– 11·647
169	170	156·48	+ 0·002	+ 0·049	+ 22·032	– 0·017	+ 22·015
170	171	157·16	+ 0·004	+ 0·053	+ 27·442	– 0·019	+ 27·423
171	172	157·45	– 0·002	+ 0·051	+ 26·110	– 0·019	+ 26·091
172	173	158·51	– 0·005	+ 0·046	+ 61·457	– 0·031	+ 61·426
173	174	159·19	– 0·002	+ 0·044	+ 78·530	– 0·037	+ 78·493
174	175	160·25	+ 0·004	+ 0·048	+ 95·742	– 0·043	+ 95·699
175	176	161·31	+ 0·007	+ 0·055	+ 113·996	– 0·049	+ 113·947
176	177	162·19	+ 0·004	+ 0·059	+ 98·383	– 0·044	+ 98·339
177	178	163·47	– 0·003	+ 0·056	+ 54·688	– 0·030	+ 54·658
178	179	164·82	0·000	+ 0·056	+ 14·833	– 0·017	+ 14·816
179	180	165·19	0·000	+ 0·056	+ 6·023	– 0·014	+ 6·009
180	181	166·50	– 0·012	+ 0·044	– 26·551	– 0·003	– 26·554

Line No. 39. Cuttack to Vizianagram.—(Continued).

Bench-marks		Distance from Cuttack	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (−) Cuttack (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Cuttack
From	To		From mark to mark (= d)	Total from Cuttack		Total from Cuttack	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
181	182	167·09	0·000	+ 0·044	− 31·470	− 0·001	− 31·471
182	183	168·41	+ 0·003	+ 0·047	− 41·220	+ 0·002	− 41·218
183	184	168·89	+ 0·005	+ 0·052	− 45·161	+ 0·003	− 45·158
184	185	169·21	− 0·007	+ 0·045	− 32·209	− 0·001	− 32·210
185	186	170·42	+ 0·003	+ 0·048	− 12·588	− 0·008	− 12·596
186	187	171·43	− 0·001	+ 0·047	− 3·728	− 0·011	− 3·739
187	188	172·21	− 0·009	+ 0·038	+ 16·272	− 0·018	+ 16·254
188	189	172·87	0·000	+ 0·038	+ 34·269	− 0·024	+ 34·245
189	190	174·42	− 0·016	+ 0·022	− 10·550	− 0·009	− 10·559
190	191	174·86	− 0·011	+ 0·011	− 15·122	− 0·008	− 15·130
191	192	176·05	0·000	+ 0·011	− 33·163	− 0·002	− 33·165
192	193	176·91	− 0·001	+ 0·010	− 40·321	0·000	− 40·321
193	194	178·05	− 0·002	+ 0·008	− 47·273	+ 0·002	− 47·271
194	195	179·30	+ 0·020	+ 0·028	− 54·365	+ 0·004	− 54·361
195	196	180·28	+ 0·015	+ 0·043	− 53·896	+ 0·004	− 53·892
196	197	181·23	+ 0·017	+ 0·060	− 47·644	+ 0·002	− 47·642
197	198	182·41	− 0·009	+ 0·051	− 62·225	+ 0·007	− 62·218
198	199	182·90	− 0·004	+ 0·047	− 62·033	+ 0·007	− 62·026
199	200	184·14	− 0·005	+ 0·042	− 60·867	+ 0·007	− 60·860
200	201	185·41	+ 0·001	+ 0·043	− 56·876	+ 0·006	− 56·870
201	202	186·17	+ 0·007	+ 0·050	− 55·406	+ 0·005	− 55·401
202	203	187·62	+ 0·017	+ 0·067	− 33·891	− 0·002	− 33·893
203	204	189·03	− 0·002	+ 0·065	− 48·136	+ 0·003	− 48·133
204	105	189·74	+ 0·009	+ 0·074	− 44·740	+ 0·002	− 44·738
205	206	190·75	− 0·001	+ 0·073	− 29·224	− 0·003	− 29·227
206	207	191·21	− 0·007	+ 0·066	− 13·256	− 0·008	− 13·264
207	208	193·00	− 0·003	+ 0·063	− 6·086	− 0·010	− 6·096
208	209	193·66	+ 0·008	+ 0·071	+ 4·952	− 0·014	+ 4·938
209	210	194·65	+ 0·013	+ 0·084	+ 8·303	− 0·015	+ 8·288
210	211	195·36	− 0·006	+ 0·078	+ 17·222	− 0·018	+ 17·204
211	212	197·34	− 0·003	+ 0·075	+ 58·275	− 0·032	+ 58·243
212	213	197·79	0·000	+ 0·075	+ 71·370	− 0·036	+ 71·334
213	214	198·24	+ 0·005	+ 0·080	+ 79·723	− 0·039	+ 79·684
214	215	198·67	− 0·018	+ 0·062	+ 67·404	− 0·035	+ 67·369
215	216	198·78	0.000	+ 0·062	+ 63·038	− 0·034	+ 63·004
216	217	199·83	− 0·019	+ 0·043	+ 27·955	− 0·022	+ 27·933
217	218	201·13	+ 0·006	+ 0·049	+ 5·360	− 0·014	+ 5·346
218	219	202·42	− 0·019	+ 0·030	− 13·252	− 0·007	− 13·259
219	220	203·90	+ 0·008	+ 0·038	− 17·422	− 0·006	− 17·428
220	221	204·70	+ 0·004	+ 0·042	− 20·362	− 0·005	− 20·367
221	222	205·65	− 0·012	+ 0·030	− 19·606	− 0·005	− 19·611
222	223	206·55	− 0·010	+ 0·020	− 15·877	− 0·006	− 15·883
223	224	207·36	+ 0·004	+ 0·024	− 8·996	− 0·008	− 9·004
224	225	207·65	+ 0·007	+ 0·031	− 8·933	− 0·008	− 8·941
225	226	208·69	− 0·016	+ 0·015	+ 1·474	− 0·012	+ 1·462
226	227	210·31	+ 0·004	+ 0·019	+ 27·133	− 0·021	+ 27·112
227	228	210·42	− 0·003	+ 0·016	+ 27·146	− 0·021	+ 27·125
228	229	210·59	+ 0·005	+ 0·021	+ 25·101	− 0·020	+ 25·081
229	230	210·99	− 0·002	+ 0·019	+ 23·882	− 0·020	+ 23·862
230	231	211·40	− 0·004	+ 0·015	+ 20·678	− 0·019	+ 20·659
231	232	212·82	− 0·011	+ 0·004	− 12·884	− 0·007	− 12·891
232	233	213·89	− 0·006	− 0·002	− 9·296	− 0·008	− 9·304
233	234	214·35	+ 0·004	+ 0·002	− 4·281	− 0·010	− 4·291
234	235	214·55	+ 0·005	+ 0·007	− 5·920	− 0·009	− 5·929
235	236	214·76	0·000	+ 0·007	− 5·675	− 0·009	− 5·684
236	237	215·31	+ 0·004	+ 0·011	− 9·878	− 0·008	− 9·886
237	238	215·94	+ 0·007	+ 0·018	− 5·342	− 0·010	− 5·352
238	239	216·74	+ 0·010	+ 0·028	− 3·647	− 0·011	− 3·658
239	240	218·81	+ 0·007	+ 0·035	+ 26·748	− 0·022	+ 26·726
240	241	219·31	+ 0·006	+ 0·041	+ 39·971	− 0·027	+ 39·944

Line No. 39. Cuttack to Vizianagram.—(Continued).

Bench-marks		Distance from Cuttack	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Cuttack (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Cuttack
From	To		From mark to mark (=d)	Total from Cuttack		Total from Cuttack	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
241	242	219·77	+ 0·005	+ 0·046	+ 44·013	− 0·028	+ 43·985
242	243	219·88	+ 0·004	+ 0·050	+ 47·371	− 0·029	+ 47·342
243	244	219·91	+ 0·001	+ 0·051	+ 44·037	− 0·028	+ 44·009
244	245	220·49	+ 0·007	+ 0·058	+ 35·473	− 0·025	+ 35·448
245	246	221·34	− 0·007	+ 0·051	+ 42·210	− 0·027	+ 42·183
246	247	221·99	+ 0·004	+ 0·055	+ 54·350	− 0·031	+ 54·319
247	248	223·54	− 0·013	+ 0·042	+ 63·017	− 0·034	+ 62·983
248	249	224·03	− 0·003	+ 0·039	+ 79·364	− 0·040	+ 79·324
249	250	225·66	+ 0·011	+ 0·050	+ 129·037	− 0·057	+ 128·980
250	251	226·07	+ 0·003	+ 0·053	+ 136·842	− 0·060	+ 136·782
251	252	226·48	+ 0·006	+ 0·059	+ 138·228	− 0·060	+ 138·168
252	253	227·08	+ 0·007	+ 0·066	+ 144·951	− 0·062	+ 144·889
253	254	228·36	+ 0·024	+ 0·090	+ 183·084	− 0·075	+ 183·009
254	255	229·06	+ 0·009	+ 0·099	+ 194·632	− 0·079	+ 194·553
255	256	229·90	+ 0·002	+ 0·101	+ 211·503	− 0·085	+ 211·418
256	257	231·78	+ 0·011	+ 0·112	+ 245·279	− 0·097	+ 245·182
257	258	232·41	− 0·003	+ 0·109	+ 250·748	− 0·099	+ 250·649
258	259	234·08	− 0·018	+ 0·091	+ 246·605	− 0·098	+ 246·507
259	260	234·34	− 0·007	+ 0·084	+ 250·199	− 0·099	+ 250·100
260	261	235·35	+ 0·001	+ 0·085	+ 236·915	− 0·094	+ 236·821
261	262	236·50	− 0·010	+ 0·075	+ 242·904	− 0·096	+ 242·808
262	263	236·81	+ 0·010	+ 0·085	+ 237·887	− 0·094	+ 237·793
263	264	237·30	− 0·006	+ 0·079	+ 237·007	− 0·094	+ 236·913
264	365	238·13	+ 0·002	+ 0·081	+ 212·798	− 0·085	− 212·713
265	266	239·86	− 0·011	+ 0·070	+ 163·748	− 0·067	+ 163·681
266	267	240·68	+ 0·001	+ 0·071	+ 141·990	− 0·059	+ 141·931
267	268	241·18	+ 0·006	+ 0·077	+ 139·845	− 0·058	+ 139·787
268	269	241·24	+ 0·002	+ 0·079	+ 139·840	− 0·058	+ 139·782
269	270	241·30	− 0·003	+ 0·076	+ 139·848	− 0·058	+ 139·790
270	271	242·34	− 0·012	+ 0·064	+ 112·662	− 0·048	+ 112·614
271	272	243·88	− 0·016	+ 0·048	+ 72·714	− 0·034	+ 72·680
272	273	244·87	+ 0·009	+ 0·057	+ 48·500	− 0·025	+ 48·475
273	274	245·21	− 0·010	+ 0·047	+ 49·153	− 0·025	+ 49·128
274	275	245·82	− 0·008	+ 0·039	+ 51·292	− 0·026	+ 51·266
275	276	245·97	+ 0·004	+ 0·043	+ 52·148	− 0·026	+ 52·122
276	277	246·43	0·000	+ 0·043	+ 49·119	− 0·025	+ 49·094
277	278	246·81	− 0·007	+ 0·036	+ 44·642	− 0·023	+ 44·619
278	279	247·19	+ 0·001	+ 0·037	+ 43·460	− 0·023	+ 43·437
279	280	248·00	+ 0·018	+ 0·055	+ 43·853	− 0·023	+ 43·830
280	281	248·84	− 0·011	+ 0·044	+ 55·621	− 0·027	+ 53·594
281	282	249·64	+ 0·002	+ 0·046	+ 66·615	− 0·032	+ 66·583
282	283	251·05	− 0·005	+ 0·041	+ 103·833	− 0·045	+ 103·788
283	284	251·45	+ 0·005	+ 0·046	+ 118·568	− 0·050	+ 118·518
284	285	252·80	0·000	+ 0·046	+ 121·227	− 0·051	+ 121·176
285	286	252·89	+ 0·001	+ 0·047	+ 119·838	− 0·051	+ 119·787
286	287	253·22	+ 0·006	+ 0·053	+ 122·278	− 0·052	+ 122·226
287	288*	253·46	− 0·005	+ 0·048	+ 116·861	− 0·050	+ 116·811

Difference of dynamic height, Cuttack to Vizianagram = + 116·811 feet.

Length of line in miles = M = 253·46. $\Sigma d^2 = 0\cdot024468$.

Probable error of the mean result per mile of double-levelling $= 0\cdot6745\sqrt{\dfrac{\Sigma d^2}{4M}} = \pm\ 0\cdot0033$.

Probable error of the difference of elevation between the terminal bench-marks $= 0\cdot6745\sqrt{\dfrac{\Sigma d^2}{4}} = \pm\ 0\cdot0528$.

* Bench-mark No. 288 is the mark at Vizianagram described on page 136.

Line No. 40. Bilaspur to Cuttack.

Bench-marks		Distance from Bilaspur	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Bilaspur (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Bilaspur
From	To		From mark to mark (= *d*)	Total from Bilaspur		Total from Bilaspur	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·86	+ 0·009	+ 0·009	– 4·794	+ 0·001	– 4·793
2	3	1·96	– 0·018	– 0·009	– 25·991	+ 0·004	– 25·987
3	4	2·25	– 0·004	– 0·013	– 26·512	+ 0·004	– 26·508
4	5	3·41	+ 0·002	– 0·011	– 25·137	+ 0·004	– 25·133
5	6	4·24	+ 0·005	– 0·006	– 20·109	+ 0·003	– 20·106
6	7	4·74	+ 0·007	+ 0·001	– 15·744	+ 0·002	– 15·742
7	8	5·62	– 0·004	– 0·003	+ 22·356	– 0·003	+ 22·353
8	9	7·28	– 0·004	– 0·007	+ 7·116	– 0·001	+ 7·115
9	10	8·81	+ 0·006	– 0·001	– 10·314	+ 0·001	– 10·313
10	11	9·29	+ 0·004	+ 0·003	– 9·888	+ 0·001	– 9·887
11	12	9·31	0·000	+ 0·003	– 9·696	+ 0·001	– 9·695
12	13	11·51	– 0·011	– 0·008	– 54·618	+ 0·007	– 54·611
13	14	12·99	– 0·006	– 0·014	– 27·974	+ 0·003	– 27·971
14	15	14·73	+ 0·005	– 0·009	+ 0·015	– 0·001	+ 0·014
15	16	15·63	+ 0·001	– 0·008	+ 3·998	– 0·002	+ 3·996
16	17	16·64	– 0·008	– 0·016	+ 17·100	– 0·004	+ 17·096
17	18	17·48	+ 0·016	0·000	+ 37·020	– 0·007	+ 37·013
18	19	17·49	0·000	0·000	+ 37·132	– 0·007	+ 37·125
19	20	18·39	– 0·025	– 0·025	+ 11·656	– 0·004	+ 11·652
20	21	18·85	– 0·004	– 0·029	+ 6·328	– 0·003	+ 6·325
21	22	19·64	0·000	– 0·029	+ 0·782	– 0·002	+ 0·780
22	23	20·59	+ 0·002	– 0·027	– 9·028	– 0·001	– 9·029
23	24	22·45	– 0·012	– 0·039	– 24·420	+ 0·001	– 24·419
24	25	23·80	+ 0·008	– 0·031	– 8·666	– 0·001	– 8·667
25	26	24·90	+ 0·004	– 0·027	– 0·492	– 0·001	– 6·493
26	27	25·91	+ 0·009	– 0·018	– 1·884	– 0·002	– 1·886
27	28	26·42	– 0·002	– 0·020	+ 2·311	– 0·003	+ 2·308
28	29	26·78	+ 0·003	– 0·017	+ 4·049	– 0·003	+ 4·046
29	30	28·21	– 0·014	– 0·031	+ 2·230	– 0·003	+ 2·227
30	31	31·37	– 0·037	– 0·068	– 56·485	+ 0·005	– 56·480
31	32	31·68	– 0·005	– 0·073	– 64·018	+ 0·006	– 64·012
32	33	31·91	+ 0·009	– 0·064	– 64·014	+ 0·006	– 64·008
33	34	33·47	+ 0·024	– 0·040	– 30·470	+ 0·002	– 30·468
34	35	34·53	– 0·008	– 0·048	– 39·683	+ 0·003	– 39·680
35	36	35·81	– 0·013	– 0·061	– 43·671	+ 0·004	– 43·667
36	37	36·69	+ 0·003	– 0·058	– 41·091	+ 0·004	– 41·087
37	38	38·62	+ 0·004	– 0·054	– 47·949	+ 0·005	– 47·944
38	39	40·28	+ 0·012	– 0·042	– 63·095	+ 0·007	– 63·088
39	40	41·83	+ 0·016	– 0·026	– 59·082	+ 0·006	– 59·076
40	41	43·12	+ 0·029	+ 0·003	– 43·288	+ 0·004	– 43·284
41	42	43·13	– 0·001	+ 0·002	– 42·882	+ 0·004	– 42·878
42	43	45·15	– 0·001	+ 0·001	– 66·098	+ 0·007	– 66·091
43	44	46·69	– 0·019	– 0·018	– 87·893	+ 0·010	– 87·883
44	45	48·14	– 0·005	– 0·023	– 104·757	+ 0·012	– 104·745
45	46	49·19	– 0·007	– 0·030	– 114·918	+ 0·013	– 114·905
46	47	49·59	– 0·002	– 0·032	– 117·165	+ 0·013	– 117·152
47	48	51·72	+ 0·003	– 0·029	– 120·847	+ 0·014	– 120·833
48	49	52·32	+ 0·011	– 0·018	– 116·128	+ 0·013	– 116·115
49	50	52·35	– 0·005	– 0·023	– 116·829	+ 0·013	– 116·816
50	51	53·13	– 0·009	– 0·032	– 110·811	+ 0·012	– 110·799
51	52	53·69	– 0·009	– 0·041	– 105·027	+ 0·011	– 105·016
52	53	55·64	+ 0·009	– 0·032	– 101·573	+ 0·010	– 101·563
53	54	57·59	– 0·035	– 0·067	– 103·036	+ 0·010	– 103·026
54	55	59·64	+ 0·020	– 0·047	– 71·959	+ 0·006	– 71·953
55	56	60·82	+ 0·017	– 0·030	– 60·024	+ 0·004	– 60·020
56	57	62·08	– 0·005	– 0·035	– 38·268	+ 0·001	– 38·267
57	58	63·86	– 0·027	– 0·062	– 84·821	+ 0·007	– 84·814
58	59	64·85	– 0·011	– 0·073	– 79·629	+ 0·006	– 79·623
59	60	65·24	+ 0·004	– 0·069	– 93·249	+ 0·008	– 93·241
60	61	66·66	– 0·028	– 0·097	– 126·054	+ 0·012	– 126·042

* Bench-mark No. 1 is the mark at Bilaspur described on page 133.

Line No. 40. Bilaspur to Cuttack.—(Continued).

Bench-marks		Distance from Bilaspur	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Bilaspur (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Bilaspur
From	To		From mark to mark (= d)	Total from Bilaspur		Total from Bilaspur	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	68·02	+ 0·013	– 0·084	– 124·562	+ 0·012	– 124·550
62	63	68·22	– 0·005	– 0·089	– 124·464	+ 0·012	– 124·452
63	64	68·87	– 0·015	– 0·104	– 135·105	+ 0·013	– 135·092
64	65	69·13	– 0·002	– 0·106	– 136·096	+ 0·013	– 136·083
65	66	70·09	+ 0·013	– 0·093	– 124·065	+ 0·011	– 124·054
66	67	70·93	+ 0·003	– 0·090	– 99·625	+ 0·008	– 99·617
67	68	71·34	– 0·012	– 0·102	– 91·184	+ 0·007	– 91·177
68	69	71·92	– 0·017	– 0·119	– 98·925	+ 0·008	– 98·917
69	70	72·85	– 0·017	– 0·136	– 98·480	+ 0·008	– 98·472
70	71	73·85	– 0·014	– 0·150	– 104·195	+ 0·009	– 104·186
71	72	74·18	+ 0·002	– 0·148	– 104·448	+ 0·009	– 104·439
72	73	75·49	– 0·004	– 0·152	– 116·294	+ 0·011	– 116·283
73	74	75·87	+ 0·002	– 0·150	– 121·065	+ 0·012	– 121·053
74	75	76·70	– 0·003	– 0·153	– 128·470	+ 0·013	– 128·457
75	76	77·38	– 0·012	– 0·165	– 138·333	+ 0·014	– 138·319
76	77	78·09	+ 0·004	– 0·161	– 116·336	+ 0·011	– 116·325
77	78	78·85	+ 0·002	– 0·159	– 108·635	+ 0·010	– 108·625
78	79	79·36	– 0·002	– 0·161	– 107·284	+ 0·010	– 107·274
79	80	80·02	– 0·004	– 0·165	– 107·184	+ 0·010	– 107·174
80	81	81·28	– 0·012	– 0·177	– 131·015	+ 0·013	– 131·002
81	82	82·13	– 0·015	– 0·192	– 156·813	+ 0·017	– 156·796
82	83	82·54	+ 0·010	– 0·182	– 171·406	+ 0·019	– 171·387
83	84	83·03	+ 0·008	– 0·174	– 179·109	+ 0·020	– 179·089
84	85	83·69	+ 0·001	– 0·173	– 178·523	+ 0·020	– 178·503
85	86	84·92	+ 0·001	– 0·172	– 179·582	+ 0·020	– 179·562
86	87	85·81	– 0·012	– 0·184	– 163·025	+ 0·018	– 163·007
87	88	86·21	+ 0·004	– 0·180	– 153·411	+ 0·017	– 153·394
88	89	87·40	– 0·005	– 0·185	– 145·596	+ 0·016	– 145·580
89	90	88·19	+ 0·010	– 0·175	– 155·551	+ 0·017	– 155·534
90	91	89·39	– 0·012	– 0·187	– 143·250	+ 0·015	– 143·235
91	92	90·20	– 0·013	– 0·200	– 148·418	+ 0·016	– 148·402
92	93	91·16	+ 0·014	– 0·186	– 171·311	+ 0·019	– 171·292
93	94	91·82	– 0·003	– 0·189	– 171·216	+ 0·019	– 171·197
94	95	92·52	– 0·022	– 0·211	– 151·954	+ 0·016	– 151·938
95	96	93·61	– 0·009	– 0·220	– 137·651	+ 0·014	– 137·637
96	97	94·29	+ 0·011	– 0·209	– 131·102	+ 0·013	– 131·089
97	98	94·98	– 0·006	– 0·215	– 117·098	+ 0·011	– 117·087
98	99	95·84	+ 0·008	– 0·207	– 72·045	+ 0·005	– 72·040
99	100	96·64	– 0·014	– 0·221	– 31·559	– 0·001	– 31·560
100	101	99·73	– 0·056	– 0·277	– 27·695	– 0·002	– 27·697
101	102	100·52	+ 0·012	– 0·265	– 48·386	+ 0·001	– 48·385
102	103	102·65	– 0·023	– 0·288	– 36·814	– 0·001	– 36·815
103	104	104·23	0·000	– 0·288	+ 36·073	– 0·011	+ 36·062
104	105	105·89	+ 0·013	– 0·275	+ 7·240	– 0·007	+ 7·233
105	106	106·15	– 0·001	– 0·276	+ 4·170	– 0·007	+ 4·163
106	107	106·41	+ 0·005	– 0·271	+ 5·359	– 0·007	+ 5·352
107	108	106·90	– 0·010	– 0·281	– 8·256	– 0·005	– 8·261
108	109	107·75	– 0·008	– 0·289	– 51·903	+ 0·001	– 51·902
109	110	108·59	+ 0·004	– 0·285	– 65·077	+ 0·003	– 65·074
110	111	109·71	+ 0·010	– 0·275	– 101·781	+ 0·008	– 101·773
111	112	110·32	– 0·008	– 0·283	– 101·423	+ 0·008	– 101·415
112	113	111·35	+ 0·006	– 0·277	– 118·131	+ 0·010	– 118·121
113	114	113·15	+ 0·013	– 0·264	– 137·540	+ 0·013	– 137·527
114	115	113·58	+ 0·001	– 0·263	– 125·423	+ 0·011	– 125·412
115	116	113·76	+ 0·004	– 0·259	– 119·251	+ 0·010	– 119·241
116	117	114·65	+ 0·016	– 0·243	– 121·458	+ 0·010	– 121·448
117	118	115·14	+ 0·001	– 0·242	– 135·024	+ 0·012	– 135·012
118	119	115·70	+ 0·003	– 0·239	– 142·665	+ 0·013	– 142·652
119	120	120·03	– 0·065	– 0·304	– 210·199	+ 0·023	– 210·176
120	121	121·39	+ 0·015	– 0·289	– 218·515	+ 0·024	– 218·491

Line No. 40. Bilaspur to Cuttack.—(Continued).

Bench-marks From	Bench-marks To	Distance from Bilaspur	Discrepancy between levellers (First − Second leveller) From mark to mark (= d)	Discrepancy between levellers (First − Second leveller) Total from Bilaspur	Observed elevation above (+) or below (−) Bilaspur (mean result by two levellers)	Dynamic correction deduced from mark to mark Total from Bilaspur	Dynamic height above (+) or below (−) Bilaspur
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
121	122	121·67	+ 0·011	− 0·278	− 218·460	+ 0·024	− 218·436
122	123	122·24	− 0·009	− 0·287	− 226·887	+ 0·025	− 226·862
123	124	123·38	− 0·006	− 0·293	− 243·788	+ 0·027	− 243·761
124	125	125·19	+ 0·007	− 0·286	− 196·259	+ 0·020	− 196·239
125	126	126·55	+ 0·018	− 0·268	− 149·942	+ 0·014	− 149·928
126	127	126·78	+ 0·006	− 0·262	− 142·326	+ 0·013	− 142·313
127	128	127·44	− 0·010	− 0·272	− 126·175	+ 0·011	− 126·164
128	129	127·47	0·000	− 0·272	− 125·184	+ 0·011	− 125·173
129	130	128·28	+ 0·011	− 0·261	− 139·353	+ 0·013	− 139·340
130	131	128·67	+ 0·005	− 0·256	− 150·792	+ 0·015	− 150·777
131	132	131·06	− 0·017	− 0·273	− 203·326	+ 0·022	− 203·304
132	133	132·67	+ 0·001	− 0·272	− 212·515	+ 0·023	− 212·492
133	134	132·81	+ 0·004	− 0·268	− 212·346	+ 0·023	− 212·323
134	135	133·80	+ 0·004	− 0·264	− 181·781	+ 0·018	− 181·763
135	136	135·93	− 0·012	− 0·276	− 173·236	+ 0·017	− 173·219
136	137	137·13	− 0·010	− 0·286	− 192·196	+ 0·020	− 192·176
137	138	137·67	+ 0·001	− 0·285	− 212·668	+ 0·023	− 212·645
138	139	138·60	+ 0·003	− 0·282	− 214·528	+ 0·023	− 214·505
139	140	139·60	− 0·017	− 0·299	− 213·514	+ 0·023	− 213·491
140	141	140·34	− 0·016	− 0·315	− 227·131	+ 0·025	− 227·106
141	142	141·60	+ 0·005	− 0·310	− 210·841	+ 0·022	− 210·819
142	143	142·98	− 0·005	− 0·315	− 193·843	+ 0·019	− 193·824
143	144	143·39	+ 0·006	− 0·309	− 215·988	+ 0·023	− 215·965
144	145	144·17	+ 0·006	− 0·303	− 229·448	+ 0·025	− 229·423
145	146	145·91	− 0·028	− 0·331	− 220·367	+ 0·024	− 220·343
146	147	147·62	+ 0·003	− 0·328	− 272·778	+ 0·032	− 272·746
147	148	147·86	− 0·005	− 0·333	− 282·929	+ 0·034	− 282·895
148	149	148·72	− 0·003	− 0·336	− 313·301	+ 0·039	− 313·262
149	150	149·49	− 0·011	− 0·347	− 329·785	+ 0·042	− 329·743
150	151	149·92	+ 0·003	− 0·344	− 334·867	+ 0·043	− 334·824
151	152	151·66	− 0·008	− 0·352	− 337·872	+ 0·044	− 337·828
152	153	152·14	− 0·007	− 0·359	− 348·260	+ 0·046	− 348·214
153	154	152·39	+ 0·004	− 0·355	− 359·581	+ 0·048	− 359·533
154	155	153·57	+ 0·020	− 0·335	− 373·981	+ 0·050	− 373·931
155	156	154·66	+ 0·001	− 0·334	− 366·849	+ 0·049	− 366·800
156	157	155·97	+ 0·003	− 0·331	− 372·456	+ 0·050	− 372·406
157	158	156·42	0·000	− 0·331	− 364·049	+ 0·049	− 364·000
158	159	156·97	+ 0·002	− 0·329	− 381·284	+ 0·052	− 381·232
159	160	157·64	− 0·001	− 0·330	− 370·519	+ 0·050	− 370·469
160	161	158·97	− 0·004	− 0·334	− 420·145	+ 0·058	− 420·087
161	162	159·62	− 0·002	− 0·336	− 379·720	+ 0·051	− 379·669
162	163	161·13	+ 0·025	− 0·311	− 343·675	+ 0·045	− 343·630
163	164	162·11	− 0·009	− 0·320	− 353·513	+ 0·047	− 353·466
164	165	163·11	+ 0·009	− 0·311	− 341·211	− 0·045	− 341·166
165	166	164·10	+ 0·007	− 0·304	− 325·351	− 0·042	− 325·309
166	167	165·10	+ 0·011	− 0·293	− 341·232	+ 0·045	− 341·187
167	168	165·20	− 0·001	− 0·294	− 351·120	+ 0·047	− 351·073
168	169	177·12	− 0·078	− 0·372	− 411·180	+ 0·058	− 411·122
169	170	181·62	− 0·037	− 0·409	− 418·388	+ 0·059	− 418·329
170	171	188·98	+ 0·007	− 0·402	− 434·105	+ 0·062	− 434·043
171	172	189·88	− 0·001	− 0·403	− 446·268	+ 0·064	− 446·204
172	173	208·24	+ 0·045	− 0·358	− 502·801	+ 0·075	− 502·726
173	174	213·00	+ 0·036	− 0·322	− 513·037	+ 0·077	− 512·960
174	175	214·93	+ 0·031	− 0·291	− 513·782	+ 0·077	− 513·705
175	176	215·38	+ 0·007	− 0·284	− 499·613	+ 0·074	− 499·539
176	177	215·94	+ 0·002	− 0·282	− 507·729	+ 0·076	− 507·653
177	178	216·38	+ 0·007	− 0·275	− 518·811	+ 0·078	− 518·733
178	179	217·03	+ 0·007	− 0·268	− 521·673	+ 0·079	− 521·594
179	180	218·04	+ 0·001	− 0·267	− 523·605	+ 0·079	− 523·526
180	181	219·05	+ 0·002	− 0·265	− 530·335	+ 0·080	− 530·255

Line No. 40. Bilaspur to Cuttack.—(Continued).

Bench-marks		Distance from Bilaspur	Discrepancy between levellers (First—Second leveller)		Observed elevation above (+) or below (−) Bilaspur (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Bilaspur
From	To		From mark to mark (=d)	Total from Bilaspur		Total from Bilaspur	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
181	182	220·05	+ 0·002	− 0·263	− 522·451	+ 0·078	− 522·373
182	183	221·06	+ 0·004	− 0·259	− 517·103	+ 0·077	− 517·026
183	184	223·07	− 0·030	− 0·289	− 531·458	+ 0·080	− 531·378
184	185	224·07	+ 0·005	− 0·284	− 555·474	+ 0·085	− 555·389
185	186	225·05	− 0·022	− 0·306	− 539·794	+ 0·082	− 539·712
186	187	225·84	− 0·017	− 0·323	− 544·213	+ 0·083	− 544·130
187	188	226·24	+ 0·006	− 0·317	− 524·931	+ 0·079	− 524·852
188	189	227·12	− 0·004	− 0·321	− 529·801	+ 0·080	− 529·721
189	190	228·27	− 0·015	− 0·336	− 524·119	+ 0·079	− 524·040
190	191	229·27	− 0·010	− 0·346	− 536·098	+ 0·082	− 536·016
191	192	230·35	+ 0·022	− 0·324	− 536·697	+ 0·082	− 536·615
192	193	231·45	0·000	− 0·324	− 544·848	+ 0·084	− 544·764
193	194	233·67	+ 0·001	− 0·323	− 521·869	+ 0·079	− 521·790
194	195	234·63	+ 0·009	− 0·314	− 536·962	+ 0·082	− 536·880
195	196	235·59	− 0·005	− 0·319	− 518·505	+ 0·078	− 518·427
196	197	235·67	− 0·003	− 0·322	− 519·144	+ 0·078	− 519·066
197	198	236·77	+ 0·012	− 0·310	− 516·858	+ 0·078	− 516·780
198	199	237·68	+ 0·006	− 0·304	− 536·293	+ 0·082	− 536·211
199	200	239·69	− 0·009	− 0·313	− 563·634	+ 0·088	− 563·546
200	201	240·69	− 0·009	− 0·322	− 572·100	+ 0·090	− 572·010
201	202	241·64	− 0·004	− 0·326	− 568·059	+ 0·089	− 567·970
202	203	242·64	+ 0·004	− 0·322	− 564·465	+ 0·088	− 564·377
203	204	243·75	+ 0·008	− 0·314	− 589·881	+ 0·093	− 589·788
204	205	244·74	+ 0·011	− 0·303	− 589·373	+ 0·093	− 589·280
205	206	245·87	+ 0·004	− 0·299	− 596·809	+ 0·094	− 596·715
206	207	246·92	+ 0·005	− 0·294	− 602·520	+ 0·095	− 602·425
207	208	247·80	+ 0·002	− 0·292	− 599·540	+ 0·094	− 599·446
208	209	248·90	− 0·012	− 0·304	− 600·370	+ 0·094	− 600·276
209	210	249·91	− 0·001	− 0·305	− 602·911	+ 0·095	− 602·816
210	211	250·70	+ 0·001	− 0·304	− 610·949	+ 0·097	− 610·852
211	212	251·55	− 0·006	− 0·310	− 613·997	+ 0·098	− 613·899
212	213	252·31	+ 0·020	− 0·290	− 611·061	+ 0·097	− 610·964
213	214	252·56	+ 0·007	− 0·283	− 621·186	+ 0·099	− 621·087
214	215	253·55	− 0·004	− 0·287	− 618·906	+ 0·099	− 618·807
215	216	256·63	− 0·018	− 0·305	− 622·385	+ 0·100	− 622·285
216	217	257·61	− 0·015	− 0·320	− 632·570	+ 0·102	− 632·468
217	218	258·57	− 0·007	− 0·327	− 628·208	+ 0·101	− 628·107
218	219	259·71	− 0·007	− 0·334	− 636·173	+ 0·103	− 636·070
219	220	260·94	− 0·016	− 0·350	− 647·393	+ 0·105	− 647·288
220	221	262·08	+ 0·007	− 0·343	− 645·774	+ 0·105	− 645·669
221	222	263·13	0·000	− 0·343	− 643·642	+ 0·105	− 643·537
222	223	264·11	− 0·004	− 0·347	− 647·396	+ 0·106	− 647·290
223	224	266·12	− 0·013	− 0·360	− 626·919	+ 0·101	− 626·818
224	225	267·16	+ 0·008	− 0·352	− 582·043	+ 0·091	− 581·952
225	226	270·21	− 0·002	− 0·354	− 639·935	+ 0·104	− 639·831
226	227	271·22	− 0·011	− 0·365	− 649·325	+ 0·106	− 649·219
227	228	271·73	− 0·005	− 0·370	− 639·530	+ 0·104	− 639·426
228	229	272·28	− 0·002	− 0·372	− 645·286	+ 0·105	− 645·181
229	230	273·43	− 0·001	− 0·373	− 656·875	+ 0·108	− 656·767
230	231	274·44	+ 0·007	− 0·366	− 647·649	+ 0·106	− 647·543
231	232	275·55	+ 0·019	− 0·347	− 647·092	+ 0·106	− 646·986
232	233	276·56	+ 0·006	− 0·341	− 666·578	+ 0·110	− 666·468
233	234	277·57	+ 0·007	− 0·334	− 667·193	+ 0·110	− 667·083
234	235	278·58	− 0·005	− 0·339	− 639·741	+ 0·104	− 639·637
235	236	279·61	+ 0·015	− 0·324	− 653·015	+ 0·107	− 652·908
236	237	280·64	− 0·006	− 0·330	− 634·982	+ 0·103	− 634·879
237	238	280·83	+ 0·005	− 0·325	− 650·536	+ 0·106	− 650·430
238	239	281·73	0·000	− 0·325	− 660·272	+ 0·108	− 660·164
239	240	282·74	− 0·013	− 0·338	− 636·136	+ 0·103	− 636·033
240	241	283·73	+ 0·006	− 0·332	− 646·803	+ 0·105	− 646·698

Line No. 40. Bilaspur to Cuttack.—(Continued).

Bench-marks		Distance from Bilaspur	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (−) Bilaspur (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Bilaspur
From	To		From mark to mark (= d)	Total from Bilaspur		Total from Bilaspur	
		miles	foot	foot	feet	foot	feet
241	242	284·34	− 0·029	− 0·361	− 664·670	+ 0·109	− 664·561
242	243	284·54	+ 0·007	− 0·354	− 670·050	+ 0·110	− 669·940
243	244	284·78	− 0·004	− 0·358	− 660·084	+ 0·108	− 659·976
244	245	285·79	+ 0·003	− 0·355	− 674·103	+ 0·111	− 673·992
245	246	286·81	− 0·005	− 0·360	− 657·468	+ 0·107	− 657·361
246	247	287·82	− 0·009	− 0·369	− 662·641	+ 0·108	− 662·533
247	248	288·85	− 0·022	− 0·391	− 649·726	+ 0·105	− 649·621
248	249	289·26	+ 0·002	− 0·389	− 658·564	+ 0·107	− 658·457
249	250	289·99	+ 0·018	− 0·371	− 679·975	+ 0·112	− 679·863
250	251	291·01	+ 0·002	− 0·369	− 651·689	+ 0·106	− 651·583
251	252	292·02	− 0·012	− 0·381	− 672·943	+ 0·111	− 672·832
252	253	293·45	+ 0·032	− 0·349	− 659·475	+ 0·108	− 659·367
253	254	293·55	+ 0·002	− 0·347	− 656·923	+ 0·107	− 656·816
254	255	294·06	+ 0·015	− 0·332	− 686·853	+ 0·114	− 686·739
255	256	296·12	+ 0·002	− 0·330	− 682·116	+ 0·113	− 682·003
256	257	297·13	+ 0·008	− 0·322	− 693·529	+ 0·116	− 693·413
257	258	298·14	− 0·005	− 0·327	− 690·269	+ 0·115	− 690·154
258	259	299·14	+ 0·019	− 0·308	− 699·991	+ 0·117	− 699·874
259	260	299·34	+ 0·015	− 0·293	− 689·338	+ 0·114	− 689·224
260	261	300·18	− 0·013	− 0·306	− 698·362	+ 0·116	− 698·246
261	262	302·21	− 0·015	− 0·321	− 701·250	+ 0·117	− 701·133
262	263	303·22	− 0·001	− 0·322	− 698·179	+ 0·116	− 698·063
263	264	304·22	− 0·020	− 0·342	− 700·043	+ 0·116	− 699·927
264	265	305·23	+ 0·003	− 0·339	− 707·619	+ 0·118	− 707·501
265	266	306·24	+ 0·005	− 0·334	− 675·608	+ 0·111	− 675·497
266	267	307·24	− 0·005	− 0·339	− 679·097	+ 0·112	− 678·985
267	268	308·25	− 0·004	− 0·343	− 649·693	+ 0·105	− 649·588
268	269	308·46	− 0·008	− 0·351	− 639·173	+ 0·103	− 639·070
269	270	309·27	+ 0·008	− 0·343	− 681·885	+ 0·113	− 681·772
270	271	310·27	+ 0·006	− 0·337	− 693·331	+ 0·116	− 693·215
271	272	311·27	− 0·003	− 0·340	− 688·384	+ 0·115	− 688·269
272	273	312·28	+ 0·007	− 0·333	− 688·869	+ 0·115	− 688·754
273	274	312·41	− 0·001	− 0·334	− 671·817	+ 0·111	− 671·706
274	275	313·29	+ 0·007	− 0·327	− 715·629	+ 0·121	− 715·508
275	276	314·30	− 0·013	− 0·340	− 721·058	+ 0·122	− 720·936
276	277	315·30	− 0·009	− 0·349	− 716·433	+ 0·121	− 716·312
277	278	317·18	+ 0·009	− 0·340	− 725·854	+ 0·123	− 725·731
278	279	317·53	− 0·009	− 0·349	− 717·454	+ 0·121	− 717·333
279	280	318·31	+ 0·002	− 0·347	− 729·659	+ 0·124	− 729·535
280	281	319·31	+ 0·011	− 0·336	− 728·907	+ 0·124	− 728·783
281	282	319·41	− 0·001	− 0·337	− 727·735	+ 0·124	− 727·611
282	283	320·06	− 0·003	− 0·340	− 731·937	+ 0·125	− 731·812
283	284	320·99	− 0·010	− 0·350	− 725·502	+ 0·124	− 725·378
284	285	321·99	+ 0·006	− 0·344	− 722·192	+ 0·123	− 722·069
285	286	322·99	− 0·001	− 0·345	− 721·167	+ 0·123	− 721·044
286	287	324·02	− 0·021	− 0·366	− 621·358	+ 0·099	− 621·259
287	288	324·55	− 0·006	− 0·373	− 617·015	+ 0·098	− 616·917
288	289	325·03	− 0·007	− 0·380	− 661·474	+ 0·109	− 661·365
289	290	326·04	− 0·005	− 0·385	− 706·796	+ 0·120	− 706·676
290	291	327·05	− 0·008	− 0·393	− 734·638	+ 0·127	− 734·511
291	292	328·03	0·000	− 0·393	− 745·630	+ 0·130	− 745·500
292	293	328·68	+ 0·004	− 0·389	− 744·173	+ 0·130	− 744·043
293	294	329·30	− 0·006	− 0·395	− 742·756	+ 0·130	− 742·626
294	295	331·31	− 0·004	− 0·399	− 756·576	+ 0·133	− 756·443
295	296	332·31	0·000	− 0·399	− 728·981	+ 0·126	− 728·855
296	297	333·31	+ 0·010	− 0·389	− 750·699	+ 0·131	− 750·568
297	298	334·32	+ 0·011	− 0·378	− 754·217	+ 0·132	− 754·085
298	299	335·34	− 0·006	− 0·384	− 758·384	+ 0·133	− 758·251
299	300	336·34	− 0·002	− 0·386	− 761·409	+ 0·134	− 761·275
300	301	337·35	− 0·012	− 0·398	− 756·788	+ 0·133	− 756·655

Line No. 40. Bilaspur to Cuttack.—(Continued).

Bench-marks		Distance from Bilaspur	Discrepancy between levellers (First—Second leveller)		Observed elevation above (+) or below (−) Bilaspur (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Bilaspur
From	To		From mark to mark (=d)	Total from Bilaspur		Total from Bilaspur	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
301	302	338·35	− 0·001	− 0·399	− 757·452	+ 0·133	− 757·319
302	303	339·35	+ 0·018	− 0·381	− 760·983	+ 0·133	− 760·850
303	304	340·36	+ 0·014	− 0·367	− 765·327	+ 0·133	− 765·194
304	305	342·34	− 0·012	− 0·379	− 765·304	+ 0·133	− 765·171
305	306	343·35	− 0·016	− 0·395	− 765·479	+ 0·133	− 765·346
306	307	343·65	− 0·001	− 0·396	− 761·527	+ 0·132	− 761·395
307	308	345·56	+ 0·006	− 0·390	− 766·327	+ 0·133	− 766·194
308	309	346·56	+ 0·003	− 0·387	− 774·327	+ 0·135	− 774·192
309	310	347·56	− 0·006	− 0·393	− 772·112	+ 0·134	− 771·978
310	311	348·59	− 0·017	− 0·410	− 773·998	+ 0·135	− 773·863
311	312	348·93	− 0·004	− 0·414	− 731·549	+ 0·125	− 731·424
312	313	349·59	+ 0·003	− 0·411	− 776·394	+ 0·135	− 776·259
313	314	350·60	+ 0·007	− 0·404	− 776·421	+ 0·135	− 776·286
314	315	351·60	+ 0·008	− 0·396	− 779·368	+ 0·136	− 779·232
315	316	352·20	+ 0·002	− 0·394	− 781·019	+ 0·136	− 780·883
316	317	352·60	+ 0·003	− 0·391	− 782·286	+ 0·136	− 782·150
317	318	353·60	− 0·012	− 0·403	− 782·719	+ 0·136	− 782·583
318	319	354·60	+ 0·013	− 0·390	− 785·247	+ 0·137	− 785·110
319	320	355·61	− 0·004	− 0·394	− 789·635	+ 0·138	− 789·497
320	321	356·61	+ 0·006	− 0·388	− 786·236	+ 0·137	− 786·099
321	322	357·32	0·000	− 0·388	− 788·185	+ 0·138	− 788·047
322	323	357·61	+ 0·003	− 0·385	− 785·824	+ 0·137	− 785·687
323	324	358·62	+ 0·002	− 0·383	− 772·035	+ 0·134	− 771·901
324	325	359·62	− 0·002	− 0·385	− 783·874	+ 0·137	− 783·737
325	326	359·72	0·000	− 0·385	− 781·690	+ 0·136	− 781·554
326	327	360·63	− 0·001	− 0·386	− 776·457	+ 0·135	− 776·322
327	328	360·78	− 0·005	− 0·391	− 775·562	+ 0·135	− 775·427
328	329	361·66	− 0·003	− 0·394	− 738·489	+ 0·126	− 738·363
329	330	362·66	− 0·006	− 0·400	− 779·897	+ 0·135	− 779·762
330	331	363·07	− 0·008	− 0·408	− 801·746	+ 0·140	− 801·606
331	332	363·37	+ 0·001	− 0·407	− 801·996	+ 0·140	− 801·856
332	333	363·66	− 0·007	− 0·414	− 804·030	+ 0·141	− 803·889
333	334	364·21	+ 0·005	− 0·409	− 800·548	+ 0·140	− 800·408
334	335	364·66	− 0·002	− 0·411	− 801·126	+ 0·140	− 800·986
335	336	366·51	− 0·008	− 0·419	− 804·849	+ 0·141	− 804·708
336	337	368·99	− 0·024	− 0·443	− 801·629	+ 0·140	− 801·489
337	338	369·77	+ 0·011	− 0·432	− 799·257	+ 0·139	− 799·118
338	339*	370·63	+ 0·007	− 0·425	− 808·809	+ 0·141	− 808·668

Difference of dynamic height, Bilaspur to Cuttack = − 808·668 feet.

Length of line in miles = M = 370·63. $\Sigma d^2 = 0{\cdot}056110$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0{\cdot}0042$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0{\cdot}0799$.

* Bench-mark No. 339 is the mark at Cuttack described on page 133.

Line No. 41. Cuttack to Kendrapara.

Bench-marks		Distance from Cuttack	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Cuttack (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Cuttack
From	To		From mark to mark (= d)	Total from Cuttack		Total from Cuttack	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·75	− 0·001	− 0·001	+ 5·681	− 0·001	+ 5·680
2	3	1·01	0·000	− 0·001	+ 4·429	− 0·001	+ 4·428
3	4	1·24	− 0·002	− 0·003	+ 9·217	− 0·002	+ 9·215
4	5	2·78	− 0·005	− 0·008	+ 3·914	− 0·001	+ 3·913
5	6	2·92	+ 0·002	− 0·006	+ 3·291	− 0·001	+ 3·290
6	7	3·85	− 0·005	− 0·011	− 14·732	+ 0·003	− 14·729
7	8	5·77	+ 0·001	− 0·010	+ 1·726	− 0·001	+ 1·725
8	9	8·13	+ 0·011	+ 0·001	+ 0·616	− 0·001	+ 0·615
9	10	8·88	− 0·014	− 0·013	− 4·059	0·000	− 4·059
10	11	9·14	− 0·005	− 0·018	− 2·981	0·000	− 2·981
11	12	10·13	+ 0·005	− 0·013	− 0·518	− 0·001	− 0·519
12	13	11·13	+ 0·025	+ 0·012	− 4·509	0·000	− 4·509
13	14	12·13	− 0·005	+ 0·007	− 3·436	0·000	− 3·436
14	15	12·20	+ 0·002	+ 0·009	− 8·977	+ 0·001	− 8·976
15	16	12·24	0·000	+ 0·009	− 5·891	0·000	− 5·891
16	17	13·15	+ 0·012	+ 0·021	− 11·702	+ 0·001	− 11·701
17	18	14·16	− 0·006	+ 0·015	− 15·109	+ 0·002	− 15·107
18	19	15·16	− 0·006	+ 0·009	− 15·826	+ 0·002	− 15·824
19	20	16·12	+ 0·001	+ 0·010	− 11·278	+ 0·001	− 11·277
20	21	17·15	− 0·006	+ 0·004	− 20·419	+ 0·003	− 20·416
21	22	18·16	− 0·022	− 0·018	− 25·375	+ 0·004	− 25·371
22	23	19·15	+ 0·006	− 0·012	− 17·598	+ 0·002	− 17·596
23	24	20·15	+ 0·007	− 0·005	− 19·139	+ 0·002	− 19·137
24	25	21·15	− 0·005	− 0·010	− 20·587	+ 0·002	− 20·585
25	26	21·98	− 0·008	− 0·018	− 21·134	+ 0·002	− 21·132
26	27	22·16	+ 0·002	− 0·016	− 21·662	+ 0·002	− 21·660
27	28	23·19	− 0·018	− 0·034	− 22·632	+ 0·002	− 22·630
28	29	24·08	− 0·012	− 0·046	− 23·775	+ 0·002	− 23·773
29	30	25·13	− 0·018	− 0·064	− 25·488	+ 0·002	− 25·486
30	31	26·12	+ 0·003	− 0·061	− 27·244	+ 0·002	− 27·242
31	32	27·13	− 0·013	− 0·074	− 29·050	+ 0·002	− 29·048
32	33	28·14	− 0·006	− 0·080	− 30·953	+ 0·002	− 30·951
33	34	28·50	− 0·004	− 0·084	− 34·442	+ 0·003	− 34·439
34	35	29·15	− 0·001	− 0·085	− 32·602	+ 0·003	− 32·599
35	36	31·15	+ 0·009	− 0·076	− 35·124	+ 0·004	− 35·120
36	37	32·15	− 0·001	− 0·077	− 36·596	+ 0·004	− 36·592
37	38	32·39	− 0·013	− 0·064	− 40·344	+ 0·005	− 40·339
38	39	32·40	0·000	− 0·064	− 37·303	+ 0·004	− 37·299
39	40	33·18	+ 0·007	− 0·057	− 38·431	+ 0·004	− 38·427
40	41	34·61	+ 0·005	− 0·052	− 44·676	+ 0·005	− 44·671
41	42	35·61	− 0·006	− 0·058	− 44·715	+ 0·005	− 44·710
42	43	36·38	− 0·008	− 0·066	− 48·520	+ 0·006	− 48·514
43	44	37·26	+ 0·002	− 0·064	− 48·598	+ 0·006	− 48·592
44	45	38·17	+ 0·015	− 0·049	− 56·833	+ 0·008	− 56·825
45	46	38·27	+ 0·003	− 0·046	− 51·536	+ 0·007	− 51·529
46	47	39·26	+ 0·004	− 0·042	− 51·595	+ 0·007	− 51·588
47	48	40·27	− 0·003	− 0·045	− 50·867	+ 0·007	− 50·860
48	49	40·77	− 0·012	− 0·057	− 54·418	+ 0·008	− 54·410
49	50	41·49	− 0·003	− 0·060	− 54·609	+ 0·008	− 54·601
50	51†	41·50	+ 0·002	− 0·058	− 53·293	+ 0·008	− 53·285

Difference of dynamic height, Cuttack to Kendrapara = − 53·285 feet.

Length of line in miles = M = 41·50. $\Sigma d^2 = 0{\cdot}003864$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4M}} = \pm\, 0{\cdot}0033$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0210$.

* Bench-mark No. 1 is the mark at Cuttack described on page 133. † Bench-mark No. 51 is the mark at Kendrapara described on page 134.

Line No. 42. False Point to Kendrapara.

Bench-marks From	Bench-marks To	Distance from False Point	Discrepancy between levellers (First – Second leveller) From mark to mark (= d)	Discrepancy between levellers (First – Second leveller) Total from False Point	Observed elevation above (+) or below (–) False Point (mean result by two levellers)	Dynamic correction deduced from mark to mark Total from False Point	Dynamic height above (+) or below (–) False Point
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	10·54	+ 0·015	+ 0·015	– 3·014	+ 0·001	– 3·013
2	3	11·54	– 0·017	– 0·002	– 2·322	+ 0·001	– 2·321
3	4	12·54	+ 0·003	+ 0·001	– 2·138	+ 0·001	– 2·137
4	5	13·54	+ 0·007	+ 0·008	– 2·158	+ 0·001	– 2·157
5	6	14·54	+ 0·006	+ 0·014	– 1·720	+ 0·001	– 1·719
6	7	15·54	– 0·011	+ 0·003	– 1·472	+ 0·001	– 1·471
7	8	16·54	– 0·003	0·000	– 1·819	+ 0·001	– 1·818
8	9	17·54	– 0·001	– 0·001	– 0·243	+ 0·001	– 0·242
9	10	18·54	– 0·006	– 0·007	– 0·215	+ 0·001	– 0·214
10	11	19·54	– 0·005	– 0·012	+ 0·939	+ 0·001	+ 0·940
11	12	20·54	+ 0·010	– 0·002	+ 0·179	+ 0·001	+ 0·180
12	13	21·74	+ 0·006	+ 0·004	+ 0·586	+ 0·001	+ 0·587
13	14	21·95	0·000	+ 0·004	+ 6·615	0·000	+ 6·615
14	15	22·56	– 0·005	– 0·001	+ 4·598	+ 0·001	+ 4·599
15	16	23·56	– 0·015	– 0·016	+ 5·509	+ 0·001	+ 5·510
16	17	23·90	– 0·006	– 0·022	+ 5·808	+ 0·001	+ 5·809
17	18	24·56	+ 0·002	– 0·020	+ 5·421	+ 0·001	+ 5·422
18	19	25·57	0·000	– 0·020	+ 6·971	+ 0·001	+ 6·972
19	20	26·57	+ 0·003	– 0·017	+ 7·470	+ 0·001	+ 7·471
20	21	29·83	– 0·011	– 0·028	+ 14·965	– 0·001	+ 14·964
21	22	30·36	– 0·001	– 0·029	+ 4·519	+ 0·001	+ 4·520
22	23†	30·37	+ 0·003	– 0·026	+ 5·848	+ 0·001	+ 5·849

Difference of dynamic height, False Point to Kendrapara = + 5·849 feet.

Length of line in miles = M = 30·37. $\Sigma d^2 = 0 \cdot 001366$.

Probable error of the mean result per mile of double-levelling $= 0 \cdot 6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm 0 \cdot 0023.$

Probable error of the difference of elevation between the terminal bench-marks $= 0 \cdot 6745 \sqrt{\frac{\Sigma d^2}{4}} = \pm 0 \cdot 0125.$

* Bench-mark No. 1 is the mark at False Point described on page 134. † Bench-mark No. 23 is the mark at Kendrapara described on page 134.

Line No. 43. Karachi to Tatta.

Bench-marks		Distance from Karachi	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Karachi (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Karachi
From	To		From mark to mark (= d)	Total from Karachi		Total from Karachi	
		miles	foot	foot	feet	foot	feet
1*	2	0·73	− 0·005	− 0·005	− 0·052	0·000	− 0·052
2	3	1·63	− 0·012	− 0·017	+ 0·393	0·000	+ 0·393
3	4	2·62	− 0·009	− 0·026	+ 3·341	0·000	+ 3·341
4	5	5·17	+ 0·028	+ 0·002	+ 3·117	0·000	+ 3·117
5	6	5·80	+ 0·030	+ 0·032	+ 1·844	0·000	+ 1·844
6	7	8·85	− 0·032	0·000	+ 36·874	+ 0·002	+ 36·876
7	8	9·48	+ 0·037	+ 0·037	+ 26·575	+ 0·001	+ 26·576
8	9	13·47	+ 0·001	+ 0·038	+ 41·493	+ 0·002	+ 41·495
9	10	14·14	− 0·017	+ 0·021	+ 42·273	+ 0·002	+ 42·275
10	11	16·14	− 0·022	− 0·001	+ 37·345	+ 0·002	+ 37·347
11	12	16·15	+ 0·041	+ 0·040	+ 37·329	+ 0·002	+ 37·331
12	13	17·12	− 0·001	+ 0·039	+ 38·272	+ 0·002	+ 38·274
13	14	18·12	− 0·007	+ 0·032	+ 52·168	+ 0·003	+ 52·171
14	15	19·12	− 0·009	+ 0·023	+ 53·686	+ 0·003	+ 53·689
15	16	20·11	− 0·009	+ 0·014	+ 63·389	+ 0·004	+ 63·393
16	17	21·11	+ 0·002	+ 0·016	+ 84·925	+ 0·005	+ 84·930
17	18	22·11	+ 0·001	+ 0·017	+ 114·536	+ 0·007	+ 114·543
18	19	23·12	− 0·015	+ 0·002	+ 126·549	+ 0·008	+ 126·557
19	20	24·48	+ 0·015	+ 0·017	+ 106·035	+ 0·007	+ 106·042
20	21	25·51	+ 0·008	+ 0·025	+ 91·914	+ 0·006	+ 91·920
21	22	26·55	0·000	+ 0·025	+ 75·869	+ 0·005	+ 75·874
22	23	27·12	− 0·001	+ 0·024	+ 70·178	+ 0·005	+ 70·183
23	24	29·16	− 0·026	− 0·002	+ 45·388	+ 0·003	+ 45·391
24	25	30·16	+ 0·004	+ 0·002	+ 24·391	+ 0·002	+ 24·393
25	26	31·21	+ 0·004	+ 0·006	+ 8·397	+ 0·001	+ 8·398
26	27	32·21	+ 0·016	+ 0·022	+ 34·871	+ 0·003	+ 34·874
27	28	33·23	+ 0·013	+ 0·035	− 1·310	+ 0·001	− 1·309
28	29	34·23	+ 0·010	+ 0·045	+ 2·641	+ 0·001	+ 2·642
29	30	35·23	+ 0·012	+ 0·057	+ 0·641	+ 0·001	+ 0·642
30	31	36·22	− 0·007	+ 0·050	− 1·522	+ 0·001	− 1·521
31	32	37·22	− 0·015	+ 0·035	− 1·052	+ 0·001	− 1·051
32	33	38·21	+ 0·015	+ 0·050	+ 0·194	+ 0·001	+ 0·195
33	34	39·21	− 0·014	+ 0·036	+ 3·934	+ 0·001	+ 3·935
34	35	40·40	− 0·006	+ 0·030	+ 0·064	+ 0·001	+ 0·065
35	36	41·20	+ 0·005	+ 0·035	+ 1·029	+ 0·001	+ 1·030
36	37	42·21	− 0·004	+ 0·031	+ 9·557	+ 0·001	+ 9·558
37	38	43·21	− 0·017	+ 0·014	+ 0·596	+ 0·001	+ 0·597
38	39	44·20	− 0·016	− 0·002	+ 4·108	+ 0·001	+ 4·109
39	40	45·19	− 0·008	− 0·010	+ 4·573	+ 0·001	+ 4·574
40	41	47·10	+ 0·026	+ 0·016	+ 6·740	+ 0·001	+ 6·741
41	42	48·04	+ 0·013	+ 0·029	+ 6·141	+ 0·001	+ 6·142
42	43	48·98	− 0·002	+ 0·027	+ 5·804	+ 0·001	+ 5·805
43	44	49·92	0·000	+ 0·027	+ 7·683	+ 0·001	+ 7·684
44	45	50·86	− 0·004	+ 0·023	+ 8·971	+ 0·001	+ 8·972
45	46	51·73	+ 0·004	+ 0·027	+ 6·683	+ 0·001	+ 6·684
46	47	51·83	− 0·006	+ 0·021	+ 10·316	+ 0·001	+ 10·317
47	48	52·79	− 0·012	+ 0·009	+ 9·834	+ 0·001	+ 9·835
48	49	53·73	− 0·010	− 0·001	+ 11·229	+ 0·001	+ 11·230
49	50	54·68	+ 0·005	+ 0·004	+ 12·669	+ 0·001	+ 12·670
50	51	55·62	+ 0·016	+ 0·020	+ 14·639	+ 0·001	+ 14·640
51	52	56·58	+ 0·015	+ 0·035	+ 14·876	+ 0·001	+ 14·877
52	53	57·45	+ 0·005	+ 0·040	+ 12·387	+ 0·001	+ 12·388
53	54	57·53	0·000	+ 0·040	+ 13·421	+ 0·001	+ 13·422
54	55	58·49	− 0·001	+ 0·039	+ 15·965	+ 0·001	+ 15·966
55	56	59·44	− 0·013	+ 0·026	+ 15·613	+ 0·001	+ 15·614

* Bench-mark No. 1 is the mark at Karachi described on page 134.

Line No. 43. Karachi to Tatta.—(Continued).

Bench-marks		Distance from Karachi	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Karachi (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Karachi
From	To		From mark to mark (= d)	Total from Karachi		Total from Karachi	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
56	57	60·37	– 0·011	+ 0·015	+ 15·191	+ 0·001	+ 15·192
57	58	61·32	+ 0·015	+ 0·030	+ 16·235	+ 0·001	+ 16·236
58	59	62·28	– 0·003	+ 0·027	+ 17·260	+ 0·001	+ 17·261
59	60	63·21	+ 0·007	+ 0·034	+ 18·860	+ 0·001	+ 18·861
60	61	64·17	+ 0·008	+ 0·042	+ 18·035	+ 0·001	+ 18·036
61	62	65·16	+ 0·003	+ 0·045	+ 62·383	+ 0·003	+ 62·386
62	63	67·00	– 0·017	+ 0·028	+ 21·401	+ 0·001	+ 21·402
63	64*	67·65	+ 0·001	+ 0·029	+ 29·823	+ 0·001	+ 29·824

Difference of dynamic height, Karachi to Tatta = + 29·824 feet.

Length of line in miles = M = 67·65. Σd^2 = 0·012901.

Probable error of the mean result per mile of double-levelling = $0 \cdot 6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0 \cdot 0047$.

Probable error of the difference of elevation between the terminal bench-marks = $0 \cdot 6745 \sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0 \cdot 0383$.

* Bench-mark No. 64 is the mark at Tatta described on page 136.

Line No. 44. Navanar to Sujawal.

Bench-marks		Distance from Navanar	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Navanar (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Navanar
From	To		From mark to mark (= d)	Total from Navanar		Total from Navanar	
		miles	foot	foot	feet	foot	feet
1*	2	5·62	− 0·038	− 0·038	+ 1·293	0·000	+ 1·293
2	3	9·43	+ 0·025	− 0·013	+ 24·955	− 0·002	+ 24·953
3	4	9·64	0·000	− 0·013	+ 30·915	− 0·003	+ 30·912
4	5	11·23	− 0·001	− 0·014	+ 55·488	− 0·005	+ 55·483
5	6	12·70	− 0·007	− 0·021	+ 74·289	− 0·006	+ 74·283
6	7	15·48	+ 0·031	+ 0·010	+ 117·892	− 0·009	+ 117·883
7	8	17·73	+ 0·006	+ 0·016	+ 125·000	− 0·010	+ 124·990
8	9	18·54	− 0·009	+ 0·007	+ 170·113	− 0·013	+ 170·100
9	10	21·05	+ 0·001	+ 0·008	+ 195·573	− 0·015	+ 195·558
10	11	21·06	− 0·001	+ 0·007	+ 188·282	− 0·014	+ 188·268
11	12	22·96	− 0·017	− 0·010	+ 219·559	− 0·016	+ 219·543
12	13	24·32	− 0·011	− 0·021	+ 239·093	− 0·017	+ 239·076
13	14	29·34	+ 0·029	+ 0·008	+ 459·286	− 0·031	+ 459·255
14	15	29·35	+ 0·001	+ 0·009	+ 455·517	− 0·031	+ 455·486
15	16	29·39	− 0·011	− 0·002	+ 433·240	− 0·030	+ 433·210
16	17	30·65	+ 0·003	+ 0·001	+ 411·418	− 0·029	+ 411·389
17	18	31·36	+ 0·007	+ 0·008	+ 429·767	− 0·030	+ 429·737
18	19	32·84	+ 0·005	+ 0·013	+ 512·624	− 0·035	+ 512·589
19	20	33·49	− 0·008	+ 0·005	+ 499·142	− 0·034	+ 499·108
20	21	34·55	+ 0·004	+ 0·009	+ 563·975	− 0·038	+ 563·937
21	22	35·55	+ 0·017	+ 0·026	+ 610·129	− 0·041	+ 610·088
22	23	36·55	− 0·011	+ 0·015	+ 507·302	− 0·035	+ 507·267
23	24	37·04	+ 0·010	+ 0·025	+ 463·730	− 0·032	+ 463·698
24	25	37·56	+ 0·003	+ 0·028	+ 500·548	− 0·034	+ 500·514
25	26	38·32	0·000	+ 0·028	+ 413·345	− 0·029	+ 413·316
26	27	38·57	+ 0·001	+ 0·029	+ 403·383	− 0·028	+ 403·355
27	28	39·57	− 0·007	+ 0·022	+ 379·794	− 0·027	+ 379·767
28	29	39·98	+ 0·006	+ 0·028	+ 381·971	− 0·027	+ 381·944
29	30	40·83	− 0·011	+ 0·017	+ 361·658	− 0·026	+ 361·632
30	31	42·13	+ 0·007	+ 0·024	+ 376·890	− 0·027	+ 376·863
31	32	43·53	+ 0·010	+ 0·034	+ 402·222	− 0·028	+ 402·194
32	33	43·88	+ 0·021	+ 0·055	+ 408·726	− 0·028	+ 408·698
33	34	45·52	+ 0·003	+ 0·058	+ 452·938	− 0·030	+ 452·908
34	35	47·51	+ 0·003	+ 0·061	+ 519·254	− 0·033	+ 519·221
35	36	48·42	− 0·009	+ 0·052	+ 568·559	− 0·036	+ 568·523
36	37	51·83	− 0·026	+ 0·026	+ 582·667	− 0·037	+ 582·630
37	38	55·63	− 0·022	+ 0·004	+ 567·583	− 0·036	+ 567·547
38	39	57·54	+ 0·012	+ 0·016	+ 473·734	− 0·031	+ 473·703
39	40	59·64	− 0·004	+ 0·012	+ 473·578	− 0·031	+ 473·547
40	41	61·61	− 0·020	− 0·008	+ 492·523	− 0·032	+ 492·491
41	42	63·26	− 0·038	− 0·046	+ 438·240	− 0·029	+ 438·211
42	43	65·09	− 0·030	− 0·076	+ 393·333	− 0·027	+ 393·306
43	44	68·32	− 0·053	− 0·129	+ 398·843	− 0·027	+ 398·816
44	45	68·34	+ 0·005	− 0·124	+ 399·868	− 0·027	+ 399·841
45	46	71·74	− 0·028	− 0·152	+ 471·230	− 0·030	+ 471·200
46	47	75·63	− 0·007	− 0·159	+ 295·305	− 0·023	+ 295·282
47	48	80·73	+ 0·069	− 0·090	+ 266·972	− 0·022	+ 266·950
48	49	84·85	+ 0·019	− 0·071	+ 264·925	− 0·022	+ 264·903
49	50	84·95	− 0·003	− 0·074	+ 258·732	− 0·022	+ 258·710
50	51	86·77	− 0·008	− 0·082	+ 236·743	− 0·021	+ 236·722
51	52	89·71	+ 0·024	− 0·058	+ 352·565	− 0·025	+ 352·540
52	53	96·79	+ 0·080	+ 0·022	+ 290·077	− 0·023	+ 290·054
53	54	96·80	0·000	+ 0·022	+ 292·346	− 0·023	+ 292·323
54	55	96·85	+ 0·002	+ 0·024	+ 293·853	− 0·023	+ 293·830
55	56	97·20	+ 0·002	+ 0·026	+ 331·338	− 0·024	+ 331·314
56	57	97·72	+ 0·008	+ 0·034	+ 387·540	− 0·025	+ 387·515
57	58	105·07	− 0·034	0·000	+ 296·710	− 0·023	+ 296·687
58	59	109·90	+ 0·035	+ 0·035	+ 208·230	− 0·021	+ 208·209
59	60	118·74	+ 0·008	+ 0·043	+ 132·456	− 0·019	+ 132·437
60	61	120·38	− 0·012	+ 0·031	+ 40·545	− 0·017	+ 40·528

* Bench-mark No. 1 is the mark at Navanar described on page 135.

Line No. 44. Navanar to Sujawal.—(Continued).

Bench-marks		Distance from Navanar	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Navanar (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Navanar
From	To		From mark to mark (= d)	Total from Navanar		Total from Navanar	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	120·70	+ 0·003	+ 0·034	+ 38·198	– 0·017	+ 38·181
62	63	124·49	– 0·008	+ 0·026	+ 27·130	– 0·017	+ 27·113
63	64	142·01	– 0·007	+ 0·019	– 0·682	– 0·017	– 0·699
64	65	142·02	+ 0·002	+ 0·021	– 0·433	– 0·017	– 0·450
65	66	163·89	+ 0·007	+ 0·028	– 4·038	– 0·017	– 4·055
66	67	176·34	+ 0·053	+ 0·081	– 1·419	– 0·017	– 1·436
67	68	183·89	+ 0·032	+ 0·113	+ 12·685	– 0·017	+ 12·668
68	69	186·51	+ 0·010	+ 0·123	+ 8·735	– 0·017	+ 8·718
69	70	188·10	– 0·003	+ 0·120	+ 11·481	– 0·017	+ 11·464
70	71	188·55	+ 0·012	+ 0·132	+ 7·565	– 0·017	+ 7·548
71	72	189·52	– 0·011	+ 0·121	+ 7·963	– 0·017	+ 7·946
72	73	189·63	– 0·003	+ 0·118	+ 11·385	– 0·017	+ 11·368
73	74	192·47	– 0·007	+ 0·111	+ 10·258	– 0·017	+ 10·241
74	75	193·27	+ 0·005	+ 0·116	+ 10·744	– 0·017	+ 10·727
75	76	195·97	+ 0·016	+ 0·132	+ 11·178	– 0·017	+ 11·161
76	77	196·01	+ 0·002	+ 0·134	+ 11·969	– 0·017	+ 11·952
77	78	197·41	– 0·001	+ 0·133	+ 11·329	– 0·017	+ 11·312
78	79	198·42	– 0·007	+ 0·126	+ 12·793	– 0·017	+ 12·776
79	80	200·51	+ 0·012	+ 0·138	+ 16·105	– 0·017	+ 16·088
80	81	201·59	– 0·010	+ 0.128	+ 14·173	– 0·017	+ 14·156
81	82	202·50	– 0·009	+ 0·119	+ 21·215	– 0·017	+ 21·198
82	83	203·81	+ 0·009	+ 0·128	+ 18·046	– 0·017	+ 18·029
83	84	205·26	+ 0·017	+ 0·145	+ 23·768	– 0·017	+ 23·751
84	85	206·01	– 0·005	+ 0·140	+ 23·999	– 0·017	+ 23·982
85	86	206·75	+ 0·007	+ 0·147	+ 22·293	– 0·017	+ 22·276
86	87	207·04	– 0·005	+ 0·142	+ 16·218	– 0·017	+ 16·201
87	88*	208·50	– 0·008	+ 0·134	+ 19·130	– 0·017	+ 19·113

Difference of dynamic height, Navanar to Sujawal = + 19·113 feet.

Length of line in miles = M = 208·50. $\Sigma d^2 = 0{\cdot}034346$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0{\cdot}0043$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0{\cdot}0625$.

* Bench-mark No. 88 is the mark at Sujawal described on page 136.

Line No. 45. Tatta to Sujawal.

Bench-marks		Distance from Tatta	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Tatta (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Tatta
From	To		From mark to mark (= d)	Total from Tatta		Total from Tatta	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·55	– 0·001	– 0·001	– 8·422	0·000	– 8·422
2	3	2·49	+ 0·017	+ 0·016	+ 32·560	+ 0·002	+ 32·562
3	4	3·20	– 0·006	+ 0·010	+ 27·163	+ 0·002	+ 27·165
4	5	3·38	– 0·009	+ 0·001	– 1·087	+ 0·001	– 1·086
5	6	4·98	– 0·008	– 0·007	+ 1·655	+ 0·001	+ 1·656
6	7	5·12	0·000	– 0·007	– 4·964	+ 0·001	– 4·963
7	8	6·75	+ 0·013	+ 0·006	– 2·873	+ 0·001	– 2·872
8	9	7·00	– 0·001	+ 0·005	– 7·520	+ 0·001	– 7·519
9	10	7·33	– 0·002	+ 0·003	– 2·691	+ 0·001	– 2·690
10	11	10·62	– 0·012	+ 0·009	– 2·347	+ 0·001	– 2·346
11	12	11·68	+ 0·015	+ 0·006	– 5·159	+ 0·001	– 5·158
12	13	12·32	– 0·005	+ 0·001	– 4·976	+ 0·001	– 4·975
13	14	12·99	– 0·001	0·000	+ 0·934	+ 0·001	+ 0·935
14	15	16·88	– 0·001	– 0·001	– 10·330	+ 0·001	– 10·329
15	16	21·09	+ 0·031	+ 0·030	– 10·484	+ 0·001	– 10·483
16	17†	21·10	0·000	+ 0·030	– 10·037	+ 0·001	– 10·036

Difference of dynamic height, Tatta to Sujawal = – 10·036 feet.

Length of line in miles = M = 21·10. Σd^2 = 0·002002.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0{\cdot}0033.$

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0{\cdot}0151.$

* Bench-mark No. 1 is the mark at Tatta described on page 136. † Bench-mark No. 17 is the mark at Sujawal described on page 136.

Line No. 46. Navanar to Shikarpur (Cutch).

Bench-marks		Distance from Navanar	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Navanar (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Navanar
From	To		From mark to mark (= d)	Total from Navanar		Total from Navanar	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	5·53	– 0·023	– 0·023	+ 1·378	0·000	+ 1·378
2	3	9·18	+ 0·028	+ 0·005	+ 25·016	– 0·002	+ 25·014
3	4	9·39	+ 0·005	+ 0·010	+ 30·978	– 0·003	+ 30·975
4	5	14·54	+ 0·021	+ 0·031	+ 84·122	– 0·007	+ 84·115
5	6	19·45	– 0·009	+ 0·022	+ 124·520	– 0·010	+ 124·510
6	7	24·42	+ 0·009	+ 0·031	+ 195·451	– 0·015	+ 195·436
7	8	27·57	+ 0·030	+ 0·061	+ 187·974	– 0·014	+ 187·960
8	9	30·41	– 0·005	+ 0·056	+ 186·252	– 0·014	+ 186·238
9	10	38·68	+ 0·025	+ 0·081	+ 193·619	– 0·014	+ 193·605
10	11	38·79	– 0·004	+ 0·077	+ 195·125	– 0·014	+ 195·111
11	12	41·99	– 0·006	+ 0·071	+ 120·901	– 0·010	+ 120·891
12	13	43·88	– 0·009	+ 0·062	+ 101·768	– 0·009	+ 101·759
13	14	46·79	– 0·014	+ 0·048	+ 79·701	– 0·008	+ 79·693
14	15	52·91	+ 0·019	+ 0·067	+ 70·385	– 0·007	+ 70·378
15	16	64·48	– 0·031	+ 0·036	+ 129·031	– 0·010	+ 129·021
16	17	72·36	+ 0·021	+ 0·057	+ 58·713	– 0·006	+ 58·707
17	18	75·72	– 0·002	+ 0·055	+ 50·821	– 0·006	+ 50·815
18	19	79·53	– 0·017	+ 0·038	+ 105·443	– 0·009	+ 105·434
19	20	83·69	– 0·021	+ 0·017	+ 73·371	– 0·007	+ 73·364
20	21†	87·49	0·000	+ 0·017	+ 44·026	– 0·005	+ 44·021

Difference of dynamic height, Navanar to Shikarpur = + 44·021 feet.

Length of line in miles = M = 87·49. $\Sigma d^2 = 0·006047$.

Probable error of the mean result per mile of double-levelling $= 0·6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm 0·0028$.

Probable error of the difference of elevation between the terminal bench-marks $= 0·6745 \sqrt{\frac{\Sigma d^2}{4}} = \pm 0·0262$.

* Bench-mark No. 1 is the mark at Navanar described on page 136. † Bench-mark No. 21 is the mark at Shikarpur described on page 135.

Line No. 47. Shikarpur (Cutch) to Jorya.

Bench-marks		Distance from Shikarpur	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Shikarpur (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Shikarpur
From	To		From mark to mark (= d)	Total from Shikarpur		Total from Shikarpur	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	3·73	– 0·003	– 0·003	– 36·044	+ 0·002	– 36·042
2	3	5·72	+ 0·005	+ 0·002	– 44·819	+ 0·002	– 44·817
3	4	7·67	+ 0·001	+ 0·003	– 44·579	+ 0·002	– 44·577
4	5	10·53	– 0·002	+ 0·001	– 39·650	+ 0·002	– 39·648
5	6	12·94	– 0·015	– 0·014	– 22·520	+ 0·001	– 22·519
6	7	20·88	– 0·042	– 0·056	– 9·499	0·000	– 9·499
7	8	25·96	+ 0·006	– 0·050	– 15·112	0·000	– 15·112
8	9	30·85	– 0·010	– 0·060	– 36·469	+ 0·002	– 36·467
9	10	40·21	– 0·014	– 0·074	+ 0·322	– 0·001	+ 0·321
10	11	44·82	– 0·026	– 0·100	– 24·777	+ 0·001	– 24·776
11	12	46·35	– 0·002	– 0·102	– 27·733	+ 0·001	– 27·732
12	13	59·15	+ 0·102	0·000	– 44·554	+ 0·002	– 44·552
13	14	59·21	– 0·031	– 0·031	– 44·157	+ 0·002	– 44·155
14	15	59·59	+ 0·013	– 0·018	– 44·679	+ 0·002	– 44·677
15	16	63·91	+ 0·017	– 0·001	– 39·289	+ 0·002	– 39·287
16	17	67·15	+ 0·008	+ 0·007	– 40·177	+ 0·002	– 40·175
17	18	70·81	– 0·031	– 0·024	– 39·456	+ 0·002	– 39·454
18	19†	74·83	– 0·003	– 0·027	– 34·575	+ 0·002	– 34·573

Difference of dynamic height, Shikarpur to Jorya = – 34·573 feet.

Length of line in miles = M = 74·83. $\Sigma d^2 = 0{\cdot}015897$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0{\cdot}0049$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745 \sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0{\cdot}0425$.

* Bench-mark No. 1 is the mark at Shikarpur described on page 135. † Bench-mark No. 19 is the mark at Jorya described on page 134.

Line No. 48. Jorya to Rajkot.

Bench-marks		Distance from Jorya	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Jorya (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Jorya
From	To		From mark to mark (= d)	Total from Jorya		Total from Jorya	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	1·86	+ 0·020	+ 0·020	+ 11·237	– 0·001	+ 11·236
2	3	3·81	– 0·011	+ 0·009	+ 24·693	– 0·002	+ 24·691
3	4	6·28	– 0·015	– 0·006	+ 29·279	– 0·002	+ 29·277
4	5	11·88	– 0·001	– 0·007	+ 60·241	– 0·005	+ 60·236
5	6	18·15	– 0·003	– 0·010	+ 174·714	– 0·017	+ 174·697
6	7	22·00	+ 0·015	+ 0·005	+ 255·364	– 0·025	+ 255·339
7	8	27·19	– 0·019	– 0·014	+ 185·175	– 0·017	+ 185·158
8	9	30·13	+ 0·026	+ 0·012	+ 221·941	– 0·021	+ 221·920
9	10	32·52	– 0·042	– 0·030	+ 244·710	– 0·024	+ 244·686
10	11	34·98	+ 0·006	– 0·024	+ 317·966	– 0·032	+ 317·934
11	12	35·65	+ 0·010	– 0·014	+ 319·236	– 0·032	+ 319·204
12	13	42·91	– 0·025	– 0·039	+ 390·348	– 0·040	+ 390·308
13	14†	43·40	+ 0·001	– 0·038	+ 385·754	– 0·039	+ 385·715

Difference of dynamic height, Jorya to Rajkot = + 385·715 feet.

Length of line in miles = M = 43·40. $\Sigma d^2 = 0·004544$.

Probable error of the mean result per mile of double-levelling $= 0·6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0·0034$.

Probable error of the difference of elevation between the terminal bench-marks $= 0·6745 \sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0·0227$.

* Bench-mark No. 1 is the mark at Jorya described on page 134. † Bench-mark No. 14 is the mark at Rájkot described on page 135.

Line No. 49. Rajkot to Viramgam.

Bench-marks		Distance from Rajkot	*Discrepancy between levellers (First – Second leveller)*		Observed elevation above (+) or below (–) Rajkot (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Rajkot
From	To		From mark to mark (= d)	Total from Rajkot		Total from Rajkot	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·40	– 0·006	– 0·006	– 25·466	+ 0·003	– 25·463
2	3	0·55	+ 0·001	– 0·005	– 25·248	+ 0·003	– 25·245
3	4	4·34	+ 0·026	+ 0·021	+ 55·635	– 0·006	+ 55·629
4	5	5·07	+ 0·003	+ 0·024	+ 70·045	– 0·008	+ 70·037
5	6	9·99	+ 0·036	+ 0·060	+ 132·061	– 0·015	+ 132·046
6	7	10·88	– 0·008	+ 0·052	+ 122·224	– 0·014	+ 122·210
7	8	14·93	– 0·020	+ 0·032	+ 76·233	– 0·009	+ 76·224
8	9	18·27	– 0·015	+ 0·017	+ 141·495	– 0·016	+ 141·479
9	10	21·26	+ 0·025	+ 0·042	+ 202·482	– 0·023	+ 202·459
10	11	24·24	– 0·004	+ 0·038	+ 251·157	– 0·028	+ 251·129
11	12	28·79	+ 0·020	+ 0·058	+ 238·409	– 0·027	+ 238·382
12	13	29·45	– 0·001	+ 0·057	+ 262·631	– 0·030	+ 262·601
13	14	31·58	+ 0·003	+ 0·060	+ 199·088	– 0·024	+ 199·064
14	15	33·47	– 0·021	+ 0·039	+ 198·930	– 0·024	+ 198·906
15	16	33·60	+ 0·004	+ 0·043	+ 194·378	– 0·023	+ 194·355
16	17	37·95	– 0·046	– 0·003	+ 111·288	– 0·015	+ 111·273
17	18	42·07	+ 0·009	+ 0·006	+ 50·685	– 0·009	+ 50·676
18	19	50·26	+ 0·040	+ 0·046	– 35·107	– 0·001	– 35·108
19	20	52·15	+ 0·032	+ 0·078	– 44·713	0·000	– 44·713
20	21	56·33	+ 0·005	+ 0·083	– 75·423	+ 0·003	– 75·420
21	22	62·13	– 0·001	+ 0·082	– 139·580	+ 0·009	– 139·571
22	23	65·72	– 0·029	+ 0·053	– 174·566	+ 0·012	– 174·554
23	24	65·77	+ 0·006	+ 0·059	– 172·232	+ 0·012	– 172·220
24	25	68·48	– 0·007	+ 0·052	– 185·841	+ 0·013	– 185·828
25	26	73·01	+ 0·010	+ 0·062	– 212·142	+ 0·015	– 212·127
26	27	74·75	– 0·011	+ 0·051	– 229·633	+ 0·016	– 229·617
27	28	76·46	+ 0·017	+ 0·068	– 242·022	+ 0·017	– 242·005
28	29	79·27	– 0·026	+ 0·042	– 264·805	+ 0·019	– 264·786
29	30	79·30	+ 0·001	+ 0·043	– 268·534	+ 0·019	– 268·515
30	31	81·41	– 0·024	+ 0·019	– 281·985	+ 0·020	– 281·965
31	32	84·14	+ 0·012	+ 0·031	– 303·576	+ 0·022	– 303·554
32	33	86·70	– 0·019	+ 0·012	– 329·753	+ 0·024	– 329·729
33	34	86·81	+ 0·001	+ 0·013	– 327·119	+ 0·024	– 327·095
34	35	87·81	+ 0·021	+ 0·034	– 334·532	+ 0·025	– 334·507
35	36	91·65	– 0·022	+ 0·012	– 351·902	+ 0·026	– 351·876
36	37	95·32	+ 0·004	+ 0·016	– 336·895	+ 0·025	– 336·870
37	38	95·34	– 0·005	+ 0·011	– 336·586	+ 0·025	– 336·561
38	39	98·93	– 0·033	– 0·022	– 324·962	+ 0·024	– 324·938
39	40†	105·15	+ 0·005	– 0·017	– 315·279	+ 0·023	– 315·256

Difference of dynamic height, Rajkot to Viramgam = – 315·256 feet.

Length of line in miles = M = 105·15. $\Sigma d^2 = 0{\cdot}014337$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\dfrac{\Sigma d^2}{4M}} = \pm\, 0{\cdot}0039$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\dfrac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0404$.

* Bench-mark No. 1 is the mark at Rajkot described on page 195. † Bench-mark No. 40 is the mark at Viramgam described on page 136.

Line No. 50. Shikarpur (Cutch) to Viramgam.

Bench-marks		Distance from Shikarpur	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Shikarpur (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Shikarpur
From	To		From mark to mark (= d)	Total from Shikarpur		Total from Shikarpur	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	12·99	+ 0·080	+ 0·080	+ 23·529	– 0·001	+ 23·528
2	3	22·01	– 0·083	– 0·003	+ 35·952	– 0·001	+ 35·951
3	4	22·09	– 0·006	– 0·009	+ 34·954	– 0·001	+ 34·953
4	5	25·43	+ 0·001	– 0·008	+ 67·035	– 0·002	+ 67·033
5	6	29·41	+ 0·031	+ 0·023	+ 57·536	– 0·002	+ 57·534
6	7	31·64	+ 0·002	+ 0·025	+ 18·263	– 0·001	+ 18·262
7	8	34·34	+ 0·025	+ 0·050	– 39·485	+ 0·001	– 39·484
8	9	36·29	– 0·003	+ 0·047	– 35·947	+ 0·001	– 35·946
9	10	39·06	– 0·011	+ 0·036	+ 3·028	0·000	+ 3·028
10	11	48·84	– 0·089	– 0·053	+ 15·001	0·000	+ 15·001
11	12	62·38	– 0·061	– 0·114	– 18·040	+ 0·001	– 18·039
12	13	73·34	+ 0·017	– 0·097	+ 10·007	0·000	+ 10·007
13	14	86·81	+ 0·078	– 0·019	+ 13·912	0·000	+ 13·912
14	15	98·84	– 0·081	– 0·100	+ 10·220	0·000	+ 10·220
15	16	109·94	+ 0·048	– 0·052	– 9·612	+ 0·001	– 9·611
16	17	110·40	– 0·009	– 0·061	– 11·718	+ 0·001	– 11·717
17	18	110·63	0·000	– 0·061	– 10·740	+ 0·001	– 10·739
18	19	110·90	– 0·002	– 0·063	– 10·006	+ 0·001	– 10·005
19	20	111·31	+ 0·011	– 0·052	– 8·303	+ 0·001	– 8·302
20	21	111·61	– 0·012	– 0·064	– 7·207	+ 0·001	– 7·206
21	22	112·77	+ 0·016	– 0·048	– 4·674	+ 0·001	– 4·673
22	23	114·23	+ 0·014	– 0·034	– 0·244	+ 0·001	– 0·243
23	24	115·50	– 0·012	– 0·046	+ 3·315	+ 0·001	+ 3·316
24	25	115·74	– 0·003	– 0·049	+ 4·284	+ 0·001	+ 4·285
25	26	117·54	+ 0·004	– 0·045	+ 17·761	0·000	+ 17·761
26	27	119·30	+ 0·007	– 0·038	+ 19·768	0·000	+ 19·768
27	28	119·32	– 0·002	– 0·040	+ 23·851	0·000	+ 23·851
28	29	120·05	– 0·006	– 0·046	+ 23·832	0·000	+ 23·832
29	30	120·71	– 0·012	– 0·058	+ 25·491	0·000	+ 25·491
30	31	121·71	– 0·003	– 0·061	+ 28·274	0·000	+ 28·274
31	32	122·15	+ 0·003	– 0·058	+ 29·724	0·000	+ 29·724
32	33	122·76	– 0·017	– 0·075	+ 32·911	0·000	+ 32·911
33	34	123·33	+ 0·001	– 0·074	+ 33·772	0·000	+ 33·772
34	35	123·80	+ 0·005	– 0·069	+ 34·237	0·000	+ 34·237
35	36	124·82	– 0·004	– 0·073	+ 36·325	0·000	+ 36·325
36	37	125·61	+ 0·006	– 0·067	+ 37·969	0·000	+ 57·969
37	38†	127·63	– 0·006	– 0·073	+ 35·365	0·000	+ 35·365

Difference of dynamic height, Shikarpur to Viramgam = + 35·365 feet.

Length of line in miles = M = 127·63. $\Sigma d^2 = 0{\cdot}043551$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745 \sqrt{\dfrac{\Sigma d^2}{4M}} = \pm\, 0{\cdot}0062$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745 \sqrt{\dfrac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0704$.

* Bench-mark No. 1 is the mark at Shikarpur described on page 135. † Bench-mark No. 38 is the mark at Viramgam described on page 136.

Line No. 51. Viramgam to Bombay.

Bench-marks From	Bench-marks To	Distance from Viramgam	Discrepancy between levellers (First – Second leveller): From mark to mark (= d)	Discrepancy between levellers (First – Second leveller): Total from Viramgam	Observed elevation above (+) or below (–) Viramgam (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Viramgam	Dynamic height above (+) or below (–) Viramgam
		miles	foot	foot	feet	foot	feet
1*	2	0·38	+ 0·011	+ 0·011	+ 4·338	0·000	+ 4·338
2	3	2·15	+ 0·010	+ 0·021	+ 6·759	0·000	+ 6·759
3	4	5·29	– 0·015	+ 0·006	+ 12·106	0·000	+ 12·106
4	5	7·73	– 0·011	– 0·005	+ 13·252	0·000	+ 13·252
5	6	8·39	+ 0·006	+ 0·001	+ 19·823	0·000	+ 19·823
6	7	11·82	+ 0·020	+ 0·021	+ 20·983	0·000	+ 20·983
7	8	13·90	– 0·013	+ 0·008	+ 25·097	0·000	+ 25·097
8	9	19·00	+ 0·029	+ 0·037	+ 30·360	0·000	+ 30·360
9	10	22·26	+ 0·008	+ 0·045	+ 44·752	– 0·001	+ 44·751
10	11	23·25	+ 0·011	+ 0·056	+ 45·819	– 0·001	+ 45·818
11	12	23·26	– 0·006	+ 0·050	+ 41·372	– 0·001	+ 41·371
12	13	28·06	+ 0·006	+ 0·056	+ 64·818	– 0·003	+ 64·815
13	14	29·19	– 0·003	+ 0·053	+ 70·299	– 0·003	+ 70·296
14	15	30·49	+ 0·009	+ 0·062	+ 72·605	– 0·003	+ 72·602
15	16	32·20	– 0·002	+ 0·060	+ 84·054	– 0·004	+ 84·050
16	17	33·81	– 0·012	+ 0·048	+ 91·019	– 0·005	+ 91·014
17	18	36·20	+ 0·003	+ 0·051	+ 97·705	– 0·006	+ 97·699
18	19	37·76	+ 0·002	+ 0·053	+ 77·808	– 0·005	+ 77·803
19	20	38·50	– 0·004	+ 0·049	+ 85·595	– 0·006	+ 85·589
20	21	40·86	– 0·019	+ 0·030	+ 77·239	– 0·005	+ 77·234
21	22	40·96	– 0·010	+ 0·020	+ 78·145	– 0·005	+ 78·140
22	23	48·00	– 0·046	– 0·026	+ 45·292	– 0·003	+ 45·289
23	24	50·23	+ 0·014	– 0·012	+ 36·598	– 0·002	+ 36·596
24	25	51·45	+ 0·003	– 0·009	+ 31·370	– 0·002	+ 31·368
25	26	51·49	0·000	– 0·009	+ 32·911	– 0·002	+ 32·909
26	27	51·50	+ 0·005	– 0·004	+ 34·698	– 0·002	+ 34·696
27	28	53·76	– 0·022	– 0·026	+ 26·892	– 0·001	+ 26·891
28	29	54·97	+ 0·009	– 0·017	+ 29·430	– 0·001	+ 29·429
29	30	57·47	– 0·002	– 0·019	+ 25·748	– 0·001	+ 25·747
30	31	57·93	– 0·001	– 0·020	+ 21·561	– 0·001	+ 21·560
31	32	58·51	0·000	– 0·020	+ 24·083	– 0·001	+ 24·082
32	33	58·61	+ 0·003	– 0·017	+ 22·436	– 0·001	+ 22·435
33	34	58·62	0·000	– 0·017	+ 23·329	– 0·001	+ 23·328
34	35	63·68	+ 0·066	+ 0·049	+ 13·618	0·000	+ 13·618
35	36	65·73	+ 0·003	+ 0·052	+ 17·526	0·000	+ 17·526
36	37	67·21	+ 0·009	+ 0·061	+ 21·125	0·000	+ 21·125
37	38	69·65	– 0·015	+ 0·046	+ 29·669	– 0·001	+ 29·668
38	39	69·67	+ 0·001	+ 0·047	+ 26·774	– 0·001	+ 26·773
39	40	69·92	+ 0·004	+ 0·051	+ 26·851	– 0·001	+ 26·850
40	41	71·21	– 0·013	+ 0·038	+ 31·825	– 0·002	+ 31·823
41	42	73·94	– 0·019	+ 0·019	+ 32·501	– 0·002	+ 32·499
42	43	75·91	– 0·001	+ 0·018	+ 34·707	– 0·002	+ 34·705
43	44	76·35	+ 0·004	+ 0·022	+ 35·313	– 0·002	+ 35·311
44	45	76·80	– 0·008	+ 0·014	+ 35·567	– 0·002	+ 35·565
45	46	78·87	– 0·014	0·000	+ 42·575	– 0·003	+ 42·572
46	47	79·40	– 0·014	– 0·014	+ 43·202	– 0·003	+ 43·199
47	48	80·26	– 0·003	– 0·017	+ 43·716	– 0·003	+ 43·713
48	49	81·02	+ 0·001	– 0·016	+ 51·369	– 0·004	+ 51·365
49	50	81·04	+ 0·002	– 0·014	+ 51·104	– 0·004	+ 51·100
50	51	81·07	0·000	– 0·014	+ 47·784	– 0·004	+ 47·780
51	52	82·92	+ 0·008	– 0·006	+ 55·928	– 0·005	+ 55·923
52	53	85·07	+ 0·001	– 0·005	+ 46·806	– 0·004	+ 46·802
53	54	85·81	+ 0·007	+ 0·002	+ 47·398	– 0·004	+ 47·394
54	55	87·21	+ 0·012	+ 0·014	+ 44·250	– 0·004	+ 44·246
55	56	88·02	+ 0·007	+ 0·021	+ 42·179	– 0·004	+ 42·175
56	57	90·68	– 0·015	+ 0·006	+ 33·736	– 0·003	+ 33·733
57	58	90·71	– 0·001	+ 0·005	+ 33·068	– 0·003	+ 33·065
58	59	92·00	+ 0·007	+ 0·012	+ 14·329	– 0·001	+ 14·328
59	60	94·13	+ 0·001	+ 0·013	+ 32·239	– 0·003	+ 32·236
60	61	95·71	– 0·017	– 0·004	+ 35·538	– 0·003	+ 35·535

* Bench-mark No. 1 is the mark at Viramgam described on page 136.

Line No. 51. Viramgam to Bombay.—(Continued).

Bench-marks		Distance from Viramgam	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Viramgam (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Viramgam
From	To		From mark to mark (=*d*)	Total from Viramgam		Total from Viramgam	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	97·19	− 0·008	− 0·012	+ 36·233	− 0·003	+ 36·230
62	63	97·66	− 0·009	− 0·021	+ 34·912	− 0·003	+ 34·909
63	64	98·03	+ 0·004	− 0·017	+ 31·926	− 0·003	+ 31·923
64	65	98·44	0·000	− 0·017	+ 31·323	− 0·003	+ 31·320
65	66	99·39	+ 0·011	− 0·006	+ 29·414	− 0·003	+ 29·411
66	67	101·04	− 0·006	− 0·012	+ 29·703	− 0·003	+ 29·700
67	68	102·33	− 0·010	− 0·022	+ 24·600	− 0·002	+ 24·598
68	69	103·09	− 0·004	− 0·026	+ 22·386	− 0·002	+ 22·384
69	70	103·18	+ 0·002	− 0·024	+ 24·105	− 0·002	+ 24·103
70	71	103·66	+ 0·005	− 0·019	+ 23·120	− 0·002	+ 23·118
71	72	105·14	+ 0·012	− 0·007	+ 18·893	− 0·002	+ 18·891
72	73	106·56	+ 0·009	+ 0·002	+ 14·021	− 0·001	+ 14·020
73	74	107·70	− 0·004	− 0·002	+ 6·840	0·000	+ 6·840
74	75	109·41	− 0·007	− 0·009	− 1·342	+ 0·001	− 1·341
75	76	111·89	+ 0·003	− 0·006	− 5·857	+ 0·002	− 5·855
76	77	112·39	+ 0·001	− 0·005	− 5·668	+ 0·002	− 5·666
77	78	114·20	+ 0·010	+ 0·005	− 2·917	+ 0·002	− 2·915
78	79	114·34	+ 0·006	+ 0·011	− 3·043	+ 0·002	− 3·041
79	80	114·37	+ 0·004	+ 0·015	− 3·713	+ 0·002	− 3·711
80	81	115·70	+ 0·007	+ 0·022	− 4·965	+ 0·002	− 4·963
81	82	117·58	+ 0·006	+ 0·028	− 10·142	+ 0·003	− 10·139
82	83	117·73	+ 0·004	+ 0·032	− 9·873	+ 0·003	− 9·870
83	84	118·98	+ 0·027	+ 0·059	− 10·765	+ 0·003	− 10·762
84	85	120·08	+ 0·001	+ 0·060	− 6·415	+ 0·002	− 6·413
85	86	121·55	+ 0·011	+ 0·071	− 0·555	+ 0·001	− 0·554
86	87	121·59	+ 0·001	+ 0·072	+ 1·987	+ 0·001	+ 1·988
87	88	122·94	− 0·004	+ 0·068	− 3·992	+ 0·002	− 3·990
88	89	123·75	+ 0·014	+ 0·082	− 4·910	+ 0·002	− 4·908
89	90	125·85	+ 0·009	+ 0·091	− 5·312	+ 0·002	− 5·310
90	91	128·71	− 0·009	+ 0·082	− 4·974	+ 0·002	− 4·972
91	92	129·21	− 0·001	+ 0·081	− 4·248	+ 0·002	− 4·246
92	93	130·91	+ 0·007	+ 0·088	− 10·053	+ 0·003	− 10·050
93	94	131·06	− 0·001	+ 0·087	− 7·948	+ 0·003	− 7·945
94	95	131·31	− 0·006	+ 0·081	− 7·345	+ 0·003	− 7·342
95	96	133·97	− 0·037	+ 0·044	− 16·654	+ 0·004	− 16·650
96	97	135·65	+ 0·016	+ 0·060	− 22·015	+ 0·005	− 22·010
97	98	137·18	+ 0·014	+ 0·074	− 23·980	+ 0·005	− 23·975
98	99	138·68	− 0·014	+ 0·060	− 24·999	+ 0·005	− 24·994
99	100	139·24	+ 0·005	+ 0·065	− 24·860	+ 0·005	− 24·855
100	101	139·25	− 0·002	+ 0·063	− 25·231	+ 0·005	− 25·226
101	102	139·65	+ 0·010	+ 0·073	− 25·201	+ 0·005	− 25·196
102	103	142·54	+ 0·034	+ 0·107	− 24·562	+ 0·005	− 24·557
103	104	144·16	− 0·019	+ 0·088	− 25·568	+ 0·005	− 25·563
104	105	145·80	+ 0·023	+ 0·111	− 30·124	+ 0·006	− 30·118
105	106	146·79	+ 0·004	+ 0·115	− 36·788	+ 0·007	− 36·781
106	107	146·82	− 0·001	+ 0·114	− 32·100	+ 0·006	− 32·094
107	108	146·90	− 0·001	+ 0·113	− 36·368	+ 0·007	− 36·361
108	109	147·05	+ 0·002	+ 0·115	− 38·671	+ 0·007	− 38·664
109	110	147·79	− 0·007	+ 0·108	− 64·413	+ 0·011	− 64·402
110	111	151·31	+ 0·002	+ 0·110	− 41·021	+ 0·007	− 41·014
111	112	152·42	− 0·002	+ 0·108	− 31·047	+ 0·005	− 31·042
112	113	152·53	− 0·003	+ 0·105	− 32·323	+ 0·005	− 32·318
113	114	153·14	+ 0·002	+ 0·107	− 30·274	+ 0·005	− 30·269
114	115	156·47	+ 0·011	+ 0·118	− 16·895	+ 0·003	− 16·892
115	116	157·80	+ 0·005	+ 0·123	− 4·877	+ 0·001	− 4·876
116	117	158·81	− 0·007	+ 0·116	+ 0·427	0·000	+ 0·427
117	118	158·82	+ 0·005	+ 0·121	+ 1·709	0·000	+ 1·709
118	119	160·23	+ 0·014	+ 0·135	+ 3·644	0·000	+ 3·644
119	120	161·37	+ 0·004	+ 0·139	+ 14·981	− 0·002	+ 14·979
120	121	161·37	0·000	+ 0·139	+ 15·086	− 0·002	+ 15·084

Line No. 51. Viramgam to Bombay.—(Continued).

Bench-marks		Distance from Viramgam	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (−) Viramgam (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Viramgam
From	To		From mark to mark (= *d*)	Total from Viramgam		Total from Viramgam	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
121	122	166·38	+ 0·007	+ 0·146	− 30·145	+ 0·006	− 30·139
122	123	167·01	− 0·003	+ 0·143	− 29·837	+ 0·006	− 29·831
123	124	168·34	+ 0·002	+ 0·145	− 34·007	+ 0·007	− 34·000
124	125	168·64	+ 0·001	+ 0·146	− 31·121	+ 0·006	− 31·115
125	126	168·67	− 0·002	+ 0·144	− 32·326	+ 0·006	− 32·320
126	127	169·95	0·000	+ 0·144	− 31·283	+ 0·006	− 31·277
127	128	174·89	− 0·003	+ 0·141	− 28·763	+ 0·005	− 28·758
128	129	174·90	− 0·002	+ 0·139	− 27·434	+ 0·005	− 27·429
129	130	175·88	+ 0·001	+ 0·140	− 28·658	+ 0·005	− 28·653
130	131	178·31	+ 0·011	+ 0·151	− 35·955	+ 0·006	− 35·949
131	132	179·71	− 0·013	+ 0·138	− 33·940	+ 0·006	− 33·934
132	133	180·85	+ 0·004	+ 0·142	− 34·516	+ 0·006	− 34·510
133	134	181·18	− 0·001	+ 0·141	− 33·669	+ 0·006	− 33·663
134	135	181·58	− 0·006	+ 0·135	− 32·248	+ 0·006	− 32·242
135	136	183·04	+ 0·001	+ 0·136	− 33·558	+ 0·006	− 33·552
136	137	183·37	+ 0·007	+ 0·143	− 36·501	+ 0·007	− 36·494
137	138	183·45	− 0·001	+ 0·142	− 34·466	+ 0·007	− 34·459
138	139	184·19	0·000	+ 0·142	− 41·127	+ 0·008	− 41·119
139	140	185·49	+ 0·027	+ 0·169	− 54·298	+ 0·010	− 54·288
140	141	186·36	+ 0·005	+ 0·174	− 45·458	+ 0·008	− 45·450
141	142	187·82	− 0·014	+ 0·160	− 47·595	+ 0·008	− 47·587
142	143	188·90	+ 0·001	+ 0·161	− 46·966	+ 0·008	− 46·958
143	144	189·36	− 0·004	+ 0·157	− 47·988	+ 0·008	− 47·980
144	145	190·40	+ 0·006	+ 0·163	− 52·943	+ 0·009	− 52·934
145	146	191·34	− 0·001	+ 0·162	− 48·480	+ 0·008	− 48·472
146	147	192·01	+ 0·006	+ 0·168	− 51·450	+ 0·009	− 51·441
147	148	192·38	+ 0·002	+ 0·170	− 53·541	+ 0·009	− 53·532
148	149	192·39	+ 0·003	+ 0·173	− 53·120	+ 0·009	− 53·111
149	150	193·03	− 0·009	+ 0·164	− 56·604	+ 0·010	− 56·594
150	151	196·03	− 0·002	+ 0·162	− 49·505	+ 0·009	− 49·496
151	152	196·35	− 0·003	+ 0·159	− 47·439	+ 0·009	− 47·430
152	153	196·36	− 0·001	+ 0·158	− 50·966	+ 0·010	− 50·956
153	154	198·29	+ 0·011	+ 0·169	− 58·857	+ 0·012	− 58·845
154	155	200·01	+ 0·003	+ 0·172	− 66·586	+ 0·014	− 66·572
155	156	201·55	+ 0·016	+ 0·188	− 55·320	+ 0·012	− 55·308
156	157	201·64	− 0·002	+ 0·186	− 56·391	+ 0·012	− 56·379
157	158	202·33	+ 0·009	+ 0·195	− 51·501	+ 0·011	− 51·490
158	159	203·29	− 0·006	+ 0·189	− 39·977	+ 0·009	− 39·968
159	160	205·30	− 0·006	+ 0·183	− 46·421	+ 0·010	− 46·411
160	161	206·73	− 0·006	+ 0·177	− 46·005	+ 0·010	− 45·995
161	162	207·89	− 0·005	+ 0·172	− 38·394	+ 0·008	− 38·386
162	163	210·19	0·000	+ 0·172	− 43·234	+ 0·009	− 43·225
163	164	210·69	− 0·002	+ 0·170	− 46·079	+ 0·010	− 46·069
164	165	211·39	+ 0·003	+ 0·173	− 52·174	+ 0·011	− 52·163
165	166	211·41	0·000	+ 0·173	− 50·467	+ 0·011	− 50·456
166	167	212·16	+ 0·004	+ 0·177	− 60·938	+ 0·013	− 60·925
167	168	212·89	+ 0·005	+ 0·182	− 66·723	+ 0·014	− 66·709
168	169	213·84	+ 0·001	+ 0·183	− 61·950	+ 0·013	− 61·937
169	170	214·65	+ 0·002	+ 0·185	− 60·143	+ 0·013	− 60·130
170	171	214·68	− 0·002	+ 0·183	− 57·802	+ 0·013	− 57·789
171	172	215·47	+ 0·001	+ 0·184	− 58·917	+ 0·013	− 58·904
172	173	216·91	− 0·017	+ 0·167	− 43·019	+ 0·010	− 43·009
173	174	217·78	+ 0·007	+ 0·174	− 47·493	+ 0·011	− 47·482
174	175	217·99	0·000	+ 0·174	− 47·858	+ 0·011	− 47·847
175	176	218·61	0·000	+ 0·174	− 44·465	+ 0·010	− 44·455
176	177	219·19	0·000	+ 0·174	− 48·875	+ 0·011	− 48·864
177	178	219·61	+ 0·005	+ 0·179	− 46·861	+ 0·011	− 46·850
178	179	220·36	+ 0·007	+ 0·186	− 36·701	+ 0·009	− 36·692
179	180	220·37	0·000	+ 0·186	− 38·801	+ 0·009	− 38·792
180	181	221·55	+ 0·006	+ 0·192	− 45·346	+ 0·010	− 45·336

Line No. 51. Viramgam to Bombay.—(Continued).

Bench-marks		Distance from Viramgam	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Viramgam (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Viramgam
From	To		From mark to mark (= *d*)	Total from Viramgam		Total from Viramgam	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
181	182	223·05	− 0·023	+ 0·169	− 49·416	+ 0·011	− 49·405
182	183	225·00	− 0·005	+ 0·164	− 55·341	+ 0·012	− 55·329
183	184	225·98	− 0·011	+ 0·153	− 49·487	+ 0·011	− 49·476
184	185	226·01	+ 0·002	+ 0·155	− 47·302	+ 0·011	− 47·291
185	186	226·02	− 0·003	+ 0·152	− 46·925	+ 0·011	− 46·914
186	187	227·43	+ 0·007	+ 0·159	− 44·482	+ 0·011	− 44·471
187	188	228·73	− 0·002	+ 0·157	− 36·418	+ 0·009	− 36·409
188	189	230·61	+ 0·018	+ 0·175	− 44·877	+ 0·011	− 44·866
189	190	230·94	− 0·008	+ 0·167	− 47·171	+ 0·011	− 47·160
190	191	231·70	+ 0·005	+ 0·172	− 36·680	+ 0·009	− 36·671
191	192	232·43	+ 0·002	+ 0·174	− 45·778	+ 0·011	− 45·767
192	193	232·47	− 0·001	+ 0·173	− 43·891	+ 0·010	− 43·881
193	194	233·75	+ 0·013	+ 0·186	− 47·446	+ 0·011	− 47·435
194	195	234·83	− 0·006	+ 0·180	− 35·963	+ 0·008	− 35·955
195	196	234·84	− 0·002	+ 0·178	− 35·547	+ 0·008	− 35·539
196	197	236·08	− 0·006	+ 0·172	− 27·912	+ 0·006	− 27·906
197	198	237·24	+ 0·002	+ 0·174	− 35·161	+ 0·008	− 35·153
198	199	238·30	− 0·017	+ 0·157	− 37·103	+ 0·009	− 37·094
199	200	239·55	− 0·004	+ 0·153	− 30·877	+ 0·008	− 30·869
200	201	240·22	− 0·005	+ 0·148	− 20·528	+ 0·006	− 20·522
201	202	242·12	+ 0·010	+ 0·158	− 2·113	+ 0·002	− 2·111
202	203	242·15	− 0·005	+ 0·153	− 5·692	+ 0·003	− 5·689
203	204	242·18	+ 0·006	+ 0·159	− 3·352	+ 0·002	− 3·350
204	205	243·30	− 0·104	+ 0·055	− 18·034	+ 0·006	− 18·028
205	206	244·33	+ 0·003	+ 0·058	− 26·589	+ 0·008	− 26·581
206	207	244·75	− 0·018	+ 0·040	− 29·340	+ 0·009	− 29·331
207	208	246·28	− 0·004	+ 0·036	− 13·722	+ 0·005	− 13·717
208	209	247·38	+ 0·005	+ 0·041	− 10·254	+ 0·004	− 10·250
209	210	248·61	+ 0·001	+ 0·042	+ 3·262	+ 0·001	+ 3·263
210	211	249·12	+ 0·002	+ 0·044	+ 11·954	− 0·001	+ 11·953
211	212	249·13	+ 0·003	+ 0·047	+ 9·060	0·000	+ 9·060
212	213	250·27	− 0·001	+ 0·046	+ 15·047	− 0·001	+ 15·046
213	214	251·18	− 0·004	+ 0·042	+ 5·430	+ 0·001	+ 5·431
214	215	251·92	− 0·011	+ 0·031	− 2·509	+ 0·003	− 2·506
215	216	253·86	+ 0·026	+ 0·057	− 25·641	+ 0·009	− 25·632
216	217	256·26	+ 0·010	+ 0·067	− 41·154	+ 0·013	− 41·141
217	218	256·30	+ 0·001	+ 0·068	− 39·621	+ 0·013	− 39·608
218	219	256·78	− 0·004	+ 0·064	− 46·969	+ 0·015	− 46·954
219	220	257·71	+ 0·006	+ 0·070	− 40·212	+ 0·013	− 40·199
220	221	259·90	+ 0·009	+ 0·079	− 27·696	+ 0·010	− 27·686
221	222	261·44	+ 0·030	+ 0·109	− 37·240	+ 0·012	− 37·228
222	223	262·76	− 0·004	+ 0·105	− 50·874	+ 0·015	− 50·859
223	224	264·16	− 0·002	+ 0·103	− 48·321	+ 0·014	− 48·307
224	225	265·35	− 0·008	+ 0·095	− 58·905	+ 0·017	− 58·888
225	226	265·37	− 0·004	+ 0·091	− 56·274	+ 0·016	− 56·258
226	227	266·57	+ 0·001	+ 0·092	− 56·158	+ 0·016	− 56·142
227	228	268·00	+ 0·006	+ 0·098	− 62·708	+ 0·018	− 62·690
228	229	270·16	− 0·011	+ 0·087	− 48·586	+ 0·014	− 48·572
229	230	270·64	+ 0·007	+ 0·094	− 49·456	+ 0·014	− 49·442
230	231	271·34	− 0·008	+ 0·086	− 56·381	+ 0·016	− 56·365
231	232	272·22	− 0·011	+ 0·075	− 62·168	+ 0·018	− 62·150
232	233	272·27	+ 0·003	+ 0·078	− 60·193	+ 0·017	− 60·176
233	234	274·95	+ 0·006	+ 0·084	− 74·346	+ 0·021	− 74·325
234	235	277·28	− 0·012	+ 0·072	− 75·245	+ 0·021	− 75·224
235	236	279·44	− 0·002	+ 0·070	− 69·013	+ 0·019	− 68·994
236	237	280·79	− 0·005	+ 0·065	− 55·459	+ 0·015	− 55·444
237	238	281·50	− 0·004	+ 0·061	− 48·656	+ 0·013	− 48·643
238	239	283·46	+ 0·014	+ 0·075	− 46·049	+ 0·012	− 46·037
239	240	285·60	− 0·009	+ 0·066	− 40·603	+ 0·010	− 40·593
240	241	285·64	+ 0·001	+ 0·067	− 43·275	+ 0·011	− 43·264

Line No. 51. Viramgam to Bombay.—(Continued).

Bench-marks From	Bench-marks To	Distance from Viramgam	Discrepancy between levellers (First – Second leveller): From mark to mark (= d)	Discrepancy between levellers (First – Second leveller): Total from Viramgam	Observed elevation above (+) or below (−) Viramgam (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Viramgam	Dynamic height above (+) or below (−) Viramgam
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
241	242	287·03	− 0·018	+ 0·049	− 58·579	+ 0·015	− 58·564
242	243	288·38	− 0·002	+ 0·047	− 56·139	+ 0·014	− 56·125
243	244	289·26	− 0·005	+ 0·042	− 63·396	+ 0·016	− 63·380
244	245	290·26	+ 0·031	+ 0·073	− 66·466	+ 0·017	− 66·449
245	246	290·92	+ 0·012	+ 0·085	− 57·883	+ 0·015	− 57·868
246	247	292·61	+ 0·007	+ 0·092	− 37·070	+ 0·009	− 37·061
247	248	292·64	+ 0·005	+ 0·097	− 39·435	+ 0·010	− 39·425
248	249	294·95	+ 0·008	+ 0·105	− 40·691	+ 0·010	− 40·681
249	250	295·91	+ 0·017	+ 0·122	− 49·981	+ 0·013	− 49·968
250	251	296·29	+ 0·011	+ 0·133	− 54·653	+ 0·014	− 54·639
251	252	298·70	+ 0·015	+ 0·148	− 59·845	+ 0·016	− 59·829
252	253	299·53	− 0·007	+ 0·141	− 61·067	+ 0·016	− 61·051
253	254	301·68	+ 0·017	+ 0·158	− 71·365	+ 0·019	− 71·346
254	255	302·60	− 0·014	+ 0·144	− 71·947	+ 0·019	− 71·928
255	256	302·61	− 0·005	+ 0·139	− 73·597	+ 0·020	− 73·577
256	257	303·84	+ 0·009	+ 0·148	− 75·004	+ 0·020	− 74·984
257	258	305·11	+ 0·001	+ 0·149	− 64·728	+ 0·017	− 64·711
258	259	306·14	− 0·002	+ 0·147	− 64·920	+ 0·017	− 64·903
259	260	311·78	− 0·002	+ 0·145	− 68·568	+ 0·018	− 68·550
260	261	311·81	− 0·004	+ 0·141	− 71·133	+ 0·019	− 71·114
261	262	313·75	+ 0·019	+ 0·160	− 76·944	+ 0·021	− 76·923
262	263	316·49	− 0·008	+ 0·152	− 76·824	+ 0·021	− 76·803
263	264	316·81	− 0·009	+ 0·143	− 75·962	+ 0·021	− 75·941
264	265	316·84	+ 0·004	+ 0·147	− 77·738	+ 0·022	− 77·716
265	266	320·08	+ 0·015	+ 0·162	− 68·358	+ 0·019	− 68·339
266	267	321·40	+ 0·010	+ 0·172	− 69·067	+ 0·019	− 69·048
267	268	321·88	− 0·003	+ 0·169	− 70·110	+ 0·019	− 70·091
268	269	321·89	+ 0·006	+ 0·175	− 73·000	+ 0·020	− 72·980
269	270	325·86	+ 0·014	+ 0·189	− 63·322	+ 0·017	− 63·305
270	271	326·66	− 0·006	+ 0·183	− 53·976	+ 0·014	− 53·962
271	272	327·74	+ 0·013	+ 0·196	− 43·028	+ 0·011	− 43·017
272	273	327·76	− 0·005	+ 0·191	− 41·151	+ 0·010	− 41·141
273	274	329·32	− 0·001	+ 0·190	− 49·256	+ 0·012	− 49·244
274	275	330·48	− 0·007	+ 0·183	− 46·901	+ 0·011	− 46·890
275	276	331·18	+ 0·009	+ 0·192	− 45·928	+ 0·011	− 45·917
276	277	333·69	+ 0·002	+ 0·194	− 55·015	+ 0·014	− 55·001
277	278	335·23	− 0·003	+ 0·191	− 54·822	+ 0·014	− 54·808
278	279	335·24	+ 0·003	+ 0·194	− 56·920	+ 0·015	− 56·905
279	280	335·97	0·000	+ 0·194	− 60·696	+ 0·016	− 60·680
280	281	337·95	− 0·025	+ 0·169	− 69·246	+ 0·019	− 69·227
281	282	338·95	− 0·002	+ 0·167	− 73·260	+ 0·020	− 73·240
282	283	339·74	− 0·009	+ 0·158	− 77·184	+ 0·021	− 77·163
283	284	340·80	0·000	+ 0·158	− 80·551	+ 0·022	− 80·529
284	285	340·83	− 0·003	+ 0·155	− 78·613	+ 0·021	− 78·592
285	286	341·52	+ 0·004	+ 0·159	− 80·385	+ 0·022	− 80·363
286	287	342·39	+ 0·002	+ 0·161	− 77·052	+ 0·021	− 77·031
287	288	342·48	+ 0·005	+ 0·166	− 79·278	+ 0·022	− 79·256
288	289	343·30	− 0·009	+ 0·157	− 80·045	+ 0·022	− 80·023
289	290	344·05	+ 0·008	+ 0·165	− 82·059	+ 0·023	− 82·036
290	291	345·57	+ 0·001	+ 0·166	− 83·047	+ 0·023	− 83·024
291	292	346·17	+ 0·013	+ 0·179	− 83·980	+ 0·023	− 83·957
292	293	347·14	− 0·005	+ 0·174	− 83·300	+ 0·023	− 83·277
293	294	347·55	+ 0·003	+ 0·177	− 80·424	+ 0·022	− 80·402
294	295	347·66	− 0·002	+ 0·175	− 82·602	+ 0·023	− 82·579
295	296	347·87	− 0·002	+ 0·173	− 81·971	+ 0·023	− 81·948
296	297	349·86	+ 0·001	+ 0·174	− 73·694	+ 0·021	− 73·673
297	298	349·86	0·000	+ 0·174	− 76·180	+ 0·022	− 76·158
298	299*	350·60	+ 0·008	+ 0·182	− 70·138	+ 0·020	− 70·118

Difference of dynamic height, Viramgam to Bombay = − 70·118 feet.

Length of line in miles = M = 350·60. $\Sigma d^2 = 0{\cdot}043892$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4\text{M}}} = \pm\ 0{\cdot}0038$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0{\cdot}0707$.

* Bench-mark No. 299 is the mark at Bombay described on page 133.

Line No. 52. Sujawal to Shikarpur (Sind).

Bench-marks From	Bench-marks To	Distance from Sujawal	Discrepancy between levellers (First − Second leveller): From mark to mark (= *d*)	Discrepancy between levellers (First − Second leveller): Total from Sujawal	Observed elevation above (+) or below (−) Sujawal (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Sujawal	Dynamic height above (+) or below (−) Sujawal
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·09	+ 0·002	+ 0·002	+ 6·004	0·000	+ 6·004
2	3	1·69	+ 0·006	+ 0·008	− 0·767	0·000	− 0·767
3	4	3·36	+ 0·002	+ 0·010	− 0·430	0·000	− 0·430
4	5	4·75	+ 0·006	+ 0·016	− 0·441	0·000	− 0·441
5	6	9·21	− 0·018	− 0·002	+ 20·693	+ 0·001	+ 20·694
6	7	13·39	− 0·002	− 0·004	+ 1·217	0·000	+ 1·217
7	8	15·04	+ 0·013	+ 0·009	+ 3·419	0·000	+ 3·419
8	9	16·11	+ 0·007	+ 0·016	+ 5·642	0·000	+ 5·642
9	10	19·31	− 0·007	+ 0·009	+ 8·424	0·000	+ 8·424
10	11	22·38	− 0·003	+ 0·006	+ 7·361	0·000	+ 7·361
11	12	26·49	− 0·003	+ 0·003	+ 6·910	0·000	+ 6·910
12	13	28·65	+ 0·007	+ 0·010	+ 9·507	0·000	+ 9·507
13	14	30·11	− 0·004	+ 0·006	+ 12·634	0·000	+ 12·634
14	15	31·42	+ 0·020	+ 0·026	+ 16·655	0·000	+ 16·655
15	16	32·46	+ 0·005	+ 0·031	+ 12·729	0·000	+ 12·729
16	17	33·27	+ 0·003	+ 0·034	+ 12·850	0·000	+ 12·850
17	18	35·33	+ 0·004	+ 0·038	+ 14·019	0·000	+ 14·019
18	19	37·51	+ 0·012	+ 0·050	+ 25·770	+ 0·001	+ 25·771
19	20	38·20	+ 0·001	+ 0·051	+ 16·051	0·000	+ 16·051
20	21	39·64	+ 0·001	+ 0·052	+ 19·166	0·000	+ 19·166
21	22	41·11	+ 0·005	+ 0·057	+ 19·174	0·000	+ 19·174
22	23	42·55	0·000	+ 0·057	+ 19·282	0·000	+ 19·282
23	24	44·04	+ 0·009	+ 0·066	+ 19·824	0·000	+ 19·824
24	25	49·13	+ 0·013	+ 0·079	+ 28·352	+ 0·001	+ 28·353
25	26	49·76	+ 0·001	+ 0·080	+ 31·116	+ 0·001	+ 31·117
26	27	51·00	− 0·002	+ 0·078	+ 28·153	+ 0·001	+ 28·154
27	28	51·40	− 0·003	+ 0·075	+ 27·307	+ 0·001	+ 27·308
28	29	52·14	+ 0·002	+ 0·077	+ 27·780	+ 0·001	+ 27·781
29	30	53·28	+ 0·001	+ 0·078	+ 27·498	+ 0·001	+ 27·499
30	31	53·61	− 0·006	+ 0·072	+ 37·180	+ 0·002	+ 37·182
31	32	55·26	+ 0·009	+ 0·081	+ 28·939	+ 0·001	+ 28·940
32	33	55·66	− 0·003	+ 0·078	+ 33·820	+ 0·002	+ 33·822
33	34	57·78	+ 0·007	+ 0·085	+ 31·394	+ 0·002	+ 31·396
34	35	58·58	− 0·004	+ 0·081	+ 31·409	+ 0·002	+ 31·411
35	36	59·53	+ 0·006	+ 0·087	+ 31·438	+ 0·002	+ 31·440
36	37	60·11	− 0·001	+ 0·086	+ 33·372	+ 0·002	+ 33·374
37	38	63·54	− 0·004	+ 0·082	+ 36·126	+ 0·002	+ 36·128
38	39	64·35	− 0·006	+ 0·076	+ 35·074	+ 0·002	+ 35·076
39	40	65·54	+ 0·007	+ 0·083	+ 36·349	+ 0·002	+ 36·351
40	41	68·26	+ 0·014	+ 0·097	+ 38·247	+ 0·002	+ 38·249
41	42	68·80	+ 0·001	+ 0·098	+ 36·384	+ 0·002	+ 36·386
42	43	70·40	+ 0·007	+ 0·105	+ 38·218	+ 0·002	+ 38·220
43	44	71·50	− 0·001	+ 0·104	+ 49·347	+ 0·003	+ 49·350
44	45	73·96	− 0·007	+ 0·097	+ 40·638	+ 0·002	+ 40·640
45	46	75·73	+ 0·003	+ 0·100	+ 42·308	+ 0·002	+ 42·310
46	47	76·58	+ 0·010	+ 0·110	+ 40·721	+ 0·002	+ 40·723
47	48	78·07	− 0·001	+ 0·109	+ 40·916	+ 0·002	+ 40·918
48	49	80·43	+ 0·007	+ 0·116	+ 41·869	+ 0·002	+ 41·871
49	50	81·61	0·000	+ 0·116	+ 41·534	+ 0·002	+ 41·536
50	51	82·11	+ 0·004	+ 0·120	+ 52·858	+ 0·003	+ 52·861
51	52	83·69	+ 0·006	+ 0·126	+ 44·802	+ 0·002	+ 44·804
52	53	83·94	0·000	+ 0·126	+ 45·806	+ 0·002	+ 45·808
53	54	85·16	− 0·003	+ 0·123	+ 53·280	+ 0·003	+ 53·283
54	55	87·64	− 0·007	+ 0·116	+ 43·800	+ 0·002	+ 43·802
55	56	89·55	− 0·009	+ 0·107	+ 43·779	+ 0·002	+ 43·781
56	57	91·15	+ 0·001	+ 0·108	+ 45·664	+ 0·002	+ 45·666
57	58	92·99	+ 0·011	+ 0·119	+ 49·310	+ 0·002	+ 49·312
58	59	93·51	− 0·002	+ 0·117	+ 48·805	+ 0·002	+ 48·807
59	60	93·76	+ 0·002	+ 0·119	+ 50·931	+ 0·002	+ 50·933
60	61	95·79	− 0·009	+ 0·110	+ 44·629	+ 0·001	+ 44·630

*** Bench-mark No. 1 is the mark at Sujawal described on page 136.**

Line No. 52. Sujawal to Shikarpur (Sind).—(Continued).

Bench-marks		Distance from Sujawal	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Sujawal (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Sujawal
From	To		From mark to mark (= d)	Total from Sujawal		Total from Sujawal	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	97·70	– 0·007	+ 0·103	+ 50·731	+ 0·002	+ 50·733
62	63	99·50	– 0·003	+ 0·100	+ 44·968	+ 0·001	+ 44·969
63	64	100·10	– 0·010	+ 0·090	+ 51·600	+ 0·002	+ 51·602
64	65	101·41	0·000	+ 0·090	+ 51·000	+ 0·002	+ 51·002
65	66	103·25	– 0·004	+ 0·086	+ 43·654	+ 0·001	+ 43·655
66	67	103·56	+ 0·002	+ 0·088	+ 46·739	+ 0·001	+ 46·740
67	68	103·81	+ 0·002	+ 0·090	+ 48·734	+ 0·001	+ 48·735
68	69	105·26	– 0·004	+ 0·086	+ 50·195	+ 0·001	+ 50·196
69	70	107·35	– 0·002	+ 0·084	+ 51·763	+ 0·001	+ 51·764
70	71	108·72	0·000	+ 0·084	+ 50·489	+ 0·001	+ 50·490
71	72	110·82	– 0·007	+ 0·077	+ 51·787	+ 0·001	+ 51·788
72	73	112·21	+ 0·003	+ 0·080	+ 53·195	+ 0·001	+ 53·196
73	74	114·09	+ 0·004	+ 0·084	+ 50·916	+ 0·001	+ 50·917
74	75	115·50	+ 0·013	+ 0·097	+ 54·462	+ 0·002	+ 54·464
75	76	115·75	0·000	+ 0·097	+ 57·071	+ 0·002	+ 57·073
76	77	116·42	– 0·001	+ 0·096	+ 58·108	+ 0·002	+ 58·110
77	78	118·40	– 0·002	+ 0·094	+ 53·469	+ 0·001	+ 53·470
78	79	120·02	+ 0·003	+ 0·097	+ 53·395	+ 0·001	+ 53·396
79	80	121·86	0·000	+ 0·097	+ 56·117	+ 0·001	+ 56·118
80	81	124·26	+ 0·001	+ 0·098	+ 61·189	+ 0·002	+ 61·191
81	82	124·50	– 0·003	+ 0·095	+ 62·408	+ 0·002	+ 62·410
82	83	125·65	0·000	+ 0·095	+ 61·466	+ 0·002	+ 61·468
83	84	127·21	+ 0·015	+ 0·110	+ 61·212	+ 0·002	+ 61·214
84	85	129·02	+ 0·007	+ 0·117	+ 59·120	+ 0·002	+ 59·122
85	86	130·64	+ 0·003	+ 0·120	+ 64·115	+ 0·003	+ 64·118
86	87	130·88	– 0·001	+ 0·119	+ 65·052	+ 0·003	+ 65·055
87	88	131·08	– 0·004	+ 0·115	+ 61·376	+ 0·002	+ 61·378
88	89	132·20	– 0·006	+ 0·109	+ 61·583	+ 0·002	+ 61·585
89	90	134·14	+ 0·001	+ 0·110	+ 65·976	+ 0·003	+ 65·979
90	91	135·42	– 0·003	+ 0·107	+ 67·965	+ 0·003	+ 67·968
91	92	137·89	– 0·014	+ 0·093	+ 70·139	+ 0·003	+ 70·142
92	93	140·08	0·000	+ 0·093	+ 68·436	+ 0·003	+ 68·439
93	94	141·56	– 0·005	+ 0·088	+ 71·341	+ 0·004	+ 71·345
94	95	141·63	– 0·004	+ 0·084	+ 71·534	+ 0·004	+ 71·538
95	96	141·87	+ 0·003	+ 0·087	+ 72·392	+ 0·004	+ 72·396
96	97	143·11	+ 0·005	+ 0·092	+ 69·163	+ 0·003	+ 69·166
97	98	145·12	– 0·015	+ 0·077	+ 72·845	+ 0·004	+ 72·849
98	99	147·13	– 0·003	+ 0·074	+ 76·795	+ 0·005	+ 76·800
99	100	149·14	– 0·005	+ 0·069	+ 79·254	+ 0·005	+ 79·259
100	101	149·65	+ 0·006	+ 0·075	+ 82·159	+ 0·006	+ 82·165
101	102	149·90	+ 0·003	+ 0·078	+ 83·349	+ 0·006	+ 83·355
102	103	151·14	– 0·001	+ 0·077	+ 80·603	+ 0·005	+ 80·608
103	104	153·15	– 0·004	+ 0·073	+ 82·543	+ 0·005	+ 82·548
104	105	155·16	– 0·008	+ 0·065	+ 84·859	+ 0·005	+ 84·864
105	106	157·41	0·000	+ 0·065	+ 88·591	+ 0·006	+ 88·597
106	107	157·65	0·000	+ 0·065	+ 89·540	+ 0·006	+ 89·546
107	108	158·35	– 0·001	+ 0·064	+ 85·866	+ 0·005	+ 85·871
108	109	160·16	– 0·002	+ 0·062	+ 88·082	+ 0·005	+ 88·087
109	110	162·16	– 0·006	+ 0·056	+ 89·856	+ 0·005	+ 89·861
110	111	164·16	+ 0·004	+ 0·060	+ 91·379	+ 0·005	+ 91·384
111	112	166·31	+ 0·012	+ 0·072	+ 97·960	+ 0·006	+ 97·966
112	113	166·56	+ 0·001	+ 0·073	+ 99·295	+ 0·006	+ 99·301
113	114	166·94	0·000	+ 0·073	+ 96·475	+ 0·005	+ 96·480
114	115	168·76	– 0·014	+ 0·059	+ 99·131	+ 0·006	+ 99·137
115	116	169·64	– 0·002	+ 0·057	+ 100·268	+ 0·006	+ 100·274
116	117	171·50	– 0·002	+ 0·055	+ 104·591	+ 0·007	+ 104·598
117	118	173·59	– 0·001	+ 0·054	+ 102·474	+ 0·007	+ 102·481
118	119	175·24	0·000	+ 0·054	+ 105·001	+ 0·008	+ 105·009
119	120	177·91	– 0·007	+ 0·047	+ 108·777	+ 0·009	+ 108·786
120	121	179·56	+ 0·003	+ 0·050	+ 111·940	+ 0·010	+ 111·950

Line No. 52. Sujawal to Shikarpur (Sind).—(Continued).

Bench-marks From	Bench-marks To	Distance from Sujawal	Discrepancy between levellers (First – Second leveller): From mark to mark (=d)	Discrepancy between levellers (First – Second leveller): Total from Sujawal	Observed elevation above (+) or below (–) Sujawal (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Sujawal	Dynamic height above (+) or below (–) Sujawal
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
121	122	179·62	+ 0·001	+ 0·051	+ 112·162	+ 0·010	+ 112·172
122	123	181·21	+ 0·004	+ 0·055	+ 111·654	+ 0·010	+ 111·664
123	124	183·21	– 0·003	+ 0·052	+ 113·069	+ 0·010	+ 113·079
124	125	185·45	+ 0·008	+ 0·060	+ 108·542	+ 0·009	+ 108·551
125	126	187·38	– 0·009	+ 0·051	+ 116·363	+ 0·011	+ 116·374
126	127	189·74	+ 0·008	+ 0·059	+ 115·819	+ 0·011	+ 115·830
127	128	191·93	– 0·016	+ 0·043	+ 116·809	+ 0·011	+ 116·820
128	129	193·60	+ 0·012	+ 0·055	+ 121·884	+ 0·012	+ 121·896
129	130	195·35	+ 0·009	+ 0·064	+ 124·859	+ 0·013	+ 124·872
130	131	197·73	– 0·008	+ 0·056	+ 122·225	+ 0·012	+ 122·237
131	132	200·09	– 0·002	+ 0·054	+ 126·174	+ 0·013	+ 126·187
132	133	202·04	+ 0·006	+ 0·060	+ 129·005	+ 0·014	+ 129·019
133	134	203·93	– 0·020	+ 0·040	+ 125·559	+ 0·013	+ 125·572
134	135	204·20	0·000	+ 0·040	+ 129·012	+ 0·014	+ 129·026
135	136	205·64	– 0·003	+ 0·037	+ 126·620	+ 0·014	+ 126·634
136	137	207·65	– 0·021	+ 0·016	+ 128·131	+ 0·014	+ 128·145
137	138	209·89	+ 0·003	+ 0·019	+ 131·604	+ 0·015	+ 131·619
138	189	211·70	0·000	+ 0·019	+ 132·114	+ 0·015	+ 132·129
139	140	212·15	+ 0·009	+ 0·028	+ 135·402	+ 0·016	+ 135·418
140	141	214·11	– 0·009	+ 0·019	+ 133·464	+ 0·015	+ 133·479
141	142	215·82	+ 0·001	+ 0·020	+ 134·871	+ 0·015	+ 134·886
142	143	217·64	– 0·009	+ 0·011	+ 134·240	+ 0·015	+ 134·255
143	144	217·92	– 0·001	+ 0·010	+ 139·064	+ 0·016	+ 139·080
144	145	220·00	– 0·010	0·000	+ 138·816	+ 0·016	+ 138·832
145	146	221·59	+ 0·001	+ 0·001	+ 139·832	+ 0·016	+ 139·848
146	147	222·25	– 0·004	– 0·003	+ 144·127	+ 0·017	+ 144·144
147	148	224·07	– 0·011	– 0·014	+ 147·264	+ 0·018	+ 147·282
148	149	225·30	– 0·006	– 0·020	+ 143·967	+ 0·017	+ 143·984
149	150	227·31	– 0·006	– 0·026	+ 144·867	+ 0·017	+ 144·884
150	151	231·22	– 0·029	– 0·055	+ 152·401	+ 0·019	+ 152·420
151	152	231·28	+ 0·004	– 0·051	+ 152·156	+ 0·019	+ 152·175
152	153	232·12	+ 0·003	– 0·048	+ 151·338	+ 0·019	+ 151·357
153	154	234·13	– 0·010	– 0·058	+ 152·420	+ 0·019	+ 152·439
154	155	236·00	– 0·014	– 0·072	+ 149·233	+ 0·018	+ 149·251
155	156	237·99	– 0·003	– 0·075	+ 152·823	+ 0·019	+ 152·842
156	157	239·75	– 0·002	– 0·077	+ 162·452	+ 0·021	+ 162·473
157	158	239·81	0·000	– 0·077	+ 161·503	+ 0·021	+ 161·524
158	159	240·05	+ 0·001	– 0·076	+ 156·954	+ 0·020	+ 156·974
159	160	242·15	0·000	– 0·076	+ 162·847	+ 0·022	+ 162·869
160	161	244·16	– 0·012	– 0·088	+ 163·529	+ 0·022	+ 163·551
161	162	246·15	– 0·006	– 0·094	+ 163·354	+ 0·022	+ 163·376
162	163	247·31	+ 0·006	– 0·088	+ 164·525	+ 0·022	+ 164·547
163	164	248·14	– 0·007	– 0·095	+ 163·597	+ 0·022	+ 163·619
164	165	250·06	– 0·013	– 0·108	+ 163·325	+ 0·022	+ 163·347
165	166	252·13	+ 0·012	– 0·096	+ 168·053	+ 0·023	+ 168·076
166	167	254·08	+ 0·004	– 0·092	+ 172·645	+ 0·024	+ 172·669
167	168	256·88	– 0·003	– 0·095	+ 192·475	+ 0·029	+ 192·504
168	169	257·80	+ 0·014	– 0·081	+ 177·086	+ 0·025	+ 177·111
169	170	258·55	+ 0·009	– 0·072	+ 172·852	+ 0·024	+ 172·876
170	171	260·06	+ 0·014	– 0·058	+ 170·100	+ 0·023	+ 170·123
171	172	261·96	+ 0·009	– 0·049	+ 171·655	+ 0·023	+ 171·678
172	173	262·01	– 0·002	– 0·051	+ 171·351	+ 0·023	+ 171·374
173	174	263·97	– 0·015	– 0·066	+ 171·009	+ 0·023	+ 171·032
174	175	265·57	+ 0·009	– 0·057	+ 169·195	+ 0·022	+ 169·217
175	176	266·09	– 0·001	– 0·058	+ 170·652	+ 0·022	+ 170·674
176	177	267·34	+ 0·006	– 0·052	+ 168·646	+ 0·021	+ 168·667
177	178	269·19	+ 0·008	– 0·044	+ 168·820	+ 0·021	+ 168·841
178	179	273·05	– 0·006	– 0·050	+ 171·472	+ 0·022	+ 171·494
179	180	273·86	+ 0·003	– 0·047	+ 164·817	+ 0·020	+ 164·837
180	181	275·51	+ 0·002	– 0·045	+ 166·638	+ 0·021	+ 166·659

Line No. 52. Sujawal to Shikarpur (Sind).—(Continued).

Bench-marks		Distance from Sujawal	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (−) Sujawal (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Sujawal
From	To		From mark to mark (= d)	Total from Sujawal		Total from Sujawal	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
181	182	276·75	+ 0·005	− 0·040	+ 166·690	+ 0·021	+ 166·711
182	183	281·04	− 0·014	− 0·054	+ 172·567	+ 0·023	+ 172·590
183	184	282·92	− 0·009	− 0·063	+ 167·443	+ 0·021	+ 167·464
184	185*	282·21	+ 0·002	− 0·061	+ 165·206	+ 0·020	+ 165·226

Difference of dynamic height, Sujawal to Shikarpur = + 165·226 feet.

Length of line in miles = M = 282·21. Σd^2 = 0·010103.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4M}} = \pm\, 0{\cdot}0020.$

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0339.$

* Bench-mark No. 185 is the mark at Shikarpur described on page 135.

Line No. 53. Shikarpur (Sind) to Tatta.

Bench-marks		Distance from Shikarpur	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Shikarpur (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Shikarpur
From	To		From mark to mark (= d)	Total from Shikarpur		Total from Shikarpur	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	2·44	+ 0·002	+ 0·002	– 2·170	– 0·001	– 2·171
2	3	39·77	– 0·087	– 0·085	– 38·573	– 0·011	– 38·584
3	4	125·14	– 0·023	– 0·108	+ 9·030	– 0·001	+ 9·029
4	5	168·75	– 0·141	– 0·249	+ 74·685	– 0·015	– 74·700
5	6	176·58	– 0·010	– 0·259	– 79·335	– 0·016	– 79·351
6	7	177·56	+ 0·028	– 0·231	– 81·284	– 0·016	– 81·300
7	8	178·54	+ 0·017	– 0·214	– 83·012	– 0·016	– 83·028
8	9	179·54	+ 0·010	– 0·204	– 85·740	– 0·017	– 85·757
9	10	180·53	+ 0·009	– 0·195	– 79·734	– 0·016	– 79·750
10	11	181·51	+ 0·034	– 0·161	– 82·909	– 0·017	– 82·926
11	12	182·51	+ 0·022	– 0·139	– 82·369	– 0·017	– 82·386
12	13	183·50	+ 0·010	– 0·129	– 83·206	– 0·017	– 83·223
13	14	184·50	– 0·002	– 0·131	– 84·908	– 0·017	– 84·925
14	15	185·50	– 0·021	– 0·152	– 90·064	– 0·018	– 90·082
15	16	186·50	– 0·008	– 0·160	– 83·878	– 0·017	– 83·895
16	17	187·54	+ 0·006	– 0·154	– 87·047	– 0·018	– 87·065
17	18	188·57	+ 0·015	– 0·139	– 83·734	– 0·017	– 83·751
18	19	189·58	– 0·023	– 0·162	– 83·868	– 0·017	– 83·885
19	20	190·57	– 0·017	– 0·179	– 84·564	– 0·017	– 84·581
20	21	191·61	+ 0·009	– 0·170	– 84·665	– 0·017	– 84·682
21	22	192·65	+ 0·001	– 0·169	– 86·349	– 0·017	– 86·366
22	23	193·68	– 0·004	– 0·173	– 86·383	– 0·017	– 86·400
23	24	194·69	– 0·029	– 0·202	– 88·102	– 0·017	– 88·119
24	25	195·70	+ 0·005	– 0·197	– 88·019	– 0·017	– 88·036
25	26	196·71	– 0·013	– 0·210	– 87·746	– 0·017	– 87·763
26	27	197·71	– 0·017	– 0·227	– 88·632	– 0·017	– 88·649
27	28	198·99	+ 0·025	– 0·202	– 91·910	– 0·018	– 91·928
28	29	200·00	+ 0·018	– 0·184	– 89·729	– 0·018	– 89·747
29	30	201·01	+ 0·002	– 0·182	– 84·216	– 0·017	– 84·233
30	31	202·06	– 0·032	– 0·214	– 85·874	– 0·017	– 85·891
31	32	203·08	– 0·012	– 0·226	– 90·677	– 0·018	– 90·695
32	33	204·11	– 0·031	– 0·257	– 91·306	– 0·018	– 91·324
33	34	205·12	– 0·027	– 0·284	– 93·201	– 0·018	– 93·219
34	35	206·13	– 0·013	– 0·297	– 92·430	– 0·018	– 92·448
35	36	207·13	– 0·006	– 0·303	– 92·788	– 0·018	– 92·806
36	37	208·12	+ 0·002	– 0·301	– 92·711	– 0·018	– 92·729
37	38	209·13	– 0·017	– 0·318	– 93·992	– 0·018	– 94·010
38	39	210·16	– 0·033	– 0·351	– 94·158	– 0·018	– 94·176
39	40	211·16	– 0·031	– 0·382	– 96·576	– 0·018	– 96·594
40	41	212·16	– 0·006	– 0·388	– 98·748	– 0·018	– 98·766
41	42	213·19	+ 0·005	– 0·383	– 98·751	– 0·018	– 98·769
42	43	213·74	0·000	– 0·383	– 105·709	– 0·019	– 105·728
43	44	214·20	– 0·003	– 0·386	– 99·374	– 0·018	– 99·392
44	45	215·21	+ 0·025	– 0·361	– 101·367	– 0·018	– 101·385
45	46	216·21	+ 0·029	– 0·332	– 98·895	– 0·018	– 98·913
46	47	217·22	– 0·002	– 0·334	– 95·305	– 0·017	– 95·322
47	48	218·22	– 0·033	– 0·367	– 99·395	– 0·018	– 99·413
48	49	219·23	– 0·024	– 0·391	– 104·606	– 0·019	– 104·625
49	50	220·27	– 0·012	– 0·403	– 106·731	– 0·019	– 106·750
50	51	221·25	– 0·001	– 0·404	– 105·203	– 0·019	– 105·222
51	52	222·29	+ 0·008	– 0·396	– 106·280	– 0·019	– 106·299
52	53	223·42	– 0·004	– 0·400	– 106·454	– 0·019	– 106·473
53	54	224·43	– 0·009	– 0·409	– 107·015	– 0·019	– 107·034
54	55	225·43	– 0·017	– 0·426	– 106·072	– 0·019	– 106·091
55	56	226·51	– 0·007	– 0·433	– 105·874	– 0·019	– 105·893
56	57	227·50	– 0·003	– 0·436	– 105·989	– 0·019	– 106·008
57	58	228·48	+ 0·001	– 0·435	– 107·819	– 0·019	– 107·838
58	59	229·44	0·000	– 0·435	– 110·727	– 0·019	– 110·746
59	60	230·47	– 0·010	– 0·445	– 111·898	– 0·019	– 111·917
60	61	231·47	+ 0·016	– 0·429	– 113·031	– 0·019	– 113·050

* Bench-mark No. 1 is the mark at Shikarpur described on page 135.

Line No. 53. Shikarpur (Sind) to Tatta.—(Continued).

Bench-marks		Distance from Shikarpur	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Shikarpur (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Shikarpur
From	To		From mark to mark (=d)	Total from Shikarpur		Total from Shikarpur	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	232·50	− 0·014	− 0·443	− 114·120	− 0·019	− 114·139
62	63	233·51	− 0·013	− 0·456	− 115·148	− 0·019	− 115·167
63	64	234·51	− 0·010	− 0·466	− 113·968	− 0·019	− 113·987
64	65	237·55	+ 0·021	− 0·445	− 118·364	− 0·019	− 118·383
65	66	238·55	+ 0·010	− 0·435	− 119·543	− 0·019	− 119·562
66	67	239·55	+ 0·019	− 0·416	− 119·086	− 0·019	− 119·105
67	68	240·54	+ 0·008	− 0·408	− 119·797	− 0·019	− 119·816
68	69	241·53	− 0·022	− 0·430	− 120·541	− 0·019	− 120·560
69	70	242·53	− 0·011	− 0·441	− 122·888	− 0·019	− 122·907
70	71	243·53	+ 0·003	− 0·438	− 117·655	− 0·018	− 117·673
71	72	244·54	+ 0·014	− 0·424	− 117·864	− 0·018	− 117·882
72	73	245·54	+ 0·013	− 0·411	− 121·224	− 0·018	− 121·242
73	74	246·54	+ 0·004	− 0·407	− 122·180	− 0·018	− 122·198
74	75	247·54	+ 0·011	− 0·396	− 121·840	− 0·018	− 121·858
75	76	248·54	− 0·025	− 0·421	− 126·746	− 0·019	− 126·765
76	77	249·55	− 0·008	− 0·429	− 122·597	− 0·019	− 122·616
77	78	250·54	− 0·001	− 0·430	− 127·416	− 0·020	− 127·436
78	79	251·55	− 0·025	− 0·455	− 124·895	− 0·020	− 124·915
79	80	252·65	− 0·006	− 0·461	− 127·348	− 0·020	− 127·368
80	81	253·69	− 0·009	− 0·470	− 127·225	− 0·020	− 127·245
81	82	254·70	− 0·028	− 0·498	− 126·135	− 0·020	− 126·155
82	83	255·54	+ 0·004	− 0·494	− 127·662	− 0·020	− 127·682
83	84	255·80	0·000	− 0·494	− 129·933	− 0·020	− 129·953
84	85	256·88	+ 0·005	− 0·489	− 130·889	− 0·020	− 130·909
85	86	257·92	+ 0·005	− 0·484	− 128·536	− 0·020	− 128·556
86	87	259·03	+ 0·009	− 0·475	− 122·038	− 0·019	− 122·057
87	88	260·13	− 0·004	− 0·479	− 114·739	− 0·018	− 114·057
88	89	261·04	− 0·015	− 0·494	− 110·050	− 0·017	− 110·067
89	90	262·07	+ 0·029	− 0·465	− 108·875	− 0·017	− 108·892
90	91	263·10	− 0·012	− 0·477	− 114·443	− 0·018	− 114·461
91	92	264·14	− 0·015	− 0·492	− 117·253	− 0·018	− 117·271
92	93	267·10	+ 0·031	− 0·461	− 128·775	− 0·019	− 128·794
93	94	268·08	+ 0·014	− 0·447	− 135·559	− 0·020	− 135·579
94	95	269·03	− 0·019	− 0·466	− 138·965	− 0·020	− 138·985
95	96	269·98	− 0·002	− 0·468	− 137·236	− 0·020	− 137·256
96	97	270·94	+ 0·002	− 0·466	− 143·368	− 0·021	− 143·389
97	98	271·90	− 0·010	− 0·476	− 137·899	− 0·020	− 137·919
98	99	272·86	+ 0·009	− 0·467	− 138·432	− 0·020	− 138·452
99	100	273·84	+ 0·005	− 0·462	− 142·159	− 0·020	− 142·179
100	101	274·80	− 0·007	− 0·469	− 148·112	− 0·021	− 148·133
101	102	275·75	+ 0·009	− 0·460	− 138·568	− 0·020	− 138·588
102	103	276·65	− 0·003	− 0·463	− 130·223	− 0·019	− 130·242
103	104	277·64	− 0·002	− 0·465	− 126·347	− 0·019	− 126·366
104	105	278·65	− 0·025	− 0·490	− 116·375	− 0·018	− 116·393
105	106	279·56	− 0·017	− 0·507	− 106·798	− 0·017	− 106·815
106	107	280·50	− 0·005	− 0·512	− 111·995	− 0·017	− 112·012
107	108	281·49	− 0·002	− 0·514	− 146·646	− 0·019	− 146·665
108	109	282·45	− 0·009	− 0·523	− 147·394	− 0·019	− 147·413
109	110	283·41	+ 0·003	− 0·520	− 113·930	− 0·017	− 113·947
110	111	284·36	− 0·006	− 0·526	− 100·547	− 0·016	− 100·563
111	112	285·40	− 0·003	− 0·529	− 60·811	− 0·013	− 60·824
112	113	286·33	+ 0·005	− 0·524	− 116·758	− 0·017	− 116·775
113	114	287·26	+ 0·009	− 0·515	− 127·994	− 0·018	− 128·012
114	115	288·94	+ 0·008	− 0·507	− 155·637	− 0·020	− 155·657
115	116	289·15	− 0·001	− 0·508	− 151·131	− 0·020	− 151·151
116	117	290·11	0·000	− 0·508	− 149·443	− 0·020	− 149·463
117	118	291·10	− 0·003	− 0·511	− 148·889	− 0·020	− 148·909
118	119	292·04	− 0·006	− 0·517	− 151·262	− 0·020	− 151·282
119	120	292·99	− 0·006	− 0·523	− 150·315	− 0·020	− 150·335
120	121	293·96	+ 0·003	− 0·520	− 150·711	− 0·020	− 150·731

Line No. 53. Shikarpur (Sind) to Tatta.—(Continued).

Bench-marks		Distance from Shikarpur	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Shikarpur (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Shikarpur
From	To		From mark to mark (= d)	Total from Shikarpur		Total from Shikarpur	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
121	122	294·89	– 0·018	– 0·538	– 152·465	– 0·020	– 152·485
122	123	295·87	– 0·001	– 0·539	– 153·645	– 0·020	– 153·665
123	124	296·77	+ 0·012	– 0·527	– 142·937	– 0·019	– 142·956
124	125	297·71	+ 0·005	– 0·522	– 140·084	– 0·019	– 140·103
125	126	298·65	+ 0·013	– 0·509	– 131·530	– 0·018	– 131·548
126	127	299·66	– 0·003	– 0·512	– 121·390	– 0·017	– 121·407
127	128	300·61	– 0·012	– 0·524	– 133·030	– 0·018	– 133·048
128	129	301·52	0·000	– 0·524	– 122·054	– 0·017	– 122·071
129	130	302·50	0·000	– 0·524	– 119·748	– 0·017	– 119·765
130	131	302·99	+ 0·010	– 0·514	– 151·916	– 0·019	– 151·935
131	132	303·45	+ 0·001	– 0·513	– 165·161	– 0·020	– 165·181
132	133	304·39	– 0·003	– 0·516	– 163·561	– 0·020	– 163·581
133	134	305·34	– 0·004	– 0·520	– 162·479	– 0·020	– 162·499
134	135	306·26	+ 0·005	– 0·515	– 160·163	– 0·020	– 160·183
135	136	307·20	+ 0·001	– 0·514	– 158·799	– 0·020	– 158·819
136	137	308·17	– 0·007	– 0·521	– 159·738	– 0·020	– 159·758
137	138	309·11	– 0·008	– 0·529	– 160·458	– 0·020	– 160·478
138	139	309·99	– 0·002	– 0·531	– 158·427	– 0·020	– 158·447
139	140*	310·05	– 0·001	– 0·532	– 155·019	– 0·020	– 155·039

Difference of dynamic height, Shikarpur to Tatta = – 155·039 feet.

Length of line in miles = M = 310·05. $\Sigma d^2 = 0·055322$.

Probable error of the mean result per mile of double-levelling $= 0·6745\sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0·0046$.

Probable error of the difference of elevation between the terminal bench-marks $= 0·6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0·0793$.

* Bench-mark No. 140 is the mark at Tatta described on page 136.

Line No. 54. Shikarpur (Sind) to Murghai.

Bench-marks From	Bench-marks To	Distance from Shikarpur	Discrepancy between levellers (First – Second leveller): From mark to mark (= d)	Discrepancy between levellers (First – Second leveller): Total from Shikarpur	Observed elevation above (+) or below (–) Shikarpur (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Shikarpur	Dynamic height above (+) or below (–) Shikarpur
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	17·61	+ 0·098	+ 0·098	+ 9·589	+ 0·003	+ 9·592
2	3	28·51	– 0·031	+ 0·067	+ 19·429	+ 0·006	+ 19·435
3	4	67·54	+ 0·060	+ 0·127	+ 46·864	+ 0·015	+ 46·879
4	5	73·58	+ 0·081	+ 0·208	+ 52·773	+ 0·017	+ 52·790
5	6	80·26	+ 0·037	+ 0·245	+ 59·311	+ 0·019	+ 59·330
6	7	99·35	– 0·016	+ 0·229	+ 76·924	+ 0·025	+ 76·949
7	8	114·83	+ 0·002	+ 0·231	+ 82·879	+ 0·027	+ 82·906
8	9†	130·60	– 0·028	+ 0·203	+ 99·769	+ 0·033	+ 99·802

Difference of dynamic height, Shikarpur to Murghai = + 99·802 feet.

Length of line in miles = M = 130·60. $\Sigma d^2 = 0\cdot023139$.

Probable error of the mean result per mile of double-levelling $= 0\cdot6745\sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0\cdot0044$.

Probable error of the difference of elevation between the terminal bench-marks $= 0\cdot6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0\cdot0513$.

* Bench-mark No. 1 is the mark at Shikarpur described on page 135. † Bench-mark No. 9 is the mark at Murghai described on page 135.

Line No. 55. Murghai to Chach.

Bench-marks		Distance from Murghai	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Murghai (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Murghai
From	To		From mark to mark (=d)	Total from Murghai		Total from Murghai	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	14·29	+ 0·078	+ 0·078	+ 11·262	+ 0·004	+ 11·266
2	3	29·68	+ 0·047	+ 0·125	+ 27·999	+ 0·011	+ 28·010
3	4	42·21	+ 0·027	+ 0·152	+ 44·368	+ 0·018	+ 44·386
4	5	55·11	– 0·024	+ 0·128	+ 54·989	+ 0·023	+ 55·012
5	6	72·53	– 0·035	+ 0·093	+ 79·276	+ 0·034	+ 79·310
6	7	79·51	– 0·034	+ 0·059	+ 92·699	+ 0·040	+ 92·739
7	8	86·52	– 0·024	+ 0·035	+ 101·013	+ 0·044	+ 101·057
8	9	100·05	+ 0·077	+ 0·112	+ 115·974	+ 0·051	+ 116·025
9	10	142·46	+ 0·220	+ 0·332	+ 180·737	+ 0·083	+ 180·820
10	11	268·26	– 0·041	+ 0·291	+ 362·375	+ 0·200	+ 362·575
11	12	275·61	+ 0·028	+ 0·319	+ 371·788	+ 0·206	+ 371·994
12	13	291·35	– 0·008	+ 0·311	+ 393·487	+ 0·221	+ 393·708
13	14	299·04	+ 0·009	+ 0·320	+ 380·522	+ 0·212	+ 380·734
14	15	308·75	+ 0·025	+ 0·345	+ 456·097	+ 0·264	+ 456·361
15	16	323·44	– 0·086	+ 0·259	+ 763·640	+ 0·477	+ 764·117
16	17	333·67	– 0·007	+ 0·252	+ 549·713	+ 0·327	+ 550·040
17	18	347·66	– 0·072	+ 0·180	+ 643·746	+ 0·394	+ 644·140
18	19	397·49	– 0·345	– 0·165	+ 1418·054	+ 0·968	+ 1419·022
19	20†	427·44	+ 0·207	+ 0·042	+ 720·938	+ 0·431	+ 721·369

Difference of dynamic height, Murghai to Chach = + 721·369 feet.

Length of line in miles = M = 427·44. $\Sigma d^2 = 0\cdot244622$.

Probable error of the mean result per mile of double-levelling $= 0\cdot6745\sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0\cdot0081$.

Probable error of the difference of elevation between the terminal bench-marks $= 0\cdot6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0\cdot1668$.

* Bench-mark No. 1 is the mark at Murghai described on page 135. † Bench-mark No. 20 is the mark at Chach described on page 133.

Line No. 56. Ferozepore to Chach.

Bench-marks		Distance from Ferozepore	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Ferozepore (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Ferozepore
From	To		From mark to mark (=d)	Total from Ferozepore		Total from Ferozepore	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·82	+ 0·003	+ 0·003	+ 7·631	+ 0·004	+ 7·635
2	3	1·79	+ 0·018	+ 0·021	+ 4·236	+ 0·002	+ 4·238
3	4	2·76	+ 0·016	+ 0·037	+ 6·027	+ 0·003	+ 6·030
4	5	3·73	+ 0·006	+ 0·043	+ 8·878	+ 0·005	+ 8·883
5	6	4·69	− 0·004	+ 0·039	+ 8·678	+ 0·005	+ 8·683
6	7	5·70	− 0·007	+ 0·032	+ 8·516	+ 0·005	+ 8·521
7	8	9·19	− 0·062	− 0·030	+ 9·562	+ 0·006	+ 9·568
8	9	9·89	+ 0·025	− 0·005	+ 11·245	+ 0·007	+ 11·252
9	10	10·87	+ 0·001	− 0·004	+ 9·070	+ 0·006	+ 9·076
10	11	11·85	+ 0·010	+ 0·006	+ 9·365	+ 0·006	+ 9·371
11	12	12·82	− 0·002	+ 0·004	+ 8·888	+ 0·006	+ 8·894
12	13	13·79	− 0·003	+ 0·001	+ 8·555	+ 0·006	+ 8·561
13	14	14·77	− 0·001	0·000	+ 8·746	+ 0·006	+ 8·752
14	15	15·20	+ 0·002	+ 0·002	+ 28·455	+ 0·017	+ 28·472
15	16	15·63	− 0·009	− 0·007	+ 27·045	+ 0·016	+ 27·061
16	17	15·77	+ 0·002	− 0·005	+ 25·431	+ 0·015	+ 25·446
17	18	16·52	+ 0·001	− 0·004	+ 27·335	+ 0·016	+ 27·351
18	19	17·73	+ 0·002	− 0·002	+ 34·825	+ 0·020	+ 34·845
19	20	18·74	+ 0·011	+ 0·009	+ 43·405	+ 0·025	+ 43·430
20	21	19·73	0·000	+ 0·009	+ 43·210	+ 0·025	+ 43·235
21	22	20·71	+ 0·002	+ 0·011	+ 44·023	+ 0·026	+ 44·049
22	23	21·69	+ 0·023	+ 0·034	+ 44·076	+ 0·026	+ 44·102
23	24	22·67	− 0·037	− 0·003	+ 43·451	+ 0·026	+ 43·477
24	25	23·64	+ 0·012	+ 0·009	+ 44·216	+ 0·026	+ 44·242
25	26	24·62	+ 0·002	+ 0·011	+ 44·628	+ 0·026	+ 44·654
26	27	24·73	+ 0·006	+ 0·017	+ 42·489	+ 0·025	+ 42·514
27	28	25·11	− 0·009	+ 0·008	+ 45·037	+ 0·026	+ 45·063
28	29	25·65	− 0·001	+ 0·007	+ 49·285	+ 0·028	+ 49·313
29	30	26·22	− 0·005	+ 0·002	+ 55·682	+ 0·031	+ 55·713
30	31	26·62	− 0·004	− 0·002	+ 45·877	+ 0·025	+ 45·902
31	32	27·60	+ 0·004	+ 0·002	+ 44·620	+ 0·024	+ 44·644
32	33	28·57	− 0·009	− 0·007	+ 47·494	+ 0·026	+ 47·520
33	34	28·92	+ 0·002	− 0·005	+ 40·053	+ 0·022	+ 40·075
34	35	29·55	+ 0·004	− 0·001	+ 47·913	+ 0·027	+ 47·940
35	36	30·52	+ 0·002	+ 0·001	+ 47·716	+ 0·027	+ 47·743
36	37	32·47	+ 0·014	+ 0·015	+ 52·607	+ 0·030	+ 52·637
37	38	33·44	− 0·015	0·000	+ 51·741	+ 0·029	+ 51·770
38	39	33·64	− 0·001	− 0·001	+ 50·076	+ 0·028	+ 50·104
39	40	35·41	+ 0·010	+ 0·009	+ 48·640	+ 0·027	+ 48·667
40	41	36·38	+ 0·002	+ 0·011	+ 51·082	+ 0·028	+ 51·110
41	42	38·33	− 0·003	+ 0·008	+ 56·901	+ 0·031	+ 56·932
42	43	38·92	− 0·004	+ 0·004	+ 51·556	+ 0·028	+ 51·584
43	44	40·29	+ 0·007	+ 0·011	+ 52·767	+ 0·029	+ 52·796
44	45	40·55	− 0·006	+ 0·005	+ 52·583	+ 0·029	+ 52·612
45	46	41·28	− 0·002	+ 0·003	+ 53·389	+ 0·030	+ 53·419
46	47	42·25	− 0·003	0·000	+ 56·808	+ 0·032	+ 56·840
47	48	43·22	+ 0·003	+ 0·003	+ 58·736	+ 0·033	+ 58·769
48	49	43·97	+ 0·002	+ 0·005	+ 67·168	+ 0·038	+ 67·206
49	50	44·20	− 0·003	+ 0·002	+ 58·274	+ 0·033	+ 58·307
50	51	45·43	− 0·004	− 0·002	+ 60·407	+ 0·034	+ 60·441
51	52	46·00	− 0·002	− 0·004	+ 47·189	+ 0·027	+ 47·216
52	53	46·15	+ 0·007	+ 0·003	+ 49·810	+ 0·029	+ 49·839
53	54	47·13	+ 0·004	+ 0·007	+ 40·535	+ 0·024	+ 40·559
54	55	47·92	+ 0·003	+ 0·010	+ 58·550	+ 0·034	+ 58·584
55	56	49·50	− 0·011	− 0·001	+ 59·918	+ 0·035	+ 59·953
56	57	49·73	− 0·004	− 0·005	+ 60·788	+ 0·036	+ 60·824
57	58	51·39	+ 0·001	− 0·004	+ 52·415	+ 0·031	+ 52·446
58	59	52·67	+ 0·002	− 0·002	+ 61·636	+ 0·036	+ 61·672
59	60	54·65	− 0·005	− 0·007	+ 51·290	+ 0·030	+ 51·320
60	61	54·77	− 0·003	− 0·010	+ 51·480	+ 0·030	+ 51·510

* Bench-mark No. 1 is the mark at Ferozepore described on page 134.

Line No. 56. Ferozepore to Chach.—(Continued).

Bench-marks From	Bench-marks To	Distance from Ferozepore	Discrepancy between levellers (First – Second leveller): From mark to mark (= d)	Discrepancy between levellers (First – Second leveller): Total from Ferozepore	Observed elevation above (+) or below (−) Ferozepore (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Ferozepore	Dynamic height above (+) or below (−) Ferozepore
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	55·07	+ 0·003	− 0·007	+ 48·668	+ 0·028	+ 48·696
62	63	55·51	+ 0·011	+ 0·004	+ 46·627	+ 0·027	+ 46·654
63	64	56·83	+ 0·015	+ 0·019	+ 51·821	+ 0·030	+ 51·851
64	65	64·47	+ 0·004	+ 0·023	+ 60·960	+ 0·035	+ 60·995
65	66	66·13	+ 0·001	+ 0·024	+ 63·832	+ 0·037	+ 63·869
66	67	66·24	+ 0·001	+ 0·025	+ 63·732	+ 0·037	+ 63·769
67	68	67·28	− 0·003	+ 0·022	+ 60·931	+ 0·035	+ 60·966
68	69	69·94	+ 0·014	+ 0·036	+ 64·258	+ 0·037	+ 64·295
69	70	72·18	0·000	+ 0·036	+ 64·645	+ 0·037	+ 64·682
70	71	74·07	+ 0·008	+ 0·044	+ 75·027	+ 0·043	+ 75·070
71	72	76·15	− 0·007	+ 0·037	+ 76·789	+ 0·044	+ 76·833
72	73	78·74	0·000	+ 0·037	+ 84·580	+ 0·049	+ 84·629
73	74	78·87	0·000	+ 0·037	+ 84·490	+ 0·049	+ 84·539
74	75	84·81	+ 0·037	+ 0·074	+ 91·349	+ 0·053	+ 91·402
75	76	86·95	+ 0·016	+ 0·090	+ 95·942	+ 0·056	+ 95·998
76	77	88·43	+ 0·010	+ 0·100	+ 97·427	+ 0·057	+ 97·484
77	78	89·23	+ 0·003	+ 0·103	+ 98·127	+ 0·057	+ 98·184
78	79	90·71	0·000	+ 0·103	+ 99·011	+ 0·058	+ 99·069
79	80	91·39	+ 0·004	+ 0·107	+ 102·245	+ 0·060	+ 102·305
80	81	92·37	+ 0·003	+ 0·110	+ 101·758	+ 0·060	+ 101·818
81	82	96·67	− 0·001	+ 0·109	+ 107·610	+ 0·064	+ 107·674
82	83	98·65	− 0·001	+ 0·108	+ 108·030	+ 0·064	+ 108·094
83	84	101·35	− 0·028	+ 0·080	+ 111·630	+ 0·066	+ 111·696
84	85	101·47	− 0·001	+ 0·079	+ 111·701	+ 0·066	+ 111·767
85	86	102·18	− 0·013	+ 0·066	+ 108·937	+ 0·064	+ 109·001
86	87	103·73	− 0·006	+ 0·060	+ 110·959	+ 0·065	+ 111·024
87	88	106·03	+ 0·005	+ 0·065	+ 113·010	+ 0·066	+ 113·076
88	89	109·65	+ 0·015	+ 0·080	+ 110·786	+ 0·065	+ 110·851
89	90	111·65	− 0·003	+ 0·077	+ 108·043	+ 0·063	+ 108·106
90	91	119·19	− 0·032	+ 0·045	+ 116·640	+ 0·069	+ 116·709
91	92	120·03	+ 0·004	+ 0·049	+ 122·449	+ 0·073	+ 122·522
92	93	120·14	− 0·003	+ 0·046	+ 122·872	+ 0·073	+ 122·945
93	94	126·20	− 0·024	+ 0·022	+ 150·255	+ 0·091	+ 150·346
94	95	129·16	+ 0·024	+ 0·046	+ 171·211	+ 0·105	+ 171·316
95	96	130·50	− 0·001	+ 0·045	+ 181·397	+ 0·112	+ 181·509
96	97	131·74	+ 0.004	+ 0·049	+ 191·525	+ 0·119	+ 191·644
97	98	131·82	− 0·006	+ 0·043	+ 186·924	+ 0·116	+ 187·040
98	99	133·13	− 0·001	+ 0·042	+ 198·752	+ 0·124	+ 198·876
99	100	134·57	− 0·009	+ 0·033	+ 197·792	+ 0·123	+ 197·915
100	101	136·34	− 0·016	+ 0·017	+ 212·356	+ 0.133	+ 212·489
101	102	138·73	− 0·004	+ 0·013	+ 241·471	+ 0·153	+ 241·624
102	103	140·76	+ 0·014	+ 0·027	+ 295·645	+ 0·190	+ 295·835
103	104	141·26	− 0·001	+ 0·026	+ 313·275	+ 0·202	+ 313·477
104	105	141·36	− 0·001	+ 0·025	+ 313·749	+ 0·202	+ 313·951
105	106	141·55	+ 0·003	+ 0·028	+ 310·759	+ 0·200	+ 310·959
106	107	144·08	− 0·004	+ 0·024	+ 371·429	+ 0·241	+ 371·670
107	108	147·41	− 0·008	+ 0·016	+ 228·613	+ 0·143	+ 228·756
108	109	147·46	0·000	+ 0·016	+ 228·200	+ 0·143	+ 228·343
109	110	149·71	− 0·022	− 0·006	+ 129·048	+ 0·075	+ 129·123
110	111	150·99	+ 0·014	+ 0·008	+ 124·458	+ 0·072	+ 124·530
111	112	152·31	− 0·008	0·000	+ 121·415	+ 0·070	+ 121·485
112	113	152·44	+ 0·001	+ 0·001	+ 121·377	+ 0·070	+ 121·447
113	114	157·75	+ 0·049	+ 0·050	+ 256·976	+ 0·164	+ 257·140
114	115	157·92	0·000	+ 0·050	+ 265·267	+ 0·170	+ 265·437
115	116	158·52	0·000	+ 0·050	+ 290·341	+ 0·188	+ 290·529
116	117	160·65	− 0·016	+ 0·034	+ 287·329	+ 0·186	+ 287·515
117	118	163·09	− 0·017	+ 0·017	+ 253·964	+ 0·163	+ 254·127
118	119	163·24	− 0·006	+ 0·011	+ 258·945	+ 0·167	+ 259·112
119	120	163·35	− 0·002	+ 0·009	+ 258·947	+ 0·167	+ 259·114
120	121	167·07	+ 0·024	+ 0·033	+ 372·307	+ 0·246	+ 372·553

Line No. 56. Ferozepore to Chach.—(Continued).

Bench-marks		Distance from Ferozepore	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Ferozepore (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Ferozepore
From	To		From mark to mark (= d)	Total from Ferozepore		Total from Ferozepore	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
121	122	167·30	+ 0·006	+ 0·039	+ 384·049	+ 0·254	+ 384·303
122	123	167·93	+ 0·002	+ 0·041	+ 417·129	+ 0·277	+ 417·406
123	124	169·06	– 0·003	+ 0·038	+ 466·955	+ 0·312	+ 467·267
124	125	169·58	– 0·009	+ 0·029	+ 487·146	+ 0·326	+ 487·472
125	126	170·34	– 0·005	+ 0·024	+ 527·743	+ 0·354	+ 528·097
126	127	171·44	+ 0·005	+ 0·029	+ 545·658	+ 0·367	+ 546·025
127	128	171·55	+ 0·001	+ 0·030	+ 545·921	+ 0·367	+ 546·288
128	129	173·00	– 0·002	+ 0·028	+ 485·963	+ 0·325	+ 486·288
129	130	173·53	– 0·004	+ 0·024	+ 460·096	+ 0·307	+ 460·403
130	131	174·44	– 0·027	– 0·003	+ 429·652	+ 0·286	+ 429·938
131	132	176·10	+ 0·002	– 0·001	+ 482·362	+ 0·323	+ 482·685
132	133	178·26	+ 0·016	+ 0·015	+ 575·044	+ 0·388	+ 575·432
133	134	178·31	0·000	+ 0·015	+ 574·996	+ 0·388	+ 575·384
134	135	179·41	– 0·004	+ 0·011	+ 626·493	+ 0·425	+ 626·918
135	136	181·16	+ 0·013	+ 0·024	+ 711·311	+ 0·485	+ 711·796
136	137	183·25	– 0·015	+ 0·009	+ 784·742	+ 0·537	+ 785·279
137	138	183·34	+ 0·004	+ 0·013	+ 784·677	+ 0·537	+ 785·214
138	139	183·45	– 0·001	+ 0·012	+ 784·797	+ 0·537	+ 785·334
139	140	183·90	– 0·001	+ 0·011	+ 795·835	+ 0·545	+ 796·380
140	141	184·49	+ 0·001	+ 0·012	+ 819·174	+ 0·561	+ 819·735
141	142	185·54	+ 0·012	+ 0·024	+ 877·922	+ 0·603	+ 878·525
142	143	186·14	– 0·002	+ 0·022	+ 884·754	+ 0·608	+ 885·362
143	144	187·83	+ 0·001	+ 0·023	+ 808·080	+ 0·553	+ 808·633
144	145	188·66	+ 0·014	+ 0·037	+ 848·310	+ 0·581	+ 848·891
145	146	189·32	+ 0·010	+ 0·047	+ 875·642	+ 0·600	+ 876·242
146	147	189·43	+ 0·005	+ 0·052	+ 875·516	+ 0·600	+ 876·116
147	148	189·57	+ 0·004	+ 0·056	+ 871·077	+ 0·597	+ 871·674
148	149	190·98	+ 0·001	+ 0·057	+ 804·658	+ 0·550	+ 805·208
149	150	191·04	– 0·002	+ 0·055	+ 803·860	+ 0·549	+ 804·409
150	151	191·25	– 0·006	+ 0·049	+ 804·784	+ 0·550	+ 805·334
151	152	195·06	+ 0·003	+ 0·052	+ 859·670	+ 0·590	+ 860·260
152	153	195·20	+ 0·007	+ 0·059	+ 859·753	+ 0·590	+ 860·343
153	154	197·80	+ 0·013	+ 0·072	+ 989·514	+ 0·684	+ 990·198
154	155	200·63	+ 0·009	+ 0·081	+ 1064·111	+ 0·738	+ 1064·849
155	156	201·53	+ 0·005	+ 0·086	+ 1120·033	+ 0·779	+ 1120·812
156	157	202·01	+ 0·008	+ 0·094	+ 1129·282	+ 0·786	+ 1130·068
157	158	202·45	– 0·002	+ 0·092	+ 1112·116	+ 0·774	+ 1112·890
158	159	203·73	+ 0·002	+ 0·094	+ 1052·652	+ 0·731	+ 1053·383
159	160	203·84	– 0·003	+ 0·091	+ 1052·746	+ 0·731	+ 1053·477
160	161	206·17	– 0·007	+ 0·084	+ 1077·998	+ 0·749	+ 1078·747
161	162	207·10	+ 0·006	+ 0·090	+ 1127·448	+ 0·785	+ 1128·233
162	163	208·70	+ 0·014	+ 0·104	+ 1183·765	+ 0·826	+ 1184·591
163	164	209·99	+ 0·010	+ 0·114	+ 1178·394	+ 0·822	+ 1179·216
164	165	211·94	– 0·008	+ 0·106	+ 1117·635	+ 0·777	+ 1118·412
165	166	212·08	+ 0·003	+ 0·109	+ 1117·661	+ 0·777	+ 1118·438
166	167	212·82	+ 0·010	+ 0·119	+ 1097·905	+ 0·762	+ 1098·667
167	168	214·22	– 0·016	+ 0·103	+ 1032·542	+ 0·714	+ 1033·256
168	169	216·52	– 0·002	+ 0·101	+ 941·099	+ 0·647	+ 941·746
169	170	218·02	+ 0·008	+ 0·109	+ 871·951	+ 0·596	+ 872·547
170	171	218·13	0·000	+ 0·109	+ 871·796	+ 0·596	+ 872·392
171	172	218·20	– 0·002	+ 0·107	+ 861·342	+ 0·588	+ 861·930
172	173	218·60	– 0·003	+ 0·104	+ 869·613	+ 0·594	+ 870·207
173	174	219·70	+ 0·003	+ 0·107	+ 899·122	+ 0·616	+ 899·738
174	175	221·18	+ 0·005	+ 0·112	+ 928·876	+ 0·638	+ 929·514
175	176	225·33	+ 0·011	+ 0·123	+ 1017·327	+ 0·704	+ 1018·031
176	177	227·06	0·000	+ 0·123	+ 1004·251	+ 0·694	+ 1004·945
177	178	228·13	– 0·001	+ 0·122	+ 1010·450	+ 0·699	+ 1011·149
178	179	228·28	– 0·002	+ 0·120	+ 1008·352	+ 0·697	+ 1009·049
179	180	228·83	– 0·006	+ 0·114	+ 1016·617	+ 0·703	+ 1017·320
180	181	230·47	+ 0·004	+ 0·118	+ 1075·983	+ 0·747	+ 1076·730

Line No. 56. Ferozepore to Chach.—(Continued).

Bench-marks		Distance from Ferozepore	Discrepancy between levellers (First—Second leveller)		Observed elevation above (+) or below (−) Ferozepore (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Ferozepore
From	To		From mark to mark (=*d*)	Total from Ferozepore		Total from Ferozepore	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
181	182	232·20	− 0·001	+ 0·117	+ 1165·773	+ 0·739	+ 1166·512
182	183	233·41	+ 0·019	+ 0·136	+ 1225·186	+ 0·783	+ 1225·969
183	184	236·78	+ 0·007	+ 0·143	+ 1348·420	+ 0·876	+ 1349·296
184	185	236·95	− 0·002	+ 0·141	+ 1354·101	+ 0·880	+ 1354·981
185	186	239·59	+ 0·002	+ 0·143	+ 1238·795	+ 0·793	+ 1239·588
186	187	246·44	− 0·028	+ 0·115	+ 1073·325	+ 0·667	+ 1073·992
187	188	248·00	− 0·007	+ 0·108	+ 1048·060	+ 0·648	+ 1048·708
188	189	250·25	− 0·021	+ 0·087	+ 951·579	+ 0·575	+ 952·154
189	190	251·35	+ 0·001	+ 0·088	+ 907·537	+ 0·542	+ 908·079
190	191	253·48	− 0·020	+ 0·068	+ 868·176	+ 0·512	+ 868·688
191	192	254·89	− 0·003	+ 0·065	+ 834·702	+ 0·486	+ 835·188
192	193	256·85	− 0·003	+ 0·062	+ 826·438	+ 0·480	+ 826·918
193	194	257·38	+ 0·007	+ 0·069	+ 810·374	+ 0·468	+ 810·842
194	195	257·47	+ 0·001	+ 0·070	+ 809·510	+ 0·467	+ 809·977
195	196	262·43	− 0·024	+ 0·046	+ 637·271	+ 0·335	+ 637·606
196	197	264·07	+ 0·001	+ 0·047	+ 613·739	+ 0·317	+ 614·056
197	198	264·22	− 0·003	+ 0·044	+ 610·419	+ 0·315	+ 610·734
198	199	266·00	+ 0·021	+ 0·065	+ 604·249	+ 0·310	+ 604·559
199	200	268·69	+ 0·020	+ 0·085	+ 644·761	+ 0·341	+ 645·102
200	201	269·19	+ 0·005	+ 0·090	+ 670·236	+ 0·361	+ 670·597
201	202	269·24	− 0·001	+ 0·089	+ 670·245	+ 0·361	+ 670·606
202	203	269·38	+ 0·001	+ 0·090	+ 653·271	+ 0·348	+ 653·619
203	204	270·63	+ 0·001	+ 0·091	+ 589·121	+ 0·299	+ 589·420
204	205	272·82	+ 0·005	+ 0·096	+ 460·684	+ 0·201	+ 460·885
205	206	274·98	0·000	+ 0·096	+ 404·365	+ 0·158	+ 404·523
206	207	275·93	− 0·024	+ 0·072	+ 375·808	+ 0·136	+ 375·944
207	208	277·95	+ 0·005	+ 0·077	+ 348·789	+ 0·115	+ 348·904
208	209*	278·29	− 0·006	+ 0·071	+ 369·743	+ 0·131	+ 369·874

Difference of dynamic height, Ferozepore to Chach = + 369·874 feet.

Length of line in miles = M = 278·29. $\Sigma d^2 = 0{\cdot}027605$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\dfrac{\Sigma d^2}{4\mathrm{M}}} = \pm\, 0{\cdot}0033$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\dfrac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0560$.

* Bench-mark No. 209 is the mark at Chach described on page 133.

Line No. 57. Murghai to Ferozepore.

Bench-marks		Distance from Murghai	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Murghai (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Murghai
From	To		From mark to mark (= d)	Total from Murghai		Total from Murghai	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	5·05	+ 0·041	+ 0·041	+ 1·403	0·000	+ 1·403
2	3	15·35	– 0·279	– 0·238	+ 1·830	0·000	+ 1·830
3	4	32·34	– 0·034	– 0·272	+ 11·851	+ 0·004	+ 11·855
4	5	56·78	– 0·018	– 0·290	+ 33·420	+ 0·012	+ 33·432
5	6	70·87	– 0·018	– 0·308	+ 54·405	+ 0·020	+ 54·425
6	7	86·53	– 0·030	– 0·338	+ 73·466	+ 0·027	+ 73·493
7	8	99·08	– 0·004	– 0·342	+ 81·326	+ 0·030	+ 81·356
8	9	112·91	– 0·051	– 0·393	+ 96·407	+ 0·036	+ 96·443
9	10	137·63	– 0·064	– 0·457	+ 125·089	+ 0·048	+ 125·137
10	11	150·68	– 0·072	– 0·529	+ 141·260	+ 0·055	+ 141·315
11	12	161·73	+ 0·010	– 0·519	+ 158·571	+ 0·062	+ 158·633
12	13	172·19	+ 0·055	– 0·464	+ 170·796	+ 0·067	+ 170·863
13	14	186·34	– 0·015	– 0·479	+ 188·186	+ 0·075	+ 188·261
14	15	195·44	– 0·070	– 0·549	+ 198·748	+ 0·080	+ 198·828
15	16	208·48	+ 0·003	– 0·546	+ 216·872	+ 0·088	+ 216·960
16	17	219·03	+ 0·002	– 0·544	+ 226·790	+ 0·093	+ 226·883
17	18	232·81	+ 0·001	– 0·543	+ 255·074	+ 0·106	+ 255·180
18	19	245·34	– 0·001	– 0·544	+ 262·340	+ 0·109	+ 262·449
19	20	253·82	– 0·016	– 0·560	+ 277·080	+ 0·116	+ 277·196
20	21	262·51	+ 0·018	– 0·542	+ 291·660	+ 0·123	+ 291·783
21	22	266·61	– 0·003	– 0·545	+ 292·536	+ 0·124	+ 292·660
22	23	270·93	+ 0·055	– 0·490	+ 295·100	+ 0·125	+ 295·225
23	24	283·66	– 0·016	– 0·506	+ 319·845	+ 0·137	+ 319·982
24	25	297·06	– 0·028	– 0·534	+ 331·655	+ 0·143	+ 331·798
25	26	302·42	– 0·032	– 0·566	+ 342·563	+ 0·149	+ 342·712
26	27†	311·97	0·000	– 0·566	+ 351·815	+ 0·154	+ 351·969

Difference of dynamic height, Murghai to Ferozepore = + 351·969 feet.

Length of line in miles = M = 311·97. $\Sigma d^2 = 0 \cdot 108066$.

Probable error of the mean result per mile of double-levelling $= 0 \cdot 6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm 0 \cdot 0062$.

Probable error of the difference of elevation between the terminal bench-marks $= 0 \cdot 6745 \sqrt{\frac{\Sigma d^2}{4}} = \pm 0 \cdot 1109$.

* Bench-mark No. 1 is the mark at Murghai described on page 135. † Bench-mark No. 27 is the mark at Ferozepore described on page 134.

Line No. 58. Bilaspur to Katni.

Bench-marks		Distance from Bilaspur	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Bilaspur (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Bilaspur
From	To		From mark to mark (= d)	Total from Bilaspur		Total from Bilaspur	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·83	– 0·010	– 0·010	– 0·933	0·000	– 0·933
2	3	9·41	+ 0·067	+ 0·057	+ 49·688	– 0·007	+ 49·681
3	4	9·93	– 0·001	+ 0·056	+ 53·842	– 0·007	+ 53·835
4	5	9·98	– 0·003	+ 0·053	+ 53·565	– 0·007	+ 53·558
5	6	9·99	– 0·001	+ 0·052	+ 54·006	– 0·007	+ 53·999
6	7	10·04	0·000	+ 0·052	+ 54·090	– 0·007	+ 54·083
7	8	10·55	0·000	+ 0·052	+ 55·393	– 0·007	+ 55·386
8	9	11·29	+ 0·015	+ 0·067	+ 62·751	– 0·008	+ 62·743
9	10	11·80	– 0·008	+ 0·059	+ 62·746	– 0·008	+ 62·738
10	11	12·49	– 0·007	+ 0·052	+ 70·502	– 0·009	+ 70·493
11	12	14·18	+ 0·026	+ 0·078	+ 84·441	– 0·011	+ 84·430
12	13	15·15	+ 0·014	+ 0·092	+ 95·050	– 0·012	+ 95·038
13	14	15·70	– 0·001	+ 0·091	+ 95·474	– 0·012	+ 95·462
14	15	17·31	– 0·019	+ 0·072	+ 108·568	– 0·013	+ 108·555
15	16	18·23	– 0·010	+ 0·062	+ 127·015	– 0·015	+ 127·000
16	17	19·20	+ 0·015	+ 0·077	+ 159·136	– 0·019	+ 159·117
17	18	19·45	– 0·004	+ 0·073	+ 164·325	– 0·020	+ 164·305
18	19	19·73	+ 0·003	+ 0·076	+ 167·502	– 0·020	+ 167·482
19	20	19·78	+ 0·001	+ 0·077	+ 167·042	– 0·020	+ 167·022
20	21	19·79	0·000	+ 0·077	+ 167·621	– 0·020	+ 167·601
21	22	19·85	+ 0·001	+ 0·078	+ 167·742	– 0·020	+ 167·722
22	23	20·08	– 0·010	+ 0·068	+ 169·188	– 0·020	+ 169·168
23	24	22·01	+ 0·001	+ 0·069	+ 196·635	– 0·023	+ 196·612
24	25	23·16	– 0·006	+ 0·063	+ 204·271	– 0·024	+ 204·247
25	26	23·91	– 0·004	+ 0·059	+ 193·607	– 0·023	+ 193·584
26	27	24·44	+ 0·001	+ 0·060	+ 195·686	– 0·023	+ 195·663
27	28	25·85	0·000	+ 0·060	+ 169·900	– 0·020	+ 169·880
28	29	27·34	– 0·007	+ 0·053	+ 195·062	– 0·023	+ 195·039
29	30	28·03	+ 0·008	+ 0·061	+ 196·678	– 0·023	+ 196·655
30	31	28·73	– 0·006	+ 0·055	+ 206·398	– 0·024	+ 206·374
31	32	29·46	+ 0·003	+ 0·058	+ 203·254	– 0·024	+ 203·230
32	33	29·51	+ 0·001	+ 0·059	+ 203·145	– 0·024	+ 203·121
33	34	29·60	+ 0·002	+ 0·061	+ 203·313	– 0·024	+ 203·289
34	35	30·13	– 0·005	+ 0·056	+ 203·061	– 0·024	+ 203·037
35	36	31·29	– 0·007	+ 0·049	+ 215·885	– 0·025	+ 215·860
36	37	31·90	0·000	+ 0·049	+ 222·227	– 0·026	+ 222·201
37	38	32·83	– 0·003	+ 0·046	+ 239·889	– 0·028	+ 239·861
38	39	33·70	+ 0·002	+ 0·048	+ 258·079	– 0·030	+ 258·049
39	40	34·35	+ 0·007	+ 0·055	+ 274·996	– 0·032	+ 274·064
40	41	35·30	– 0·001	+ 0·054	+ 306·713	– 0·035	+ 306·678
41	42	36·08	– 0·009	+ 0·045	+ 306·790	– 0·035	+ 306·755
42	43	36·59	– 0·008	+ 0·037	+ 316·841	– 0·036	+ 316·805
43	44	37·03	+ 0·004	+ 0·041	+ 309·465	– 0·035	+ 309·430
44	45	37·75	+ 0·013	+ 0·054	+ 293·169	– 0·033	+ 293·136
45	46	38·99	+ 0·008	+ 0·062	+ 324·117	– 0·036	+ 324·081
46	47	39·39	0·000	+ 0·062	+ 329·072	– 0·037	+ 329·035
47	48	40·14	– 0·004	+ 0·058	+ 327·519	– 0·037	+ 327·482
48	49	40·77	+ 0·006	+ 0·064	+ 335·045	– 0·038	+ 335·007
49	50	40·82	+ 0·002	+ 0·066	+ 335·592	– 0·038	+ 335·554
50	51	40·83	– 0·002	+ 0·064	+ 335·031	– 0·038	+ 334·993
51	52	40·89	+ 0·002	+ 0·066	+ 335·057	– 0·038	+ 335·019
52	53	41·80	+ 0·036	+ 0·102	+ 334·840	– 0·038	+ 334·802
53	54	43·50	+ 0·007	+ 0·109	+ 348·786	– 0·039	+ 348·747
54	55	45·34	+ 0·007	+ 0·116	+ 437·441	– 0·048	+ 437·393
55	56	45·84	+ 0·008	+ 0·124	+ 464·369	– 0·050	+ 464·319
56	57	46·84	+ 0·010	+ 0·134	+ 517·440	– 0·055	+ 517·385
57	58	49·29	+ 0·015	+ 0·149	+ 627·906	– 0·056	+ 627·850
58	59	49·50	+ 0·003	+ 0·152	+ 638·387	– 0·057	+ 638·330
59	60	49·72	+ 0·005	+ 0·157	+ 650·598	– 0·058	+ 650·540
60	61	50·44	+ 0·001	+ 0·158	+ 691·691	– 0·062	+ 691·629

* Bench-mark No. 1 is the mark at Bilaspur described on page 189.

Line No. 58. Bilaspur to Katni.—(Continued).

Bench-marks		Distance from Bilaspur	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Bilaspur (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Bilaspur
From	To		From mark to mark (= d)	Total from Bilaspur		Total from Bilaspur	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	50·96	+ 0·014	+ 0·172	+ 712·809	− 0·064	+ 712·745
62	63	51·35	+ 0·016	+ 0·188	+ 735·584	− 0·066	+ 735·518
63	64	51·69	+ 0·012	+ 0·200	+ 752·572	− 0·068	+ 752·504
64	65	53·79	+ 0·049	+ 0·249	+ 863·519	− 0·078	+ 863·441
65	66	53·95	+ 0·003	+ 0·252	+ 873·039	− 0·079	+ 872·960
66	67	55·08	+ 0·008	+ 0·260	+ 930·300	− 0·084	+ 930·216
67	68	55·47	+ 0·009	+ 0·269	+ 934·572	− 0·084	+ 934·488
68	69	55·52	+ 0·001	+ 0·270	+ 935·022	− 0·084	+ 934·938
69	70	55·53	+ 0·002	+ 0·272	+ 934·870	− 0·084	+ 934·786
70	71	55·58	+ 0·001	+ 0·273	+ 935·120	− 0·084	+ 935·036
71	72	55·79	+ 0·006	+ 0·279	+ 936·140	− 0·084	+ 936·056
72	73	56·85	+ 0·013	+ 0·292	+ 964·858	− 0·087	+ 964·771
73	74	57·93	− 0·003	+ 0·289	+ 998·755	− 0·090	+ 998·665
74	75	58·46	0·000	+ 0·289	+ 1005·937	− 0·091	+ 1005·846
75	76	59·26	+ 0·010	+ 0·299	+ 1036·540	− 0·094	+ 1036·446
76	77	60·47	+ 0·002	+ 0·301	+ 1070·823	− 0·097	+ 1070·726
77	78	62·57	+ 0·011	+ 0·312	+ 1145·457	− 0·103	+ 1145·354
78	79	62·62	− 0·004	+ 0·308	+ 1145·772	− 0·103	+ 1145·669
79	80	62·63	0·000	+ 0·308	+ 1145·541	− 0·103	+ 1145·438
80	81	62·68	0·000	+ 0·308	+ 1145·448	− 0·103	+ 1145·345
81	82	63·18	+ 0·001	+ 0·309	+ 1136·224	− 0·102	+ 1136·122
82	83	64·38	− 0·024	+ 0·285	+ 1093·884	− 0·099	+ 1093·785
83	84	66·66	− 0·005	+ 0·280	+ 1063·297	− 0·097	+ 1063·200
84	85	69·01	+ 0·003	+ 0·283	+ 1020·551	− 0·094	+ 1020·457
85	86	70·37	+ 0·003	+ 0·286	+ 978·730	− 0·091	+ 978·639
86	87	74·23	− 0·006	+ 0·280	+ 911·915	− 0·086	+ 911·829
87	88	74·25	− 0·002	+ 0·278	+ 911·795	− 0·086	+ 911·709
88	89	74·26	+ 0·003	+ 0·281	+ 911·566	− 0·086	+ 911·480
89	90	74·85	− 0·001	+ 0·280	+ 903·534	− 0·085	+ 903·449
90	91	76·82	− 0·007	+ 0·273	+ 856·315	− 0·082	+ 856·233
91	92	77·74	+ 0·012	+ 0·285	+ 879·186	− 0·084	+ 879·102
92	93	78·41	− 0·003	+ 0·282	+ 879·076	− 0·084	+ 878·992
93	94	79·25	+ 0·004	+ 0·286	+ 886·923	− 0·085	+ 886·838
94	95	80·05	− 0·004	+ 0·282	+ 865·451	− 0·083	+ 865·368
95	96	80·54	− 0·008	+ 0·274	+ 853·256	− 0·082	+ 853·174
96	97	81·50	− 0·022	+ 0·252	+ 853·898	− 0·082	+ 853·816
97	98	82·82	− 0·003	+ 0·249	+ 851·943	− 0·082	+ 851·861
98	99	84·63	− 0·005	+ 0·244	+ 807·349	− 0·079	+ 807·270
99	100	85·13	+ 0·005	+ 0·249	+ 807·049	− 0·079	+ 806·970
100	101	85·70	− 0·009	+ 0·240	+ 796·125	− 0·078	+ 796·047
101	102	92·51	0·000	+ 0·240	+ 677·924	− 0·071	+ 677·853
102	103	93·59	+ 0·004	+ 0·244	+ 702·463	− 0·073	+ 702·390
103	104	93·64	+ 0·001	+ 0·245	+ 702·526	− 0·073	+ 702·453
104	105	93·90	− 0·002	+ 0·243	+ 701·841	− 0·073	+ 701·768
105	106	94·32	− 0·001	+ 0·242	+ 698·491	− 0·073	+ 698·418
106	107	96·99	+ 0·005	+ 0·247	+ 731·650	− 0·075	+ 731·575
107	108	97·93	− 0·001	+ 0·246	+ 703·221	− 0·073	+ 703·148
108	109	99·16	− 0·007	+ 0·239	+ 733·223	− 0·075	+ 733·148
109	110	100·00	+ 0·008	+ 0·247	+ 738·498	− 0·075	+ 738·423
110	111	101·06	+ 0·004	+ 0·251	+ 732·526	− 0·075	+ 732·451
111	112	102·48	− 0·016	+ 0·235	+ 702·833	− 0·073	+ 702·760
112	113	103·24	+ 0·009	+ 0·244	+ 683·643	− 0·072	+ 683·571
113	114	103·59	+ 0·006	+ 0·250	+ 672·091	− 0·071	+ 672·020
114	115	104·61	+ 0·005	+ 0·255	+ 649·355	− 0·070	+ 649·285
115	116	105·62	+ 0·006	+ 0·261	+ 681·870	− 0·072	+ 681·798
116	117	106·88	− 0·006	+ 0·255	+ 708·112	− 0·074	+ 708·038
117	118	106·89	− 0·002	+ 0·253	+ 708·215	− 0·074	+ 708·141
118	119	106·90	+ 0·002	+ 0·255	+ 708·103	− 0·074	+ 708·029
119	120	107·22	+ 0·002	+ 0·257	+ 707·572	− 0·074	+ 707·498
120	121	108·76	− 0·011	+ 0·246	+ 659·802	− 0·072	+ 659·730

Line No. 58. Bilaspur to Katni.—(Continued).

Bench-marks: From	Bench-marks: To	Distance from Bilaspur	Discrepancy between levellers (First – Second leveller): From mark to mark (= d)	Discrepancy between levellers (First – Second leveller): Total from Bilaspur	Observed elevation above (+) or below (–) Bilaspur (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Bilaspur	Dynamic height above (+) or below (–) Bilaspur
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
121	122	108·99	+ 0·006	+ 0·252	+ 652·286	– 0·072	+ 652·214
122	123	109·99	+ 0·001	+ 0·253	+ 618·861	– 0·070	+ 618·791
123	124	110·71	– 0·001	+ 0·252	+ 611·278	– 0·070	+ 611·208
124	125	111·31	– 0·013	+ 0·239	+ 631·081	– 0·071	+ 631·010
125	126	111·76	+ 0·009	+ 0·248	+ 646·853	– 0·072	+ 646·781
126	127	112·66	+ 0·011	+ 0·259	+ 679·620	– 0·074	+ 679·546
127	128	114·71	– 0·004	+ 0·255	+ 728·441	– 0·076	+ 728·365
128	129	118·07	+ 0·021	+ 0·276	+ 647·888	– 0·072	+ 647·816
129	130	118·48	+ 0·008	+ 0·284	+ 642·970	– 0·072	+ 642·898
130	131	119·03	0·000	+ 0·284	+ 634·698	– 0·072	+ 634·626
131	132	120·10	– 0·012	+ 0·272	+ 615·728	– 0·071	+ 615·657
132	133	120·88	– 0·002	+ 0·270	+ 620·313	– 0·071	+ 620·242
133	134	121·43	+ 0·010	+ 0·280	+ 614·789	– 0·071	+ 614·718
134	135	121·85	+ 0·004	+ 0·284	+ 609·842	– 0·071	+ 609·771
135	136	122·90	+ 0·002	+ 0·286	+ 644·908	– 0·073	+ 644·835
136	137	123·10	– 0·002	+ 0·284	+ 645·501	– 0·073	+ 645·428
137	138	123·97	+ 0·004	+ 0·288	+ 661·015	– 0·074	+ 660·941
138	139	124·69	– 0·003	+ 0·285	+ 668·458	– 0·074	+ 668·384
139	140	125·06	– 0·001	+ 0·284	+ 690·216	– 0·075	+ 690·141
140	141	126·05	+ 0·005	+ 0·289	+ 705·510	– 0·076	+ 705·434
141	142	126·30	+ 0·004	+ 0·293	+ 695·921	– 0·075	+ 695·846
142	143	127·14	+ 0·004	+ 0·297	+ 727·362	– 0·077	+ 727·285
143	144	127·99	– 0·001	+ 0·296	+ 737·704	– 0·078	+ 737·626
144	145	128·40	+ 0·006	+ 0·302	+ 758·824	– 0·079	+ 758·745
145	146	129·08	– 0·001	+ 0·301	+ 789·758	– 0·081	+ 789·677
146	147	129·44	– 0·001	+ 0·300	+ 808·590	– 0·082	+ 808·508
147	148	129·76	– 0·003	+ 0·297	+ 826·172	– 0·083	+ 826·089
148	149	130·19	+ 0·007	+ 0·304	+ 849·075	– 0·084	+ 848·991
149	150	130·87	– 0·007	+ 0·297	+ 833·483	– 0·083	+ 833·400
150	151	131·75	– 0·016	+ 0·281	+ 806·491	– 0·082	+ 806·409
151	152	131·97	+ 0·009	+ 0·290	+ 806·894	– 0·082	+ 806·812
152	153	132·24	– 0·001	+ 0·289	+ 805·841	– 0·082	+ 805·759
153	154	132·60	+ 0·014	+ 0·303	+ 798·262	– 0·082	+ 798·180
154	155	132·91	– 0·011	+ 0·292	+ 791·616	– 0·082	+ 791·534
155	156	133·18	+ 0·004	+ 0·296	+ 796·633	– 0·082	+ 796·551
156	157	133·56	+ 0·012	+ 0·308	+ 811·429	– 0·083	+ 811·346
157	158	134·51	– 0·016	+ 0·292	+ 781·650	– 0·082	+ 781·568
158	159	134·82	– 0·006	+ 0·286	+ 772·275	– 0·082	+ 772·193
159	160	135·23	– 0·007	+ 0·279	+ 763·265	– 0·082	+ 763·183
160	161	136·44	+ 0·006	+ 0·285	+ 730·667	– 0·081	+ 730·586
161	162	136·64	+ 0·007	+ 0·292	+ 723·344	– 0·081	+ 723·263
162	163	137·67	– 0·015	+ 0·277	+ 683·458	– 0·079	+ 683·379
163	164	138·30	– 0·010	+ 0·267	+ 657·527	– 0·078	+ 657·449
164	165	139·36	– 0·002	+ 0·265	+ 638·594	– 0·077	+ 638·517
165	166	142·04	– 0·002	+ 0·263	+ 626·173	– 0·076	+ 626·097
166	167	144·01	– 0·005	+ 0·258	+ 584·001	– 0·074	+ 583·927
167	168	144·46	+ 0·009	+ 0·267	+ 568·873	– 0·073	+ 568·800
168	169	144·72	– 0·012	+ 0·255	+ 561·264	– 0·073	+ 561·191
169	170	145·02	+ 0·011	+ 0·266	+ 573·188	– 0·074	+ 573·114
170	171	145·63	– 0·006	+ 0·260	+ 596·256	– 0·075	+ 596·181
171	172	146·82	+ 0·003	+ 0·263	+ 600·747	– 0·075	+ 600·672
172	173	147·54	– 0·009	+ 0·254	+ 575·677	– 0·074	+ 575·603
173	174	147·81	– 0·010	+ 0·244	+ 566·653	– 0·074	+ 566·579
174	175	149·19	– 0·005	+ 0·239	+ 582·882	– 0·075	+ 582·807
175	176	150·04	– 0·005	+ 0·234	+ 562·157	– 0·074	+ 562·083
176	177	150·73	+ 0·003	+ 0·237	+ 584·253	– 0·075	+ 584·178
177	178	151·89	– 0·008	+ 0·229	+ 624·462	– 0·077	+ 624·385
178	179	152·61	– 0·009	+ 0·220	+ 636·140	– 0·078	+ 636·062
179	180	152·62	+ 0·002	+ 0·222	+ 636·045	– 0·078	+ 635·967
180	181	153·25	– 0·001	+ 0·221	+ 644·653	– 0·078	+ 644·575

Line No. 58. Bilaspur to Katni.—(Continued).

Bench-marks From	Bench-marks To	Distance from Bilaspur	Discrepancy between levellers (First – Second leveller): From mark to mark (=d)	Discrepancy between levellers (First – Second leveller): Total from Bilaspur	Observed elevation above (+) or below (–) Bilaspur (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Bilaspur	Dynamic height above (+) or below (–) Bilaspur
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
181	182	155·33	+ 0·026	+ 0·247	+ 673·534	– 0·079	+ 673·455
182	183	155·98	+ 0·005	+ 0·252	+ 666·523	– 0·079	+ 666·444
183	184	156·50	0·000	+ 0·252	+ 654·570	– 0·079	+ 654·491
184	185	156·86	0·000	+ 0·252	+ 644·818	– 0·079	+ 644·739
185	186	157·50	+ 0·007	+ 0·259	+ 624·682	– 0·078	+ 624·604
186	187	158·48	– 0·017	+ 0·242	+ 608·468	– 0·077	+ 608·391
187	188	159·61	– 0·020	+ 0·222	+ 617·310	– 0·077	+ 617·233
188	189	160·39	+ 0·007	+ 0·229	+ 636·952	– 0·078	+ 636·874
189	190	160·40	– 0·003	+ 0·226	+ 637·057	– 0·078	+ 636·979
190	191	161·52	+ 0·004	+ 0·230	+ 612·428	– 0·077	+ 612·351
191	192	162·06	+ 0·005	+ 0·235	+ 604·674	– 0·077	+ 604·597
192	193	162·58	– 0·001	+ 0·234	+ 580·442	– 0·076	+ 580·366
193	194	164·46	– 0·013	+ 0·221	+ 635·227	– 0·078	+ 635·149
194	195	164·82	– 0·002	+ 0·219	+ 624·235	– 0·078	+ 624·157
195	196	165·85	+ 0·005	+ 0·224	+ 574·946	– 0·076	+ 574·870
196	197	166·46	– 0·002	+ 0·222	+ 589·871	– 0·076	+ 589·795
197	198	166·70	+ 0·007	+ 0·229	+ 590·054	– 0·076	+ 589·978
198	199	167·42	– 0·002	+ 0·227	+ 566·072	– 0·075	+ 565·997
199	200	168·19	– 0·011	+ 0·216	+ 536·886	– 0·074	+ 536·812
200	201	168·59	– 0·003	+ 0·213	+ 537·189	– 0·074	+ 537·115
201	202	169·54	– 0·004	+ 0·209	+ 500·898	– 0·073	+ 500·825
202	203	171·63	– 0·005	+ 0·204	+ 441·887	– 0·072	+ 441·815
203	204	172·09	– 0·008	+ 0·196	+ 438·757	– 0·072	+ 438·685
204	205	172·10	0·000	+ 0·196	+ 439·277	– 0·072	+ 439·205
205	206	172·51	+ 0·005	+ 0·201	+ 430·485	– 0·072	+ 430·413
206	207	173·31	– 0·010	+ 0·191	+ 419·507	– 0·072	+ 419·435
207	208	174·30	– 0·002	+ 0·189	+ 394·606	– 0·071	+ 394·535
208	209	174·63	+ 0·002	+ 0·191	+ 387·647	– 0·071	+ 387·576
209	210	174·99	+ 0·003	+ 0·194	+ 396·099	– 0·071	+ 396·028
210	211	175·87	+ 0·003	+ 0·197	+ 407·408	– 0·071	+ 407·337
211	212	177·47	+ 0·016	+ 0·213	+ 467·397	– 0·072	+ 467·325
212	213	178·16	– 0·011	+ 0·202	+ 476·393	– 0·072	+ 476·321
213	214	179·23	– 0·017	+ 0·185	+ 495·477	– 0·072	+ 495·405
214	215	179·53	0·000	+ 0·185	+ 494·133	– 0·072	+ 494·061
215	216	180·48	0·000	+ 0·185	+ 473·590	– 0·072	+ 473·518
216	217	180·71	– 0·001	+ 0·184	+ 475·510	– 0·072	+ 475·438
217	218	181·13	+ 0·006	+ 0·190	+ 486·501	– 0·072	+ 486·429
218	219	181·31	0·000	+ 0·190	+ 492·508	– 0·072	+ 492·436
219	220	181·78	– 0·005	+ 0·185	+ 482·777	– 0·072	+ 482·705
220	221	182·28	+ 0·007	+ 0·192	+ 462·989	– 0·072	+ 462·917
221	222	182·57	– 0·009	+ 0·183	+ 467·373	– 0·072	+ 467·301
222	223	183·54	– 0·011	+ 0·172	+ 482·336	– 0·072	+ 482·264
223	224	183·68	– 0·001	+ 0·171	+ 486·263	– 0·072	+ 486·191
224	225	184·57	0·000	+ 0·171	+ 500·763	– 0·072	+ 500·691
225	226	185·31	0·000	+ 0·171	+ 486·893	– 0·072	+ 486·821
226	227	185·84	– 0·002	+ 0·169	+ 483·392	– 0·072	+ 483·320
227	228	186·90	– 0·002	+ 0·167	+ 496·919	– 0·072	+ 496·847
228	229	187·63	– 0·002	+ 0·165	+ 473·662	– 0·072	+ 473·590
229	230	188·25	+ 0·003	+ 0·168	+ 465·043	– 0·072	+ 464·971
230	231	188·60	– 0·006	+ 0·162	+ 456·608	– 0·072	+ 456·536
231	232	189·15	0·000	+ 0·162	+ 445·528	– 0·072	+ 445·456
232	233	189·60	– 0·015	+ 0·147	+ 435·697	– 0·072	+ 435·625
233	234	190·21	+ 0·002	+ 0·149	+ 432·833	– 0·072	+ 432·761
234	235	192·56	+ 0·010	+ 0·159	+ 383·874	– 0·071	+ 383·803
235	236	195·34	+ 0·012	+ 0·171	+ 363·865	– 0·071	+ 363·794

Line No. 58. Bilaspur to Katni.—(Continued).

Bench-marks		Distance from Bilaspur	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Bilaspur (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Bilaspur
From	To		From mark to mark (= d)	Total from Bilaspur		Total from Bilaspur	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
236	237	195·95	− 0·009	+ 0·162	+ 364·221	− 0·071	+ 364·150
237	238	196·09	− 0·001	+ 0·161	+ 365·806	− 0·071	+ 365·735
238	239*	196·45	− 0·006	+ 0·155	+ 369·794	− 0·071	+ 369·723

Difference of dynamic height, Bilaspur to Katni = + 369·723 feet.

Length of line in miles = M = 196·45. $\Sigma d^2 = 0{\cdot}022857$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm\, 0{\cdot}0037$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745 \sqrt{\frac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0510$.

* Bench-mark No. 239 is the mark at Katni described on page 134.

Line No. 59. Katni to Allahabad.

Bench-marks		Distance from Katni	Discrepancy between levellers (First−Second leveller)		Observed elevation above (+) or below (−) Katni (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Katni
From	To		From mark to mark (=d)	Total from Katni		Total from Katni	
		miles	foot	foot	feet	foot	feet
1*	2	0·06	− 0·003	− 0·003	− 0·048	0·000	− 0·048
2	3	1·02	− 0·021	− 0·024	− 23·900	0·000	− 23·900
3	4	1·73	+ 0·002	− 0·022	− 22·586	0·000	− 22·586
4	5	2·06	− 0·009	− 0·031	− 21·454	0·000	− 21·454
5	6	3·35	− 0·011	− 0·042	− 13·851	0·000	− 13·851
6	7	4·55	+ 0·008	− 0·034	+ 11·867	0·000	+ 11·867
7	8	6·31	+ 0·015	− 0·019	+ 18·703	0·000	+ 18·703
8	9	7·89	− 0·009	− 0·028	− 3·132	0·000	− 3·132
9	10	8·86	+ 0·002	− 0·026	+ 10·390	0·000	+ 10·390
10	11	10·24	+ 0·020	− 0·006	+ 39·654	0·000	+ 39·654
11	12	10·71	+ 0·002	− 0·004	+ 49·319	0·000	+ 49·319
12	13	11·99	− 0·001	− 0·005	+ 25·302	0·000	+ 25·302
13	14	12·54	+ 0·013	+ 0·008	+ 18·831	0·000	+ 18·831
14	15	13·52	− 0·015	− 0·007	+ 12·963	0·000	+ 12·963
15	16	13·94	− 0·002	− 0·009	+ 10·239	0·000	+ 10·239
16	17	14·23	− 0·004	− 0·013	+ 8·144	0·000	+ 8·144
17	18	14·95	+ 0·008	− 0·005	+ 3·792	0·000	+ 3·792
18	19	15·86	+ 0·010	+ 0·005	− 4·546	0·000	− 4·546
19	20	16·71	− 0·013	− 0·008	− 11·775	0·000	− 11·775
20	21	17·41	+ 0·012	+ 0·004	− 18·570	0·000	− 18·570
21	22	18·56	− 0·015	− 0·011	− 28·220	0·000	− 28·220
22	23	19·28	− 0·002	− 0·013	− 34·375	0·000	− 34·375
23	24	20·06	+ 0·009	− 0·004	− 38·664	0·000	− 38·664
24	25	21·01	− 0·008	− 0·012	− 43·676	0·000	− 43·676
25	26	21·94	+ 0·001	− 0·011	− 43·982	0·000	− 43·982
26	27	22·45	+ 0·002	− 0·009	− 46·313	0·000	− 46·313
27	28	22·83	− 0·004	− 0·013	− 42·664	0·000	− 42·664
28	29	22·89	− 0·001	− 0·014	− 44·904	0·000	− 44·904
29	30	23·24	− 0·006	− 0.020	− 43·987	0·000	− 43·987
30	31	23·94	− 0·008	− 0·028	− 52·699	0·000	− 52·699
31	32	24·68	− 0·007	− 0·035	− 62·806	0·000	− 62·806
32	33	25·42	+ 0·010	− 0·025	− 68·638	0·000	− 68·638
33	34	26·81	+ 0·004	− 0·021	− 67·006	0·000	− 67·006
34	35	27·65	+ 0·007	− 0·014	− 70·713	0·000	− 70·713
35	36	28·35	− 0·017	− 0·031	− 77·566	0·000	− 77·566
36	37	29·47	+ 0·015	− 0·016	− 84·602	0·000	− 84·602
37	38	30·26	+ 0·007	− 0·009	− 82·161	0·000	− 82·161
38	39	30·77	− 0·002	− 0·011	− 80·709	0·000	− 80·709
39	40	30·96	+ 0·001	− 0·010	− 82·501	0·000	− 82·501
40	41	33·16	− 0·002	− 0·012	− 84·937	0·000	− 84·937
41	42	34·56	0·000	− 0·012	− 80·325	0·000	− 80·325
42	43	35·31	− 0·006	− 0·018	− 89·458	0·000	− 89·458
43	44	36·30	+ 0·015	− 0·003	− 98·944	0·000	− 98·944
44	45	37·40	− 0·006	− 0·009	− 101·447	0·000	− 101·447
45	46	38·21	− 0·010	− 0·019	− 105·368	0·000	− 105·368
46	47	38·75	− 0·008	− 0·027	− 107·362	0·000	− 107·362
47	48	39·01	− 0·001	− 0·028	− 111·496	0·000	− 111·496
48	49	39·15	0·000	− 0·028	− 108·809	0·000	− 108·809
49	50	39·25	+ 0·005	− 0·023	− 109·513	0·000	− 109·513
50	51	40·44	− 0·005	− 0·028	− 147·307	− 0·001	− 147·308
51	52	41·44	− 0·002	− 0·030	− 161·789	− 0·001	− 161·790
52	53	43·50	+ 0·024	− 0·006	− 161·812	− 0·001	− 161·813
53	54	44·51	− 0·003	− 0·009	− 142·604	− 0·001	− 142·605
54	55	45·51	+ 0·008	− 0·001	− 122·337	− 0·001	− 122·338
55	56	46·51	+ 0·001	0·000	− 114·146	− 0·001	− 114·147
56	57	47·52	+ 0·023	+ 0·023	− 113·343	− 0·001	− 113·344
57	58	49·52	+ 0·017	+ 0·040	− 78·461	0·000	− 78·461
58	59	50·34	− 0·007	+ 0·033	− 75·520	0·000	− 75·520
59	60	50·91	0·000	+ 0·033	− 77·279	0·000	− 77·279
60	61	52·54	0·000	+ 0·033	− 116·387	− 0·001	− 116·388

* Bench-mark No. 1 is the mark at Katni described on page 134.

Line No. 59. Katni to Allahabad.—(Continued).

Bench-marks		Distance from Katni	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Katni (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Katni
From	To		From mark to mark (= d)	Total from Katni		Total from Katni	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	53·55	+ 0·004	+ 0·037	– 116·491	– 0·001	– 116·492
62	63	55·55	– 0·005	+ 0·032	– 93·893	0·000	– 93·893
63	64	57·55	– 0·006	+ 0·026	– 112·946	0·000	– 112·946
64	65	58·53	+ 0·004	+ 0·030	– 134·317	0·000	– 134·317
65	66	59·56	+ 0·015	+ 0·045	– 108·082	+ 0·001	– 108·081
66	67	60·57	– 0·003	+ 0·042	– 106·911	+ 0·001	– 106·910
67	68	61·57	– 0·011	+ 0·031	– 124·740	0·000	– 124·740
68	69	62·57	+ 0·012	+ 0·043	– 77·222	+ 0·001	– 77·221
69	70	64·95	+ 0·019	+ 0·062	– 97·234	0·000	– 97·234
70	71	65·59	+ 0·003	+ 0·065	– 102·087	0·000	– 102·087
71	72	66·45	0·000	+ 0·065	– 131·343	– 0·001	– 131·344
72	73	67·09	– 0·004	+ 0·061	– 133·494	– 0·001	– 133·495
73	74	67·60	+ 0·005	+ 0·066	– 132·657	– 0·001	– 132·658
74	75	68·39	– 0·003	+ 0·063	– 146·087	– 0·001	– 146·088
75	76	68·61	+ 0·007	+ 0·070	– 140·054	– 0·001	– 140·055
76	77	69·54	– 0·004	+ 0·066	– 147·399	– 0·001	– 147·400
77	78	70·62	– 0·004	+ 0·062	– 152·897	– 0·001	– 152·898
78	79	70·70	0·000	+ 0·062	– 153·351	– 0·001	– 153·352
79	80	71·94	– 0·025	+ 0·037	– 184·026	– 0·002	– 184·028
80	81	72·98	+ 0·007	+ 0·044	– 177·224	– 0·002	– 177·226
81	82	73·20	+ 0·012	+ 0·056	– 172·090	– 0·002	– 172·092
82	83	73·35	– 0·003	+ 0·053	– 167·286	– 0·002	– 167·288
83	84	73·95	– 0·005	+ 0·048	– 180·924	– 0·002	– 180·926
84	85	74·64	– 0·004	+ 0·044	– 186·926	– 0·002	– 186·928
85	86	75·47	+ 0·002	+ 0·046	– 193·133	– 0·002	– 193·135
86	87	75·87	+ 0·002	+ 0·048	– 193·680	– 0·002	– 193·682
87	88	76·09	– 0·003	+ 0·045	– 204·008	– 0·002	– 204·010
88	89	76·51	– 0·002	+ 0·043	– 213·520	– 0·002	– 213·522
89	90	76·85	– 0·005	+ 0·038	– 233·016	– 0·003	– 233·019
90	91	77·70	– 0·012	+ 0·026	– 259·560	– 0·004	– 259·564
91	92	78·54	– 0·003	+ 0·023	– 258·825	– 0·004	– 258·829
92	93	78·65	0·000	+ 0·023	– 258·923	– 0·004	– 258·927
93	94	79·34	+ 0·002	+ 0·025	– 274·002	– 0·005	– 274·007
94	95	79·65	+ 0·008	+ 0·033	– 275·521	– 0·005	– 275·526
95	96	80·32	– 0·009	+ 0·024	– 315·224	– 0·007	– 315·231
96	97	80·72	– 0·001	+ 0·023	– 276·447	– 0·005	– 276·452
97	98	81·30	– 0·011	+ 0·012	– 273·406	– 0·005	– 273·411
98	99	81·72	+ 0·010	+ 0·022	– 261·969	– 0·005	– 261·974
99	100	82·74	+ 0·008	+ 0·030	– 247·930	– 0·004	– 247·934
100	101	83·07	– 0·004	+ 0·026	– 241·882	– 0·004	– 241·886
101	102	84·41	+ 0·004	+ 0·030	– 220·585	– 0·003	– 220·588
102	103	84·74	+ 0·010	+ 0·040	– 208·387	– 0·002	– 208·389
103	104	87·76	+ 0·058	+ 0·098	– 170·707	0·000	– 170·707
104	105	88·31	– 0·004	+ 0·094	– 161·180	0·000	– 161·180
105	106	88·75	– 0·005	+ 0·089	– 159·794	0·000	– 159·794
106	107	88·81	– 0·001	+ 0·088	– 164·837	0·000	– 164·837
107	108	89·84	– 0·010	+ 0·078	– 195·364	– 0·001	– 195·365
108	109	92·04	– 0·014	+ 0·064	– 234·127	– 0·003	– 234·130
109	110	94·70	+ 0·011	+ 0·075	– 234·885	– 0·003	– 234·888
110	111	95·60	– 0·007	+ 0·068	– 235·689	– 0·003	– 235·692
111	112	96·58	– 0·013	+ 0·055	– 240·935	– 0·003	– 240·938
112	113	96·99	+ 0·005	+ 0·060	– 237·182	– 0·003	– 237·185
113	114	98·61	+ 0·004	+ 0·064	– 242·219	– 0·003	– 242·222
114	115	99·78	+ 0·002	+ 0·066	– 217·277	– 0·002	– 217·279
115	116	101·36	– 0·010	+ 0·056	– 261·305	– 0·004	– 261·309
116	117	103·17	+ 0·007	+ 0·063	– 265·351	– 0·004	– 265·355
117	118	104·98	+ 0·004	+ 0·067	– 234·723	– 0·002	– 234·725
118	119	106·33	+ 0·012	+ 0·079	– 204·282	0·000	– 204·282
119	120	107·07	– 0·014	+ 0·065	– 197·565	0·000	– 197·565
120	121	107·56	+ 0·001	+ 0·066	– 204·878	0·000	– 204·878

Line No. 59. Katni to Allahabad.—(Continued).

Bench-marks		Distance from Katni	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Katni (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Katni
From	To		From mark to mark (= *d*)	Total from Katni		Total from Katni	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
121	122	108·94	− 0·001	+ 0·065	− 185·923	+ 0·001	− 185·922
122	123	109·60	− 0·004	+ 0·061	− 186·184	+ 0·001	− 186·183
123	124	110·40	+ 0·003	+ 0·064	− 182·921	+ 0·001	− 182·920
124	125	111·95	− 0·005	+ 0·059	− 171·707	+ 0·002	− 171·705
125	126	112·47	+ 0·003	+ 0·062	− 171·021	+ 0·002	− 171·019
126	127	113·48	+ 0·004	+ 0·066	− 144·411	+ 0·004	− 144·407
127	128	115·64	− 0·024	+ 0·042	− 135·863	+ 0·005	− 135·858
128	129	116·61	+ 0·006	+ 0·048	− 114·888	+ 0·006	− 114·882
129	130	118·35	+ 0·003	+ 0·051	− 131·652	+ 0·005	− 131·647
130	131	118·95	− 0·003	+ 0·048	− 145·790	+ 0·004	− 145·786
131	132	119·33	0·000	+ 0·048	− 127·790	+ 0·005	− 127·785
132	133	121·53	+ 0·003	+ 0·051	− 137·387	+ 0·004	− 137·383
133	134	122·10	− 0·001	+ 0·050	− 87·192	+ 0·008	− 87·184
134	135	123·01	− 0·031	+ 0·019	− 229·558	− 0·002	− 229·560
135	136	124·17	− 0·009	+ 0·010	− 247·205	− 0·003	− 247·208
136	137	128·30	− 0·052	− 0·042	− 919·606	− 0·050	− 919·656
137	138	129·89	− 0·010	− 0·052	− 923·625	− 0·050	− 923·675
138	139	131·31	− 0·001	− 0·053	− 923·534	− 0·050	− 923·584
139	140	132·76	+ 0·004	− 0·049	− 919·635	− 0·050	− 919·685
140	141	133·00	+ 0·001	− 0·048	− 914·271	− 0·050	− 914·321
141	142	134·05	− 0·002	− 0·050	− 897·473	− 0·049	− 897·522
142	143	134·84	− 0·007	− 0·057	− 895·571	− 0·049	− 895·620
143	144	136·00	− 0·004	− 0·061	− 901·706	− 0·050	− 901·756
144	145	136·53	− 0·011	− 0·072	− 928·082	− 0·052	− 928·134
145	146	137·00	− 0·005	− 0·077	− 933·688	− 0·052	− 933·740
146	147	138·17	− 0·018	− 0·095	− 948·776	− 0·053	− 948·829
147	148	139·01	− 0·004	− 0·099	− 946·736	− 0·053	− 946·789
148	149	139·73	+ 0·004	− 0·095	− 945·636	− 0·053	− 945·689
149	150	140·26	+ 0·007	− 0·088	− 941·042	− 0·053	− 941·095
150	151	142·02	− 0·009	− 0·097	− 935·829	− 0·053	− 935·882
151	152	142·60	0·000	− 0·097	− 934·355	− 0·053	− 934·408
152	153	143·20	+ 0·004	− 0·093	− 935·728	− 0·053	− 935·781
153	154	144·05	− 0·005	− 0·098	− 935·130	− 0·053	− 935·183
154	155	145·05	+ 0·005	− 0·093	− 933·976	− 0·053	− 934·029
155	156	146·16	− 0·016	− 0·109	− 936·381	− 0·053	− 936·434
156	157	147·32	− 0·011	− 0·120	− 940·139	− 0·053	− 940·192
157	158	148·31	+ 0·005	− 0·115	− 942·175	− 0·053	− 942·228
158	159	149·04	− 0·004	− 0·119	− 943·252	− 0·053	− 943·305
159	160	149·67	+ 0·005	− 0·114	− 943·048	− 0·053	− 943·101
160	161	150·04	− 0·002	− 0·116	− 944·375	− 0·053	− 944·428
161	162	150·82	− 0·001	− 0·117	− 944·699	− 0·053	− 944·752
162	163	151·04	− 0·002	− 0·119	− 941·689	− 0·053	− 941·742
163	164	152·05	+ 0·005	− 0·114	− 943·918	− 0·053	− 943·971
164	165	153·05	− 0·014	− 0·128	− 944·133	− 0·053	− 944·186
165	166	153·88	− 0·007	− 0·135	− 946·172	− 0·053	− 946·225
166	167	154·65	− 0·001	− 0·136	− 942·619	− 0·053	− 942·672
167	168	155·36	+ 0·001	− 0·135	− 938·951	− 0·053	− 939·004
168	169	156·06	− 0·002	− 0·137	− 943·057	− 0·053	− 943·110
169	170	157·07	+ 0·002	− 0·135	− 941·970	− 0·053	− 942·023
170	171	157·20	+ 0·002	− 0·133	− 943·322	− 0·053	− 943·375
171	172	157·95	− 0·004	− 0·137	− 969·102	− 0·056	− 969·158
172	173	159·15	− 0·005	− 0·142	− 955·374	− 0·055	− 955·429
173	174	159·79	+ 0·001	− 0·141	− 953·842	− 0·055	− 953·897
174	175	159·81	0·000	− 0·141	− 952·845	− 0·055	− 952·900
175	176	160·36	+ 0·005	− 0·136	− 962·708	− 0·056	− 962·764

Line No. 59. Katni to Allahabad.—(Continued).

Bench-marks		Distance from Katni	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Katni (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Katni
From	To		From mark to mark (= d)	Total from Katni		Total from Katni	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
176	177	161·30	– 0·010	– 0·146	– 969·245	– 0·057	– 969·302
177	178	161·46	+ 0·003	– 0·143	– 965·652	– 0·057	– 965·709
178	179	161·51	+ 0·002	– 0·141	– 956·310	– 0·056	– 956·366
179	180*	161·54	0·000	– 0·141	– 955·963	– 0·056	– 956·019

Difference of dynamic height, Katni to Allahabad = – 956·019 feet.

Length of line in miles = M = 161·54. $\Sigma d^2 = 0{\cdot}019223$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0{\cdot}0037$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0{\cdot}0468$.

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* Bench-mark No. 180 is the mark at Allahabad described on page 133.

Line No. 60. Katni to Sironj.

Bench-marks From	Bench-marks To	Distance from Katni	Discrepancy between levellers (First − Second leveller) From mark to mark (= *d*)	Discrepancy between levellers (First − Second leveller) Total from Katni	Observed elevation above (+) or below (−) Katni (mean result by two levellers)	Dynamic correction deduced from mark to mark Total from Katni	Dynamic height above (+) or below (−) Katni
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·66	+ 0·003	+ 0·003	+ 1·027	0·000	+ 1·027
2	3	1·14	− 0·010	− 0·007	− 2·766	0·000	− 2·766
3	4	1·72	− 0·008	− 0·015	− 15·560	0·000	− 15·560
4	5	2·04	0·000	− 0·015	− 14·583	0·000	− 14·583
5	6	3·05	+ 0·001	− 0·014	− 8·949	0·000	− 8·949
6	7	3·49	− 0·003	− 0·017	− 4·273	0·000	− 4·273
7	8	4·05	+ 0·001	− 0·016	+ 22·251	0·000	+ 22·251
8	9	4·61	− 0·003	− 0·019	+ 8·052	0·000	+ 8·052
9	10	5·05	+ 0·001	− 0·018	+ 23·021	0·000	+ 23·021
10	11	5·81	− 0·001	− 0·019	+ 40·098	0·000	+ 40·098
11	12	6·42	+ 0·005	− 0·014	+ 23·952	0·000	+ 23·952
12	13	7·83	− 0·014	− 0·028	− 4·461	0·000	− 4·461
13	14	8·03	+ 0·002	− 0·026	− 1·441	0·000	− 1·441
14	15	8·62	0·000	− 0·026	− 1·684	0·000	− 1·684
15	16	8·90	− 0·016	− 0·042	+ 3·278	0·000	+ 3·278
16	17	9·18	+ 0·002	− 0·040	+ 7·447	0·000	+ 7·447
17	18	9·91	+ 0·004	− 0·036	+ 20·549	0·000	+ 20·549
18	19	10·42	+ 0·002	− 0·034	+ 27·187	0·000	+ 27·187
19	20	10·47	+ 0·001	− 0·033	+ 31·320	0·000	+ 31·320
20	21	11·06	+ 0·008	− 0·025	+ 37·384	0·000	+ 37·384
21	22	12·06	+ 0·002	− 0·023	+ 42·795	0·000	+ 42·795
22	23	13·06	− 0·003	− 0·026	+ 43·709	0·000	+ 43·709
23	24	14·31	+ 0·004	− 0·022	+ 32·608	0·000	+ 32·608
24	25	15·35	+ 0·009	− 0·013	+ 58·476	0·000	+ 58·476
25	26	16·43	+ 0·019	+ 0·006	+ 72·512	0·000	+ 72·512
26	27	17·36	+ 0·007	+ 0·013	+ 82·823	0·000	+ 82·823
27	28	17·92	− 0·001	+ 0·012	+ 91·310	0·000	+ 91·310
28	29	19·03	+ 0·010	+ 0·022	+ 124·848	0·000	+ 124·848
29	30	19·33	− 0·001	+ 0·021	+ 133·644	0·000	+ 133·644
30	31	19·82	− 0·002	+ 0·019	+ 143·469	0·000	+ 143·469
31	32	19·86	+ 0·004	+ 0·023	+ 143·701	0·000	+ 143·701
32	33	20·36	+ 0·004	+ 0·027	+ 132·831	0·000	+ 132·831
33	34	20·67	− 0·001	+ 0·026	+ 126·737	0·000	+ 126·737
34	35	21·07	0·000	0·000	+ 126·776	0·000	+ 126·776
35	36	21·26	+ 0·002	+ 0·028	+ 126·054	0·000	+ 126·054
36	37	23·07	+ 0·016	+ 0·044	+ 150·474	0·000	+ 150·474
37	38	23·37	− 0·003	+ 0·041	+ 150·382	0·000	+ 150·382
38	39	24·07	+ 0·002	+ 0·043	+ 145·799	0·000	+ 145·799
39	40	24·77	− 0·009	+ 0·034	+ 138·570	0·000	+ 138·570
40	41	25·42	+ 0·006	+ 0·040	+ 140·590	0·000	+ 140·590
41	42	27·08	+ 0·006	+ 0·046	+ 133·467	0·000	+ 133·467
42	43	27·28	+ 0·001	+ 0·047	+ 133·490	0·000	+ 133·490
43	44	28·37	− 0·001	+ 0·046	+ 156·279	0·000	+ 156·279
44	45	29·41	− 0·005	+ 0·041	+ 168·472	0·000	+ 168·472
45	46	30·47	− 0·003	+ 0·038	+ 141·251	0·000	+ 141·251
46	47	31·43	+ 0·006	+ 0·044	+ 158·544	0·000	+ 158·544
47	48	31·46	0·000	+ 0·044	+ 160·747	0·000	+ 160·747
48	49	32·51	+ 0·003	+ 0·047	+ 140·065	0·000	+ 140·065
49	50	33·34	+ 0·007	+ 0·054	+ 160·302	0·000	+ 160·302
50	51	33·85	− 0·003	+ 0·051	+ 173·050	0·000	+ 173·050
51	52	34·39	+ 0·005	+ 0·056	+ 189·392	0·000	+ 189·392
52	53	35·14	+ 0·003	+ 0·059	+ 207·508	0·000	+ 207·508
53	54	35·93	− 0·002	+ 0·057	+ 199·911	0·000	+ 199·911
54	55	36·52	− 0·024	+ 0·033	+ 169·298	0·000	+ 169·298
55	56	37·28	− 0·013	+ 0·020	+ 129·623	0·000	+ 129·623
56	57	37·58	− 0·001	+ 0·019	+ 116·302	0·000	+ 116·302
57	58	38·16	+ 0·003	+ 0·022	+ 83·019	0·000	+ 83·019
58	59	38·76	− 0·017	+ 0·005	+ 50·505	0·000	+ 50·505
59	60	39·42	− 0·010	− 0·005	+ 24·795	0·000	+ 24·795
60	61	40·13	− 0·002	− 0·007	− 10·717	0·000	− 10·717

* Bench-mark No. 1 is the mark at Katni described on page 184.

Line No. 60. Katni to Sironj.—(Continued).

Bench-marks		Distance from Katni	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Katni (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Katni
From	To		From mark to mark (= *d*)	Total from Katni		Total from Katni	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	40·34	− 0·003	− 0·010	− 22·218	0·000	− 22·218
62	63	40·94	− 0·005	− 0·015	− 54·622	0·000	− 54·622
63	64	42·13	+ 0·001	− 0·014	− 78·521	0·000	− 78·521
64	65	42·59	− 0·017	− 0·031	− 105·779	0·000	− 105·779
65	66	42·87	− 0·007	− 0·038	− 104·296	0·000	− 104·296
66	67	42·88	+ 0·004	− 0·034	− 107·353	0·000	− 107·353
67	68	43·93	− 0·003	− 0·037	− 112·691	0·000	− 112·691
68	69	44·52	− 0·002	− 0·039	− 101·078	0·000	− 101·078
69	70	45·06	+ 0·006	− 0·033	− 84·113	0·000	− 84·113
70	71	45·46	− 0·009	− 0·042	− 78·295	0·000	− 78·295
71	72	47·08	+ 0·014	− 0·028	− 78·042	0·000	− 78·042
72	73	48·17	− 0·011	− 0·039	− 70·407	0·000	− 70·407
73	74	49·35	+ 0·002	− 0·037	− 57·271	0·000	− 57·271
74	75	50·17	− 0·003	− 0·040	− 94·218	0·000	− 94·218
75	76	50·70	− 0·008	− 0·048	− 117·724	0·000	− 117·724
76	77	52·02	− 0·015	− 0·063	− 174·906	+ 0·001	− 174·905
77	78	52·37	− 0·004	− 0·067	− 172·995	+ 0·001	− 172·994
78	79	52·98	+ 0·004	− 0·063	− 168·269	+ 0·001	− 168·268
79	80	52·99	0·000	− 0·063	− 172·168	+ 0·001	− 172·167
80	81	53·59	+ 0·001	− 0·062	− 170·202	+ 0·001	− 170·201
81	82	54·04	− 0·005	− 0·067	− 169·947	+ 0·001	− 169·946
82	83	56·00	− 0·013	− 0·080	− 125·453	+ 0·001	− 125·452
83	84	57·00	0·000	− 0·080	− 116·491	+ 0·001	− 116·490
84	85	57·20	+ 0·002	− 0·078	− 116·640	+ 0·001	− 116·639
85	86	58·56	− 0·002	− 0·080	− 123·600	+ 0·001	− 123·599
86	87	59·26	+ 0·003	− 0·077	− 126·539	+ 0·001	− 126·538
87	88	59·59	+ 0·006	− 0·071	− 126·482	+ 0·001	− 126·481
88	89	60·19	+ 0·005	− 0·066	− 126·624	+ 0·001	− 126·623
89	90	60·55	+ 0·006	− 0·060	− 125·677	+ 0·001	− 125·676
90	91	60·90	+ 0·004	− 0·056	− 123·625	+ 0·001	− 123·624
91	92	62·24	+ 0·012	− 0·044	− 105·785	+ 0·001	− 105·784
92	93	63·82	− 0·001	− 0·045	− 75·644	+ 0·001	− 75·643
93	94	64·22	− 0·003	− 0·048	− 65·708	+ 0·001	− 65·707
94	95	64·79	+ 0·004	− 0·044	− 56·708	+ 0·001	− 56·707
95	96	65·44	− 0·007	− 0·051	− 39·804	+ 0·001	− 39·803
96	97	66·59	+ 0·004	− 0·047	− 19·577	+ 0·001	− 19·576
97	98	67·35	+ 0·006	− 0·041	− 19·766	+ 0·001	− 19·765
98	99	67·94	− 0·002	− 0·043	− 26·686	+ 0·001	− 26·685
99	100	68·23	+ 0·001	− 0·042	− 35·277	+ 0·001	− 35·276
100	101	68·53	+ 0·004	− 0·038	− 45·938	+ 0·001	− 45·937
101	102	69·17	+ 0·001	− 0·037	− 52·348	+ 0·001	− 52·347
102	103	69·19	+ 0·001	− 0·036	− 51·336	+ 0·001	− 51·335
103	104	69·24	− 0·001	− 0·037	− 51·326	+ 0·001	− 51·325
104	105	69·87	− 0·004	− 0·041	− 62·694	+ 0·001	− 62·693
105	106	70·68	− 0·016	− 0·057	− 73·758	+ 0·001	− 73·757
106	107	71·27	− 0·008	− 0·065	− 74·727	+ 0·001	− 74·726
107	108	73·29	0·000	− 0·065	− 82·289	+ 0·001	− 82·288
108	109	73·87	+ 0·002	− 0·063	− 84·843	+ 0·001	− 84·842
109	110	76·78	− 0·023	− 0·086	− 40·480	+ 0·001	− 40·479
110	111	77·42	+ 0·007	− 0·079	− 42·332	+ 0·001	− 42·331
111	112	79·18	+ 0·017	− 0·062	− 64·857	+ 0·001	− 64·856
112	113	79·42	− 0·009	− 0·071	− 66·728	+ 0·001	− 66·727
113	114	80·76	− 0·001	− 0·072	− 68·757	+ 0·001	− 68·756
114	115	84·50	− 0·006	− 0·078	− 21·871	0·000	− 21·871
115	116	85·53	+ 0·010	− 0·068	+ 3·059	0·000	+ 3·059
116	117	85·78	− 0·005	− 0·073	+ 1·233	0·000	+ 1·233
117	118	87·07	+ 0·004	− 0·069	+ 34·961	0·000	+ 34·961
118	119	87·37	+ 0·005	− 0·064	+ 41·294	0·000	+ 41·294
119	120	88·33	+ 0·019	− 0·045	+ 69·542	0·000	+ 69·542
120	121	89·88	− 0·009	− 0·054	+ 108·053	0·000	+ 108·053

Line No. 60. Katni to Sironj.—(Continued).

Bench-marks From	Bench-marks To	Distance from Katni	Discrepancy between levellers (First – Second leveller) From mark to mark (= d)	Discrepancy between levellers (First – Second leveller) Total from Katni	Observed elevation above (+) or below (−) Katni (mean result by two levellers)	Dynamic correction deduced from mark to mark Total from Katni	Dynamic height above (+) or below (−) Katni
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
121	122	90·58	+ 0·005	− 0·049	+ 107·720	0·000	+ 107·720
122	123	91·86	+ 0·003	− 0·046	+ 115·974	0·000	+ 115·974
123	124	92·85	+ 0·001	− 0·045	+ 116·788	0·000	+ 116·788
124	125	93·45	+ 0·004	− 0·041	+ 123·671	0·000	+ 123·671
125	126	93·58	+ 0·002	− 0·039	+ 126·905	0·000	+ 126·905
126	127	94·10	− 0·001	− 0·040	+ 112·681	0·000	+ 112·681
127	128	94·46	+ 0·003	− 0·037	+ 105·338	0·000	+ 105·338
128	129	95·09	+ 0·010	− 0·027	+ 120·436	0·000	+ 120·436
129	130	96·27	+ 0·019	− 0·008	+ 141·581	0·000	+ 141·581
130	131	99·56	− 0·009	− 0·017	+ 227·736	− 0·001	+ 227·735
131	132	100·36	+ 0·014	− 0·003	+ 249·987	− 0·001	+ 249·986
132	133	100·58	+ 0·006	+ 0·003	+ 251·618	− 0·001	+ 251·617
133	134	102·16	+ 0·027	+ 0·030	+ 290·034	− 0·001	+ 290·033
134	135	102·97	− 0·007	+ 0·023	+ 312·107	− 0·001	+ 312·106
135	136	103·37	+ 0·004	+ 0·027	+ 323·340	− 0·001	+ 323·339
136	137	104·37	+ 0·011	+ 0·038	+ 350·655	− 0·001	+ 350·654
137	138	105·73	+ 0·003	+ 0·041	+ 346·370	− 0·001	+ 346·369
138	139	106·36	+ 0·007	+ 0·048	+ 337·877	− 0·001	+ 337·876
139	140	107·20	+ 0·009	+ 0·057	+ 347·202	− 0·001	+ 347·201
140	141	107·78	+ 0·004	+ 0·061	+ 361·382	− 0·001	+ 361·381
141	142	108·32	+ 0·002	+ 0·063	+ 372·336	− 0·001	+ 372·335
142	143	108·33	+ 0·002	+ 0·065	+ 369·649	− 0·001	+ 369·648
143	144	108·87	+ 0·012	+ 0·077	+ 378·245	− 0·001	+ 378·244
144	145	109·55	+ 0·001	+ 0·078	+ 398·039	− 0·001	+ 398·038
145	146	110·55	+ 0·005	+ 0·083	+ 424·723	− 0·001	+ 424·722
146	147	111·06	− 0·003	+ 0·080	+ 438·043	− 0·001	+ 438·042
147	148	111·52	+ 0·005	+ 0·085	+ 450·173	− 0·001	+ 450·172
148	149	111·92	− 0·009	+ 0·076	+ 460·959	− 0·001	+ 460·958
149	150	112·98	+ 0·009	+ 0·085	+ 471·850	− 0·001	+ 471·849
150	151	113·83	− 0·015	+ 0·070	+ 472·713	− 0·001	+ 472·712
151	152	114·64	− 0·021	+ 0·049	+ 470·987	− 0·001	+ 470·986
152	153	115·12	+ 0·004	+ 0·053	+ 473·585	− 0·001	+ 473·584
153	154	115·42	− 0·002	+ 0·051	+ 477·414	− 0·001	+ 477·413
154	155	116·19	+ 0·004	+ 0·055	+ 476·052	− 0·001	+ 476·051
155	156	116·57	− 0·002	+ 0·053	+ 456·886	− 0·001	+ 456·885
156	157	117·13	0·000	+ 0·053	+ 444·440	− 0·001	+ 444·439
157	158	117·21	+ 0·003	+ 0·056	+ 446·215	− 0·001	+ 446·214
158	159	117·45	− 0·005	+ 0·051	+ 441·471	− 0·001	+ 441·470
159	160	118·80	+ 0·001	+ 0·052	+ 429·502	− 0·001	+ 429·501
160	161	120·04	+ 0·009	+ 0·061	+ 444·193	− 0·001	+ 444·192
161	162	121·14	− 0·002	+ 0·059	+ 430·627	− 0·001	+ 430·626
162	163	122·17	− 0·010	+ 0·049	+ 394·903	− 0·001	+ 394·902
163	164	122·83	+ 0·002	+ 0·051	+ 391·888	− 0·001	+ 391·887
164	165	123·24	− 0·007	+ 0·044	+ 403·067	− 0·001	+ 403·066
165	166	123·87	− 0·001	+ 0·043	+ 422·154	− 0·001	+ 422·153
166	167	124·83	+ 0·016	+ 0·059	+ 431·869	− 0·001	+ 431·868
167	168	125·63	+ 0·010	+ 0·069	+ 430·508	− 0·001	+ 430·507
168	169	126·72	+ 0·001	+ 0·070	+ 402·601	− 0·001	+ 402·600
169	170	127·10	− 0·008	+ 0·062	+ 409·600	− 0·001	+ 409·599
170	171	128·15	− 0·011	+ 0·051	+ 383·524	− 0·001	+ 383·523
171	172	128·66	− 0·012	+ 0·039	+ 381·658	− 0·001	+ 381·657
172	173	128·76	+ 0·006	+ 0·045	+ 383·931	− 0·001	+ 383·930
173	174	128·82	+ 0·001	+ 0·046	+ 385·350	− 0·001	+ 385·349
174	175	128·88	− 0·002	+ 0·044	+ 383·917	− 0·001	+ 383·916
175	176	129·18	− 0·002	+ 0·042	+ 382·578	− 0·001	+ 382·577
176	177	129·58	+ 0·001	+ 0·043	+ 381·892	− 0·001	+ 381·891
177	178	129·98	+ 0·004	+ 0·047	+ 382·064	− 0·001	+ 382·063
178	179	130·53	− 0·005	+ 0·042	+ 366·366	− 0·001	+ 366·365
179	180	131·43	− 0·003	+ 0·039	+ 340·956	− 0·001	+ 340·955
180	181	133·94	− 0·033	+ 0·006	+ 344·926	− 0·001	+ 344·925

Line No. 60. Katni to Sironj.—(Continued).

Bench-marks		Distance from Katni	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Katni (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Katni
From	To		From mark to mark (= d)	Total from Katni		Total from Katni	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
181	182	134·38	+ 0·004	+ 0·010	+ 336·782	– 0·001	+ 336·781
182	183	134·96	+ 0.001	+ 0·011	+ 339·432	– 0·001	+ 339·431
183	184	135·98	+ 0·005	+ 0·016	+ 354·588	– 0·001	+ 354·587
184	185	136·96	– 0·002	+ 0·014	+ 377·526	– 0·001	+ 377·525
185	186	137·59	– 0·010	+ 0·004	+ 368·806	– 0·001	+ 368·805
186	187	138·39	+ 0·003	+ 0·007	+ 368·893	– 0·001	+ 368·892
187	188	138·97	– 0·001	+ 0·006	+ 380·412	– 0·001	+ 380·411
188	189	139·02	+ 0·003	+ 0·009	+ 379·172	– 0·001	+ 379·171
189	190	139·96	+ 0·006	+ 0·015	+ 397·703	– 0·001	+ 397·702
190	191	141·04	– 0·023	– 0·008	+ 350·053	– 0·001	+ 350·052
191	192	141·47	– 0·009	– 0·017	+ 325·831	– 0·001	+ 325·830
192	193	141·85	– 0·008	– 0·025	+ 308·022	– 0·001	+ 308·021
193	194	144·40	– 0·021	– 0·046	+ 207·413	– 0·001	+ 207·412
194	195	146·15	– 0·002	– 0·048	+ 181·111	+ 0·001	+ 181·110
195	196	147·91	– 0·022	– 0·070	+ 160·260	– 0·001	+ 160·259
196	197	149·25	– 0·014	– 0·084	+ 174·864	– 0·001	+ 174·863
197	198	150·14	– 0·007	– 0·091	+ 192·952	– 0·001	+ 192·951
198	199	150·20	– 0·001	– 0·092	+ 191·387	– 0·001	+ 191·386
199	200	151·65	– 0·004	– 0·096	+ 176·082	– 0·001	+ 176·081
200	201	153·01	– 0·008	– 0·104	+ 174·754	– 0·001	+ 174·753
201	202	153·37	+ 0·001	– 0·103	+ 159·994	– 0·001	+ 159·993
202	203	154·01	– 0·008	– 0·111	+ 156·167	– 0·001	+ 156·166
203	204	155·26	– 0·019	– 0·130	+ 138·756	– 0·001	+ 138·755
204	205	156·82	+ 0·005	– 0·125	+ 115·389	– 0·001	+ 115·388
205	206	158·06	+ 0·019	– 0·106	+ 119·293	– 0·001	+ 119·292
206	207	159·74	– 0·015	– 0·121	+ 127·278	– 0·001	+ 127·277
207	208	160·68	+ 0·008	– 0·113	+ 138·234	– 0·001	+ 138·233
208	209	161·28	– 0·003	– 0·116	+ 133·565	– 0·001	+ 133·564
209	210	162·64	– 0·004	– 0·120	+ 113·112	– 0·001	+ 113·111
210	211	163·73	– 0·011	– 0·131	+ 98·984	– 0·001	+ 98·983
211	212	165·37	– 0·017	– 0·148	+ 77·159	– 0·001	+ 77·158
212	213	165·95	– 0·002	– 0·150	+ 76·852	– 0·001	+ 76·851
213	214	169·46	+ 0·004	– 0·146	+ 76·993	– 0·001	+ 76·992
214	215	169·49	– 0·001	– 0·147	+ 78·386	– 0·001	+ 78·385
215	216	169·56	– 0·004	– 0·151	+ 71·455	– 0·001	+ 71·454
216	217	170·55	– 0·017	– 0·168	+ 78·709	– 0·001	+ 78·708
217	218	171·56	– 0·012	– 0·180	+ 61·753	– 0·001	+ 61·752
218	219	172·56	+ 0·004	– 0·176	+ 76·128	– 0·001	+ 76·127
219	220	173·54	– 0·003	– 0·179	+ 54·670	– 0·001	+ 54·669
220	221	174·12	– 0·005	– 0·184	+ 55·217	– 0·001	+ 55·216
221	222	174·51	– 0·001	– 0·185	+ 54·576	– 0·001	+ 54·575
222	223	175·36	+ 0·004	– 0·181	+ 8·589	– 0·002	+ 8·587
223	224	175·66	– 0·006	– 0·187	+ 45·697	– 0·002	+ 45·695
224	225	177·35	– 0·003	– 0·190	+ 77·262	– 0·002	+ 77·260
225	226	178·37	– 0·009	– 0·199	+ 102·879	– 0·002	+ 102·877
226	227	179·36	– 0·011	– 0·210	+ 120·305	– 0·002	+ 120·303
227	228	180·36	+ 0·022	– 0·188	+ 122·053	– 0·002	+ 122·051
228	229	181·36	– 0·008	– 0·196	+ 135·061	– 0·002	+ 135·059
229	230	182·37	+ 0·007	– 0·189	+ 151·905	– 0·002	+ 151·903
230	231	183·70	– 0·001	– 0·190	+ 159·665	– 0·002	+ 159·663
231	232	185·70	– 0·008	– 0·198	+ 156·085	– 0·002	+ 156·083
232	233	187·71	+ 0·010	– 0·188	+ 147·436	– 0·002	+ 147·434
233	234*	192·97	– 0·002	– 0·190	+ 224·597	– 0·001	+ 224·596

Difference of dynamic height, Katni to Sironj = + 224·596 feet.

Length of line in miles = M = 192·97. $\Sigma d^2 = 0·017248$.

Probable error of the mean result per mile of double-levelling $= 0·6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm\, 0·0032$.

Probable error of the difference of elevation between the terminal bench-marks $= 0·6745 \sqrt{\frac{\Sigma d^2}{4}} = \pm\, 0·0443$.

* Bench-mark No. 234 is the mark at Sironj described on page 135.

Line No. 61. Ferozepore to Meerut.

Bench-marks		Distance from Ferozepore	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Ferozepore (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Ferozepore
From	To		From mark to mark (= d)	Total from Ferozepore		Total from Ferozepore	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	2·18	+ 0·012	+ 0·012	+ 3·119	+ 0·002	+ 3·121
2	3	15·34	+ 0·002	+ 0·014	+ 30·491	+ 0·016	+ 30·507
3	4	20·78	– 0·008	+ 0·006	+ 46·961	+ 0·025	+ 46·986
4	5	27·12	+ 0·034	+ 0·040	+ 71·786	+ 0·038	+ 71·824
5	6	40·12	+ 0·083	+ 0·123	+ 90·058	+ 0·047	+ 90·105
6	7	47·20	+ 0·069	+ 0·192	+ 110·709	+ 0·058	+ 110·767
7	8	51·89	– 0·012	+ 0·180	+ 119·413	+ 0·062	+ 119·475
8	9	63·60	+ 0·013	+ 0·193	+ 150·656	+ 0·078	+ 150·734
9	10	74·77	+ 0·029	+ 0·222	+ 160·781	+ 0·083	+ 160·864
10	11	87·16	+ 0·044	+ 0·266	+ 198·219	+ 0·102	+ 198·321
11	12	101·44	+ 0·079	+ 0·345	+ 218·163	+ 0·112	+ 218·275
12	13	111·05	+ 0·037	+ 0·382	+ 225·148	+ 0·116	+ 225·264
13	14	122·17	– 0·025	+ 0·357	+ 228·843	+ 0·118	+ 228·961
14	15	132·96	– 0·075	+ 0·282	+ 242·957	+ 0·125	+ 243·082
15	16	143·13	+ 0·019	+ 0·301	+ 256·138	+ 0·131	+ 256·269
16	17	165·73	+ 0·085	+ 0·386	+ 273·782	+ 0·139	+ 273·921
17	18	173·90	+ 0·006	+ 0·392	+ 278·044	+ 0·141	+ 278·185
18	19	179·00	+ 0·002	+ 0·394	+ 260·574	+ 0·133	+ 260·707
19	20	188·08	+ 0·075	+ 0·469	+ 250·976	+ 0·129	+ 251·105
20	21	195·44	+ 0·014	+ 0·483	+ 261·772	+ 0·134	+ 261·906
21	22	199·26	– 0·005	+ 0·478	+ 257·259	+ 0·132	+ 257·391
22	23	219·84	+ 0·023	+ 0·501	+ 186·465	+ 0·102	+ 186·567
23	24	231·12	+ 0·003	+ 0·504	+ 151·394	+ 0·088	+ 151·482
24	25	235·14	+ 0·017	+ 0·521	+ 144·530	+ 0·085	+ 144·615
25	26	238·14	– 0·003	+ 0·518	+ 156·499	+ 0·090	+ 156·589
26	27	245·88	+ 0·021	+ 0·539	+ 146·240	+ 0·086	+ 146·326
27	28	248·43	+ 0·032	+ 0·571	+ 144·346	+ 0·085	+ 144·431
28	29	250·98	+ 0·039	+ 0·610	+ 121·135	+ 0·076	+ 121·211
29	30	267·69	+ 0·044	+ 0·654	+ 88·981	+ 0·064	+ 89·045
30	31	267·71	– 0·002	+ 0·652	+ 89·990	+ 0·064	+ 90·054
31	32†	267·76	+ 0·001	+ 0·653	+ 93·830	+ 0·066	+ 93·896

Difference of dynamic height, Ferozepore to Meerut = + 93·896 feet.

Length of line in miles = M = 267·76. $\Sigma d^2 = 0·049203$.

Probable error of the mean result per mile of double-levelling $= 0·6745\sqrt{\dfrac{\Sigma d^2}{4M}} = \pm\, 0·0046$.

Probable error of the difference of elevation between the terminal bench-marks $= 0·6745\sqrt{\dfrac{\Sigma d^2}{4}} = \pm\, 0·0748$.

* Bench-mark No. 1 is the mark at Ferozepore described on page 134. † Bench-mark No. 32 is the mark at Meerut described on page 136.

Line No. 62. Meerut to Agra.

Bench-marks		Distance from Meerut	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Meerut (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Meerut
From	To		From mark to mark (= d)	Total from Meerut		Total from Meerut	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	5·63	+ 0·009	+ 0·009	– 6·516	– 0·002	– 6·518
2	3	12·56	+ 0·007	+ 0·016	– 25·792	– 0·009	– 25·801
3	4	20·15	+ 0·018	+ 0·034	– 46·368	– 0·016	– 46·384
4	5	22·56	+ 0·028	+ 0·062	– 44·182	– 0·015	– 44·197
5	6	30·38	– 0·029	+ 0·033	– 58·789	– 0·020	– 58·809
6	7	44·41	– 0·029	+ 0·004	– 65·599	– 0·022	– 65·621
7	8	44·42	+ 0·005	+ 0·009	– 68·529	– 0·023	– 68·552
8	9	48·44	+ 0·018	+ 0·027	– 80·200	– 0·027	– 80·227
9	10	54·67	+ 0·035	+ 0·062	– 91·549	– 0·030	– 91·579
10	11	65·50	+ 0·010	+ 0·072	– 103·062	– 0·034	– 103·096
11	12	67·66	+ 0·015	+ 0·087	– 117·000	– 0·038	– 117·038
12	13	70·37	+ 0·026	+ 0·113	– 114·550	– 0·037	– 114·587
13	14	81·79	+ 0·039	+ 0·152	– 129·419	– 0·041	– 129·460
14	15	81·81	+ 0·001	+ 0·153	– 133·453	– 0·042	– 133·495
15	16	86·54	– 0·004	+ 0·149	– 136·896	– 0·043	– 136·939
16	17	92·51	+ 0·014	+ 0·163	– 146·919	– 0·046	– 146·965
17	18	95·18	+ 0·001	+ 0·164	– 150·102	– 0·047	– 150·149
18	19	95·50	+ 0·006	+ 0·170	– 152·227	– 0·048	– 152·275
19	20	99·47	+ 0·006	+ 0·176	– 151·266	– 0·048	– 151·314
20	21	102·51	– 0·015	+ 0·161	– 153·294	– 0·049	– 153·343
21	22	109·44	+ 0·012	+ 0·173	– 164·138	– 0·052	– 164·190
22	23	110·45	– 0·003	+ 0·170	– 164·897	– 0·052	– 164·949
23	24	119·45	– 0·005	+ 0·165	– 181·801	– 0·056	– 181·857
24	25	123·47	+ 0·013	+ 0·178	– 184·408	– 0·057	– 184·465
25	26†	133·11	+ 0·010	+ 0·188	– 223·044	– 0·066	– 223·110

Difference of dynamic height, Meerut to Agra = – 223·110 feet.

Length of line in miles = M = 133·11. $\Sigma d^2 = 0{\cdot}007974$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4M}} = \pm\, 0{\cdot}0026$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0301$.

* Bench-mark No. 1 is the mark at Meerut described on page 135. † Bench-mark No. 26 is the mark at Agra described on page 133.

Line No. 63. Agra to Sironj.

Bench-marks From	Bench-marks To	Distance from Agra	Discrepancy between levellers (First − Second leveller) From mark to mark (= d)	Discrepancy between levellers (First − Second leveller) Total from Agra	Observed elevation above (+) or below (−) Agra (mean result by two levellers)	Dynamic correction deduced from mark to mark Total from Agra	Dynamic height above (+) or below (−) Agra
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	9·64	− 0·011	− 0·011	+ 38·636	+ 0·009	+ 38·645
2	3	21·89	+ 0·013	+ 0·002	+ 34·782	+ 0·008	+ 34·790
3	4	35·62	+ 0·030	+ 0·032	+ 33·442	+ 0·008	+ 33·450
4	5	43·38	− 0·001	+ 0·031	+ 42·441	+ 0·010	+ 42·451
5	6	51·08	+ 0·007	+ 0·038	+ 70·925	+ 0·016	+ 70·941
6	7	60·68	− 0·012	+ 0·026	+ 50·552	+ 0·012	+ 50·564
7	8	69·82	+ 0·025	+ 0·051	+ 57·192	+ 0·013	+ 57·205
8	9	79·20	− 0·001	+ 0·050	+ 71·643	+ 0·016	+ 71·659
9	10	97·21	− 0·022	+ 0·028	+ 298·096	+ 0·051	+ 298·147
10	11	106·20	− 0·003	+ 0·025	+ 431·567	+ 0·071	+ 431·638
11	12	115·79	− 0·014	+ 0·011	+ 596·069	+ 0·094	+ 596·163
12	13	134·87	+ 0·028	+ 0·039	+ 593·320	+ 0·094	+ 593·414
13	14	153·67	− 0·025	+ 0·014	+ 821·511	+ 0·118	+ 821·629
14	15	176·10	+ 0·092	+ 0·106	+ 1002·235	+ 0·133	+ 1002·368
15	16	185·49	0·000	+ 0·106	+ 985·236	+ 0·132	+ 985·368
16	17	195·50	+ 0·054	+ 0·160	+ 975·991	+ 0·131	+ 976·122
17	18	205·34	+ 0·034	+ 0·194	+ 1024·864	+ 0·134	+ 1024·998
18	19	215·68	+ 0·022	+ 0·216	+ 1081·544	+ 0·137	+ 1081·681
19	20	227·93	+ 0·051	+ 0·267	+ 1220·159	+ 0·142	+ 1220·301
20	21	238·04	+ 0·028	+ 0·295	+ 1223·210	+ 0·142	+ 1223·352
21	22	248·67	+ 0·008	+ 0·303	+ 1285·930	+ 0·143	+ 1286·073
22	23	261·27	− 0·012	+ 0·291	+ 1013·103	+ 0·140	+ 1013·243
23	24	265·44	− 0·025	+ 0·266	+ 961·900	+ 0·139	+ 962·039
24	25†	268·48	− 0·022	+ 0·244	+ 963·010	+ 0·139	+ 963·149

Difference of dynamic height, Agra to Sironj = + 963·149 feet.

Length of line in miles = M = 268·48. $\Sigma d^2 = 0{\cdot}021830$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0{\cdot}0030$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0{\cdot}0498$.

* Bench-mark No. 1 is the mark at Agra described on page 133. † Bench-mark No. 25 is the mark at Sironj described on page 135.

Line No. 64. Meerut to Lucknow.

Bench-marks		Distance from Meerut	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Meerut (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Meerut
From	To		From mark to mark (= *d*)	Total from Meerut		Total from Meerut	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·81	+ 0·004	+ 0·004	– 6·657	– 0·003	– 6·660
2	3	1·24	+ 0·003	+ 0·007	– 4·324	– 0·002	– 4·326
3	4	1·98	– 0·014	– 0·007	– 12·120	– 0·005	– 12·125
4	5	3·85	+ 0·001	– 0·006	– 15·784	– 0·006	– 15·790
5	6	4·21	+ 0·005	– 0·001	– 14·485	– 0·006	– 14·491
6	7	4·91	0·000	– 0·001	– 15·061	– 0·006	– 15·067
7	8	5·94	0·000	– 0·001	– 14·676	– 0·006	– 14·682
8	9	6·35	+ 0.006	+ 0·005	– 19·022	– 0·007	– 19·029
9	10	6·47	– 0·002	+ 0·003	– 17·009	– 0·006	– 17·015
10	11	6·98	+ 0·006	+ 0·009	– 14·732	– 0·005	– 14·737
11	12	8·01	+ 0·007	+ 0·016	– 14·902	– 0·005	– 14·907
12	13	9·01	– 0·001	+ 0·015	– 14·555	– 0·005	– 14·560
13	14	10·01	– 0·007	+ 0·008	– 13·967	– 0·005	– 13·972
14	15	11·05	+ 0·001	+ 0·009	– 17·172	– 0·006	– 17·178
15	16	11·45	– 0·003	+ 0·006	– 17·371	– 0·006	– 17·377
16	17	11·94	+ 0·003	+ 0·009	– 16·831	– 0·006	– 16·837
17	18	12·94	+ 0·016	+ 0·025	– 19·989	– 0·007	– 19·996
18	19	13·32	– 0·006	+ 0·019	– 17·242	– 0·006	– 17·248
19	20	13·94	– 0·002	+ 0·017	– 21·360	– 0·007	– 21·367
20	21	14·94	+ 0·002	+ 0·019	– 26·824	– 0·009	– 26·833
21	22	15·34	– 0·003	+ 0·016	– 27·472	– 0·009	– 27·481
22	23	15·94	– 0·002	+ 0·014	– 26·291	– 0·009	– 26·300
23	24	16·96	– 0·004	+ 0·010	– 16·079	– 0·005	– 16·084
24	25	17·98	– 0·006	+ 0·004	– 22·357	– 0·007	– 22·364
25	26	18·76	– 0·015	– 0·011	– 20·794	– 0·006	– 20·800
26	27	18·98	+ 0·002	– 0·009	– 26·692	– 0·008	– 26·700
27	28	19·30	– 0·005	– 0·014	– 13·728	– 0·003	– 13·731
28	29	19·99	+ 0·005	– 0·009	– 27·843	– 0·008	– 27·851
29	30	20·60	+ 0·008	– 0·001	– 26·712	– 0·008	– 26·720
30	31	20·99	– 0·006	– 0·007	– 28·268	– 0·009	– 28·277
31	32	21·10	0·000	– 0·007	– 22·102	– 0·007	– 22·109
32	33	21·98	– 0·004	– 0·011	– 29·732	– 0·010	– 29·742
33	34	22·98	+ 0·009	– 0·002	– 31·618	– 0·011	– 31·629
34	35	23·98	+ 0·003	+ 0·001	– 33·653	– 0·012	– 33·665
35	36	24·99	– 0·007	– 0·006	– 36·841	– 0·013	– 36·854
36	37	26·01	+ 0·004	– 0·002	– 40·507	– 0·014	– 40·521
37	38	27·02	+ 0·006	+ 0·004	– 39·073	– 0·014	– 39·087
38	39	28·02	+ 0·001	+ 0·005	– 30·582	– 0·011	– 30·593
39	40	28·70	– 0·006	– 0·001	– 37·925	– 0·014	– 37·939
40	41	29·03	– 0·007	– 0·008	– 44·954	– 0·017	– 44·971
41	42	29·56	0·000	– 0·008	– 80·909	– 0·030	– 80·939
42	43	34·89	+ 0·014	+ 0·006	– 75·138	– 0·028	– 75·166
43	44	35·12	+ 0·010	+ 0·016	– 77·958	– 0·029	– 77·987
44	45	36·12	+ 0·002	+ 0·018	– 79·204	– 0·029	– 79·233
45	46	37·10	0·000	+ 0·018	– 74·004	– 0·027	– 74·031
46	47	37·13	0·000	+ 0·018	– 73·833	– 0·027	– 73·860
47	48	37·89	– 0·001	+ 0·017	– 69·976	– 0·026	– 70·002
48	49	38·14	+ 0·006	+ 0·023	– 77·936	– 0·029	– 77·965
49	50	38·64	– 0·002	+ 0·021	– 71·701	– 0·027	– 71·728
50	51	39·15	– 0·003	+ 0·018	– 62·696	– 0·024	– 62·720
51	52	40·15	– 0·007	+ 0·011	– 55·216	– 0·021	– 55·237
52	53	41·15	+ 0·010	+ 0·021	– 55·280	– 0·021	– 55·301
53	54	41·58	+ 0·003	+ 0·024	– 55·368	– 0·021	– 55·389
54	55	42·16	+ 0·005	+ 0·029	– 51·199	– 0·020	– 51·219
55	56	43·16	+ 0·006	+ 0·035	– 50·686	– 0·020	– 50·706
56	57	44·16	+ 0·018	+ 0·053	– 48·548	– 0·019	– 48·567
57	58	45·17	+ 0·007	+ 0·060	– 48·094	– 0·019	– 48·113
58	59	46·17	+ 0·014	+ 0·074	– 43·956	– 0·018	– 43·974
59	60	47·17	+ 0·002	+ 0·076	– 45·811	– 0·019	– 45·830
60	61	47·27	+ 0·001	+ 0·077	– 46·469	– 0·019	– 46·488

* Bench-mark No. 1 is the mark at Meerut described on page 135.

Line No. 64. Meerut to Lucknow.—(Continued).

Bench-marks		Distance from Meerut	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Meerut (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Meerut
From	To		From mark to mark (= d)	Total from Meerut		Total from Meerut	
		miles	foot	foot	feet	foot	feet
61	62	47·47	– 0·003	+ 0·074	– 36·292	– 0·015	– 36·307
62	63	47·62	+ 0·004	+ 0·078	– 46·321	– 0·019	– 46·340
63	64	48·19	+ 0·006	+ 0·084	– 44·283	– 0·018	– 44·301
64	65	49·19	– 0·008	+ 0·076	– 46·504	– 0·019	– 46·523
65	66	50·20	+ 0·008	+ 0·084	– 49·508	– 0·020	– 49·528
66	67	51·08	– 0·007	+ 0·077	– 50·355	– 0·020	– 50·375
67	68	51·20	+ 0·005	+ 0·082	– 49·824	– 0·020	– 49·844
68	69	51·63	– 0·002	+ 0·080	– 50·830	– 0·020	– 50·850
69	70	52·21	+ 0·014	+ 0·094	– 49·910	– 0·020	– 49·930
70	71	53·21	+ 0·019	+ 0·113	– 55·849	– 0·022	– 55·871
71	72	53·52	– 0·004	+ 0·109	– 53·992	– 0·021	– 54·013
72	73	54·22	– 0·003	+ 0·106	– 51·882	– 0·020	– 51·902
73	74	54·83	– 0·002	+ 0·104	– 52·550	– 0·020	– 52·570
74	75	55·22	+ 0·003	+ 0·107	– 51·325	– 0·020	– 51·345
75	76	55·39	– 0·003	+ 0·104	– 53·375	– 0·021	– 53·396
76	77	56·22	– 0·003	+ 0·101	– 53·659	– 0·021	– 53·680
77	78	57·23	– 0·002	+ 0·099	– 61·102	– 0·024	– 61·126
78	79	57·96	– 0·008	+ 0·091	– 59·964	– 0·024	– 59·988
79	80	58·22	– 0·007	+ 0·084	– 59·705	– 0·024	– 59·729
80	81	58·51	+ 0·005	+ 0·089	– 60·927	– 0·024	– 60·951
81	82	59·23	– 0·012	+ 0·077	– 63·752	– 0·025	– 63·777
82	83	59·46	– 0·004	+ 0·073	– 61·878	– 0·024	– 61·902
83	84	62·24	– 0·024	+ 0·049	– 67·035	– 0·026	– 67·061
84	85	63·24	+ 0·016	+ 0·065	– 68·976	– 0·027	– 69·003
85	86	64·13	0·000	+ 0·065	– 73·735	– 0·029	– 73·764
86	87	64·25	+ 0·003	+ 0·068	– 74·358	– 0·029	– 74·387
87	88	65·27	+ 0·008	+ 0·076	– 74·572	– 0·029	– 74·601
88	89	66·25	+ 0·004	+ 0·080	– 76·762	– 0·030	– 76·792
89	90	66·83	+ 0·001	+ 0·081	– 82·123	– 0·032	– 82·155
90	91	67·26	+ 0·002	+ 0·083	– 90·961	– 0·035	– 90·996
91	92	67·49	– 0·005	+ 0·078	– 96·100	– 0·037	– 96·137
92	93	68·26	– 0·012	+ 0·066	– 97·867	– 0·038	– 97·905
93	94	68·47	+ 0·005	+ 0·071	– 98·803	– 0·038	– 98·841
94	95	69·27	– 0·008	+ 0·063	– 101·942	– 0·039	– 101·981
95	96	69·55	+ 0·001	+ 0·064	– 101·801	– 0·039	– 101·840
96	97	70·10	– 0·001	+ 0·063	– 101·505	– 0·039	– 101·544
97	98	70·27	– 0·001	+ 0·062	– 100·939	– 0·039	– 100·978
98	99	70·76	– 0·004	+ 0·058	– 105·750	– 0·041	– 105·791
99	100	70·91	– 0·001	+ 0·057	– 102·848	– 0·040	– 102·888
100	101	71·55	– 0·004	+ 0·053	– 98·918	– 0·039	– 98·957
101	102	72·04	– 0·002	+ 0·051	– 95·227	– 0·038	– 95·265
102	103	72·99	– 0·004	+ 0·047	– 97·657	– 0·039	– 97·696
103	104	77·08	– 0·010	+ 0·037	– 114·024	– 0·045	– 114·069
104	105	78·37	+ 0·005	+ 0·042	– 116·419	– 0·046	– 116·465
105	106	78·50	– 0·002	+ 0·040	– 109·164	– 0·043	– 109·207
106	107	80·40	– 0·011	+ 0·029	– 119·475	– 0·047	– 119·522
107	108	80·64	– 0·003	+ 0·026	– 118·600	– 0·047	– 118·647
108	109	80·99	– 0·006	+ 0·020	– 118·897	– 0·047	– 118·944
109	110	81·87	– 0·008	+ 0·012	– 120·998	– 0·048	– 121·046
110	111	81·92	0·000	+ 0·012	– 120·557	– 0·048	– 120·605
111	112	82·11	+ 0·004	+ 0·016	– 119·520	– 0·048	– 119·568
112	113	82·69	0·000	+ 0·016	– 118·375	– 0·048	– 118·423
113	114	83·60	+ 0·014	+ 0·030	– 122·210	– 0·049	– 122·259
114	115	83·75	– 0·002	+ 0·028	– 123·693	– 0·050	– 123·743
115	116	84·57	0·000	+ 0·028	– 121·622	– 0·049	– 121·671
116	117	84·99	– 0·002	+ 0·026	– 123·285	– 0·050	– 123·335
117	118	85·14	– 0·003	+ 0·023	– 124·935	– 0·051	– 124·986
118	119	88·80	+ 0·018	+ 0·041	– 123·800	– 0·051	– 123·851
119	120	89·90	– 0·004	+ 0·037	– 125·249	– 0·051	– 125·300
120	121	90·99	+ 0·007	+ 0·044	– 127·934	– 0·052	– 127·986

Line No. 64. Meerut to Lucknow.—(Continued).

Bench-marks		Distance from Meerut	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Meerut (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Meerut
From	To		From mark to mark (= *d*)	Total from Meerut		Total from Meerut	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
121	122	91·45	− 0·006	+ 0·038	− 130·560	− 0·053	− 130·613
122	123	91·89	− 0·004	+ 0·034	− 130·386	− 0·053	− 130·439
123	124	96·63	+ 0·005	+ 0·039	− 141·415	− 0·057	− 141·472
124	125	100·52	+ 0·005	+ 0·044	− 151·786	− 0·060	− 151·846
125	126	101·28	− 0·002	+ 0·042	− 156·992	− 0·062	− 157·054
126	127	102·60	+ 0·008	+ 0·050	− 155·805	− 0·062	− 155·867
127	128	103·06	− 0·003	+ 0·047	− 155·141	− 0·062	− 155·203
128	129	103·25	+ 0·001	+ 0·048	− 157·310	− 0·063	− 157·373
129	130	103·56	+ 0·005	+ 0·053	− 158·112	− 0·063	− 158·175
130	131	105·16	− 0·002	+ 0·051	− 161·367	− 0·064	− 161·431
131	132	105·73	+ 0·001	+ 0·052	− 161·274	− 0·064	− 161·338
132	133	107·04	+ 0·016	+ 0·068	− 167·989	− 0·066	− 168·055
133	134	107·60	+ 0·004	+ 0·072	− 165·928	− 0·065	− 165·993
134	135	108·20	+ 0·002	+ 0·074	− 169·571	− 0·066	− 169·637
135	136	109·64	+ 0·018	+ 0·092	− 171·506	− 0·067	− 171·573
136	137	109·87	0·000	+ 0·092	− 168·179	− 0·066	− 168·245
137	138	110·73	+ 0·017	+ 0·109	− 176·846	− 0·069	− 176·915
138	139	111·94	+ 0·008	+ 0·117	− 177·607	− 0·069	− 177·676
139	140	112·45	− 0·007	+ 0·110	− 175·720	− 0·068	− 175·788
140	141	112·61	− 0·001	+ 0·109	− 177·564	− 0·069	− 177·633
141	142	113·60	− 0·003	+ 0·106	− 178·374	− 0·069	− 178·443
142	143	114·49	+ 0·020	+ 0·126	− 185·895	− 0·072	− 185·967
143	144	114·86	− 0·004	+ 0·122	− 176·819	− 0·069	− 176·888
144	145	115·42	+ 0·002	+ 0·124	− 180·475	− 0·070	− 180·545
145	146	115·56	0·000	+ 0·124	− 180·396	− 0·070	− 180·466
146	147	116·47	− 0·004	+ 0·120	− 177·323	− 0·069	− 177·392
147	148	117·56	+ 0·009	+ 0·129	− 183·031	− 0·071	− 183·102
148	149	119·25	+ 0·009	+ 0·138	− 181·028	− 0·070	− 181·098
149	150	119·49	+ 0·008	+ 0·146	− 184·372	− 0·071	− 184·443
150	151	119·78	+ 0·005	+ 0·151	− 187·632	− 0·072	− 187·704
151	152	120·10	− 0·003	+ 0·148	− 187·717	− 0·072	− 187·789
152	153	120·41	− 0·004	+ 0·144	− 184·813	− 0·071	− 184·884
153	154	120·78	− 0·003	+ 0·141	− 188·806	− 0·072	− 188·878
154	155	120·86	− 0·004	+ 0·137	− 184·796	− 0·071	− 184·867
155	156	121·66	+ 0·006	+ 0·143	− 185·551	− 0·071	− 185·622
156	157	121·76	+ 0·003	+ 0·146	− 189·860	− 0·072	− 189·932
157	158	122·18	− 0·001	+ 0·145	− 184·393	− 0·070	− 184·463
158	159	122·76	+ 0·001	+ 0·146	− 190·382	− 0·072	− 190·454
159	160	123·76	− 0·005	+ 0·141	− 190·073	− 0·072	− 190·145
160	161	124·76	+ 0·003	+ 0·144	− 192·461	− 0·073	− 192·534
161	162	125·06	+ 0·001	+ 0·145	− 193·093	− 0·073	− 193·166
162	163	125·78	+ 0·007	+ 0·152	− 186·734	− 0·071	− 186·805
163	164	125·89	+ 0·004	+ 0·156	− 192·258	− 0·073	− 192·331
164	165	126·68	+ 0·010	+ 0·166	− 188·379	− 0·072	− 188·451
165	166	126·78	− 0·001	+ 0·165	− 190·529	− 0·073	− 190·602
166	167	126·93	− 0·001	+ 0·164	− 187·615	− 0·072	− 187·687
167	168	127·25	− 0·002	+ 0·162	− 183·442	− 0·071	− 183·513
168	169	127·94	+ 0·009	+ 0·171	− 173·155	− 0·068	− 173·223
169	170	128·51	+ 0·008	+ 0·179	− 175·727	− 0·069	− 175·796
170	171	128·60	0·000	+ 0·179	− 177·266	− 0·070	− 177·336
171	172	129·74	+ 0·011	+ 0·190	− 179·752	− 0·071	− 179·823
172	173	130·30	− 0·009	+ 0·181	− 183·899	− 0·072	− 183·971
173	174	131·01	− 0·003	+ 0·178	− 180·420	− 0·071	− 180·491
174	175	132·44	+ 0·001	+ 0·179	− 182·496	− 0·072	− 182·568
175	176	133·39	− 0·001	+ 0·178	− 186·807	− 0·073	− 186·880
176	177	135·20	− 0·007	+ 0·171	− 187·178	− 0·073	− 187·251
177	178	136·66	− 0·011	+ 0·160	− 188·727	− 0·074	− 188·801
178	179	138·20	+ 0·003	+ 0·163	− 187·042	− 0·073	− 187·115
179	180	138·87	+ 0·002	+ 0·165	− 189·266	− 0·074	− 189·340
180	181	139·13	+ 0·003	+ 0·168	− 189·950	− 0·074	− 190·024

Line No. 64. Meerut to Lucknow.—(Continued).

Bench-marks		Distance from Meerut	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Meerut (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Meerut
From	To		From mark to mark (=d)	Total from Meerut		Total from Meerut	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
181	182	140·12	– 0·017	+ 0·151	– 193·127	– 0·075	– 193·202
182	183	140·92	+ 0·001	+ 0·152	– 190·507	– 0·074	– 190·581
183	184	141·11	+ 0·001	+ 0·153	– 191·610	– 0·074	– 191·684
184	185	142·69	– 0·018	+ 0·135	– 197·125	– 0·076	– 197·201
185	186	143·01	+ 0·006	+ 0·141	– 196·889	– 0·076	– 196·965
186	187	143·36	– 0·009	+ 0·132	– 197·703	– 0·076	– 197·779
187	188	144·17	0·000	+ 0·132	– 200·127	– 0·077	– 200·204
188	189	145·10	+ 0·014	+ 0·146	– 200·378	– 0·077	– 200·455
189	190	145·92	– 0·008	+ 0·138	– 202·508	– 0·078	– 202·586
190	191	146·11	– 0·001	+ 0·137	– 200·475	– 0·077	– 200·552
191	192	147·10	+ 0·001	+ 0·138	– 205·219	– 0·078	– 205·297
192	193	147·71	+ 0·009	+ 0·147	– 210·572	– 0·080	– 210·652
193	194	148·09	– 0·007	+ 0·140	– 208·949	– 0·079	– 209·028
194	195	149·08	– 0·007	+ 0·133	– 208·471	– 0·079	– 208·550
195	196	150·08	+ 0·007	+ 0·140	– 214·179	– 0·081	– 214·260
196	197	150·99	– 0·004	+ 0·136	– 212·351	– 0·080	– 212·431
197	198	151·44	+ 0·002	+ 0·138	– 215·737	– 0·081	– 215·818
198	199	151·93	+ 0·002	+ 0·140	– 215·279	– 0·081	– 215·360
199	200	152·09	+ 0·004	+ 0·144	– 214·923	– 0·081	– 215·004
200	201	153·08	+ 0·001	+ 0·145	– 214·010	– 0·081	– 214·091
201	202	153·09	+ 0·004	+ 0·149	– 219·021	– 0·083	– 219·104
202	203	153·58	– 0·004	+ 0·145	– 219·136	– 0·083	– 219·219
203	204	153·63	– 0·148	– 0·003	– 220·243	– 0·083	– 220·326
204	205	155·62	+ 0·013	+ 0·010	– 217·484	– 0·082	– 217·566
205	206	156·61	– 0·003	+ 0·007	– 217·132	– 0·082	– 217·214
206	207	162·01	+ 0·023	+ 0·030	– 227·181	– 0·085	– 227·266
207	208	166·13	– 0·009	+ 0·021	– 239·559	– 0·089	– 239·648
208	209	168·68	+ 0·007	+ 0·028	– 245·445	– 0·091	– 245·536
209	210	169·59	+ 0·015	+ 0·043	– 250·452	– 0·093	– 250·545
210	211	174·47	+ 0·007	+ 0·050	– 248·218	– 0·092	– 248·310
211	212	175·44	– 0·009	+ 0·041	– 233·740	– 0·088	– 233·828
212	213	177·45	+ 0·002	+ 0·043	– 234·024	– 0·088	– 234·112
213	214	178·50	– 0·005	+ 0·038	– 239·501	– 0·090	– 239·591
214	215	181·56	+ 0·013	+ 0·051	– 235·974	– 0·089	– 236·063
215	216	190·26	+ 0·003	+ 0·054	– 249·287	– 0·094	– 249·381
216	217	193·66	– 0·007	+ 0·047	– 249·127	– 0·094	– 249·221
217	218	194·49	– 0·001	+ 0·046	– 252·724	– 0·095	– 252·819
218	219	196·50	+ 0·005	+ 0·051	– 249·913	– 0·094	– 250·007
219	220	202·78	+ 0·018	+ 0·069	– 259·330	– 0·096	– 259·426
220	221	206·14	+ 0·024	+ 0·093	– 264·577	– 0·097	– 264·674
221	222	211·30	+ 0·022	+ 0·115	– 274·134	– 0·100	– 274·234
222	223	214·22	+ 0·012	+ 0·127	– 295·963	– 0·106	– 296·069
223	224	215·07	– 0·011	+ 0·116	– 272·417	– 0·100	– 272·517
224	225	218·42	+ 0·025	+ 0·141	– 273·408	– 0·100	– 273·508
225	226	219·25	– 0·009	+ 0·132	– 276·441	– 0·101	– 276·542
226	227	219·29	– 0·001	+ 0·131	– 277·718	– 0·101	– 277·819
227	228	224·81	– 0·019	+ 0·112	– 284·691	– 0·103	– 284·794
228	229	228·50	+ 0·001	+ 0·113	– 290·213	– 0·104	– 290·317
229	230	228·90	+ 0·002	+ 0·115	– 292·186	– 0·105	– 292·291
230	231	229·46	+ 0·003	+ 0·118	– 294·240	– 0·106	– 294·346
231	232	230·24	– 0·002	+ 0·116	– 291·419	– 0·105	– 291·524
232	233	232·95	– 0·007	+ 0·109	– 291·415	– 0·105	– 291·520
233	234	234·02	+ 0·015	+ 0·124	– 291·843	– 0·105	– 291·948
234	235	235·37	+ 0·016	+ 0·140	– 300·144	– 0·107	– 300·251
235	236	237·89	+ 0·004	+ 0·144	– 307·702	– 0·109	– 307·811
236	237	238·09	– 0·006	+ 0·138	– 296·353	– 0·106	– 296·459
237	238	240·68	+ 0·011	+ 0·149	– 306·228	– 0·109	– 306·337
238	239	240·83	+ 0·003	+ 0·152	– 303·661	– 0·108	– 303·769
239	240	241·94	+ 0·014	+ 0·166	– 312·126	– 0·110	– 312·236
240	241	244·25	+ 0·013	+ 0·179	– 303·180	– 0·108	– 303·288

Line No. 64. Meerut to Lucknow.—(Continued).

Bench-marks From	Bench-marks To	Distance from Meerut	Discrepancy between levellers (First – Second leveller) From mark to mark (=d)	Discrepancy between levellers (First – Second leveller) Total from Meerut	Observed elevation above (+) or below (–) Meerut (mean result by two levellers)	Dynamic correction deduced from mark to mark Total from Meerut	Dynamic height above (+) or below (–) Meerut
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
241	242	244·70	0·000	+ 0·179	– 306·805	– 0·109	– 306·914
242	243	246·81	– 0·007	+ 0·172	– 304·123	– 0·108	– 304·231
243	244	250·91	+ 0·034	+ 0·206	– 305·750	– 0·108	– 305·858
244	245	254·88	+ 0·018	+ 0·224	– 314·640	– 0·110	– 314·750
245	246	260·23	– 0·001	+ 0·223	– 321·241	– 0·112	– 321·353
246	247	261·70	+ 0·004	+ 0·227	– 320·948	– 0·112	– 321·060
247	248	262·54	0·000	+ 0·227	– 320·617	– 0·112	– 320·729
248	249	265·32	+ 0·012	+ 0·239	– 322·594	– 0·113	– 322·707
249	250	273·31	+ 0·016	+ 0·255	– 337·615	– 0·116	– 337·731
250	251	275·87	– 0·002	+ 0·253	– 345·102	– 0·118	– 345·220
251	252	281·27	– 0·003	+ 0·250	– 373·533	– 0·124	– 373·657
252	253	282·48	+ 0·020	+ 0·270	– 362·366	– 0·122	– 362·488
253	254	283·53	– 0·008	+ 0·262	– 376·954	– 0·125	– 377·079
254	255	283·72	– 0·001	+ 0·261	– 375·850	– 0·125	– 375·975
255	256*	284·82	– 0·018	+ 0·243	– 355·642	– 0·121	– 355·763

Difference of dynamic height, Meerut to Lucknow = – 355·763 feet.

Length of line in miles = M = 284·82. $\Sigma d^2 = 0{\cdot}040015$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0{\cdot}0041$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0{\cdot}0675$.

* Bench-mark No. 256 is the mark at Lucknow described on page 135.

Line No. 65. Lucknow to Cawnpore.

Bench-marks		Distance from Lucknow	Discrepancy between levellers (First—Second leveller)		Observed elevation above (+) or below (−) Lucknow (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Lucknow
From	To		From mark to mark (= d)	Total from Lucknow		Total from Lucknow	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	1·10	+ 0·018	+ 0·018	− 20·208	− 0·004	− 20·212
2	3	3·15	+ 0·006	+ 0·024	+ 15·609	+ 0·003	+ 15·612
3	4	3·70	+ 0·010	+ 0·034	+ 15·981	+ 0·003	+ 15·984
4	5	11·60	+ 0·030	+ 0·064	+ 15·179	+ 0·003	+ 15·182
5	6	17·04	+ 0·022	+ 0·086	+ 14·897	+ 0·003	+ 14·900
6	7	24·90	− 0·033	+ 0·053	+ 19·045	+ 0·004	+ 19·049
7	8	25·10	+ 0·002	+ 0·055	+ 19·144	+ 0·004	+ 19·148
8	9	26·40	− 0·009	+ 0·046	+ 18·535	+ 0·004	+ 18·539
9	10	28·60	+ 0·004	+ 0·050	+ 23·438	+ 0·005	+ 23·443
10	11	30·03	+ 0·004	+ 0·054	+ 22·450	+ 0·005	+ 22·455
11	12	32·50	− 0·010	+ 0·044	+ 20·513	+ 0·005	+ 20·518
12	13	34·70	− 0·004	+ 0·040	+ 26·095	+ 0·006	+ 26·101
13	14	37·20	+ 0·001	+ 0·041	+ 22·500	+ 0·005	+ 22·505
14	15	38·70	+ 0·003	+ 0·044	+ 22·050	+ 0·005	+ 22·055
15	16	42·80	− 0·013	+ 0·031	+ 16·527	+ 0·004	+ 16·531
16	17	43·70	+ 0·003	+ 0·034	+ 11·235	+ 0·003	+ 11·238
17	18	49·04	+ 0·007	+ 0·041	+ 24·143	+ 0·005	+ 24·148
18	19†	49·40	+ 0·006	+ 0·047	+ 23·438	+ 0·005	+ 23·443

Difference of dynamic height, Lucknow to Cawnpore = + 23·443 feet.

Length of line in miles = M = 49·40. $\Sigma d^2 = 0·003439$.

Probable error of the mean result per mile of double-levelling $= 0·6745\sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0·0028$.

Probable error of the difference of elevation between the terminal bench-marks $= 0·6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0·0198$.

* Bench-mark No. 1 is the mark at Lucknow described on page 135. † Bench-mark No. 19 is the mark at Cawnpore described on page 133.

Line No. 66. Agra to Cawnpore.

Bench-marks		Distance from Agra	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Agra (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Agra
From	To		From mark to mark (= *d*)	Total from Agra		Total from Agra	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·16	0·000	0·000	– 5·343	– 0·001	– 5·344
2	3	2·01	+ 0·010	+ 0·010	– 3·590	– 0·001	– 3·591
3	4	6·74	– 0·041	– 0·031	+ 35·902	+ 0·008	+ 35·910
4	5	12·74	+ 0·033	+ 0·002	+ 32·397	+ 0·007	+ 32·404
5	6	13·01	+ 0·004	+ 0·006	+ 32·103	+ 0·007	+ 32·110
6	7	13·09	– 0·001	+ 0·005	+ 35·715	+ 0·008	+ 35·723
7	8	13·15	– 0·001	+ 0·004	+ 31·275	+ 0·007	+ 31·282
8	9	22·93	+ 0·006	+ 0·010	+ 23·926	+ 0·005	+ 23·931
9	10	23·13	0·000	+ 0·010	+ 27·416	+ 0·006	+ 27·422
10	11	23·16	– 0·003	+ 0·007	+ 24·132	+ 0·005	+ 24·137
11	12	27·15	+ 0·007	+ 0·014	+ 20·797	+ 0·004	+ 20·801
12	13	28·12	+ 0·002	+ 0·016	+ 19·122	+ 0·004	+ 19·126
13	14	29·11	0·000	+ 0·016	+ 17·817	+ 0·004	+ 17·821
14	15	35·67	+ 0·001	+ 0·017	+ 25·800	+ 0·006	+ 25·806
15	16	38·75	– 0·016	+ 0·001	+ 11·760	+ 0·003	+ 11·763
16	17	40·71	– 0·002	– 0·001	+ 10·321	+ 0·003	+ 10·324
17	18	41·69	+ 0·001	0·000	+ 8·972	+ 0·003	+ 8·975
18	19	44·63	– 0·015	– 0·015	+ 9·976	+ 0·003	+ 9·979
19	20	45·61	– 0·008	– 0·023	+ 19·377	+ 0·005	+ 19·382
20	21	46·59	+ 0·001	– 0·022	+ 5·984	+ 0·002	+ 5·986
21	22	47·56	+ 0·007	– 0·015	+ 8·982	+ 0·003	+ 8·985
22	23	49·52	– 0·006	– 0·021	+ 5·893	+ 0·002	+ 5·895
23	24	50·50	+ 0·001	– 0·020	+ 9·486	+ 0·003	+ 9·489
24	25	52·30	+ 0·001	– 0·019	+ 17·972	+ 0·005	+ 17·977
25	26	52·51	+ 0·001	– 0·018	+ 9·224	+ 0·003	+ 9·227
26	27	53·49	+ 0·006	– 0·012	+ 8·555	+ 0·003	+ 8·558
27	28	56·42	+ 0·011	– 0·001	+ 5·585	+ 0·002	+ 5·587
28	29	58·19	+ 0·004	+ 0·003	+ 15·451	+ 0·004	+ 15·455
29	30	58·51	+ 0·004	+ 0·007	+ 9·294	+ 0·003	+ 9·297
30	31	60·46	+ 0·005	+ 0·012	+ 6·012	+ 0·002	+ 6·014
31	32	63·40	– 0·001	+ 0·011	+ 4·291	+ 0·002	+ 4·293
32	33	65·03	+ 0·004	+ 0·015	+ 7·034	+ 0·003	+ 7·037
33	34	66·38	+ 0·002	+ 0·017	+ 0·671	+ 0·002	+ 0·673
34	35	68·35	– 0·007	+ 0·010	– 0·548	+ 0·002	– 0·546
35	36	70·31	– 0·004	+ 0·006	– 2·889	+ 0·001	– 2·888
36	37	72·29	+ 0·007	+ 0·013	– 4·595	+ 0·001	– 4·594
37	38	74·25	– 0·006	+ 0·007	– 8·167	0·000	– 8·167
38	39	75·23	+ 0·003	+ 0·010	– 10·892	– 0·001	– 10·893
39	40	77·43	+ 0·006	+ 0·016	– 5·798	0·000	– 5·798
40	41	79·19	+ 0·003	+ 0·019	– 14·670	– 0·002	– 14·672
41	42	80·16	+ 0·008	+ 0·027	– 15·438	– 0·002	– 15·440
42	43	80·78	+ 0·005	+ 0·032	– 8·851	– 0·001	– 8·852
43	44	81·16	– 0·007	+ 0·025	– 14·541	– 0·002	– 14·543
44	45	83·15	– 0·009	+ 0·016	– 17·702	– 0·003	– 17·705
45	46	84·12	– 0·007	+ 0·009	– 19·433	– 0·003	– 19·436
46	47	85·11	– 0·007	+ 0·002	– 19·483	– 0·003	– 19·486
47	48	87·08	+ 0·002	+ 0·004	– 21·508	– 0·003	– 21·511
48	49	87·26	– 0·004	0·000	– 15·731	– 0·002	– 15·733
49	50	90·45	+ 0·012	+ 0·012	– 19·164	– 0·003	– 19·167
50	51	92·03	– 0·003	+ 0·009	– 26·180	– 0·004	– 26·184
51	52	93·01	+ 0·011	+ 0·020	– 28·369	– 0·004	– 28·373
52	53	93·18	– 0·005	+ 0·015	– 22·643	– 0·003	– 22·646
53	54	96·97	– 0·004	+ 0·011	– 32·699	– 0·005	– 32·704
54	55	98·94	+ 0·006	+ 0·017	– 35·932	– 0·006	– 35·938
55	56	100·90	+ 0·016	+ 0·033	– 37·023	– 0·006	– 37·029
56	57	102·20	– 0·002	+ 0·031	– 32·963	– 0·005	– 32·968
57	58	102·90	– 0·001	+ 0·030	– 41·177	– 0·007	– 41·184
58	59	103·88	– 0·005	+ 0·025	– 43·226	– 0·007	– 43·233
59	60	106·81	+ 0·005	+ 0·030	– 44·966	– 0·007	– 44·973
60	61	107·78	– 0·001	+ 0·029	– 46·040	– 0·007	– 46·047

* Bench-mark No. 1 is the mark at Agra described on page 138.

Line No. 66. Agra to Cawnpore.—(Continued).

Bench-marks		Distance from Agra	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Agra (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Agra
From	To		From mark to mark (= d)	Total from Agra		Total from Agra	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	108·47	− 0·003	+ 0·026	− 39·038	− 0·006	− 39·044
62	63	109·75	− 0·002	+ 0·024	− 47·725	− 0·008	− 47·733
63	64	111·70	− 0·008	+ 0·016	− 49·868	− 0·008	− 49·876
64	65	113·56	+ 0·003	+ 0·019	− 44·300	− 0·007	− 44·307
65	66	113·68	+ 0·002	+ 0·021	− 51·712	− 0·008	− 51·720
66	67	115·55	+ 0·001	+ 0·022	− 46·567	− 0·007	− 46·574
67	68	118·61	+ 0·003	+ 0·025	− 52·230	− 0·008	− 52·238
68	69	120·59	+ 0·012	+ 0·037	− 57·894	− 0·009	− 57·903
69	70	121·68	− 0·002	+ 0·035	− 58·170	− 0·009	− 58·179
70	71	121·73	− 0·007	+ 0·028	− 53·157	− 0·008	− 53·165
71	72	122·59	− 0·002	+ 0·026	− 61·664	− 0·010	− 61·674
72	73	123·58	+ 0·006	+ 0·032	− 61·085	− 0·010	− 61·095
73	74	124·56	+ 0·003	+ 0·035	− 63·682	− 0·011	− 63·693
74	75	125·55	+ 0·002	+ 0·037	− 63·015	− 0·011	− 63·026
75	76	126·77	+ 0·003	+ 0·040	− 57·654	− 0·010	− 57·664
76	77	128·56	+ 0·005	+ 0·045	− 64·638	− 0·011	− 64·649
77	78	129·55	0·000	+ 0·045	− 66·678	− 0·011	− 66·689
78	79	130·53	+ 0·005	+ 0·050	− 68·499	− 0·011	− 68·510
79	80	131·52	− 0·009	+ 0·041	− 67·483	− 0·011	− 67·494
80	81	132·51	+ 0·009	+ 0·050	− 70·146	− 0·012	− 70·158
81	82	134·48	+ 0·005	+ 0·055	− 71·015	− 0·012	− 71·027
82	83	137·44	− 0·002	+ 0·053	− 74·675	− 0·013	− 74·688
83	84	138·42	− 0·003	+ 0·050	− 76·642	− 0·013	− 76·655
84	85	139·82	− 0·001	+ 0·049	− 70·968	− 0·012	− 70·980
85	86	141·85	+ 0·002	+ 0·051	− 72·462	− 0·012	− 72·474
86	87	142·38	− 0·006	+ 0·045	− 79·594	− 0·013	− 79·607
87	88	144·35	+ 0·006	+ 0·051	− 80·773	− 0·013	− 80·786
88	89	144·59	− 0·003	+ 0·048	− 75·687	− 0·012	− 75·699
89	90	145·35	+ 0·009	+ 0·057	− 82·724	− 0·013	− 82·737
90	91	146·34	− 0·008	+ 0·049	− 84·516	− 0·013	− 84·529
91	92	146·45	− 0·004	+ 0·045	− 77·595	− 0·012	− 77·607
92	93	147·33	+ 0·011	+ 0·056	− 85·211	− 0·014	− 85·225
93	94	148·32	− 0·001	+ 0·055	− 85·210	− 0·014	− 85·224
94	95	149·31	+ 0·004	+ 0·059	− 88·003	− 0·015	− 88·018
95	96	150·30	+ 0·009	+ 0·068	− 86·723	− 0·015	− 86·738
96	97	152·60	− 0·002	+ 0·066	− 84·117	− 0·014	− 84·131
97	98	153·26	+ 0·001	+ 0·067	− 90·834	− 0·015	− 90·849
98	99	155·24	+ 0·003	+ 0·070	− 91·480	− 0·015	− 91·495
99	100	155·36	− 0·002	+ 0·068	− 86·936	− 0·014	− 86·950
100	101	156·23	− 0·001	+ 0·067	− 92·549	− 0·015	− 92·564
101	102	157·64	+ 0·019	+ 0·086	− 88·039	− 0·014	− 88·053
102	103	159·19	+ 0·006	+ 0·092	− 94·966	− 0·015	− 94·981
103	104	161·63	− 0·011	+ 0·081	− 92·573	− 0·015	− 92·588
104	105	165·65	0·000	+ 0·081	− 99·879	− 0·016	− 99·895
105	106	166·21	+ 0·013	+ 0·094	− 100·302	− 0·016	− 100·318
106	107	166·91	− 0·003	+ 0·091	− 103·346	− 0·017	− 103·363
107	108	167·89	− 0·020	+ 0·071	− 106·595	− 0·018	− 106·613
108	109*	167·95	+ 0·004	+ 0·075	− 108·513	− 0·018	− 108·531

Difference of dynamic height, Agra to Cawnpore = − 108·531 feet.

Length of line in miles = M = 167·95. $\Sigma d^2 = 0{\cdot}007271$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\dfrac{\Sigma d^2}{4M}} = \pm\, 0{\cdot}0022$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\dfrac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0288$.

* Bench-mark No. 109 is the mark at Cawnpore described on page 133.

Line No. 67. Cawnpore to Allahabad.

Bench-marks		Distance from Cawnpore	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Cawnpore (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Cawnpore
From	To		From mark to mark (= d)	Total from Cawnpore		Total from Cawnpore	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·06	+ 0·071	+ 0·071	+ 1·918	0·000	+ 1·918
2	3	1·05	+ 0·020	+ 0·091	+ 5·167	+ 0·001	+ 5·168
3	4	1·75	+ 0·003	+ 0·094	+ 8·210	+ 0·002	+ 8·212
4	5	2·34	– 0·007	+ 0·087	+ 14·673	+ 0·003	+ 14·676
5	6	3·77	+ 0·007	+ 0·094	+ 5·421	+ 0·001	+ 5·422
6	7	4·79	– 0·006	+ 0·088	+ 5·536	+ 0·001	+ 5·537
7	8	6·54	– 0·005	+ 0·083	+ 2·597	0·000	+ 2·597
8	9	7·54	– 0·002	+ 0·081	+ 0·128	0·000	+ 0·128
9	10	8·55	– 0·002	+ 0·079	+ 0·966	0·000	+ 0·966
10	11	10·56	+ 0·007	+ 0·086	– 9·710	– 0·002	– 9·712
11	12	11·57	+ 0·004	+ 0·090	– 4·985	– 0·001	– 4·986
12	13	12·58	– 0·012	+ 0·078	– 2·048	0·000	– 2·048
13	14	13·35	– 0·003	+ 0·075	– 4·964	– 0·001	– 4·965
14	15	13·58	+ 0·002	+ 0·077	– 5·604	– 0·001	– 5·605
15	16	14·59	+ 0·004	+ 0·081	– 2·614	0·000	– 2·614
16	17	15·59	+ 0·018	+ 0·099	– 4·751	0·000	– 4·751
17	18	17·62	– 0·013	+ 0·086	– 5·760	0·000	– 5·760
18	19	18·62	+ 0·003	+ 0·089	– 9·053	– 0·001	– 9·054
19	20	19·63	+ 0·005	+ 0·094	– 11·763	– 0·001	– 11·764
20	21	20·64	+ 0·004	+ 0·098	– 12·049	– 0·001	– 12·050
21	22	22·65	– 0·009	+ 0·089	– 18·376	– 0·002	– 18·378
22	23	23·66	– 0·005	+ 0·084	– 25·786	– 0·003	– 25·789
23	24	24·66	+ 0·010	+ 0·094	– 11·488	– 0·001	– 11·489
24	25	26·68	+ 0·003	+ 0·097	– 12·212	– 0·001	– 12·213
25	26	26·95	– 0·005	+ 0·092	– 15·337	– 0·002	– 15·339
26	27	27·70	0·000	+ 0·092	– 12·978	– 0·002	– 12·980
27	28	29·71	– 0·006	+ 0·086	– 9·870	– 0·001	– 9·871
28	29	30·53	– 0·005	+ 0·081	– 12·649	– 0·001	– 12·650
29	30	31·60	+ 0·001	+ 0·082	– 14·755	– 0·001	– 14·756
30	31	34·68	– 0·007	+ 0·075	– 12·294	– 0·001	– 12·295
31	32	36·64	– 0·005	+ 0·070	– 15·516	– 0·002	– 15·518
32	33	37·65	+ 0·010	+ 0·080	– 17·381	– 0·002	– 17·383
33	34	38·66	– 0·001	+ 0·079	– 17·881	– 0·002	– 17·883
34	35	40·04	+ 0·008	+ 0·087	– 20·317	– 0·002	– 20·319
35	36	41·44	– 0·004	+ 0·083	– 22·323	– 0·002	– 22·325
36	37	43·71	+ 0·009	+ 0·092	– 24·651	– 0·002	– 24·653
37	38	50·54	+ 0·017	+ 0·109	– 35·169	– 0·004	– 35·173
38	39	51·65	– 0·005	+ 0·104	– 42·519	– 0·005	– 42·524
39	40	53·67	+ 0·010	+ 0·114	– 40·677	– 0·005	– 40·682
40	41	55·69	+ 0·007	+ 0·121	– 34·894	– 0·004	– 34·898
41	42	56·70	+ 0·009	+ 0·130	– 36·564	– 0·004	– 36·568
42	43	58·73	+ 0·003	+ 0·133	– 38·260	– 0·004	– 38·264
43	44	59·74	– 0·004	+ 0·129	– 41·687	– 0·004	– 41·691
44	45	60·74	+ 0·003	+ 0·132	– 40·185	– 0·004	– 40·189
45	46	64·78	+ 0·005	+ 0·137	– 47·812	– 0·005	– 47·817
46	47	65·79	– 0·008	+ 0·129	– 50·054	– 0·005	– 50·059
47	48	66·80	+ 0·003	+ 0·132	– 50·386	– 0·005	– 50·391
48	49	67·81	– 0·010	+ 0·122	– 51·572	– 0·005	– 51·577
49	50	68·81	– 0·005	+ 0·117	– 50·471	– 0·005	– 50·476
50	51	69·83	0·000	+ 0·117	– 50·621	– 0·005	– 50·626
51	52	71·85	– 0·003	+ 0·114	– 55·674	– 0·006	– 55·680
52	53	72·85	– 0·003	+ 0·111	– 53·512	– 0·006	– 53·518
53	54	74·87	– 0·003	+ 0·108	– 55·675	– 0·006	– 55·681
54	55	76·89	– 0·002	+ 0·106	– 56·579	– 0·006	– 56·585
55	56	77·90	– 0·008	+ 0·098	– 60·106	– 0·006	– 60·112
56	57	78·91	+ 0·001	+ 0·099	– 62·396	– 0·006	– 62·402
57	58	81·94	+ 0·008	+ 0·107	– 60·128	– 0·006	– 60·134
58	59	83·87	– 0·002	+ 0·105	– 57·942	– 0·006	– 57·948
59	60	85·98	– 0·003	+ 0·102	– 61·347	– 0·006	– 61·353
60	61	86·99	+ 0·004	+ 0·106	– 64·286	– 0·006	– 64·292

* Bench-mark No. 1 is the mark at Cawnpore described on page 133.

Line No. 67. Cawnpore to Allahabad.—(Continued).

Bench-marks		Distance from Cawnpore	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Cawnpore (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Cawnpore
From	To		From mark to mark (= d)	Total from Cawnpore		Total from Cawnpore	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	88·00	0·000	+ 0·106	– 60·690	– 0·006	– 60·696
62	63	88·29	– 0·003	+ 0·103	– 58·866	– 0·006	– 58·872
63	64	89·01	+ 0·007	+ 0·110	– 61·442	– 0·006	– 61·448
64	65	90·02	– 0·001	+ 0·109	– 63·203	– 0·006	– 63·209
65	66	91·03	+ 0·011	+ 0·120	– 62·402	– 0·006	– 62·408
66	67	93·04	+ 0·012	+ 0·132	– 67·907	– 0·007	– 67·914
67	68	95·06	– 0·002	+ 0·130	– 65·543	– 0·007	– 65·550
68	69	96·06	– 0·011	+ 0·119	– 64·771	– 0·007	– 64·778
69	70	98·07	+ 0·009	+ 0·128	– 75·296	– 0·008	– 75·304
70	71	99·08	– 0·002	+ 0·126	– 70·918	– 0·008	– 70·926
71	72	100·09	– 0·004	+ 0·122	– 72·133	– 0·008	– 72·141
72	73	101·10	+ 0·007	+ 0·129	– 73·064	– 0·008	– 73·072
73	74	101·47	0·000	+ 0·129	– 79·400	– 0·009	– 79·409
74	75	102·11	– 0·010	+ 0·119	– 74·900	– 0·008	– 74·908
75	76	103·14	+ 0·001	+ 0·120	– 93·063	– 0·010	– 93·073
76	77	104·11	+ 0·008	+ 0·128	– 77·976	– 0·008	– 77·984
77	78	106·14	– 0·004	+ 0·124	– 74·819	– 0·008	– 74·827
78	79	107·14	– 0·007	+ 0·117	– 79·173	– 0·008	– 79·181
79	80	109·15	+ 0·009	+ 0·126	– 94·938	– 0·010	– 94·948
80	81	110·16	+ 0·008	+ 0·134	– 78·381	– 0·008	– 78·389
81	82	111·17	+ 0·006	+ 0·140	– 77·572	– 0·008	– 77·580
82	83	113·18	– 0·014	+ 0·126	– 81·906	– 0·008	– 81·914
83	84	114·84	+ 0·003	+ 0·129	– 77·102	– 0·007	– 77·109
84	85	116·71	+ 0·005	+ 0·134	– 83·916	– 0·008	– 83·924
85	86	117·70	– 0·001	+ 0·133	– 85·693	– 0·008	– 85·701
86	87	120·92	+ 0·002	+ 0·135	– 89·805	– 0·008	– 89·813
87	88	123·76	– 0·016	+ 0·119	– 91·558	– 0·008	– 91·566
88	89	124·76	– 0·002	+ 0·117	– 91·698	– 0·008	– 91·706
89	90	125·73	– 0·004	+ 0·113	– 88·146	– 0·008	– 88·154
90	91	128·90	0·000	+ 0·113	– 118·778	– 0·011	– 118·789
91	92	128·96	– 0·002	+ 0·111	– 109·365	– 0·010	– 109·375
92	93*	128·98	0·000	+ 0·111	– 109·023	– 0·010	– 109·033

Difference of dynamic height, Cawnpore to Allahabad = – 109·033 feet.

Length of line in miles = M = 128·98. $\Sigma d^2 = 0{\cdot}009551$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\dfrac{\Sigma d^2}{4M}} = \pm\ 0{\cdot}0029$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\dfrac{\Sigma d^2}{4}} = \pm\ 0{\cdot}0330$.

* Bench-mark No. 93 is the mark at Allahabad described on page 133.

Line No. 68. Lucknow to Gorakhpur.

Bench-marks From	Bench-marks To	Distance from Lucknow	Discrepancy between levellers (First – Second leveller) From mark to mark (= d)	Discrepancy between levellers (First – Second leveller) Total from Lucknow	Observed elevation above (+) or below (–) Lucknow (mean result by two levellers)	Dynamic correction deduced from mark to mark Total from Lucknow	Dynamic height above (+) or below (–) Lucknow
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	1·10	– 0·018	– 0·018	– 20·208	– 0·004	– 20·212
2	3	1·29	– 0·001	– 0·019	– 21·312	– 0·004	– 21·316
3	4	2·34	– 0·008	– 0·027	– 6·724	– 0·001	– 6·725
4	5	4·87	+ 0·028	+ 0·001	– 18·077	– 0·003	– 18·080
5	6	6·88	+ 0·014	+ 0·015	– 2·034	0·000	– 2·034
6	7	9·41	+ 0·002	+ 0·017	– 0·480	0·000	– 0·480
7	8	10·72	– 0·004	+ 0·013	+ 1·427	0·000	+ 1·427
8	9	12·06	– 0·008	+ 0·005	+ 5·296	+ 0·001	+ 5·297
9	10	13·72	– 0·012	– 0·007	+ 7·317	+ 0·001	+ 7·318
10	11	14·05	– 0·003	– 0·010	+ 6·506	+ 0·001	+ 6·507
11	12	14·60	+ 0·009	– 0·001	+ 7·562	+ 0·001	+ 7·563
12	13	15·81	– 0·007	– 0·008	+ 1·138	0·000	+ 1·138
13	14	18·23	+ 0·010	+ 0·002	+ 2·688	0·000	+ 2·688
14	15	19·05	– 0·002	0·000	– 6·252	– 0·002	– 6·254
15	16	19·11	– 0·001	– 0·001	– 5·724	– 0·002	– 5·726
16	17	19·73	+ 0·002	+ 0·001	+ 3·202	0·000	+ 3·202
17	18	20·45	0·000	+ 0·001	+ 4·652	0·000	+ 4·652
18	19	21·04	+ 0·006	+ 0·007	+ 2·255	0·000	+ 2·255
19	20	21·37	– 0·001	+ 0·006	+ 5·167	+ 0·001	+ 5·168
20	21	22·58	+ 0·002	+ 0·008	+ 5·913	+ 0·001	+ 5·914
21	22	23·02	+ 0·009	+ 0·017	+ 4·548	+ 0·001	+ 4·549
22	23	23·83	+ 0·004	+ 0·021	+ 7·593	+ 0·002	+ 7·595
23	24	24·99	– 0·007	+ 0·014	+ 0·925	+ 0·001	+ 0·926
24	25	25·51	– 0·011	+ 0·003	+ 5·114	+ 0·002	+ 5·116
25	26	26·98	– 0·010	– 0·007	– 0·846	+ 0·001	– 0·845
26	27	28·15	– 0·013	– 0·020	– 1·285	+ 0·001	– 1·284
27	28	28·96	+ 0·002	– 0·018	– 10·416	– 0·001	– 10·417
28	29	29·30	+ 0·007	– 0·011	– 8·508	– 0·001	– 8·509
29	30	30·16	– 0·004	– 0·015	– 4·290	0·000	– 4·290
30	31	30·03	– 0·015	– 0·030	– 9·024	– 0·001	– 9·025
31	32	32·13	+ 0·016	– 0·014	– 3·978	0·000	– 3·978
32	33	32·91	– 0·007	– 0·021	– 10·312	– 0·001	– 10·313
33	34	34·24	– 0·008	– 0·029	– 10·954	– 0·001	– 10·955
34	35	34·90	+ 0·004	– 0·025	– 15·820	– 0·002	– 15·822
35	36	36·88	+ 0·007	– 0·018	– 14·459	– 0·002	– 14·461
36	37	37·87	– 0·006	– 0·024	– 15·759	– 0·002	– 15·761
37	38	39·85	– 0·001	– 0·025	– 18·738	– 0·003	– 18·741
38	39	41·83	– 0·012	– 0·037	– 26·249	– 0·005	– 26·254
39	40	43·19	+ 0·008	– 0·029	– 22·163	– 0·004	– 22·167
40	41	43·46	– 0·007	– 0·036	– 26·791	– 0·005	– 26·796
41	42	43·80	+ 0·001	– 0·035	– 31·163	– 0·006	– 31·169
42	43	44·43	+ 0·002	– 0·033	– 30·616	– 0·006	– 30·622
43	44	45·80	+ 0·001	– 0·032	– 24·498	– 0·005	– 24·503
44	45	47·77	– 0·029	– 0·061	– 27·462	– 0·006	– 27·468
45	46	49·75	– 0·023	– 0·084	– 26·312	– 0·006	– 26·318
46	47	51·73	+ 0·002	– 0·082	– 32·250	– 0·007	– 32·257
47	48	53·71	+ 0·029	– 0·053	– 33·144	– 0·007	– 33·151
48	49	55·70	– 0·010	– 0·063	– 31·829	– 0·007	– 31·836
49	50	56·42	– 0·009	– 0·072	– 32·167	– 0·007	– 32·174
50	51	57·80	– 0·006	– 0·078	– 39·859	– 0·008	– 39·867
51	52	58·79	– 0·007	– 0·085	– 41·456	– 0·008	– 41·464
52	53	59·41	– 0·006	– 0·091	– 43·648	– 0·008	– 43·656
53	54	59·78	+ 0·001	– 0·090	– 41·234	– 0·008	– 41·242
54	55	61·76	+ 0·001	– 0·089	– 43·291	– 0·008	– 43·299
55	56	62·75	– 0·002	– 0·091	– 45·402	– 0·008	– 45·410
56	57	65·72	– 0·006	– 0·097	– 49·985	– 0·009	– 49·994
57	58	66·71	0·000	– 0·097	– 46·397	– 0·008	– 46·405
58	59	68·67	+ 0·021	– 0·076	– 47·865	– 0·008	– 47·873
59	60	69·66	+ 0·006	– 0·070	– 45·165	– 0·007	– 45·172
60	61	70·66	– 0·002	– 0·072	– 47·259	– 0·007	– 47·266

* Bench-mark No. 1 is the mark at Lucknow described on page 135.

Line No. 68. Lucknow to Gorakhpur.—(Continued).

Bench-marks		Distance from Lucknow	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Lucknow (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Lucknow
From	To		From mark to mark (= d)	Total from Lucknow		Total from Lucknow	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	72·64	− 0·014	− 0·086	− 51·746	− 0·008	− 51·754
62	63	73·63	− 0·012	− 0·098	− 51·297	− 0·008	− 51·305
63	64	74·62	+ 0·006	− 0·092	− 51·916	− 0·008	− 51·924
64	65	77·63	− 0·018	− 0·110	− 62·635	− 0·010	− 62·645
65	66	79·14	+ 0·001	− 0·109	− 52·643	− 0·008	− 52·651
66	67	79·83	+ 0·003	− 0·106	− 52·863	− 0·008	− 52·871
67	68	79·87	− 0·003	− 0·109	− 54·853	− 0·008	− 54·861
68	69	80·81	− 0·001	− 0·110	− 48·175	− 0·007	− 48·182
69	70	83·10	− 0·011	− 0·121	− 58·046	− 0·009	− 58·055
70	71	85·09	− 0·025	− 0·146	− 55·411	− 0·008	− 55·419
71	72	85·31	0·000	− 0·146	− 74·920	− 0·012	− 74·932
72	73	87·58	− 0·001	− 0·147	− 78·538	− 0·013	− 78·551
73	74	89·96	+ 0·001	− 0·146	− 77·562	− 0·013	− 77·575
74	75	90·92	− 0·011	− 0·157	− 80·555	− 0·014	− 80·569
75	76	93·65	− 0·008	− 0·165	− 83·010	− 0·015	− 83·025
76	77	98·04	− 0·010	− 0·175	− 81·539	− 0·015	− 81·554
77	78	100·72	− 0·007	− 0·182	− 89·562	− 0·017	− 89·579
78	79	102·84	+ 0·001	− 0·181	− 83·061	− 0·016	− 83·077
79	80	103·50	− 0·007	− 0·188	− 91·918	− 0·018	− 91·936
80	81	105·30	+ 0·010	− 0·178	− 87·226	− 0·017	− 87·243
81	82	107·26	+ 0·010	− 0·168	− 89·343	− 0·017	− 89·360
82	83	107·69	− 0·006	− 0·174	− 91·030	− 0·017	− 91·047
83	84	108·71	+ 0·004	− 0·170	− 88·927	− 0·017	− 88·944
84	85	109·35	− 0·006	− 0·176	− 88·566	− 0·017	− 88·583
85	86	110·52	+ 0·004	− 0·172	− 94·547	− 0·018	− 94·565
86	87	112·15	− 0·006	− 0·178	− 91·457	− 0·017	− 91·474
87	88	114·20	− 0·002	− 0·180	− 91·751	− 0·017	− 91·768
88	89	115·66	+ 0·005	− 0·175	− 93·084	− 0·017	− 93·101
89	90	119·11	+ 0·006	− 0·169	− 98·478	− 0·018	− 98·496
90	91	119·61	− 0·002	− 0·171	− 93·504	− 0·017	− 93·521
91	92	119·75	0·000	− 0·171	− 92·416	− 0·017	− 92·433
92	93	119·80	− 0·001	− 0·172	− 92·981	− 0·017	− 92·998
93	94	120·85	− 0·001	− 0·173	− 92·613	− 0·017	− 92·630
94	95	127·48	− 0·017	− 0·190	− 97·982	− 0·018	− 98·000
95	96	130·96	+ 0·003	− 0·187	− 104·510	− 0·019	− 104·529
96	97	132·22	+ 0·003	− 0·184	− 104·497	− 0·019	− 104·516
97	98	133·65	+ 0·003	− 0·181	− 103·264	− 0·019	− 103·283
98	99	141·58	+ 0·007	− 0·174	− 118·061	− 0·022	− 118·083
99	100	142·45	− 0·013	− 0·187	− 117·549	− 0·022	− 117·571
100	101	143·42	− 0·003	− 0·190	− 119·255	− 0·022	− 119·277
101	102	146·96	− 0·009	− 0·199	− 129·521	− 0·024	− 129·545
102	103	151·54	+ 0·031	− 0·168	− 130·319	− 0·024	− 130·343
103	104	154·54	+ 0·009	− 0·159	− 126·686	− 0·023	− 126·709
104	105	156·01	− 0·010	− 0·169	− 134·788	− 0·025	− 134·813
105	106	160·86	+ 0·002	− 0·167	− 136·161	− 0·025	− 136·186
106	107*	162·36	+ 0·004	− 0·163	− 129·481	− 0·024	− 129·505

Difference of dynamic height, Lucknow to Gorakhpur = − 129·505 feet.

Length of line in miles = M = 162·36. $\Sigma d^2 = 0{\cdot}010539$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4\text{M}}} = \pm\,0{\cdot}0027$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\,0{\cdot}0346$.

* Bench-mark No. 107 is the mark at Gorakhpur described on page 134.

Line No. 69. Gorakhpur to Dildarnagar.

Bench-marks		Distance from Gorakhpur	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Gorakhpur (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Gorakhpur
From	To		From mark to mark (= *d*)	Total from Gorakhpur		Total from Gorakhpur	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	3·25	+ 0·013	+ 0·013	− 3·918	− 0·001	− 3·919
2	3	4·61	+ 0·004	+ 0·017	− 6·249	− 0·001	− 6·250
3	4	7·32	+ 0·029	+ 0·046	− 5·512	− 0·001	− 5·513
4	5	10·82	− 0·003	+ 0·043	− 5·317	− 0·001	− 5·318
5	6	14·50	− 0·007	+ 0·036	+ 0·132	0·000	+ 0·132
6	7	15·79	0·000	+ 0·036	− 1·085	0·000	− 1·085
7	8	16·45	− 0·010	+ 0·026	− 4·748	− 0·001	− 4·749
8	9	19·79	+ 0·001	+ 0·027	− 4·272	− 0·001	− 4·273
9	10	22·26	− 0·002	+ 0·025	− 13·873	− 0·003	− 13·876
10	11	25·19	− 0·010	+ 0·015	− 12·677	− 0·003	− 12·680
11	12	27·14	0·000	+ 0·015	− 16·083	− 0·004	− 16·087
12	13	30·68	+ 0·001	+ 0·016	− 17·926	− 0·004	− 17·930
13	14	31·83	− 0·003	+ 0·013	− 14·411	− 0·003	− 14·414
14	15	35·08	+ 0·017	+ 0·030	− 23·661	− 0·004	− 23·665
15	16	36·31	− 0·008	+ 0·022	− 15·404	− 0·003	− 15·407
16	17	43·06	+ 0·011	+ 0·033	− 15·254	− 0·003	− 15·257
17	18	44·24	+ 0·002	+ 0·035	− 15·768	− 0·003	− 15·771
18	19	47·65	+ 0·015	+ 0·050	− 14·191	− 0·003	− 14·194
19	20	49·66	− 0·003	+ 0·047	− 9·696	− 0·002	− 9·698
20	21	50·66	− 0·012	+ 0·035	− 8·172	− 0·002	− 8·174
21	22	51·67	− 0·002	+ 0·033	− 8·538	− 0·002	− 8·540
22	23	52·68	− 0·001	+ 0·032	− 8·508	− 0·002	− 8·510
23	24	55·09	+ 0·001	+ 0·033	− 11·617	− 0·003	− 11·620
24	25	55·50	+ 0·005	+ 0·038	− 7·868	− 0·002	− 7·870
25	26	56·69	− 0·009	+ 0·029	− 6·816	− 0·002	− 6·818
26	27	58·60	+ 0·001	+ 0·030	− 6·065	− 0·002	− 6·067
27	28	60·70	+ 0·008	+ 0·038	− 1·125	− 0·001	− 1·126
28	29	61·55	+ 0·004	+ 0·042	− 5·697	− 0·002	− 5·699
29	30	61·69	+ 0·003	+ 0·045	− 8·461	− 0·002	− 8·463
30	31	63·10	+ 0·003	+ 0·048	− 8·113	− 0·002	− 8·115
31	32	63·40	− 0·006	+ 0·042	− 8·511	− 0·002	− 8·513
32	33	63·75	− 0·001	+ 0·041	− 8·406	− 0·002	− 8·408
33	34	66·35	− 0·001	+ 0·040	+ 1·865	− 0·001	+ 1·864
34	35	67·58	− 0·015	+ 0·025	+ 0·341	− 0·001	+ 0·340
35	36	68·34	+ 0·012	+ 0·037	− 1·800	− 0·001	− 1·801
36	37	70·49	+ 0·013	+ 0·050	− 2·373	− 0·001	− 2·374
37	38	73·31	− 0·007	+ 0·043	− 5·919	− 0·002	− 5·921
38	39	76·30	+ 0·016	+ 0·059	− 3·415	− 0·002	− 3·417
39	40	76·75	− 0·013	+ 0·046	− 2·406	− 0·002	− 2·408
40	41	78·30	− 0·017	+ 0·029	− 6·023	− 0·003	− 6·026
41	42	79·21	+ 0·006	+ 0·035	− 7·340	− 0·003	− 7·343
42	43	79·37	0·000	+ 0·035	− 6·911	− 0·003	− 6·914
43	44	80·30	+ 0·005	+ 0·040	− 10·795	− 0·004	− 10·799
44	45	82·69	− 0·001	+ 0·039	− 11·682	− 0·004	− 11·686
45	46	83·29	− 0·008	+ 0·031	− 12·387	− 0·004	− 12·391
46	47	83·80	− 0·001	+ 0·030	− 8·920	− 0·003	− 8·923
47	48	84·29	− 0·002	+ 0·028	− 13·146	− 0·004	− 13·150
48	49	86·98	− 0·005	+ 0·023	− 14·137	− 0·004	− 14·141
49	50	87·98	+ 0·001	+ 0·024	− 14·767	− 0·004	− 14·771
50	51	88·99	+ 0·008	+ 0·032	− 17·419	− 0·004	− 17·423
51	52	93·00	0·000	+ 0·032	− 19·100	− 0·004	− 19·104
52	53	94·00	+ 0·001	+ 0·033	− 21·909	− 0·004	− 21·913
53	54	95·23	+ 0·002	+ 0·035	− 24·012	− 0·004	− 24·016
54	55	95·99	+ 0·004	+ 0·039	− 24·961	− 0·004	− 24·965
55	56	96·33	− 0·003	+ 0·036	− 22·715	− 0·004	− 22·719
56	57	96·87	− 0·007	+ 0·029	− 25·488	− 0·004	− 25·492
57	58	97·37	+ 0·001	+ 0·030	− 23·818	− 0·004	− 23·822
58	59	97·85	0·000	+ 0·030	− 25·470	− 0·004	− 25·474
59	60	98·83	− 0·015	+ 0·015	− 26·063	− 0·004	− 26·067
60	61	99·73	+ 0·001	+ 0·016	− 17·863	− 0·003	− 17·866

* Bench-mark No. 1 is the mark at Gorakhpur described on page 134.

Line No. 69. Gorakhpur to Dildarnagar.—(Continued).

Bench-marks		Distance from Gorakhpur	Discrepancy between levellers* (First – Second leveller)		Observed elevation above (+) or below (–) Gorakhpur (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Gorakhpur
From	To		From mark to mark (= d)	Total from Gorakhpur		Total from Gorakhpur	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	100·84	+ 0·004	+ 0·020	– 27·270	– 0·004	– 27·274
62	63	101·94	+ 0·023	+ 0·043	– 23·473	– 0·004	– 23·477
63	64	103·12	– 0·001	+ 0·042	– 29·890	– 0·005	– 29·895
64	65	106·02	+ 0·011	+ 0·053	– 29·994	– 0·005	– 29·999
65	66	107·10	+ 0·009	+ 0·062	– 28·815	– 0·005	– 28·820
66	67	111·07	+ 0·009	+ 0·071	– 26·010	– 0·005	– 26·015
67	68	113·11	– 0·004	+ 0·067	– 24·977	– 0·005	– 24·982
68	69	115·11	– 0·018	+ 0·049	– 16·869	– 0·004	– 16·873
69	70	116·11	+ 0·002	+ 0·051	– 16·884	– 0·004	– 16·888
70	71	116·54	– 0·001	+ 0·050	– 16·223	– 0·004	– 16·227
71	72	120·72	– 0·016	+ 0·034	– 22·795	– 0·005	– 22·800
72	73	121·37	+ 0·013	+ 0·047	– 20·272	– 0·005	– 20·277
73	74	125·14	+ 0·023	+ 0·070	– 32·430	– 0·006	– 32·436
74	75*	142·05	+ 0·006	+ 0·076	– 29·729	– 0·006	– 29·735

Difference of dynamic height, Gorakhpur to Dildarnagar = – 29·735 feet.

Length of line in miles = M = 142·05. $\Sigma d^2 = 0{\cdot}006396$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0{\cdot}0023$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0{\cdot}0270$.

* Bench-mark No. 75 is the mark at Dildarnagar described on page 133.

Line No. 70. Allahabad to Dildarnagar.

Bench-marks		Distance from Allahabad	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Allahabad (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Allahabad
From	To		From mark to mark (=d)	Total from Allahabad		Total from Allahabad	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	1·15	− 0·003	− 0·003	− 21·152	− 0·002	− 21·154
2	3	2·60	+ 0·003	0·000	− 6·019	0·000	− 6·019
3	4	2·92	+ 0·010	+ 0·010	+ 4·827	+ 0·001	+ 4·828
4	5	2·95	+ 0·001	+ 0·011	+ 1·859	+ 0·001	+ 1·860
5	6	3·53	− 0·004	+ 0·007	+ 8·462	+ 0·002	+ 8·464
6	7	4·54	+ 0·012	+ 0·019	+ 10·284	+ 0·002	+ 10·286
7	8	5·55	+ 0·004	+ 0·023	+ 5·880	+ 0·002	+ 5·882
8	9	6·55	− 0·005	+ 0·018	+ 9·188	+ 0·002	+ 9·190
9	10	8·56	− 0·009	+ 0·009	+ 7·442	+ 0·002	+ 7·444
10	11	9·59	+ 0·002	+ 0·011	+ 8·375	+ 0·002	+ 8·377
11	12	10·60	− 0·001	+ 0·010	+ 6·075	+ 0·002	+ 6·077
12	13	11·61	+ 0·001	+ 0·011	+ 7·997	+ 0·002	+ 7·999
13	14	13·66	− 0·004	+ 0·007	+ 9·181	+ 0·002	+ 9·183
14	15	14·64	− 0·006	+ 0·001	+ 3·875	+ 0·001	+ 3·876
15	16	15·65	− 0·001	0·000	+ 5·491	+ 0·001	+ 5·492
16	17	16·66	+ 0·001	+ 0·001	+ 2·173	+ 0·001	+ 2·174
17	18	17·64	+ 0·004	+ 0·005	+ 5·036	+ 0·001	+ 5·037
18	19	18·65	− 0·004	+ 0·001	+ 3·438	+ 0·001	+ 3·439
19	20	19·65	− 0·002	− 0·001	+ 1·968	+ 0·001	+ 1·969
20	21	20·65	0·000	− 0·001	− 3·679	0·000	− 3·679
21	22	21·66	− 0·001	− 0·002	− 1·292	0·000	− 1·292
22	23	22·85	− 0·004	− 0·006	+ 1·067	0·000	+ 1·067
23	24	23·86	+ 0·007	+ 0·001	− 3·488	− 0·001	− 3·489
24	25	24·87	− 0·007	− 0·006	− 5·960	− 0·001	− 5·961
25	26	25·88	+ 0·003	− 0·003	− 5·770	− 0·001	− 5·771
26	27	26·45	+ 0·010	+ 0·007	− 6·969	− 0·001	− 6·970
27	28	26·48	− 0·003	+ 0·004	− 8·297	− 0·001	− 8·298
28	29	26·90	+ 0·009	+ 0·013	− 4·020	− 0·001	− 4·021
29	30	27·90	− 0·005	+ 0·008	− 4·060	− 0·001	− 4·061
30	31	28·91	+ 0·008	+ 0·016	− 4·951	− 0·001	− 4·952
31	32	29·91	+ 0·012	+ 0·028	− 6·017	− 0·001	− 6·018
32	33	31·93	− 0·023	+ 0·005	− 6·856	− 0·001	− 6·857
33	34	32·93	− 0·014	− 0·009	− 6·917	− 0·001	− 6·918
34	35	33·94	− 0·005	− 0·014	− 12·378	− 0·002	− 12·380
35	36	34·94	− 0·004	− 0·018	− 10·234	− 0·002	− 10·236
36	37	35·95	+ 0·010	− 0·008	− 12·300	− 0·002	− 12·302
37	38	36·95	− 0·003	− 0·011	− 12·204	− 0·002	− 12·206
38	39	37·90	+ 0·001	− 0·010	− 9·232	− 0·002	− 9·234
39	40	38·02	+ 0·005	− 0·005	− 10·190	− 0·002	− 10·192
40	41	39·02	− 0·011	− 0·016	− 16·009	− 0·003	− 16·012
41	42	40·03	− 0·001	− 0·017	− 15·956	− 0·003	− 15·959
42	43	41·04	+ 0·005	− 0·012	− 14·361	− 0·003	− 14·364
43	44	42·04	− 0·001	− 0·013	− 15·148	− 0·003	− 15·151
44	45	43·05	− 0·013	− 0·026	− 15·250	− 0·003	− 15·253
45	46	43·45	+ 0·001	− 0·025	− 16·957	− 0·003	− 16·960
46	47	44·05	+ 0·001	− 0·024	− 15·231	− 0·003	− 15·234
47	48	44·29	+ 0·004	− 0·020	− 14·900	− 0·003	− 14·903
48	49	45·06	− 0·005	− 0·025	− 16·407	− 0·003	− 16·410
49	50	46·07	− 0·003	− 0·028	− 17·051	− 0·003	− 17·054
50	51	47·07	+ 0·006	− 0·022	− 17·842	− 0·003	− 17·845
51	52	48·08	− 0·003	− 0·025	− 19·200	− 0·003	− 19·203
52	53	49·10	+ 0·002	− 0·023	− 18·106	− 0·003	− 18·109
53	54	50·10	− 0·003	− 0·026	− 20·888	− 0·003	− 20·891
54	55	52·10	+ 0·014	− 0·012	− 21·182	− 0·003	− 21·185
55	56	53·09	+ 0·009	− 0·003	− 24·658	− 0·003	− 24·661
56	57	54·08	0·000	− 0·003	− 25·870	− 0·003	− 25·873
57	58	55·06	− 0·003	− 0·006	− 26·808	− 0·003	− 26·811
58	59	56·05	+ 0·001	− 0·005	− 25·722	− 0·003	− 25·725
59	60	57·05	− 0·001	− 0·006	− 26·528	− 0·003	− 26·531
60	61	58·04	− 0·005	− 0·011	− 27·397	− 0·003	− 27·400

* Bench-mark No. 1 is the mark at Allahabad described on page 133.

Line No. 70. Allahabad to Dildarnagar.—(Continued).

Bench-marks From	Bench-marks To	Distance from Allahabad	Discrepancy between levellers (First – Second leveller) From mark to mark (=d)	Discrepancy between levellers (First – Second leveller) Total from Allahabad	Observed elevation above (+) or below (–) Allahabad (mean result by two levellers)	Dynamic correction deduced from mark to mark Total from Allahabad	Dynamic height above (+) or below (–) Allahabad
		miles	foot	foot	feet	foot	feet
61	62	59·03	– 0·005	– 0·016	– 28·301	– 0·003	– 28·304
62	63	60·01	+ 0·001	– 0·015	– 27·046	– 0·003	– 27·049
63	64	61·01	– 0·003	– 0·018	– 28·411	– 0·003	– 28·414
64	65	61·96	+ 0·006	– 0·012	– 29·288	– 0·003	– 29·291
65	66	62·95	– 0·003	– 0·015	– 33·540	– 0·003	– 33·543
66	67	63·94	– 0·002	– 0·017	– 34·222	– 0·003	– 34·225
67	68	64·93	+ 0·001	– 0·016	– 34·582	– 0·003	– 34·585
68	69	65·92	+ 0·004	– 0·012	– 34·194	– 0·003	– 34·197
69	70	66·91	+ 0·002	– 0·010	– 36·787	– 0·003	– 36·790
70	71	67·90	+ 0·014	+ 0·004	– 36·281	– 0·003	– 36·284
71	72	68·89	– 0·005	– 0·001	– 35·599	– 0·003	– 35·602
72	73	69·87	– 0·001	– 0·002	– 37·825	– 0·003	– 37·828
73	74	70·86	+ 0·002	0·000	– 39·882	– 0·003	– 39·885
74	75	71·53	+ 0·002	+ 0·002	– 41·022	– 0·003	– 41·025
75	76	71·85	+ 0·004	+ 0·006	– 40·089	– 0·003	– 40·092
76	77	72·84	+ 0·005	+ 0·011	– 41·872	– 0·003	– 41·875
77	78	73·94	– 0·004	+ 0·007	– 47·067	– 0·004	– 47·071
78	79	75·18	– 0·008	– 0·001	– 43·392	– 0·004	– 43·396
79	80	76·26	+ 0·005	+ 0·004	– 48·817	– 0·005	– 48·822
80	81	76·56	+ 0·001	+ 0·005	– 35·951	– 0·004	– 35·955
81	82	83·47	+ 0·021	+ 0·026	– 43·753	– 0·005	– 43·758
82	83	89·44	+ 0·009	+ 0·035	– 60·216	– 0·007	– 60·223
83	84	90·63	+ 0·003	+ 0·038	– 50·769	– 0·006	– 50·775
84	85	93·27	+ 0·008	+ 0·046	– 52·204	– 0·006	– 52·210
85	86	94·79	+ 0·002	+ 0·048	– 52·623	– 0·006	– 52·629
86	87	100·06	– 0·006	+ 0·042	– 56·357	– 0·006	– 56·363
87	88*	126·59	– 0·007	+ 0·035	– 73·917	– 0·008	– 73·925

Difference of dynamic height, Allahabad to Dildarnagar = – **73·925** feet.

Length of line in miles = M = 126·59. $\Sigma d^2 = 0\cdot003851$.

Probable error of the mean result per mile of double-levelling $= 0\cdot6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm 0\cdot0019$.

Probable error of the difference of elevation between the terminal bench-marks $= 0\cdot6745 \sqrt{\frac{\Sigma d^2}{4}} = \pm 0\cdot0209$.

* Bench-mark No. 88 is the mark at Dildarnagar described on page 133.

Line No. 71. Gorakhpur to Purnea.

Bench-marks		Distance from Gorakhpur	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Gorakhpur (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Gorakhpur
From	To		From mark to mark (= d)	Total from Gorakhpur		Total from Gorakhpur	
		miles	foot	foot	feet	foot	feet
1*	2	1·24	− 0·018	− 0·018	+ 4·822	+ 0·001	+ 4·823
2	3	1·91	0·000	− 0·018	+ 5·305	+ 0·001	+ 5·306
3	4	3·29	+ 0·024	+ 0·006	+ 4·535	+ 0·001	+ 4·536
4	5	7·24	− 0·001	+ 0·005	+ 6·484	+ 0·001	+ 6·485
5	6	11·19	− 0·020	− 0·015	+ 6·809	+ 0·001	+ 6·810
6	7	11·69	− 0·009	− 0·024	+ 16·117	+ 0·003	+ 16·120
7	8	13·32	− 0·010	− 0·034	+ 17·730	+ 0·003	+ 17·733
8	9	16·03	− 0·001	− 0·035	+ 25·333	+ 0·005	+ 25·338
9	10	18·64	− 0·015	− 0·050	+ 29·291	+ 0·006	+ 29·297
10	11	21·93	+ 0·010	− 0·040	+ 24·585	+ 0·005	+ 24·590
11	12	28·19	+ 0·009	− 0·031	+ 30·801	+ 0·006	+ 30·807
12	13	29·44	− 0·011	− 0·042	+ 29·237	+ 0·006	+ 29·243
13	14	36·90	+ 0·027	− 0·015	+ 29·057	+ 0·006	+ 29·063
14	15	43·29	− 0·006	− 0·021	+ 28·132	+ 0·006	+ 28·138
15	16	43·95	+ 0·012	− 0·009	+ 23·773	+ 0·005	+ 23·778
16	17	61·51	− 0·079	− 0·088	+ 39·296	+ 0·008	+ 39·304
17	18	67·89	− 0·001	− 0·089	+ 29·752	+ 0·006	+ 29·758
18	19	81·67	+ 0·022	− 0·067	+ 8·667	+ 0·002	+ 8·669
19	20	85·00	− 0·028	− 0·095	+ 9·017	+ 0·002	+ 9·019
20	21	90·41	− 0·002	− 0·097	+ 0·165	0·000	+ 0·165
21	22	94·11	+ 0·014	− 0·083	− 13·482	− 0·003	− 13·485
22	23	96·19	+ 0·009	− 0·074	− 5·587	− 0·001	− 5·588
23	24	99·55	+ 0·018	− 0·056	− 17·742	− 0·003	− 17·745
24	25	102·56	− 0·016	− 0·072	− 18·202	− 0·003	− 18·205
25	26	105·86	− 0·015	− 0·087	− 21·558	− 0·004	− 21·562
26	27	109·89	+ 0·040	− 0·047	− 25·853	− 0·005	− 25·858
27	28	121·72	+ 0·016	− 0·031	− 33·610	− 0·007	− 33·617
28	29	125·39	+ 0·009	− 0·022	− 37·737	− 0·008	− 37·745
29	30	126·48	+ 0·019	− 0·003	− 38·131	− 0·008	− 38·139
30	31	127·24	− 0·017	− 0·020	− 39·631	− 0·008	− 39·639
31	32	146·78	+ 0·017	− 0·003	− 53·426	− 0·011	− 53·437
32	33	149·31	− 0·017	− 0·020	− 54·721	− 0·011	− 54·732
33	34	155·69	− 0·041	− 0·061	− 58·576	− 0·012	− 58·588
34	35	158·00	− 0·005	− 0·066	− 65·471	− 0·013	− 65·484
35	36	165·94	+ 0·010	− 0·056	− 69·478	− 0·014	− 69·492
36	37	167·93	+ 0·009	− 0·047	− 73·926	− 0·015	− 73·941
37	38	168·77	− 0·007	− 0·054	− 74·029	− 0·015	− 74·044
38	39	175·68	+ 0·005	− 0·049	− 78·411	− 0·016	− 78·427
39	40	177·44	− 0·029	− 0·078	− 74·104	− 0·015	− 74·119
40	41	177·82	+ 0·012	− 0·066	− 77·490	− 0·016	− 77·506
41	42	181·81	− 0·009	− 0·075	− 81·484	− 0·017	− 81·501
42	43	182·60	+ 0·011	− 0·064	− 74·771	− 0·016	− 74·787
43	44	183·41	− 0·002	− 0·066	− 77·523	− 0·016	− 77·539
44	45	184·51	− 0·010	− 0·076	− 81·068	− 0·017	− 81·085
45	46	186·86	0·000	− 0·076	− 81·072	− 0·017	− 81·089
46	47	188·86	+ 0·006	− 0·070	− 84·212	− 0·018	− 84·230
47	48	189·86	− 0·003	− 0·073	− 86·249	− 0·018	− 86·267
48	49	192·87	+ 0·020	− 0·053	− 88·723	− 0·018	− 88·741
49	50	193·87	− 0·004	− 0·057	− 88·447	− 0·018	− 88·465
50	51	197·92	0·000	− 0·057	− 89·006	− 0·018	− 89·024
51	52	199·01	+ 0·015	− 0·042	− 89·673	− 0·018	− 89·691
52	53	200·02	− 0·001	− 0·043	− 91·244	− 0·018	− 91·262
53	54	201·03	+ 0·009	− 0·034	− 91·355	− 0·018	− 91·373
54	55	202·06	+ 0·007	− 0·027	− 89·969	− 0·018	− 89·987
55	56	203·06	− 0·002	− 0·029	− 91·670	− 0·018	− 91·688
56	57	203·14	− 0·003	− 0·032	− 91·167	− 0·018	− 91·185
57	58	205·10	+ 0·023	− 0·009	− 91·694	− 0·018	− 91·712
58	59	206·10	− 0·002	− 0·011	− 90·428	− 0·018	− 90·446
59	60	207·10	+ 0·001	− 0·010	− 89·612	− 0·018	− 89·630
60	61	208·11	− 0·006	− 0·016	− 91·815	− 0·018	− 91·833

* Bench-mark No. 1 is the mark at Gorakhpur described on page 134.

Line No. 71. Gorakhpur to Purnea.—(Continued).

Bench-marks From	Bench-marks To	Distance from Gorakhpur	Discrepancy between levellers (First – Second leveller): From mark to mark (= d)	Discrepancy between levellers (First – Second leveller): Total from Gorakhpur	Observed elevation above (+) or below (–) Gorakhpur (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Gorakhpur	Dynamic height above (+) or below (–) Gorakhpur
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	209·14	− 0·020	− 0·036	− 88·314	− 0·017	− 88·331
62	63	209·64	+ 0·004	− 0·032	− 91·787	− 0·018	− 91·805
63	64	211·14	− 0·012	− 0·044	− 93·985	− 0·018	− 94·003
64	65	213·14	− 0·012	− 0·056	− 91·367	− 0·018	− 91·385
65	66	213·20	− 0·007	− 0·063	− 88·315	− 0·017	− 88·332
66	67	216·24	− 0·013	− 0·076	− 91·342	− 0·018	− 91·360
67	68	217·23	+ 0·001	− 0·075	− 90·959	− 0·018	− 90·977
68	69	218·27	− 0·002	− 0·077	− 91·337	− 0·018	− 91·355
69	70	219·27	+ 0·009	− 0·068	− 89·034	− 0·018	− 89·052
70	71	220·30	− 0·007	− 0·075	− 89·316	− 0·018	− 89·334
71	72	221·32	− 0·002	− 0·077	− 91·673	− 0·018	− 91·691
72	73	222·38	− 0·008	− 0·085	− 84·575	− 0·017	− 84·592
73	74	223·42	+ 0·001	− 0·084	− 88·959	− 0·018	− 88·977
74	75	224·42	− 0·009	− 0·093	− 86·793	− 0·018	− 86·811
75	76	225·43	+ 0·005	− 0·088	− 90·399	− 0·019	− 90·418
76	77	226·43	+ 0·009	− 0·079	− 90·352	− 0·019	− 90·371
77	78	227·43	+ 0·005	− 0·074	− 90·083	− 0·019	− 90·102
78	79	228·46	− 0·002	− 0·076	− 89·284	− 0·019	− 89·303
79	80	229·46	− 0·005	− 0·081	− 90·803	− 0·019	− 90·822
80	81	229·93	− 0·004	− 0·085	− 93·475	− 0·019	− 93·494
81	82	230·47	− 0·005	− 0·090	− 91·477	− 0·019	− 91·496
82	83	231·50	+ 0·004	− 0·086	− 94·725	− 0·020	− 94·745
83	84	232·50	+ 0·006	− 0·080	− 92·259	− 0·020	− 92·279
84	85	233·51	− 0·002	− 0·082	− 89·305	− 0·019	− 89·324
85	86	234·52	0·000	− 0·082	− 89·131	− 0·019	− 89·150
86	87	235·58	+ 0·004	− 0·078	− 87·471	− 0·019	− 87·490
87	88	236·57	− 0·009	− 0·087	− 91·329	− 0·020	− 91·349
88	89	238·60	+ 0·010	− 0·077	− 95·260	− 0·021	− 95·281
89	90	240·60	− 0·031	− 0·108	− 92·972	− 0·021	− 92·993
90	91	241·66	+ 0·012	− 0·096	− 96·321	− 0·022	− 96·343
91	92	242·71	+ 0·014	− 0·082	− 95·628	− 0·022	− 95·650
92	93	243·78	− 0·015	− 0·097	− 99·679	− 0·023	− 99·702
93	94	245·88	+ 0·006	− 0·091	− 100·765	− 0·023	− 100·788
94	95	246·89	+ 0·005	− 0·086	− 102·751	− 0·023	− 102·774
95	96	247·92	+ 0·007	− 0·079	− 104·296	− 0·023	− 104·319
96	97	248·93	− 0·012	− 0·091	− 104·660	− 0·023	− 104·683
97	98	249·95	− 0·002	− 0·093	− 109·684	− 0·024	− 109·708
98	99	250·98	+ 0·006	− 0·087	− 107·611	− 0·024	− 107·635
99	100	252·21	− 0·009	− 0·096	− 109·843	− 0·024	− 109·867
100	101	259·49	− 0·011	− 0·107	− 103·470	− 0·023	− 103·493
101	102	261·55	+ 0·004	− 0·103	− 102·801	− 0·023	− 102·824
102	103	273·64	+ 0·117	+ 0·014	− 103·075	− 0·023	− 103·098
103	104	276·45	− 0·006	+ 0·008	− 101·675	− 0·023	− 101·698
104	105	276·85	+ 0·008	+ 0·016	− 102·690	− 0·023	− 102·713
105	106	287·66	− 0·034	− 0·018	− 82·092	− 0·020	− 82·112
106	107	296·84	− 0·025	− 0·043	− 62·300	− 0·017	− 62·317
107	108	299·15	− 0·014	− 0·057	− 59·596	− 0·017	− 59·613
108	109	303·01	− 0·009	− 0·066	− 50·749	− 0·016	− 50·765
109	110	304·29	+ 0·009	− 0·057	− 54·605	− 0·017	− 54·622
110	111	311·49	− 0·006	− 0·063	− 41·445	− 0·015	− 41·460
111	112	311·75	− 0·004	− 0·067	− 42·655	− 0·015	− 42·670
112	113	329·18	+ 0·046	− 0·021	− 74·915	− 0·020	− 74·935
113	114	337·56	− 0·054	− 0·075	− 98·812	− 0·024	− 98·836
114	115	337·74	0·000	− 0·075	− 100·097	− 0·024	− 100·121
115	116	343·05	+ 0·033	− 0·042	− 104·847	− 0·025	− 104·872

Line No. 71. Gorakhpur to Purnea.—(Continued).

Bench-marks		Distance from Gorakhpur	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Gorakhpur (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Gorakhpur
From	To		From mark to mark (= d)	Total from Gorakhpur		Total from Gorakhpur	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
116	117	351·88	– 0·041	– 0·083	– 119·437	– 0·027	– 119·464
117	118	353·36	0·000	– 0·083	– 119·158	– 0·027	– 119·185
118	119	355·01	– 0·012	– 0·095	– 124·472	– 0·028	– 124·500
119	120	359·61	+ 0·026	– 0·069	– 133·213	– 0·029	– 133·242
120	121	361·87	+ 0·018	– 0·051	– 129·327	– 0·028	– 129·355
121	122*	361·65	– 0·005	– 0·056	– 134·681	– 0·029	– 134·710

Difference of dynamic height, Gorakhpur to Purnea = – 134·710 feet.

Length of line in miles = M = 361·65. $\Sigma d^2 = 0\cdot047982$.

Probable error of the mean result per mile of double-levelling $= 0\cdot6745\sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0\cdot0039$.

Probable error of the difference of elevation between the terminal bench-marks $= 0\cdot6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0\cdot0739$.

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* Bench-mark No. 122 is the mark at Purnea described on page 135.

Line No. 72. Dildarnagar to Pirpanti.

Bench-marks		Distance from Dildarnagar	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Dildarnagar (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Dildarnagar
From	To		From mark to mark (= *d*)	Total from Dildarnagar		Total from Dildarnagar	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	19·28	+ 0·039	+ 0·039	− 16·460	− 0·002	− 16·462
2	3	21·57	+ 0·006	+ 0·045	− 24·165	− 0·003	− 24·168
3	4	23·44	− 0·009	+ 0·036	− 17·987	− 0·002	− 17·989
4	5	24·32	+ 0·002	+ 0·038	− 20·168	− 0·002	− 20·170
5	6	26·05	+ 0·011	+ 0·049	− 20·808	− 0·002	− 20·810
6	7	32·66	+ 0·042	+ 0·091	− 25·010	− 0·002	− 25·012
7	8	35·12	+ 0·006	+ 0·097	− 3·128	0·000	− 3·128
8	9	35·15	− 0·001	+ 0·096	− 2·742	0·000	− 2·742
9	10	36·99	+ 0·003	+ 0·099	− 1·565	0·000	− 1·565
10	11	40·31	+ 0·011	+ 0·110	− 23·246	− 0·002	− 23·248
11	12	45·06	+ 0·005	+ 0·115	− 28·426	− 0·003	− 28·429
12	13	53·70	+ 0·037	+ 0·152	− 29·011	− 0·003	− 29·014
13	14	56·99	− 0·001	+ 0·151	− 21·075	− 0·002	− 21·077
14	15	69·81	+ 0·024	+ 0·175	− 33·826	− 0·003	− 33·829
15	16	69·91	0·000	+ 0·175	− 34·148	− 0·003	− 34·151
16	17	71·99	− 0·006	+ 0·169	− 31·052	− 0·003	− 31·055
17	18	78·42	− 0·009	+ 0·160	− 2·308	0·000	− 2·308
18	19	79·06	+ 0·014	+ 0·174	− 2·338	0·000	− 2·338
19	20	83·59	+ 0·011	+ 0·185	− 35·100	− 0·004	− 35·104
20	21	92·70	+ 0·008	+ 0·193	− 46·066	− 0·005	− 46·071
21	22	94·18	+ 0·004	+ 0·197	− 49·705	− 0·005	− 49·710
22	23	96·68	− 0·006	+ 0·191	− 49·568	− 0·005	− 49·573
23	24	99·89	+ 0·002	+ 0·193	− 56·236	− 0·006	− 56·242
24	25	100·88	0·000	+ 0·193	− 55·109	− 0·006	− 55·115
25	26	103·18	+ 0·001	+ 0·194	− 56·885	− 0·006	− 56·891
26	27	106·07	− 0·009	+ 0·185	− 48·093	− 0·005	− 48·098
27	28	108·85	0·000	+ 0·185	− 56·995	− 0·006	− 57·001
28	29	113·55	− 0·006	+ 0·179	− 59·603	− 0·006	− 59·609
29	30	115·72	− 0·022	+ 0·157	− 57·706	− 0·006	− 57·712
30	31	127·98	+ 0·011	+ 0·168	− 65·308	− 0·007	− 65·315
31	32	138·98	− 0·031	+ 0·137	− 72·725	− 0·008	− 72·733
32	33	156·46	+ 0·031	+ 0·168	− 79·559	− 0·009	− 79·568
33	34	156·47	0·000	+ 0·168	− 75·791	− 0·009	− 75·800
34	35	156·53	0·000	+ 0·168	− 79·400	− 0·009	− 79·409
35	36	175·05	+ 0·006	+ 0·174	− 81·458	− 0·009	− 81·467
36	37	193·02	+ 0·064	+ 0·238	− 92·000	− 0·010	− 92·010
37	38	205·15	− 0·062	+ 0·176	− 94·738	− 0·010	− 94·748
38	39	206·24	+ 0·032	+ 0·208	− 76·878	− 0·008	− 76·886
39	40	213·34	+ 0·018	+ 0·226	− 100·438	− 0·010	− 100·448
40	41	216·23	− 0·001	+ 0·225	− 97·701	− 0·010	− 97·711
41	42	217·65	+ 0·009	+ 0·234	− 96·000	− 0·010	− 96·010
42	43	222·94	− 0·017	+ 0·217	− 93·648	− 0·010	− 93·658
43	44	228·59	+ 0·007	+ 0·224	− 97·504	− 0·010	− 97·514
44	45	228·63	− 0·002	+ 0·222	− 98·706	− 0·010	− 98·716
45	46	243·49	+ 0·009	+ 0·231	− 78·421	− 0·008	− 78·429
46	47	243·62	− 0·001	+ 0·230	− 78·766	− 0·008	− 78·774
47	48	243·80	+ 0·097	+ 0·327	− 75·405	− 0·008	− 75·413
48	49	256·06	− 0·051	+ 0·276	− 104·005	− 0·011	− 104·016
49	50	256·11	+ 0·005	+ 0·281	− 107·085	− 0·011	− 107·096
50	51	256·36	− 0·013	+ 0·268	− 108·760	− 0·011	− 108·771
51	52	261·56	+ 0·016	+ 0·284	− 105·817	− 0·011	− 105·828
52	53	262·01	+ 0·008	+ 0·292	− 103·923	− 0·011	− 103·934
53	54	262·16	+ 0·001	+ 0·293	− 104·040	− 0·011	− 104·051
54	55	266·50	− 0·011	+ 0·282	− 62·766	− 0·007	− 62·773
55	56	269·50	+ 0·028	+ 0·310	− 96·937	− 0·010	− 96·947

* Bench-mark No. 1 is the mark at Dildarnagar described on page 183.

Line No. 72. Dildarnagar to Pirpanti.—(Continued).

Bench-marks		Distance from Dildarnagar	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Dildarnagar (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Dildarnagar
From	To		From mark to mark (= d)	Total from Dildarnagar		Total from Dildarnagar	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
56	57	273·78	0·000	+ 0·310	– 78·990	– 0·008	– 78·998
57	58	274·48	– 0·006	+ 0·304	– 73·097	– 0·007	– 73·104
58	59*	274·55	+ 0·004	+ 0·308	– 69·970	– 0·007	– 69·977

Difference of dynamic height, Dildarnagar to Pirpanti = – 69·977 feet.

Length of line in miles = M = 274·55. $\Sigma d^2 = 0{\cdot}032176$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4M}} = \pm\, 0{\cdot}0037$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0605$.

* Bench-mark No. 59 is the mark at Pirpanti described on page 185.

Line No. 73. Purnea to Pirpanti.

Bench-marks		Distance from Purnea	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Purnea (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Purnea
From	To		From mark to mark (= *d*)	Total from Purnea		Total from Purnea	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·65	− 0·002	− 0·002	+ 2·770	0·000	+ 2·770
2	3	1·69	+ 0·015	+ 0·013	+ 2·752	0·000	+ 2·752
3	4	3·74	− 0·012	+ 0·001	+ 1·667	0·000	+ 1·667
4	5	4·68	− 0·015	− 0·014	+ 0·999	0·000	+ 0·999
5	6	5·68	− 0·008	− 0·022	− 0·510	0·000	− 0·510
6	7	5·92	− 0·001	− 0·023	+ 1·172	0·000	+ 1·172
7	8	6·68	− 0·008	− 0·031	+ 0·705	0·000	+ 0·705
8	9	7·68	− 0·001	− 0·032	− 0·926	0·000	− 0·926
9	10	8·69	+ 0·006	− 0·026	+ 0·475	0·000	+ 0·475
10	11	9·69	+ 0·005	− 0·021	− 3·420	0·000	− 3·420
11	12	10·26	0·000	− 0·021	− 2·339	0·000	− 2·339
12	13	10·69	− 0·004	− 0·025	− 2·141	0·000	− 2·141
13	14	11·69	+ 0·013	− 0·012	− 2·780	0·000	− 2·780
14	15	12·66	− 0·016	− 0·028	− 10·362	− 0·001	− 10·363
15	16	12·76	− 0·003	− 0·031	− 4·917	0·000	− 4·917
16	17	13·76	− 0·010	− 0·041	− 6·646	0·000	− 6·646
17	18	13·92	+ 0·001	− 0·040	− 9·921	0·000	− 9·921
18	19	14·76	0·000	− 0·040	− 8·094	0·000	− 8·094
19	20	15·76	+ 0·002	− 0·038	− 5·848	0·000	− 5·848
20	21	16·76	− 0·007	− 0·045	− 9·761	0·000	− 9·761
21	22	16·95	− 0·005	− 0·050	− 9·651	0·000	− 9·651
22	23	17·76	+ 0·004	− 0·046	− 7·738	0·000	− 7·738
23	24	18·59	− 0·006	− 0·052	− 8·363	0·000	− 8·363
24	25	18·76	− 0·001	− 0·053	− 9·517	0·000	− 9·517
25	26	19·76	− 0·006	− 0·059	− 8·671	0·000	− 8·671
26	27	20·76	+ 0·006	− 0·053	− 10·010	0·000	− 10·010
27	28	21·78	+ 0·010	− 0·043	− 10·972	0·000	− 10·972
28	29	22·78	+ 0·003	− 0·040	− 8·827	0·000	− 8·827
29	30	23·78	+ 0·031	− 0·009	− 10·103	0·000	− 10·103
30	31	24·77	− 0·001	− 0·010	− 10·413	0·000	− 10·413
31	32	26·25	+ 0·011	+ 0·001	− 15·764	− 0·001	− 15·765
32	33	26·57	− 0·021	− 0·020	− 16·477	− 0·001	− 16·478
33	34	34·46	− 0·054	− 0·074	− 8·047	0·000	− 8·047
34	35†	36·75	− 0·009	− 0·083	+ 35·803	+ 0·004	+ 35·807

Difference of dynamic height, Purnea to Pirpanti = + 35·807 feet.

Length of line in miles = M = 36·75. $\Sigma d^2 = 0{\cdot}006173$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745 \sqrt{\frac{\Sigma d^2}{4M}} = \pm\, 0{\cdot}0043$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745 \sqrt{\frac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0265$.

* Bench-mark No. 1 is the mark at Purnea described on page 135. † Bench-mark No. 35 is the mark at Pirpanti described on page 135.

Line No. 74. Pirpanti to Howrah.

Bench-marks		Distance from Pirpanti	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Pirpanti (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Pirpanti
From	To		From mark to mark (= *d*)	Total from Pirpanti		Total from Pirpanti	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	4·20	+ 0·031	+ 0·031	– 32·910	– 0·003	– 32·913
2	3	6·26	+ 0·007	+ 0·038	– 45·631	– 0·004	– 45·635
3	4	7·57	– 0·017	+ 0·021	– 41·582	– 0·004	– 41·586
4	5	8·81	– 0·031	– 0·010	– 36·553	– 0·003	– 36·556
5	6	11·76	+ 0·052	+ 0·042	– 36·104	– 0·003	– 36·107
6	7	14·54	– 0·005	+ 0·037	– 40·363	– 0·003	– 40·366
7	8	14·56	+ 0·005	+ 0·042	– 42·174	– 0·003	– 42·177
8	9	19·22	– 0·006	+ 0·036	– 34·192	– 0·002	– 34·194
9	10	23·32	– 0·002	+ 0·034	– 54·700	– 0·004	– 54·704
10	11	37·88	+ 0·032	+ 0·066	– 43·952	– 0·003	– 43·955
11	12	37·92	+ 0·026	+ 0·092	– 48·701	– 0·003	– 48·704
12	13	43·10	– 0·026	+ 0·066	– 7·301	0·000	– 7·301
13	14	48·11	– 0·009	+ 0·057	– 49·174	– 0·003	– 49·177
14	15	49·56	+ 0·024	+ 0·081	– 57·982	– 0·004	– 57·986
15	16	55·55	– 0·042	+ 0·039	– 57·141	– 0·004	– 57·145
16	17	64·12	+ 0·008	+ 0·047	– 48·089	– 0·004	– 48·093
17	18	68·37	– 0·015	+ 0·032	– 64·156	– 0·005	– 64·161
18	19	69·24	+ 0·001	+ 0·033	– 71·071	– 0·005	– 71·076
19	20	70·84	+ 0·002	+ 0·035	– 65·551	– 0·005	– 65·556
20	21	72·43	– 0·006	+ 0·029	– 52·713	– 0·004	– 52·717
21	22	73·99	– 0·030	– 0·001	– 49·043	– 0·004	– 49·047
22	23	74·83	+ 0·010	+ 0·009	– 37·506	– 0·003	– 37·509
23	24	77·81	– 0·006	+ 0·003	– 55·175	– 0·004	– 55·179
24	25	79·17	+ 0·012	+ 0·015	– 48·814	– 0·004	– 48·818
25	26	80·57	– 0·002	+ 0·013	– 53·547	– 0·004	– 53·551
26	27	82·67	– 0·010	+ 0·003	– 32·954	– 0·003	– 32·957
27	28	87·19	+ 0·002	+ 0·005	– 21·193	– 0·003	– 21·196
28	29	87·71	– 0·007	– 0·002	– 20·566	– 0·003	– 20·569
29	30	87·73	+ 0·002	0·000	– 23·133	– 0·003	– 23·136
30	31	92·34	+ 0·002	+ 0·002	– 25·221	– 0·003	– 25·224
31	32	93·50	– 0·008	– 0·006	– 18·989	– 0·003	– 18·992
32	33	96·49	+ 0·001	– 0·005	– 35·672	– 0·003	– 35·675
33	34	100·58	– 0·007	– 0·012	– 35·387	– 0·003	– 35·390
34	35	104·24	+ 0·006	– 0·006	– 14·446	– 0·003	– 14·449
35	36	109·00	– 0·006	– 0·012	– 3·827	– 0·003	– 3·830
36	37	113·47	0·000	– 0·012	+ 16·204	– 0·003	+ 16·201
37	38	113·67	– 0·005	– 0·017	+ 15·843	– 0·003	+ 15·840
38	39	121·87	– 0·016	– 0·033	– 18·271	– 0·003	– 18·274
39	40	127·91	– 0·002	– 0·035	– 12·255	– 0·003	– 12·258
40	41	133·74	– 0·008	– 0·043	+ 9·263	– 0·003	+ 9·260
41	42	133·80	– 0·007	– 0·050	+ 7·145	– 0·003	+ 7·142
42	43	133·80	– 0·001	– 0·051	+ 10·135	– 0·003	+ 10·132
43	44	138·45	– 0·008	– 0·059	– 20·214	– 0·002	– 20·216
44	45	145·37	+ 0·018	– 0·041	– 44·298	– 0·001	– 44·299
45	46	145·43	– 0·004	– 0·045	– 41·975	– 0·001	– 41·976
46	47	157·41	– 0·001	– 0·046	– 30·645	– 0·002	– 30·647
47	48	157·51	– 0·005	– 0·051	– 30·943	– 0·002	– 30·945
48	49	160·10	+ 0·007	– 0·044	– 34·393	– 0·002	– 34·395
49	50	161·10	+ 0·003	– 0·041	– 38·377	– 0·002	– 38·379
50	51	163·09	– 0·020	– 0·061	– 46·342	– 0·002	– 46·344
51	52	164·09	– 0·011	– 0·072	– 52·802	– 0·002	– 52·804
52	53	165·09	+ 0·011	– 0·061	– 54·563	– 0·002	– 54·565
53	54	166·10	+ 0·019	– 0·042	– 57·804	– 0·002	– 57·806
54	55	166·12	– 0·004	– 0·046	– 54·413	– 0·002	– 54·415
55	56	168·12	– 0·010	– 0·056	– 55·631	– 0·002	– 55·633
56	57	169·11	– 0·007	– 0·063	– 57·171	– 0·002	– 57·173
57	58	176·06	+ 0·024	– 0·039	– 77·710	– 0·001	– 77·711
58	59	181·02	– 0·006	– 0·045	– 82·760	– 0·001	– 82·761
59	60	183·00	+ 0·021	– 0·024	– 88·119	– 0·001	– 88·120
60	61	186·96	+ 0·016	– 0·008	– 92·136	– 0·001	– 92·137

* Bench-mark No. 1 is the mark at Pirpanti described on page 135.

Line No. 74. Pirpanti to Howrah.—(Continued).

Bench-marks		Distance from Pirpanti	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Pirpanti (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Pirpanti
From	To		From mark to mark (= d)	Total from Pirpanti		Total from Pirpanti	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	190·90	+ 0·011	+ 0·003	– 104·910	0·000	– 104·910
62	63	192·20	– 0·001	+ 0·002	– 104·458	0·000	– 104·458
63	64	193·88	– 0·005	– 0·003	– 109·191	0·000	– 109·191
64	65	194·88	– 0·002	– 0·005	– 106·321	0·000	– 106·321
65	66	196·88	– 0·003	– 0·008	– 111·734	0·000	– 111·734
66	67	198·88	+ 0·001	– 0·007	– 115·158	0·000	– 115·158
67	68	199·88	+ 0·003	– 0·004	– 117·510	0·000	– 117·510
68	69	202·87	– 0·015	– 0·019	– 120·248	0·000	– 120·248
69	70	203·88	– 0·006	– 0·025	– 123·565	0·000	– 123·565
70	71	205·89	– 0·019	– 0·044	– 122·049	0·000	– 122·049
71	72	207·90	+ 0·019	– 0·025	– 117·295	0·000	– 117·295
72	73	209·89	+ 0·004	– 0·021	– 124·057	+ 0·001	– 124·056
73	74	211·87	+ 0·006	– 0·015	– 122·263	+ 0·001	– 122·262
74	75	212·86	– 0·003	– 0·018	– 127·902	+ 0·002	– 127·900
75	76	220·13	+ 0·004	– 0·014	– 127·035	+ 0·002	– 127·033
76	77	223·93	+ 0·038	+ 0·024	– 125·319	+ 0·002	– 125·317
77	78	226·01	– 0·013	+ 0·011	– 134·116	+ 0·003	– 134·113
78	79	226·91	– 0·010	+ 0·001	– 134·296	+ 0·003	– 134·293
79	80	228·32	+ 0·012	+ 0·013	– 131·545	+ 0·003	– 131·542
80	81	229·88	+ 0·009	+ 0·022	– 130·618	+ 0·003	– 130·615
81	82	230·88	0·000	+ 0·022	– 131·092	+ 0·003	– 131·089
82	83	231·88	– 0·013	+ 0·009	– 133·508	+ 0·003	– 133·505
83	84	232·87	– 0·015	– 0·006	– 134·695	+ 0·003	– 134·692
84	85	233·87	– 0·016	– 0·022	– 129·495	+ 0·002	– 129·493
85	86	234·85	– 0·011	– 0·033	– 131·343	+ 0·002	– 131·341
86	87	236·83	– 0·027	– 0·060	– 131·257	+ 0·002	– 131·255
87	88	241·59	– 0·012	– 0·072	– 164·091	+ 0·005	– 164·086
88	89	241·83	– 0·011	– 0·083	– 136·764	+ 0·003	– 136·761
89	90	242·51	– 0·007	– 0·090	– 137·067	+ 0·003	– 137·064
90	91	245·06	– 0·006	– 0·096	– 135·139	+ 0·003	– 135·136
91	92	246·15	– 0·035	– 0·131	– 161·273	+ 0·006	– 161·267
92	93	246·46	+ 0·007	– 0·124	– 131·097	+ 0·003	– 131·094
93	94	246·89	– 0·003	– 0·127	– 125·993	+ 0·002	– 125·991
94	95	247·49	+ 0·016	– 0·111	– 135·144	+ 0·003	– 135·141
95	96	248·30	+ 0·006	– 0·105	– 134·512	+ 0·003	– 134·509
96	97	248·61	– 0·001	– 0·106	– 135·389	+ 0·003	– 135·386
97	98	249·30	– 0·004	– 0·110	– 135·526	+ 0·003	– 135·523
98	99	249·89	+ 0·009	– 0·101	– 134·881	+ 0·003	– 134·878
99	100	250·24	– 0·001	– 0·102	– 138·951	+ 0·003	– 138·948
100	101	250·25	+ 0·002	– 0·100	– 138·166	+ 0·003	– 138·163
101	102*	251·09	+ 0·001	– 0·099	– 135·366	+ 0·003	– 135·363

Difference of dynamic height, Pirpanti to Howrah = – 135·363 feet.

Length of line in miles = M = 251·09. $\Sigma d^2 = 0·021773$.

Probable error of the mean result per mile of double-levelling $= 0·6745\sqrt{\frac{\Sigma d^2}{4M}} = \pm 0·0032$.

Probable error of the difference of elevation between the terminal bench-marks $= 0·6745\sqrt{\frac{\Sigma d^2}{4}} = \pm 0·0498$.

* Bench-mark No. 102 is the mark at Howrah described on page 134.

Line No. 75. Kendrapara to Howrah.

Bench-marks		Distance from Kendrapara	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Kendrapara (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Kendrapara
From	To		From mark to mark (= *d*)	Total from Kendrapara		Total from Kendrapara	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·05	− 0·003	− 0·003	− 1·330	0·000	− 1·330
2	3	1·63	− 0·018	− 0·021	− 2·156	0·000	− 2·156
3	4	3·19	− 0·013	− 0·034	− 6·286	+ 0·001	− 6·285
4	5	4·31	+ 0·018	− 0·016	− 7·725	+ 0·001	− 7·724
5	6	6·34	+ 0·018	+ 0·002	− 5·882	+ 0·001	− 5·881
6	7	7·29	+ 0·007	+ 0·009	− 6·779	+ 0·001	− 6·778
7	8	8·42	+ 0·006	+ 0·015	− 3·457	0·000	− 3·457
8	9	8·79	+ 0·004	+ 0·019	+ 14·182	− 0·004	+ 14·178
9	10	18·04	− 0·009	+ 0·010	+ 8·917	− 0·003	+ 8·914
10	11	18·53	− 0·004	+ 0·006	+ 10·224	− 0·003	+ 10·221
11	12	19·73	+ 0·001	+ 0·007	− 1·184	− 0·001	− 1·185
12	13	27·25	− 0·014	− 0·007	+ 12·750	− 0·004	+ 12·746
13	14	28·46	− 0·024	− 0·031	+ 17·663	− 0·005	+ 17·658
14	15	29·76	− 0·010	− 0·041	+ 25·535	− 0·007	+ 25·528
15	16	30·39	− 0·002	− 0·043	+ 23·626	− 0·007	+ 23·619
16	17	34·60	− 0·031	− 0·074	+ 35·411	− 0·009	+ 35·402
17	18	36·07	− 0·028	− 0·102	+ 36·825	− 0·009	+ 36·816
18	19	37·07	+ 0·003	− 0·099	+ 37·551	− 0·009	+ 37·542
19	20	38·07	+ 0·008	− 0·091	+ 38·312	− 0·009	+ 38·303
20	21	38·69	− 0·007	− 0·098	+ 37·681	− 0·009	+ 37·672
21	22	39·43	+ 0·005	− 0·093	+ 28·989	− 0·007	+ 28·982
22	23	41·06	0·000	− 0·093	+ 28·859	− 0·007	+ 28·852
23	24	41·62	− 0·001	− 0·094	+ 24·537	− 0·006	+ 24·531
24	25	42·42	− 0·002	− 0·096	+ 29·567	− 0·007	+ 29·560
25	26	43·04	− 0·004	− 0·100	+ 28·833	− 0·007	+ 28·826
26	27	44·03	+ 0·003	− 0·097	+ 28·910	− 0·007	+ 28·903
27	28	45·03	− 0·009	− 0·106	+ 27·940	− 0·007	+ 27·933
28	29	46·03	+ 0·005	− 0·101	+ 28·584	− 0·007	+ 28·577
29	30	47·02	− 0·004	− 0·105	+ 30·896	− 0·007	+ 30·889
30	31	48·06	+ 0·003	− 0·102	+ 32·591	− 0·007	+ 32·584
31	32	49·29	− 0·002	− 0·104	+ 34·499	− 0·007	+ 34·492
32	33	49·99	+ 0·010	− 0·094	+ 33·813	− 0·007	+ 33·806
33	34	50·84	+ 0·017	− 0·077	+ 37·925	− 0·008	+ 37·917
34	35	51·98	+ 0·006	− 0·071	+ 32·182	− 0·007	+ 32·175
35	36	52·89	+ 0·013	− 0·058	+ 31·816	− 0·007	+ 31·809
36	37	53·95	− 0·007	− 0·065	+ 31·315	− 0·007	+ 31·308
37	38	54·79	− 0·004	− 0·069	+ 32·570	− 0·007	+ 32·563
38	39	55·94	+ 0·001	− 0·068	+ 30·772	− 0·007	+ 30·765
39	40	56·93	− 0·007	− 0·075	+ 33·015	− 0·007	+ 33·008
40	41	57·89	+ 0·024	− 0·051	+ 36·846	− 0·008	+ 36·838
41	42	58·91	+ 0·001	− 0·050	+ 29·345	− 0·006	+ 29·339
42	43	59·71	+ 0·004	− 0·046	+ 26·858	− 0·005	+ 26·853
43	44	59·90	− 0·003	− 0·049	+ 24·400	− 0·004	+ 24·396
44	45	60·87	− 0·002	− 0·051	+ 18·635	− 0·003	+ 18·632
45	46	61·00	− 0·002	− 0·053	+ 22·214	− 0·004	+ 22·210
46	47	61·99	+ 0·007	− 0·046	+ 17·284	− 0·003	+ 17·281
47	48	62·98	+ 0·020	− 0·026	+ 14·468	− 0·002	+ 14·466
48	49	63·74	− 0·015	− 0·041	+ 16·661	− 0·002	+ 16·659
49	50	64·34	− 0·005	− 0·046	+ 12·203	− 0·001	+ 12·202
50	51	64·90	− 0·009	− 0·055	+ 19·976	− 0·003	+ 19·973
51	52	65·95	− 0·009	− 0·064	+ 10·328	− 0·001	+ 10·327
52	53	66·94	− 0·002	− 0·066	+ 14·975	− 0·002	+ 14·973
53	54	67·93	− 0·006	− 0·072	+ 23·202	− 0·004	+ 23·198
54	55	68·92	− 0·010	− 0·082	+ 25·890	− 0·005	+ 25·885
55	56	70·45	+ 0·007	− 0·075	+ 29·705	− 0·006	+ 29·699
56	57	70·90	0·000	− 0·075	+ 30·880	− 0·006	+ 30·874
57	58	71·43	+ 0·016	− 0·059	+ 28·738	− 0·006	+ 28·732
58	59	71·90	+ 0·003	− 0·056	+ 29·128	− 0·006	+ 29·122
59	60	72·89	+ 0·014	− 0·042	+ 31·529	− 0·006	+ 31·523
60	61	73·10	− 0·001	− 0·043	+ 33·419	− 0·006	+ 33·413

* Bench-mark No. 1 is the mark at Kendrapara described on page 184.

Line No. 75. Kendrapara to Howrah.—(Continued).

Bench-marks From	Bench-marks To	Distance from Kendrapara	Discrepancy between levellers (First – Second leveller) From mark to mark (= d)	Discrepancy between levellers (First – Second leveller) Total from Kendrapara	Observed elevation above (+) or below (–) Kendrapara (mean result by two levellers)	Dynamic correction deduced from mark to mark Total from Kendrapara	Dynamic height above (+) or below (–) Kendrapara
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	73·88	− 0·007	− 0·050	+ 33·118	− 0·006	+ 33·112
62	63	74·86	+ 0·008	− 0·042	+ 41·265	− 0·008	+ 41·257
63	64	75·16	− 0·002	− 0·044	+ 40·993	− 0·008	+ 40·985
64	65	75·44	− 0·004	− 0·048	+ 40·593	− 0·008	+ 40·585
65	66	76·60	+ 0·005	− 0·043	+ 40·324	− 0·008	+ 40·316
66	67	77·96	+ 0·004	− 0·039	+ 32·193	− 0·007	+ 32·186
67	68	78·84	+ 0·027	− 0·012	+ 29·856	− 0·007	+ 29·849
68	69	79·83	+ 0·010	− 0·002	+ 27·844	− 0·007	+ 27·837
69	70	80·86	− 0·021	− 0·023	+ 28·300	− 0·007	+ 28·293
70	71	81·81	+ 0·003	− 0·020	+ 32·041	− 0·008	+ 32·033
71	72	82·50	− 0·005	− 0·025	+ 33·841	− 0·008	+ 33·833
72	73	83·66	+ 0·003	− 0·022	+ 28·624	− 0·007	+ 28·617
73	74	84·80	− 0·006	− 0·028	+ 28·679	− 0·007	+ 28·672
74	75	85·80	+ 0·005	− 0·023	+ 22·536	− 0·006	+ 22·530
75	76	86·49	+ 0·001	− 0·022	+ 24·694	− 0·006	+ 24·688
76	77	87·80	− 0·008	− 0·030	+ 32·754	− 0·007	+ 32·747
77	78	88·81	− 0·006	− 0·036	+ 46·246	− 0·009	+ 46·237
78	79	89·81	− 0·017	− 0·053	+ 44·185	− 0·009	+ 44·176
79	80	90·81	+ 0·001	− 0·052	+ 51·950	− 0·010	+ 51·940
80	81	91·06	+ 0·006	− 0·046	+ 48·242	− 0·009	+ 48·233
81	82	91·79	+ 0·004	− 0·042	+ 40·785	− 0·008	+ 40·777
82	83	91·88	− 0·002	− 0·044	+ 38·499	− 0·008	+ 38·491
83	84	91·89	− 0·003	− 0·047	+ 38·513	− 0·008	+ 38·505
84	85	92·91	− 0·010	− 0·057	+ 22·643	− 0·005	+ 22·638
85	86	93·36	− 0·011	− 0·068	+ 11·616	− 0·003	+ 11·613
86	87	93·91	+ 0·004	− 0·064	+ 1·419	− 0·001	+ 1·418
87	88	94·91	+ 0·008	− 0·056	+ 7·883	− 0·002	+ 7·881
88	89	96·23	+ 0·035	− 0·021	+ 5·848	− 0·002	+ 5·846
89	90	96·94	0·000	− 0·021	− 2·917	− 0·001	− 2·918
90	91	97·93	− 0·006	− 0·027	+ 2·541	− 0·002	+ 2·539
91	92	99·04	− 0·007	− 0·034	+ 1·337	− 0·002	+ 1·335
92	93	99·95	− 0·011	− 0·045	− 3·063	− 0·001	− 3·064
93	94	100·10	0·000	− 0·045	− 1·364	− 0·001	− 1·365
94	95	100·95	0·000	− 0·045	− 1·705	− 0·001	− 1·706
95	96	102·38	+ 0·008	− 0·037	+ 1·505	− 0·002	+ 1·503
96	97	103·08	− 0·011	− 0·048	− 3·342	− 0·001	− 3·343
97	98	104·08	− 0·010	− 0·058	− 3·728	− 0·001	− 3·729
98	99	105·08	− 0·009	− 0·049	− 1·009	− 0·001	− 1·010
99	100	106·08	+ 0·002	− 0·047	− 1·790	− 0·001	− 1·791
100	101	107·07	+ 0·005	− 0·042	− 0·960	− 0·001	− 0·961
101	102	107·67	− 0·006	− 0·048	+ 3·131	− 0·002	+ 3·129
102	103	108·07	− 0·005	− 0·053	+ 2·007	− 0·002	+ 2·005
103	104	109·07	+ 0·007	− 0·046	+ 6·849	− 0·003	+ 6·846
104	105	109·57	+ 0·003	− 0·043	+ 0·555	− 0·002	+ 0·553
105	106	110·27	+ 0·003	− 0·040	+ 6·611	− 0·003	+ 6·608
106	107	111·27	+ 0·001	− 0·039	+ 4·394	− 0·003	+ 4·391
107	108	111·94	+ 0·002	− 0·037	+ 8·925	− 0·004	+ 8·921
108	109	113·26	− 0·002	− 0·039	+ 4·508	− 0·003	+ 4·505
109	110	115·25	+ 0·011	− 0·028	+ 5·243	− 0·003	+ 5·240
110	111	115·51	− 0·006	− 0·034	+ 6·747	− 0·003	+ 6·744
111	112	116·24	− 0·009	− 0·043	+ 6·779	− 0·003	+ 6·776
112	113	117·24	+ 0·005	− 0·038	+ 9·687	− 0·003	+ 9·684
113	114	118·23	− 0·007	− 0·045	+ 15·377	− 0·004	+ 15·373
114	115	119·16	+ 0·010	− 0·035	+ 21·340	− 0·005	+ 21·335
115	116	120·21	− 0·017	− 0·052	+ 22·627	− 0·005	+ 22·622
116	117	122·24	+ 0·039	− 0·013	+ 24·631	− 0·005	+ 24·626
117	118	123·06	− 0·008	− 0·021	+ 21·576	− 0·004	+ 21·572
118	119	124·18	+ 0·008	− 0·013	+ 21·810	− 0·004	+ 21·806
119	120	125·92	+ 0·008	− 0·005	+ 20·999	− 0·004	+ 20·995
120	121	127·92	− 0·008	− 0·013	+ 10·126	− 0·002	+ 10·124

Line No. 75. Kendrapara to Howrah.—(Continued).

Bench-marks: From	Bench-marks: To	Distance from Kendrapara	Discrepancy between levellers (First – Second leveller): From mark to mark (= d)	Discrepancy between levellers (First – Second leveller): Total from Kendrapara	Observed elevation above (+) or below (–) Kendrapara (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Kendrapara	Dynamic height above (+) or below (–) Kendrapara
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
121	122	130·29	+ 0·004	– 0·009	+ 8·731	– 0·002	+ 8·729
122	123	131·45	+ 0·021	+ 0·012	+ 12·367	– 0·003	+ 12·364
123	124	132·29	– 0·010	+ 0·002	+ 12·393	– 0·003	+ 12·390
124	125	132·95	– 0·010	– 0·008	+ 11·489	– 0·003	+ 11·486
125	126	134·65	+ 0·006	– 0·002	+ 11·879	– 0·003	+ 11·876
126	127	135·75	+ 0·008	+ 0·006	+ 12·085	– 0·003	+ 12·082
127	128	135·87	+ 0·009	+ 0·015	+ 10·306	– 0·003	+ 10·303
128	129	137·86	– 0·013	+ 0·002	+ 7·365	– 0·003	+ 7·362
129	130	139·22	+ 0·024	+ 0·026	+ 8·395	– 0·003	+ 8·392
130	131	140·26	– 0·005	+ 0·021	+ 5·780	– 0·003	+ 5·777
131	132	141·70	– 0·008	+ 0·013	– 1·278	– 0·002	– 1·280
132	133	143·65	– 0·004	+ 0·009	– 9·391	– 0·001	– 9·392
133	134	144·54	– 0·020	– 0·011	– 9·050	– 0·001	– 9·051
134	135	146·76	– 0·013	– 0·024	– 10·656	– 0·001	– 10·657
135	136	148·87	– 0·005	– 0·029	– 9·308	– 0·001	– 9·309
136	137	150·41	0·000	– 0·029	– 10·393	– 0·001	– 10·394
137	138	154·20	+ 0·015	– 0·014	– 10·460	– 0·001	– 10·461
138	139	155·83	0·000	– 0·014	– 7·031	– 0·002	– 7·033
139	140	156·73	+ 0·006	– 0·008	– 5·828	– 0·002	– 5·830
140	141	160·18	+ 0·014	+ 0·006	– 8·032	– 0·002	– 8·034
141	142	160·68	+ 0·007	+ 0·013	+ 17·018	– 0·006	+ 17·012
142	143	161·58	– 0·019	– 0·006	– 9·058	– 0·002	– 9·060
143	144	163·99	+ 0·019	+ 0·013	– 9·935	– 0·002	– 9·937
144	145	168·45	+ 0·020	+ 0·033	– 8·559	– 0·002	– 8·561
145	146	171·06	+ 0·012	+ 0·045	– 6·876	– 0·002	– 6·878
146	147	171·26	+ 0·028	+ 0·073	– 8·335	– 0·002	– 8·337
147	148	174·34	– 0·002	+ 0·071	– 7·004	– 0·002	– 7·006
148	149	176·10	0·000	+ 0·071	– 4·947	– 0·002	– 4·949
149	150	177·51	+ 0·020	+ 0·091	– 7·093	– 0·002	– 7·095
150	151	180·04	– 0·018	+ 0·073	– 1·947	– 0·003	– 1·950
151	152	182·97	+ 0·005	+ 0·078	– 3·719	– 0·003	– 3·722
152	153	187·22	+ 0·013	+ 0·091	– 7·631	– 0·002	– 7·633
153	154	190·56	+ 0·043	+ 0·134	– 5·103	– 0·002	– 5·105
154	155	193·83	– 0·036	+ 0·098	– 4·201	– 0·002	– 4·203
155	156	194·88	– 0·009	+ 0·089	– 4·517	– 0·002	– 4·519
156	157	197·98	+ 0·022	+ 0·111	– 4·740	– 0·002	– 4·742
157	158	201·71	+ 0·033	+ 0·144	– 4·906	– 0·002	– 4·908
158	159	203·21	– 0·001	+ 0·143	+ 0·079	– 0·003	+ 0·076
159	160	203·40	+ 0·003	+ 0·146	– 0·308	– 0·003	– 0·311
160	161	203·94	– 0·007	+ 0·139	– 8·392	– 0·002	– 8·394
161	162	204·89	+ 0·005	+ 0·144	– 0·874	– 0·003	– 0·877
162	163	205·90	– 0·004	+ 0·140	– 0·130	– 0·003	– 0·133
163	164	206·51	+ 0·006	+ 0·146	– 5·195	– 0·002	– 5·197
164	165	208·37	– 0·011	+ 0·135	– 4·466	– 0·002	– 4·468
165	166	208·93	– 0·002	+ 0·133	– 4·382	– 0·002	– 4·384
166	167	209·42	– 0·011	+ 0·122	– 5·405	– 0·002	– 5·407
167	168	211·37	+ 0·008	+ 0·130	– 3·508	– 0·002	– 3·510
168	169	211·86	– 0·002	+ 0·128	– 0·657	– 0·002	– 0·659
169	170	212·12	– 0·005	+ 0·123	– 4·179	– 0·002	– 4·181
170	171	213·36	– 0·008	+ 0·115	– 2·053	– 0·002	– 2·055
171	172	213·54	0·000	+ 0·115	– 2·749	– 0·002	– 2·751
172	173	213·62	0·000	+ 0·115	– 3·845	– 0·002	– 3·847
173	174	213·63	– 0·002	+ 0·113	– 1·438	– 0·002	– 1·440
174	175	214·27	– 0·006	+ 0·107	– 8·629	– 0·001	– 8·630
175	176	216·05	+ 0·016	+ 0·123	– 2·973	– 0·002	– 2·975
176	177	216·86	+ 0·005	+ 0·128	– 4·160	– 0·002	– 4·162
177	178	218·32	+ 0·001	+ 0·129	– 10·949	– 0·001	– 10·950
178	179	218·98	+ 0·001	+ 0·130	– 8·789	– 0·001	– 8·790
179	180	219·91	– 0·016	+ 0·114	– 4·010	– 0·002	– 4·012
180	181	221·45	– 0·008	+ 0·106	– 7·914	– 0·002	– 7·916

Line No. 75. Kendrapara to Howrah.—(Continued).

Bench-marks		Distance from Kendrapara	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Kendrapara (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Kendrapara
From	To		From mark to mark (=d)	Total from Kendrapara		Total from Kendrapara	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
181	182	223·06	+ 0·015	+ 0·121	– 6·315	– 0·002	– 6·317
182	183	224·94	+ 0·009	+ 0·130	– 7·771	– 0·002	– 7·773
183	184	226·27	– 0·020	+ 0·110	– 4·943	– 0·002	– 4·945
184	185	227·26	– 0·006	+ 0·104	– 4·976	– 0·002	– 4·978
185	186	228·24	+ 0·016	+ 0·120	– 10·131	– 0·001	– 10·132
186	187	228·92	– 0·003	+ 0·117	– 5·018	– 0·002	– 5·020
187	188	229·28	+ 0·004	+ 0·121	– 3·989	– 0·002	– 3·991
188	189	229·78	– 0·004	+ 0·117	– 4·353	– 0·002	– 4·355
189	190	229·91	0·000	+ 0·117	– 4·695	– 0·002	– 4·697
190	191	232·80	+ 0·004	+ 0·121	– 5·664	– 0·002	– 5·666
191	192	233·99	+ 0·022	+ 0·143	– 4·895	– 0·002	– 4·897
192	193	234·55	+ 0·004	+ 0·147	– 6·436	– 0·002	– 6·438
193	194	235·08	+ 0·001	+ 0·148	– 6·238	– 0·002	– 6·240
194	195	235·37	+ 0·011	+ 0·159	– 3·736	– 0·002	– 3·738
195	196	237·15	– 0·015	+ 0·144	– 7·982	– 0·002	– 7·984
196	197	238·06	– 0·012	+ 0·132	– 7·631	– 0·002	– 7·633
197	198	240·07	+ 0·032	+ 0·164	– 4·975	– 0·002	– 4·977
198	199	240·91	– 0·001	+ 0·163	– 2·032	– 0·002	– 2·034
199	200	241·90	– 0·022	+ 0·141	– 1·514	– 0·002	– 1·516
200	201	244·01	– 0·005	+ 0·136	– 6·606	– 0·001	– 6·607
201	202	244·39	+ 0·008	+ 0·144	– 10·774	– 0·001	– 10·775
202	203	246·25	+ 0·029	+ 0·173	– 1·765	– 0·002	– 1·767
203	204	247·65	– 0·004	+ 0·169	– 4·632	– 0·002	– 4·634
204	205	249·98	+ 0·009	+ 0·178	– 4·092	– 0·002	– 4·094
205	206*	250·98	+ 0·022	+ 0·200	– 2·686	– 0·002	– 2·688

Difference of dynamic height, Kendrapara to Howrah = – 2·688 feet.

Length of line in miles = M = 250·98. $\Sigma d^2 = 0{\cdot}030666$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0{\cdot}0037$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0{\cdot}0591$.

* Bench-mark No. 206 is the mark at Howrah described on page 134.

Line No. 76. Purnea to Ramganj.

Bench-marks From	Bench-marks To	Distance from Purnea	Discrepancy between levellers (First – Second leveller): From mark to mark (= *d*)	Discrepancy between levellers (First – Second leveller): Total from Purnea	Observed elevation above (+) or below (–) Purnea (mean result by two levellers)	Dynamic correction deduced from mark to mark: Total from Purnea	Dynamic height above (+) or below (–) Purnea
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·78	0·000	0·000	+ 5·359	+ 0·001	+ 5·360
2	3	2·65	– 0·002	– 0·002	– 2·027	0·000	– 2·027
3	4	3·68	+ 0·008	+ 0·006	+ 7·330	+ 0·001	+ 7·331
4	5	4·68	+ 0·002	+ 0·008	+ 5·748	+ 0·001	+ 5·749
5	6	5·68	+ 0·004	+ 0·012	+ 6·959	+ 0·001	+ 6·960
6	7	6·68	– 0·001	+ 0·011	+ 5·121	+ 0·001	+ 5·122
7	8	7·68	– 0·024	– 0·013	+ 5·998	+ 0·001	+ 5·999
8	9	9·68	– 0·005	– 0·018	+ 8·633	+ 0·001	+ 8·634
9	10	10·68	– 0·018	– 0·036	+ 7·600	+ 0·001	+ 7·601
10	11	11·68	– 0·002	– 0·038	+ 6·102	+ 0·001	+ 6·103
11	12	12·68	+ 0·003	– 0·035	+ 6·883	+ 0·001	+ 6·884
12	13	13·68	– 0·001	– 0·036	+ 8·574	+ 0·001	+ 8·575
13	14	14·17	– 0·004	– 0·040	+ 2·630	0·000	+ 2·630
14	15	14·69	– 0·005	– 0·045	+ 9·483	+ 0·001	+ 9·484
15	16	15·69	– 0·003	– 0·048	+ 8·471	+ 0·001	+ 8·472
16	17	16·69	– 0·003	– 0·051	+ 10·613	+ 0·001	+ 10·614
17	18	17·70	– 0·002	– 0·053	+ 9·743	+ 0·001	+ 9·744
18	19	19·71	– 0·011	– 0·064	+ 9·439	+ 0·001	+ 9·440
19	20	20·75	– 0·010	– 0·074	+ 9·732	+ 0·001	+ 9·733
20	21	22·79	+ 0·004	– 0·070	+ 5·841	0·000	+ 5·841
21	22	24·66	0·000	– 0·070	+ 6·117	0·000	+ 6·117
22	23	25·66	– 0·014	– 0·084	+ 7·144	0·000	+ 7·144
23	24	26·66	0·000	– 0·084	+ 11·077	+ 0·001	+ 11·078
24	25	27·66	0·000	– 0·084	+ 11·741	+ 0·001	+ 11·742
25	26	28·66	+ 0·013	– 0·071	+ 13·070	+ 0·001	+ 13·071
26	27	29·66	+ 0·002	– 0·069	+ 14·099	+ 0·001	+ 14·100
27	28	30·65	+ 0·007	– 0·062	+ 23·616	+ 0·002	+ 23·618
28	29	31·65	– 0·009	– 0·071	+ 16·498	+ 0·001	+ 16·499
29	30	32·64	– 0·015	– 0·086	+ 17·443	+ 0·001	+ 17·444
30	31	33·64	– 0·006	– 0·092	+ 20·504	+ 0·001	+ 20·505
31	32	34·63	– 0·006	– 0·098	+ 21·574	+ 0·001	+ 21·575
32	33	35·62	– 0·012	– 0·110	+ 23·821	+ 0·001	+ 23·822
33	34	36·61	– 0·007	– 0·117	+ 25·331	+ 0·001	+ 25·332
34	35	37·61	+ 0·026	– 0·091	+ 24·534	+ 0·001	+ 24·535
35	36	38·60	– 0·004	– 0·095	+ 25·255	+ 0·001	+ 25·256
36	37	39·60	– 0·010	– 0·105	+ 29·066	+ 0·002	+ 29·068
37	38	40·59	+ 0·017	– 0·088	+ 32·981	+ 0·003	+ 32·984
38	39	41·59	+ 0·014	– 0·074	+ 36·187	+ 0·004	+ 36·191
39	40	42·58	+ 0·013	– 0·061	+ 37·080	+ 0·004	+ 37·084
40	41	43·57	– 0·002	– 0·063	+ 42·133	+ 0·005	+ 42·138
41	42	44·59	– 0·010	– 0·073	+ 39·643	+ 0·005	+ 39·648
42	43	45·56	+ 0·005	– 0·068	+ 46·441	+ 0·006	+ 46·447
43	44	46·55	– 0·004	– 0·072	+ 49·059	+ 0·006	+ 49·065
44	45	47·93	+ 0·017	– 0·055	+ 51·652	+ 0·006	+ 51·658
45	46	48·58	0·000	– 0·055	+ 54·899	+ 0·007	+ 54·906
46	47	49·57	– 0·021	– 0·076	+ 53·689	+ 0·007	+ 53·696
47	48	50·57	0·000	– 0·076	+ 60·199	+ 0·008	+ 60·207
48	49	51·56	+ 0·008	– 0·068	+ 62·769	+ 0·008	+ 62·777
49	50	52·43	– 0·017	– 0·085	+ 61·588	+ 0·008	+ 61·596
50	51	52·56	– 0·002	– 0·087	+ 65·604	+ 0·009	+ 65·613
51	52	53·55	– 0·011	– 0·098	+ 70·135	+ 0·010	+ 70·145
52	53	54·90	– 0·011	– 0·109	+ 69·977	+ 0·010	+ 69·987
53	54	56·53	+ 0·009	– 0·100	+ 76·314	+ 0·011	+ 76·325
54	55	57·52	+ 0·007	– 0·093	+ 79·574	+ 0·012	+ 79·586
55	56	58·52	– 0·003	– 0·096	+ 78·707	+ 0·012	+ 78·719
56	57	59·51	+ 0·001	– 0·095	+ 81·626	+ 0·013	+ 81·639
57	58	59·94	– 0·004	– 0·099	+ 85·274	+ 0·014	+ 85·288
58	59	60·59	+ 0·005	– 0·094	+ 92·565	+ 0·015	+ 92·580
59	60	61·52	+ 0·004	– 0·090	+ 97·238	+ 0·016	+ 97·254
60	61	62·51	– 0·003	– 0·093	+ 101·080	+ 0·017	+ 101·097

* Bench-mark No. 1 is the mark at Purnea described on page 185.

Line No. 76. Purnea to Ramganj.—(Continued).

Bench-marks		Distance from Purnea	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Purnea (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Purnea
From	To		From mark to mark (= d)	Total from Purnea		Total from Purnea	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
61	62	62·73	– 0·007	– 0·100	+ 102·187	+ 0·017	+ 102·204
62	63	63·51	– 0·012	– 0·112	+ 102·802	+ 0·017	+ 102·819
63	64	65·51	– 0·004	– 0·116	+ 108·058	+ 0·018	+ 108·076
64	65	66·45	+ 0·006	– 0·110	+ 107·620	+ 0·018	+ 107·638
65	66	67·48	– 0·003	– 0·113	+ 107·624	+ 0·018	+ 107·642
66	67	67·94	+ 0·001	– 0·112	+ 102·897	+ 0·017	+ 102·914
67	68	68·79	+ 0·019	– 0·093	+ 109·033	+ 0·018	+ 109·051
68	69*	68·81	+ 0·001	– 0·092	+ 112·041	+ 0·019	+ 112·060

Difference of dynamic height, Purnea to Ramganj = + 112·060 feet.

Length of line in miles = M = 68·81. $\Sigma d^2 = 0{\cdot}006060$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4M}} = \pm\ 0{\cdot}0032$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4}} = \pm\ 0{\cdot}0263$.

* Bench-mark No. 69 is the mark at Ramganj described on page 135.

Line No. 77. Howrah to Ramganj.

Bench-marks		Distance from Howrah	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Howrah (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Howrah
From	To		From mark to mark (= d)	Total from Howrah		Total from Howrah	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
1*	2	0·83	– 0·001	– 0·001	– 2·800	0·000	– 2·800
2	3	0·84	– 0·002	– 0·003	– 3·585	0·000	– 3·585
3	4	1·10	0·000	– 0·003	– 1·118	0·000	– 1·118
4	5	1·36	+ 0·008	+ 0·005	– 3·686	0·000	– 3·686
5	6	1·71	+ 0·004	+ 0·009	+ 0·469	0·000	+ 0·469
6	7	2·29	+ 0·015	+ 0·024	– 0·153	0·000	– 0·153
7	8	2·99	– 0·012	+ 0·012	– 0·022	0·000	– 0·022
8	9	3·31	– 0·001	+ 0·011	+ 0·865	0·000	+ 0·865
9	10	4·07	– 0·001	+ 0·010	+ 3·151	0·000	+ 3·151
10	11	4·86	– 0·004	+ 0·006	– 1·015	0·000	– 1·015
11	12	5·32	– 0·007	– 0·001	+ 1·584	0·000	+ 1·584
12	13	5·90	+ 0·018	+ 0·017	+ 0·340	0·000	+ 0·340
13	14	5·93	0·000	+ 0·017	+ 0·944	0·000	+ 0·944
14	15	8·19	+ 0·007	+ 0·024	+ 4·542	0·000	+ 4·542
15	16	8·23	– 0·001	+ 0·023	+ 2·542	0·000	+ 2·542
16	17	16·46	+ 0·026	+ 0·049	+ 0·033	0·000	+ 0·033
17	18	17·85	+ 0·004	+ 0·053	+ 2·534	0·000	+ 2·534
18	19	18·50	+ 0·002	+ 0·055	– 1·638	0·000	– 1·638
19	20	20·35	0·000	+ 0·055	– 0·382	0·000	– 0·382
20	21	23·29	+ 0·026	+ 0·081	– 0·876	0·000	– 0·876
21	22	24·68	+ 0·019	+ 0·100	+ 1·635	0·000	+ 1·635
22	23	26·87	+ 0·016	+ 0·116	+ 10·269	– 0·001	+ 10·268
23	24	28·12	– 0·002	+ 0·114	+ 1·347	0·000	+ 1·347
24	25	29·25	+ 0·008	+ 0·122	+ 4·263	0·000	+ 4·263
25	26	30·69	+ 0·012	+ 0·134	+ 5·536	0·000	+ 5·536
26	27	32·30	+ 0·009	+ 0·143	+ 8·186	0·000	+ 8·186
27	28	34·34	+ 0·025	+ 0·168	+ 13·529	0·000	+ 13·529
28	29	35·75	+ 0·013	+ 0·181	+ 8·823	0·000	+ 8·823
29	30	36·16	– 0·005	+ 0·176	+ 10·277	0·000	+ 10·277
30	31	36·66	0·000	+ 0·176	+ 5·778	0·000	+ 5·778
31	32	38·19	– 0·004	+ 0·172	+ 6·308	0·000	+ 6·308
32	33	40·10	– 0·001	+ 0·171	+ 7·942	0·000	+ 7·942
33	34	40·98	+ 0·002	+ 0·173	+ 14·329	0·000	+ 14·329
34	35	42·37	– 0·009	+ 0·164	+ 13·196	0·000	+ 13·196
35	36	43·99	+ 0·005	+ 0·169	+ 15·496	0·000	+ 15·496
36	37	45·74	+ 0·015	+ 0·184	+ 17·601	0·000	+ 17·601
37	38	46·61	– 0·004	+ 0·180	+ 16·905	0·000	+ 16·905
38	39	47·76	– 0·004	+ 0·176	+ 11·925	0·000	+ 11·925
39	40	48·75	– 0·007	+ 0·169	+ 10·331	0·000	+ 10·331
40	41	50·40	– 0·007	+ 0·162	+ 14·724	0·000	+ 14·724
41	42	52·14	+ 0·008	+ 0·170	+ 13·492	0·000	+ 13·492
42	43	54·68	+ 0·005	+ 0·175	+ 9·364	0·000	+ 9·364
43	44	56·52	+ 0·007	+ 0·182	+ 12·336	0·000	+ 12·336
44	45	58·13	+ 0·005	+ 0·187	+ 11·551	0·000	+ 11·551
45	46	59·54	– 0·003	+ 0·184	+ 11·363	0·000	+ 11·363
46	47	61·22	+ 0·004	+ 0·188	+ 11·952	0·000	+ 11·952
47	48	62·85	+ 0·001	+ 0·189	+ 12·416	0·000	+ 12·416
48	49	64·13	– 0·012	+ 0·177	+ 11·829	0·000	+ 11·829
49	50	69·63	+ 0·010	+ 0·187	+ 13·237	0·000	+ 13·237
50	51	70·48	– 0·008	+ 0·179	+ 11·614	0·000	+ 11·614
51	52	76·76	+ 0·037	+ 0·216	+ 13·363	0·000	+ 13·363
52	53	78·37	– 0·005	+ 0·211	+ 21·837	0·000	+ 21·837
53	54	78·41	+ 0·001	+ 0·212	+ 20·346	0·000	+ 20·346
54	55	83·59	– 0·021	+ 0·191	+ 10·053	0·000	+ 10·053
55	56	85·15	– 0·004	+ 0·187	+ 18·167	0·000	+ 18·167
56	57	86·87	+ 0·002	+ 0·189	+ 23·236	0·000	+ 23·236
57	58	87·48	0·000	+ 0·189	+ 26·605	0·000	+ 26·605
58	59	88·86	– 0·009	+ 0·180	+ 13·718	0·000	+ 13·718
59	60	90·73	– 0·011	+ 0·169	+ 20·390	0·000	+ 20·390
60	61	92·47	– 0·009	+ 0·160	+ 20·487	0·000	+ 20·487

* Bench-mark No. 1 is the mark at Howrah described on page 134.

Line No. 77. Howrah to Ramganj.—(Continued).

Bench-marks		Distance from Howrah	Discrepancy between levellers (First − Second leveller)		Observed elevation above (+) or below (−) Howrah (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (−) Howrah
From	To		From mark to mark (= d)	Total from Howrah		Total from Howrah	
		miles	foot	foot	feet	foot	feet
61	62	94·65	+ 0·005	+ 0·165	+ 21·457	0·000	+ 21·457
62	63	95·54	0·000	+ 0·165	+ 21·474	0·000	+ 21·474
63	64	97·64	+ 0·012	+ 0·177	+ 22·134	0·000	+ 22·134
64	65	99·48	− 0·001	+ 0·176	+ 22·238	0·000	+ 22·238
65	66	103·55	+ 0·010	+ 0·186	+ 37·754	0·000	+ 37·754
66	67	105·59	− 0·017	+ 0·169	+ 31·340	0·000	+ 31·340
67	68	106·61	− 0·014	+ 0·155	+ 24·445	0·000	+ 24·445
68	69	108·32	− 0·005	+ 0·150	+ 25·046	0·000	+ 25·046
69	70	110·20	− 0·015	+ 0·135	+ 18·232	0·000	+ 18·232
70	71	113·15	− 0·013	+ 0·122	+ 28·555	0·000	+ 28·555
71	72	121·01	+ 0·013	+ 0·135	+ 30·975	0·000	+ 30·975
72	73	123·36	0·000	+ 0·135	+ 33·958	0·000	+ 33·958
73	74	125·15	+ 0·009	+ 0·144	+ 25·182	0·000	+ 25·182
74	75	129·68	+ 0·006	+ 0·150	+ 30·065	0·000	+ 30·065
75	76	130·03	− 0·003	+ 0·147	+ 31·473	0·000	+ 31·473
76	77	131·31	0·000	+ 0·147	+ 33·608	0·000	+ 33·608
77	78	132·13	− 0·008	+ 0·139	+ 35·518	0·000	+ 35·518
78	79	136·48	− 0·025	+ 0·114	+ 36·259	0·000	+ 36·259
79	80	138·47	− 0·034	+ 0·080	+ 32·085	0·000	+ 32·085
80	81	139·87	− 0·012	+ 0·068	+ 34·118	0·000	+ 34·118
81	82	144·43	− 0·033	+ 0·035	+ 33·709	0·000	+ 33·709
82	83	147·49	− 0·035	0·000	+ 37·008	0·000	+ 37·008
83	84	149·02	+ 0·009	+ 0·009	+ 35·978	0·000	+ 35·978
84	85	150·15	+ 0·002	+ 0·011	+ 36·311	0·000	+ 36·311
85	86	152·63	+ 0·020	+ 0·031	+ 34·670	0·000	+ 34·670
86	87	154·16	− 0·008	+ 0·023	+ 45·747	0·000	+ 45·747
87	88	155·16	0·000	+ 0·023	+ 34·122	0·000	+ 34·122
88	89	156·83	0·000	+ 0·023	+ 32·999	0·000	+ 32·999
89	90	157·94	+ 0·010	+ 0·033	+ 45·750	0·000	+ 45·750
90	91	159·58	− 0·003	+ 0·030	+ 32·177	0·000	+ 32·177
91	92	161·09	+ 0·012	+ 0·042	+ 32·890	0·000	+ 32·890
92	93	163·78	+ 0·010	+ 0·052	+ 33·552	0·000	+ 33·552
93	94	166·05	+ 0·008	+ 0·060	+ 33·985	0·000	+ 33·985
94	95	167·41	− 0·005	+ 0·055	+ 33·689	0·000	+ 33·689
95	96	168·70	+ 0·009	+ 0·064	+ 33·707	0·000	+ 33·707
96	97	169·88	− 0·007	+ 0·057	+ 34·710	0·000	+ 34·710
97	98	171·39	+ 0·006	+ 0·063	+ 34·111	0·000	+ 34·111
98	99	173·57	+ 0·006	+ 0·069	+ 33·886	0·000	+ 33·886
99	100	175·49	0·000	+ 0·069	+ 33·770	0·000	+ 33·770
100	101	178·14	− 0·010	+ 0·059	+ 33·774	0·000	+ 33·774
101	102	178·84	+ 0·004	+ 0·063	+ 33·543	0·000	+ 33·543
102	103	179·77	+ 0·021	+ 0·084	+ 33·221	0·000	+ 33·221
103	104	182·73	− 0·006	+ 0·078	+ 35·040	0·000	+ 35·040
104	105	183·53	− 0·009	+ 0·069	+ 35·878	0·000	+ 35·878
105	106	189·83	− 0·020	+ 0·049	+ 37·920	0·000	+ 37·920
106	107	191·78	+ 0·020	+ 0·069	+ 50·973	+ 0·001	+ 50·974
107	108	194·08	− 0·002	+ 0·067	+ 41·567	0·000	+ 41·567
108	109	196·96	+ 0·022	+ 0·089	+ 42·335	0·000	+ 42·335
109	110	200·57	+ 0·005	+ 0·094	+ 47·705	0·000	+ 47·705
110	111	203·41	+ 0·005	+ 0·099	+ 50·154	0·000	+ 50·154
111	112	205·14	+ 0·001	+ 0·100	+ 53·928	0·000	+ 53·928
112	113	207·13	0·000	+ 0·100	+ 56·222	0·000	+ 56·222
113	114	209·50	− 0·002	+ 0·098	+ 60·118	0·000	+ 60·118
114	115	211·92	+ 0·007	+ 0·105	+ 62·030	0·000	+ 62·030
115	116	213·53	+ 0·010	+ 0·115	+ 63·280	0·000	+ 63·280
116	117	215·73	+ 0·013	+ 0·128	+ 66·532	0·000	+ 66·532
117	118	217·47	− 0·009	+ 0·119	+ 66·826	0·000	+ 66·826
118	119	219·28	− 0·022	+ 0·097	+ 67·292	0·000	+ 67·292
119	120	221·02	+ 0·015	+ 0·112	+ 74·874	+ 0·001	+ 74·875
120	121	222·82	− 0·012	+ 0·100	+ 76·772	+ 0·001	+ 76·773

Line No. 77. Howrah to Ramganj—(Continued).

Bench-marks		Distance from Howrah	Discrepancy between levellers (First – Second leveller)		Observed elevation above (+) or below (–) Howrah (mean result by two levellers)	Dynamic correction deduced from mark to mark	Dynamic height above (+) or below (–) Howrah
From	To		From mark to mark (= d)	Total from Howrah		Total from Howrah	
		miles	*foot*	*foot*	*feet*	*foot*	*feet*
121	122	225·16	0·000	+ 0·100	+ 79·673	+ 0·001	+ 79·674
122	123	226·94	– 0·021	+ 0·079	+ 80·210	+ 0·001	+ 80·211
123	124	227·83	– 0·013	+ 0·066	+ 82·093	+ 0·001	+ 82·094
124	125	229·20	+ 0·003	+ 0·069	+ 83·906	+ 0·001	+ 83·907
125	126	230·91	– 0·010	+ 0·059	+ 87·521	+ 0·001	+ 87·522
126	127	232·36	+ 0·003	+ 0·062	+ 86·389	+ 0·001	+ 86·390
127	128	236·82	+ 0·015	+ 0·077	+ 94·535	+ 0·002	+ 94·537
128	129	238·03	+ 0·017	+ 0·094	+ 95·099	+ 0·002	+ 95·101
129	130	239·37	– 0·008	+ 0·086	+ 95·058	+ 0·002	+ 95·060
130	131	242·26	+ 0·009	+ 0·095	+ 96·917	+ 0·002	+ 96·919
131	132	245·41	+ 0·013	+ 0·108	+ 105·514	+ 0·003	+ 105·517
132	133	248·46	+ 0·007	+ 0·115	+ 108·988	+ 0·003	+ 108·991
133	134	249·97	– 0·012	+ 0·103	+ 112·188	+ 0·003	+ 112·191
134	135	251·50	+ 0·003	+ 0·106	+ 116·516	+ 0·003	+ 116·519
135	136	253·24	+ 0·012	+ 0·118	+ 120·393	+ 0·004	+ 120·397
136	137	255·78	– 0·009	+ 0·109	+ 128·260	+ 0·005	+ 128·265
137	138	257·17	+ 0·004	+ 0·113	+ 126·864	+ 0·005	+ 126·869
138	139	261·45	+ 0·005	+ 0·118	+ 137·689	+ 0·007	+ 137·696
139	140	267·24	+ 0·006	+ 0·124	+ 149·042	+ 0·009	+ 149·051
140	141	269·57	– 0·018	+ 0·106	+ 150·930	+ 0·009	+ 150·939
141	142	274·03	+ 0·010	+ 0·116	+ 162·302	+ 0·011	+ 162·313
142	143	278·61	+ 0·003	+ 0·119	+ 173·194	+ 0·013	+ 173·207
143	144	280·37	– 0·012	+ 0·107	+ 179·724	+ 0·014	+ 179·738
144	145	285·40	+ 0·034	+ 0·141	+ 191·479	+ 0·017	+ 191·496
145	146	286·74	– 0·002	+ 0·139	+ 199·356	+ 0·018	+ 199·374
146	147	288·35	0·000	+ 0·139	+ 206·741	+ 0·019	+ 206·760
147	148	290·39	– 0·003	+ 0·136	+ 213·287	+ 0·020	+ 213·307
148	149	294·12	+ 0·009	+ 0·145	+ 221·403	+ 0·021	+ 221·424
149	150	298·88	0·000	+ 0·145	+ 235·388	+ 0·024	+ 235·412
150	151	302·53	+ 0·031	+ 0·176	+ 248·240	+ 0·026	+ 248·266
151	152	303·74	+ 0·007	+ 0·183	+ 251·609	+ 0·027	+ 251·636
152	153	305·92	– 0·003	+ 0·180	+ 262·151	+ 0·029	+ 262·180
153	154	310·26	+ 0·015	+ 0·195	+ 276·953	+ 0·032	+ 276·985
154	155	315·81	+ 0·001	+ 0·196	+ 299·741	+ 0·036	+ 299·777
155	156	317·44	+ 0·001	+ 0·197	+ 312·938	+ 0·039	+ 312·977
156	157	319·18	+ 0·021	+ 0·218	+ 324·548	+ 0·041	+ 324·589
157	158	322·74	+ 0·002	+ 0·220	+ 349·873	+ 0·046	+ 349·919
158	159	325·37	+ 0·008	+ 0·228	+ 364·941	+ 0·049	+ 364·990
159	160	326·59	– 0·010	+ 0·218	+ 375·281	+ 0·051	+ 375·332
160	161	332·42	– 0·086	+ 0·132	+ 326·760	+ 0·042	+ 326·802
161	162	333·76	– 0·005	+ 0·127	+ 314·850	+ 0·040	+ 314·890
162	163	334·62	+ 0·007	+ 0·134	+ 310·112	+ 0·039	+ 310·151
163	164	336·32	– 0·006	+ 0·128	+ 302·855	+ 0·038	+ 302·893
164	165	340·70	+ 0·002	+ 0·130	+ 275·912	+ 0·033	+ 275·945
165	166	341·50	+ 0·001	+ 0·131	+ 272·696	+ 0·032	+ 272·728
166	167	343·05	+ 0·011	+ 0·142	+ 271·454	+ 0·032	+ 271·486
167	168	346·20	+ 0·006	+ 0·148	+ 261·660	+ 0·030	+ 261·690
168	169	350·68	+ 0·018	+ 0·166	+ 220·349	+ 0·023	+ 220·372
169	170	351·66	– 0·031	+ 0·135	+ 210·046	+ 0·021	+ 210·067
170	171*	351·69	– 0·003	+ 0·132	+ 213·060	+ 0·022	+ 213·082

Difference of dynamic height, Howrah to Ramganj = + 213·082 feet.

Length of line in miles = M = 351·69. $\Sigma d^2 = 0{\cdot}032052$.

Probable error of the mean result per mile of double-levelling $= 0{\cdot}6745\sqrt{\dfrac{\Sigma d^2}{4M}} = \pm\, 0{\cdot}0032$.

Probable error of the difference of elevation between the terminal bench-marks $= 0{\cdot}6745\sqrt{\dfrac{\Sigma d^2}{4}} = \pm\, 0{\cdot}0604$.

* Bench-mark No. 171 is the mark at Ramganj described on page 135.

In the following table are given the results of the nine short lines of levelling, that connect the level-net with the accepted tidal stations:—

Level line	From	To	Distance from the Sea	Discrepancy between levellers (First – Second leveller)	Observed elevation above mean-sea-level (mean result by two levellers)	Dynamic correction deduced from mark to mark / Total from mean-sea-level	Dynamic height above the mean level of the sea
Line No. 78. Mean-Sea-Level to Karachi	Mean-sea-level	Karachi reference bench-mark	*mile* 0·07	*foot* 0·000	*feet* + 8·948	*foot* + 0·001	*feet* + 8·949
Line No. 79. Mean-Sea-Level to Bombay	Mean-sea-level	Reference bench-mark Apollo Bandar	*mile* 0·00	*foot* 0·000	*feet* + 13·704	*foot* − 0·004	*feet* + 13·700
	Reference bench-mark Apollo Bandar	Bench-mark at Town Hall, Bombay	0·75	+ 0·003	+ 19·746	− 0·006	+ 19·740
Line No. 80. Mean-Sea-Level to Karwar	Mean-sea-level	Karwar reference bench-mark	*mile* 0·06	*foot* 0·000	*feet* + 11·772	*foot* − 0·006	*feet* + 11·766
Line No. 81. Mean-Sea-Level to Beypore	Mean-sea-level	Original reference bench-mark for Beypore	*mile* 0·02	*foot* 0·000	*feet* + 14·324	*foot* − 0·010	*feet* + 14·314
Line No. 82. Mean-Sea-Level to Cochin	Mean-sea-level	Cochin reference bench-mark	*mile* 0·05	*foot* 0·000	*feet* + 6·572	*foot* − 0·004	*feet* + 6·568
Line No. 83. Mean-Sea-Level to Negapatam	Mean-sea-level	Negapatam reference bench-mark	*mile* 0·21	*foot* 0·000	*feet* + 9·615	*foot* − 0·007	*feet* + 9·608
Line No. 84. Mean-Sea-Level to Madras	Mean-sea-level	Madras reference bench-mark, Prince of Wales Memorial	*miles* 1·41	*foot* + 0·008	*feet* + 15·711	*foot* − 0·009	*feet* + 15·702

Level line	From	To	Distance from the Sea	Discrepancy between levellers (First − Second leveller)	Observed elevation above mean-sea-level (mean result by two levellers)	Dynamic correction deduced from mark to mark Total from mean-sea-level	Dynamic height above the mean level of the sea
			mile	*foot*	*feet*	*foot*	*feet*
Line No. 85. Mean-Sea-Level to Vizagapatam	Mean-sea-level	Vizagapatam reference bench-mark	0·20	0·000	+ 14·126	− 0·005	+ 14·121
			miles	*foot*	*feet*	*foot*	*feet*
Line No. 86. Mean-Sea-Level to False Point	Mean-sea-level	Reference bench-mark	0·59	0·000	+ 10·392	− 0·002	+ 10·390
	Reference bench-mark	Bench-mark at Light House, False Point	9·05	− 0·085	+ 14·901	− 0·003	+ 14·898

Section (3).—RESULTS OF REVISIONS.

Line No. 32. Bombay to Kalyan.

Bench-marks of the original levelling that were connected during the revisionary operations		Distance from Bombay	Observed height above (+) or below (−) Bombay as determined in		Difference in height (Revised − Original). The + sign denotes that the height was *greater*, and the − sign *less* in 1906-07 than it was in 1877-78
Description	Number		1877-78	1906-07	
		miles	*feet*	*feet*	*foot*
Bombay town-hall	1	0·00	0·000	0·000	0·000
Cut on coping	c/1	1·71	− 9·004	− 9·028	− 0·024
Cut on masonry block	a/3	5·70	− 9·472	− 9·460	+ 0·012
Embedded at Dadar	b/3	6·81	− 8·857	− 8·934	− 0·077
Dadar G. T. Survey Station ...	5	7·09	− 8·044	− 8·143	− 0·099
Cut on bridge parapet	6	7·20	− 7·236	− 7·249	− 0·013
Embedded at Kurla	7	10·56	− 9·804	− 9·874	− 0·070
Cut on bridge parapet	9	11·85	− 7·857	− 7·852	+ 0·005
Cut on bridge parapet	11	16·80	− 4·826	− 4·391	+ 0·435*
Cut on bridge parapet	12	17·13	+ 1·500	+ 1·483	− 0·017
Cut on bridge parapet	a/12	19·75	− 1·278	− 1·314	− 0·036
Embedded at Thana	a/13	22·04	+ 4·315	+ 4·330	+ 0·015
Cut on bridge parapet	15	23·34	− 2·430	− 2·459	− 0·029
Cut on bridge parapet	16	24·73	+ 17·960	+ 18·022	+ 0·062
Cut on bridge parapet	18	26·60	+ 3·963	+ 3·980	+ 0·017
Cut on bridge parapet	20	31·43	+ 16·205	+ 16·211	+ 0·006
Embedded at Kalyan	21	34·54	+ 5·411	+ 5·399	− 0·012

* This mark appears to have been raised since it was erected in 1877.

Line No. 31. Kalyan to Kedgaon.

Bench-marks of the original levelling that were connected during the revisionary operations		Distance from Kalyan	Observed height above (+) or below (−) Kalyan as determined in		Difference in height (Revised − Original). The + sign denotes that the height was *greater*, and the − sign *less* in 1906-07 than it was in 1877-78
Description	Number		1877-78	1906-07	
		miles	*feet*	*feet*	*feet*
Embedded at Kalyan	1	0·00	0·000	0·000	0·000
Cut on railway platform ...	2	0·05	+ 1·656	+ 1·709	+ 0·053
Cut on bridge parapet ..	3	1·04	+ 12·487	+ 13·999	+ 1·512*
Do.	5	7·70	+ 67·103	+ 67·148	+ 0·045
Do.	6	8·15	+ 54·905	+ 56·463	+ 1·558*
Do.	$\frac{a}{7}$	10·53	+ 39·485	+ 40·452	+ 0·967*
Do.	8	12·17	+ 43·349	+ 43·416	+ 0·067
Do.	9	13·10	+ 46·557	+ 46·624	+ 0·067
Do.	11	14·69	+ 96·155	+ 96·245	+ 0·090
Do.	12	15·09	+ 105·567	+ 105·616	+ 0·049
Do.	13	18·05	+ 103·080	+ 103·329	+ 0·249*
Do.	17	20·86	+ 121·246	+ 121·323	+ 0·077
Do.	18	21·91	+ 143·565	+ 143·625	+ 0·060
Do.	$\frac{a}{18}$	23·34	+ 141·685	+ 141·751	+ 0·066
Do.	20	25·96	+ 128·210	+ 129·747	+ 1·537*
Do.	21	28·05	+ 135·215	+ 135·381	+ 0·166
Embedded at Karjat	22	28·94	+ 144·542	+ 144·628	+ 0·086
Embedded at Kampuli	27	37·72	+ 206·970	+ 207·071	+ 0·101
Cut on pillar	$\frac{a}{27}$	40·56	+ 1278·919	+ 1278·917	− 0·002
Cut on step	$\frac{a}{28}$	43·28	+ 1748·028	+ 1748·018	− 0·010
Embedded at Khandala	29	43·72	+ 1765·615	+ 1765·513	− 0·102
Cut on bridge parapet	$\frac{a}{30}$	46·33	+ 2010·553	+ 2010·479	− 0·074
Do.	32	50·27	+ 1997·796	+ 1997·789	− 0·007
Cut on railway platform	$\frac{a}{32}$	50·96	+ 1996·868	+ 1996·848	− 0·020
Cut on bridge parapet	35	54·52	+ 1978·483	+ 1978·482	− 0·001
Do.	$\frac{a}{40}$	61·91	+ 2013·068	+ 2013·026	− 0·042
Do.	41	62·95	+ 1991·963	+ 1991·901	− 0·062
Embedded at Talegaon	$\frac{a}{41}$	64·54	+ 2000·315	+ 2000·253	− 0·062
Cut on railway platform	45	70·37	+ 1970·531	+ 1970·434	− 0·097
Cut on bridge parapet	46	71·18	+ 1951·085	+ 1951·022	− 0·063
Do.	47	71·78	+ 1932·000	+ 1931·946	− 0·054
Embedded at Chinchvad	$\frac{a}{49}$	75·45	+ 1846·530	+ 1846·486	− 0·044
Embedded at Kirkee	$\frac{a}{62}$	81·70	+ 1811·976	+ 1812·193	+ 0·217
Cut on bridge parapet	$\frac{b}{59}$	88·21	+ 1885·679	+ 1885·618	− 0·061
Do.	$\frac{c}{59}$	88·92	+ 1862·327	+ 1862·278	− 0·049
Do.	60	90·67	+ 1836·714	+ 1836·626	− 0·088
Do.	$\frac{a}{60}$	91·21	+ 1838·736	+ 1838·668	− 0·068
Do.	61	92·36	+ 1841·278	+ 1841·194	− 0·084
Do.	65	100·36	+ 1777·382	+ 1776·954	− 0·428†
Do.	$\frac{b}{65}$	101·51	+ 1772·062	+ 1771·972	− 0·090

* These marks, cut on bridges, appear to have been raised by railway engineers, since they were first erected in 1877.

† This mark appears to have been lowered since 1877.

Line No. 31. Kalyan to Kedgaon.—(Continued).

Bench-marks of the original levelling that were connected during the revisionary operations		Distance from Kalyan	Observed height above (+) or below (−) Kalyan as determined in		Difference in height (Revised − Original). The + sign denotes that the height was *greater*, and the − sign *less* in 1906-07 than it was in 1877-78
Description	Number		1877-78	1906-07	
		miles	*feet*	*feet*	*feet*
Embedded at Uruli	67	104·31	+ 1776·027	+ 1775·818	− 0·209
Cut on bridge parapet	70	106·75	+ 1784·630	+ 1784·559	− 0·071
Do.	73	111·01	+ 1794·762	+ 1796·227	+ 1·465*
Do.	a/73	111·36	+ 1790·430	+ 1790·356	− 0·074
Cut on railway platform	b/73	112·31	+ 1796·951	+ 1796·845	− 0·106
Cut on bridge parapet	75	112·87	+ 1785·505	+ 1785·410	− 0·095
Do.	77	115·29	+ 1812·523	+ 1812·458	− 0·065
Do.	a/78	116·99	+ 1805·344	+ 1805·266	− 0·078
Do.	b/78	118·39	+ 1769·882	+ 1769·797	− 0·085
Do.	79	119·65	+ 1761·646	+ 1761·584	− 0·062
Embedded at Kedgaon	80	119·98	+ 1751·619	+ 1751·532	− 0·087

* This bench-mark, cut on bridge, appears to have been raised by Railway Engineers, since it was first erected in 1877.

Line No. 25. Kedgaon to Diksal.

Bench-marks of the original levelling that were connected during the revisionary operations — Description	Number	Distance from Kedgaon	Observed height above (+) or below (−) Kedgaon as determined in 1878-79	1906-07	Difference in height (Revised − Original). The + sign denotes that the height was *greater*, and the − sign *less* in 1906-07 than it was in 1878-79
		miles	*feet*	*feet*	*feet*
Embedded at Kedgaon	1	0·00	0·000	0·000	0·000
Cut on parapet of bridge ...	2	0·65	− 11·636	− 11·601	+ 0·035
Cut on bridge	3	2·01	− 36·427	− 36·358	+ 0·069
Embedded at Patas	a/3	6·36	− 43·253	− 43·364	− 0·111
Cut on bridge parapet	c/3	7·39	− 60·886	− 59·127	+ 1·759*
Embedded at Dhond	8	12·96	− 89·842	− 90·339	− 0·497†
Cut on platform	9	13·56	− 83·593	− 83·666	− 0·073
Embedded at Boribyal	a/12	19·85	− 54·955	− 54·999	− 0·044
Cut on bridge parapet	14	21·65	− 64·637	− 64·721	− 0·084
Do.	a/14	22·74	− 65·351	− 65·442	− 0·091
Cut on bridge parapet	17	26·74	− 67·695	− 67·779	− 0·084
Cut on bridge parapet	a/18	28·63	− 98·314	− 98·413	− 0·099
Do.	19	29·81	− 110·272	− 110·352	− 0·080
Embedded at Diksal	20	30·64	− 118·183	− 118·267	− 0·084

* This bench-mark has been raised, since it was originally erected.
† The embedded bench-mark at Dhond appears to have sunk half a foot, since it was first erected.

Line No. 26. Diksal to Gulbarga.

Bench-marks of the original levelling that were connected during the revisionary operations: Description	Number	Distance from Diksal	Observed height above (+) or below (−) Diksal as determined in: 1878-80	1906-07	Difference in height (Revised − Original). The + sign denotes that the height was *greater*, and the − sign *less* in 1906-07 than it was in 1878-80
		miles	*feet*	*feet*	*feet*
Embedded at Diksal	1	0·00	0·000	0·000	0·000
Cut on bridge parapet	a/1	2·25	− 23·031	− 23·065	− 0·034
Cut on bridge coping	3	4·16	− 24·056	− 23·585	+ 0·471*
Embedded at Katraj	a/3	4·95	− 17·714	− 18·031	− 0·317†
Cut on bridge parapet	5	7·27	+ 0·029	+ 0·882	+ 0·853*
Do. ...	6	7·64	− 8·592	− 8·643	− 0·051
Embedded at Pomalvadi	8	11·51	− 31·455	− 31·579	− 0·124
Cut on bridge parapet	9	12·39	− 42·744	− 41·149	+ 1·595*
Cut on bridge abutment ...	a/9	13·55	− 34·333	− 33·870	+ 0·463*
Cut on bridge parapet	b/10	17·74	− 55·711	− 55·192	+ 0·519*
Embedded at Washimbe	11	18·87	− 52·919	− 52·969	− 0·050
Cut on bridge parapet	12	19·02	− 54·408	− 53·230	+ 1·178*
Do.	13	19·62	− 58·982	− 57·341	+ 1·641*
Do.	15	21·74	− 4·775	− 3·332	+ 1·443*
Cut on bridge abutment	a/16	24·38	+ 88·038	+ 88·020	− 0·018
Embedded at Pophlaj	18	25·09	+ 111·112	+ 111·060	− 0·052
Cut on bridge parapet	19	28·85	+ 60·884	+ 60·832	− 0·052
Embedded at Jeur	a/19	29·25	+ 50·337	+ 50·281	− 0·056
Cut on bridge parapet	21	29·94	+ 41·047	+ 40·980	− 0·067
Do.	24	33·71	+ 38·106	+ 39·519	+ 1·413*
Do.	25	35·94	+ 95·601	+ 96·965	+ 1·364*
Embedded at Kem	a/25	39·10	+ 124·190	+ 124·050	− 0·140
Cut on railway platform	26	39·20	+ 125·632	+ 125·573	− 0·059
Cut on bridge parapet	34	47·62	+ 53·266	+ 55·237	+ 1·971*
Do.	a/34	50·10	+ 25·962	+ 26·545	+ 0·583*
Embedded at Barsi Road	a/36	50·53	+ 19·834	+ 19·559	− 0·275
Cut on bridge parapet	38	51·85	+ 2·340	+ 3·569	+ 1·229*
Do.	a/38	52·38	− 7·099	− 6·066	+ 1·033*
Do.	39	53·52	− 29·233	− 29·478	− 0·245
Do.	a/40	55·53	− 46·759	− 46·452	+ 0·307*
Do.	b/40	56·71	− 62·040	− 60·758	+ 1·282*
Do.	41	57·62	− 67·506	− 67·778	− 0·272
Cut on culvert	a/41	59·70	− 90·331	− 90·694	− 0·363
Embedded at Madha	d/41	60·41	− 89·980	− 90·567	− 0·587
Cut on culvert	e/41	61·35	− 87·927	− 88·276	− 0·349
Cut on bridge parapet	f/41	63·38	− 128·998	− 127·457	+ 1·541*
Do.	g/41	65·00	− 127·207	− 126·528	+ 0·679*
Do.	h/41	65·80	− 134·941	− 135·127	− 0·186

* These bench-marks have been raised, since they were originally erected.
† The embedded bench-mark at Katraj appears to have sunk, since it was first erected.

Line No. 26. Diksal to Gulbarga.—(Continued).

Bench-marks of the original levelling that were connected during the revisionary operations — Description	Number	Distance from Diksal	Observed height above (+) or below (−) Diksal as determined in 1878-80	1906-07	Difference in height (Revised − Original). The + sign denotes that the height was *greater*, and the − sign *less* in 1906-07 than it was in 1878-78
		miles	*feet*	*feet*	*feet*
Cut on culvert	i/41	66·35	− 125·603	− 125·929	− 0·326
Cut on bridge parapet	j/41	66·79	− 125·774	− 126·085	− 0·311
Cut on culvert	k/41	67·21	− 127·613	− 127·914	− 0·301
Cut on bridge parapet	l/41	67·60	− 146·483	− 144·805	+ 1·678*
Embedded at Angar	42	68·88	− 129·686	− 130·063	− 0·377
Cut on bridge parapet	43	69·89	− 147·298	− 144·948	+ 2·350*
Cut on culvert	a/43	73·48	− 146·196	− 146·624	− 0·428
Do.	b/43	75·70	− 156·266	− 156·671	− 0·405
Cut on bridge parapet	c/43	76·33	− 166·513	− 164·707	+ 1·806*
Do.	d/43	77·00	− 152·204	− 151·141	+ 1·063*
Cut on culvert	44	78·08	− 174·971	− 175·575	− 0·604
Embedded at Mohol	a/44	79·13	− 170·168	− 170·658	− 0·490
Cut on platform coping	b/44	79·21	− 168·873	− 166·995	+ 1·878*
Cut on bridge parapet	e/44	80·80	− 165·692	− 166·203	− 0·511
Cut on culvert	f/44	80·98	− 171·487	− 171·783	− 0·296
Cut on bridge parapet	g/44	82·18	− 185·749	− 186·306	− 0·557
Do.	h/44	82·53	− 185·220	− 185·759	− 0·539
Do.	j/44	83·52	− 172·781	− 173·340	− 0·559
Cut on culvert	k/44	84·76	− 178·720	− 179·311	− 0·591
Cut on bridge parapet	m/44	86·54	− 180·395	− 179·299	+ 1·096*
Do.	n/44	87·24	− 186·648	− 186·155	+ 0·493*
Do.	45	88·39	− 198·017	− 198·536	− 0·519
Do.	46	89·55	− 191·728	− 191·639	+ 0·089
Embedded at Pakni	a/46	89·91	− 190·873	− 191·434	− 0·561
Cut on bridge parapet	47	90·31	− 199·903	− 198·602	+ 1·301*
Do.	a/47	91·46	− 173·774	− 173·999	− 0·225
Do.	48	92·76	− 142·524	− 143·120	− 0·596
Do.	49	94·24	− 142·029	− 142·635	− 0·606
Cut on culvert	50	95·15	− 172·111	− 172·731	− 0·620
Cut on bridge abutment	a/51	98·63	− 205·820	− 206·448	− 0·628
Cut on bridge parapet	52	98·64	− 188·655	− 189·307	− 0·652
Cut on bridge abutment	53	99·33	− 176·050	− 176·684	− 0·634
Embedded at Sholapur	54	99·91	− 165·355	− 165·981	− 0·626
Cut on bridge parapet	55	100·17	− 161·763	− 162·385	− 0·622
Cut on church step	56	101·10	− 108·298	− 108·890	− 0·592

* These bench-marks have been raised, since they were originally erected.

Line No. 26. Diksal to Gulbarga.—(Continued).

Bench-marks of the original levelling that were connected during the revisionary operations — Description	Number	Distance from Diksal	Observed height above (+) or below (−) Diksal as determined in 1878-80	1906-07	Difference in height (Revised − Original). The + sign denotes that the height was *greater*, and the − sign *less* in 1906-07 than it was in 1878-80
		miles	*feet*	*feet*	*feet*
Cut on bridge parapet	57	101·28	− 127·337	− 127·953	− 0·616
Do.	a/57	101·78	− 114·362	− 114·950	− 0·588
Do.	59	103·07	− 92·677	− 93·230	− 0·553
Do.	60	103·85	− 118·465	− 119·049	− 0·584
Do.	62	105·08	− 127·193	− 127·790	− 0·597
Do.	63	106·70	− 193·394	− 193·352	+ 0·042*
Cut on culvert	64	107·39	− 175·016	− 175·706	− 0·690
Cut on bridge parapet	65	107·83	− 178·954	− 180·833	− 1·879†
Do.	67	108·37	− 164·871	− 165·560	− 0·689
Embedded at Hotgi	68	109·53	− 128·148	− 128·832	− 0·684
Cut on bridge parapet	a/70	110·31	− 115·534	− 116·161	− 0·627
Do.	71	111·83	− 154·026	− 154·681	− 0·655
Do.	a/71	112·45	− 172·302	− 171·275	+ 1·027*
Do.	b/71	113·66	− 151·555	− 152·200	− 0·645
Do.	a/73	116·48	− 212·331	− 212·997	− 0·666
Do.	b/73	121·73	− 181·273	− 181·869	− 0·596
Embedded at Kadabgaon	74	122·24	− 182·302	− 182·904	− 0·602
Cut on railway platform	75	122·29	− 177·233	− 177·823	− 0·590
Cut on step	78	130·96	− 139·286	− 140·170	− 0·884
Cut on bridge parapet	a/78	132·28	− 181·917	− 182·603	− 0·686
Do.	79	134·66	− 255·604	− 256·458	− 0·854
Do.	80	136·42	− 220·617	− 221·372	− 0·755
Do.	81	139·17	− 183·611	− 184·321	− 0·710
Cut on railway platform	b/81	139·56	− 177·696	− 178·127	− 0·431
Embedded at Dudhni	82	139·58	− 180·461	− 181·327	− 0·866
Cut on bridge parapet	83	139·88	− 169·360	− 170·096	− 0·736
Do.	84	140·67	− 127·597	− 128·274	− 0·677
Do.	85	141·40	− 96·143	− 96·805	− 0·662
Do.	a/89	151·95	− 280·058	− 279·817	+ 0·241*
Embedded at Ghangapur	90	153·91	− 219·123	− 219·890	− 0·767
Cut on bridge parapet	91	155·34	− 208·249	− 209·464	− 1·215†
Do.	92	156·51	− 148·763	− 148·247	+ 0·516*
Do.	93	157·85	− 89·491	− 90·467	− 0·976
Do.	a/93	160·21	− 154·292	− 155·125	− 0·833
Do.	94	162·97	− 160·204	− 161·040	− 0·836
Do.	95	164·65	− 100·208	− 100·937	− 0·729
Do.	a/95	165·91	− 124·686	− 125·436	− 0·750
Do.	b/95	167·78	− 180·902	− 182·131	− 1·229†
Do.	c/95	169·42	− 168·270	− 169·001	− 0·731
Cut on Gulbarga railway platform ...	96	170·41	− 167·782	− 168·520	− 0·738

* These bench-marks have been raised, since they were originally erected.
† These bench-marks appear to have been lowered since they were originally erected.

Line No. 22. Gulbarga to Raichur.

Bench-marks of the original levelling that were connected during the revisionary operations: Description	Number	Distance from Gulbarga	Observed height above (+) or below (−) Gulbarga as determined in: 1877-78	1906-07	Difference in height (Revised − Original). The + sign denotes that the height was *greater*, and the − sign *less* in 1906-07 than it was in 1877-78
		miles	*feet*	*feet*	*feet*
Embedded at Gulbarga	1	0·00	0·000	0·000	0·000
Cut on bridge parapet	3	0·65	− 12·867	− 12·877	− 0·010
Do.	4	2·34	− 27·760	− 27·797	− 0·037
Do.	5	4·17	+ 38·134	+ 38·109	− 0·025
Do.	6	6·33	− 3·180	− 3·275	− 0·095
Cut on bridge abutment	7	8·47	− 67·849	− 68·091	− 0·242
Cut on culvert	$\frac{a}{7}$	9·02	− 91·732	− 91·983	− 0·251
Cut on bridge parapet	8	9·57	− 104·140	− 104·405	− 0·265
Do.	9	11·07	− 122·747	− 122·999	− 0·252
Do.	10	12·22	− 146·214	− 146·461	− 0·247
Do.	$\frac{a}{10}$	13·58	− 169·534	− 169·796	− 0·262
Do.	$\frac{b}{10}$	15·98	− 196·169	− 196·450	− 0·281
Embedded at Shahabad	12	16·59	− 180·548	− 180·868	− 0·320
Cut on railway platform	$\frac{a}{12}$	16·59	− 180·324	− 180·632	− 0·308
Mile-stone	13	17·23	− 187·974	− 186·505	+ 1·469*
Cut on bridge parapet	$\frac{a}{13}$	17·98	− 197·301	− 197·673	− 0·372
Do.	14	20·57	− 189·951	− 189·140	+ 0·811*
Embedded at Wadi	$\frac{a}{14}$	22·91	− 89·010	− 89·573	− 0·563
Cut on railway platform	15	22·96	− 84·060	− 84·234	− 0·174
Cut on culvert	17	24·46	− 113·713	− 114·092	− 0·379
Cut on bridge parapet	18	27·37	− 182·923	− 183·327	− 0·404
Mile-stone	19	28·28	− 147·203	− 147·994	− 0·791
Cut on bridge abutment	20	28·84	− 137·483	− 137·843	− 0·360
Cut on bridge parapet	21	29·89	− 163·527	− 163·933	− 0·406
Cut on railway platform	$\frac{a}{21}$	31·45	− 164·444	− 164·865	− 0·421
Embedded at Nalvar	23	31·43	− 167·811	− 168·306	− 0·495
Cut on bridge parapet	$\frac{a}{23}$	33·08	− 160·555	− 160·957	− 0·402
Do.	$\frac{b}{23}$	35·42	− 147·150	− 147·590	− 0·440
Do.	24	37·41	− 190·708	− 191·163	− 0·455
Do.	25	39·14	− 235·184	− 235·724	− 0·540
Do.	26	42·45	− 242·582	− 243·167	− 0·585
Do.	27	43·79	− 255·158	− 255·756	− 0·598
Do.	28	45·92	− 293·843	− 294·519	− 0·676
Cut on bridge pier	29	46·07	− 298·363	− 299·054	− 0·691
Embedded at Yadgiri	30	47·06	− 293·799	− 294·455	− 0·656
Cut on railway platform	$\frac{a}{31}$	47·16	− 290·536	− 290·893	− 0·357
Cut on bridge parapet	$\frac{a}{32}$	47·78	− 291·025	− 291·722	− 0·697
Cut on bridge abutment	$\frac{b}{32}$	49·18	− 291·819	− 292·527	− 0·708
Cut on bridge parapet	$\frac{c}{32}$	50·56	− 293·528	− 294·236	− 0·708
Do.	$\frac{d}{32}$	52·11	− 291·388	− 292·140	− 0·752

* These bench-marks appear to have been raised, since they were originally erected.

Line No. 22. Gulbarga to Raichur.—(Continued).

Bench-marks of the original levelling that were connected during the revisionary operations — Description	Number	Distance from Gulbarga	Observed height above (+) or below (−) Gulbarga as determined in 1877-78	1906-07	Difference in height (Revised − Original). The + sign denotes that the height was *greater*, and the − sign *less* in 1906-07 than it was in 1877-78
		miles	*feet*	*feet*	*feet*
Cut on bridge parapet	33	54·09	− 280·516	− 281·266	− 0·750
Do.	34	55·84	− 283·920	− 284·738	− 0·818
Do.	35	57·55	− 283·362	− 284·175	− 0·813
Do.	$\frac{a}{35}$	58·44	− 264·990	− 264·354	+ 0·636
Do.	36	60·30	− 269·596	− 270·396	− 0·800
Embedded at Saidapur	$\frac{a}{36}$	61·53	− 262·602	− 263·467	− 0·865
Cut on bridge parapet	$\frac{a}{38}$	62·85	− 281·910	− 282·714	− 0·804
Do.	$\frac{b}{38}$	64·88	− 309·598	− 310·560	− 0·962
Do.	39	66·80	− 316·546	− 317·464	− 0·918
Do.	40	68·74	− 278·659	− 279·503	− 0·844
Do.	41	70·88	− 311·830	− 312·725	− 0·895
Cut on railway platform	$\frac{a}{41}$	74·29	− 350·461	− 351·404	− 0·943
Cut on step	$\frac{b}{41}$	74·31	− 352·163	− 353·161	− 0·998
Cut on railway platform	42	74·32	− 350·538	− 351·481	− 0·943
Do.	$\frac{a}{42}$	74·32	− 350·477	− 351·452	− 0·975
Mile-stone	43	74·55	− 349·425	− 350·429	− 1·004
Cut on pillar of viaduct	$\frac{a}{43}$	74·84	− 345·375	− 346·286	− 0·911
Do.	$\frac{b}{43}$	75·46	− 345·364	− 346·299	− 0·935
Cut on bridge parapet	44	76·46	− 356·529	− 357·447	− 0·918
Mile-stone	45	78·55	− 307·086	− 308·438	− 1·352†
Cut on railway platform	$\frac{a}{45}$	79·61	− 315·842	− 316·896	− 1·054
Embedded at Chiksugur	$\frac{b}{45}$	79·64	− 317·503	− 318·925	− 1·422†
Cut on railway platform	46	79·80	− 316·097	− 317·230	− 1·133
Cut on bridge abutment	47	80·85	− 347·292	− 348·326	− 1·034
Cut on bridge parapet	48	83·96	− 267·702	− 268·680	− 0·978
Do.	$\frac{a}{49}$	86·70	− 221·836	− 222·763	− 0·927
Do.	50	88·31	− 201·920	− 202·852	− 0·932
Embedded at Raichur	51	89·86	− 178·348	− 179·450	− 1·102

† These bench-marks appear to have been lowered since they were originally erected.

Line No. 21. Raichur to Gooty.

Bench-marks of the original levelling that were connected during the revisionary operations: Description	Number	Distance from Raichur	Observed height above (+) or below (−) Raichur as determined in 1877-78	1906-07	Difference in height (Revised − Original). The + sign denotes that the height was *greater*, and the − sign *less* in 1906-07 than it was in 1877-78
		miles	*feet*	*feet*	*feet*
Embedded at Raichur	1	0·00	0·000	0·000	0·000
Cut on bridge parapet	4	4·26	− 9·828	− 9·498	+ 0·330
Cut on culvert	5	5·01	− 13·310	− 13·166	+ 0·144
Do.	a/5	6·37	− 45·101	− 44·998	+ 0·103
Do.	6	6·85	− 47·342	− 47·232	+ 0·110
Do.	a/6	9·35	− 70·847	− 70·773	+ 0·074
Cut on bridge parapet	7	11·22	− 84·901	− 84·828	+ 0·073
Do.	a/7	13·47	− 97·442	− 97·417	+ 0·025
Embedded at Matmari	b/7	13·85	− 100·855	− 100·917	− 0·062
Cut on railway platform	c/7	13·85	− 100·414	− 100·385	+ 0·029
Cut on culvert	d/7	15·55	− 154·551	− 154·583	− 0·032
Do.	8	17·66	− 180·621	− 180·669	− 0·048
Cut on railway platform	9	20·81	− 225·887	− 225·948	− 0·061
Cut on bridge parapet	10	21·33	− 228·257	− 228·320	− 0·063
Cut on culvert	11	23·48	− 195·165	− 195·155	+ 0·010
Do.	12	25·13	− 141·986	− 141·462	+ 0·524*
Cut on bridge parapet	a/12	25·63	− 142·702	− 142·660	+ 0·042
Do.	13	26·48	− 129·821	− 129·768	+ 0·053
Cut on culvert	a/13	28·68	− 87·171	− 87·039	+ 0·132
Embedded at Kosgi	14	28·99	− 72·270	− 72·172	+ 0·098
Cut on culvert	15	30·44	− 36·471	− 36·299	+ 0·172
Cut on bridge parapet	16	32·14	− 29·241	− 29·070	+ 0·171
Cut on culvert	17	33·28	− 6·760	− 6·561	+ 0·199
Cut on bridge abutment	18	34·86	− 11·748	− 11·552	+ 0·196
Cut on culvert	a/18	36·28	+ 18·826	+ 19·067	+ 0·241
Do.	20	37·51	+ 37·534	+ 37·784	+ 0·250
Cut on bridge pier	21	37·87	+ 34·891	+ 35·171	+ 0·280
Cut on culvert	b/21	40·10	+ 99·015	+ 99·301	+ 0·286
Do.	c/21	42·01	+ 50·805	+ 51·054	+ 0·249
Do.	d/21	42·47	+ 51·450	+ 51·698	+ 0·248
Cut on paving stone	22	42·67	+ 50·688	+ 51·117	+ 0·429
Cut on bridge parapet	a/22	44·48	+ 49·392	+ 49·659	+ 0·267
Cut on culvert	b/22	46·02	+ 52·392	+ 52·594	+ 0·202
Do.	c/22	46·03	+ 50·866	+ 52·264	+ 1·398*
Do.	23	46·05	+ 52·946	+ 53·168	+ 0·222
Embedded at Adoni	25	46·43	+ 51·921	+ 51·781	− 0·140
Cut on culvert	a/25	47·53	+ 75·111	+ 75·391	+ 0·280
Cut on bridge abutment	26	48·78	+ 57·459	+ 57·727	+ 0·268

* These bench-marks appear to have been raised since they were originally erected.

Line No. 21. Raichur to Gooty.—(Continued).

Bench-marks of the original levelling that were connected during the revisionary operations — Description	Number	Distance from Raichur	Observed height above (+) or below (−) Raichur as determined in 1877-78	1906-07	Difference in height (Revised − Original). The + sign denotes that the height was *greater*, and the − sign *less* in 1906-07 than it was in 1877-78
		miles	*feet*	*feet*	*feet*
Cut on culvert	27	50·29	+ 91·274	+ 91·556	+ 0·282
Cut on bridge parapet	a/27	51·04	+ 66·485	+ 68·188	+ 1·703*
Cut on culvert	28	52·02	+ 90·509	+ 90·778	+ 0·269
Cut on bridge abutment	29	55·16	+ 135·953	+ 136·270	+ 0·317
Do.	30	56·12	+ 159·537	+ 159·872	+ 0·335
Cut on culvert	a/30	56·63	+ 180·524	+ 180·903	+ 0·379
Cut on bridge abutment	32	59·89	+ 173·390	+ 173·766	+ 0·376
Cut on culvert	33	61·14	+ 208·817	+ 209·232	+ 0·415
Cut on bridge abutment ...	a/33	63·24	+ 171·825	+ 172·177	+ 0·352
Cut on mile-stone	b/33	65·25	+ 205·349	+ 205·700	+ 0·351
Cut on bridge abutment	a/34	66·83	+ 203·232	+ 203·604	+ 0·372
Do.	35	69·36	+ 213·184	+ 213·631	+ 0·447
Cut on culvert	36	70·16	+ 233·659	+ 234·145	+ 0·486
Cut on bridge abutment	37	70·97	+ 231·654	+ 232·109	+ 0·455
Cut on railway platform	38	72·76	+ 243·132	+ 243·551	+ 0·419
Embedded at Nancherla	a/38	72·81	+ 242·303	+ 242·471	+ 0·168
Cut on bridge abutment	a/39	75·46	+ 227·417	+ 227·875	+ 0·458
Cut on mile-stone	40	75·74	+ 230·625	+ 230·171	− 0·454
Cut on bridge parapet	42	80·27	+ 108·781	+ 109·160	+ 0·379
Cut on railway platform ...	43	80·59	+ 101·631	+ 101·912	+ 0·281
Embedded at Timmanacherla ...	44	80·67	+ 100·995	+ 101·340	+ 0·345
Cut on bridge parapet	46	82·69	+ 31·495	+ 31·774	+ 0·279
Cut on bridge abutment	47	83·90	+ 4·629	+ 4·910	+ 0·281
Cut on bridge parapet	50	85·38	− 25·066	− 24·785	+ 0·281
Cut on bridge abutment	51	86·30	− 34·480	− 34·226	+ 0·254
Cut on culvert	52	87·51	− 46·891	− 48·042	− 1·151†
Cut on bridge parapet	55	90·89	− 91·185	− 90·938	+ 0·247
Do.	56	92·59	− 72·809	− 72·536	+ 0·273
Cut on railway platform ...	59	96·27	− 105·888	− 105·843	+ 0·045
Embedded at Gooty	60	96·45	− 110·483	− 110·433	+ 0·050

* This bench-mark appears to have been raised since it was originally erected.
† This bench-mark appears to have been lowered since it was originally erected.

Line No. 14. Gooty to Arkonam.

Bench-marks of the original levelling that were connected during the revisionary operations		Distance from Gooty	Observed height above (+) or below (−) Gooty as determined in		Difference in height (Revised − Original). The + sign denotes that the height was *greater*, and the − sign *less* in 1906-07 than it was in 1877-78
Description	Number		1877-78	1906-07	
		miles	*feet*	*feet*	*feet*
Embedded at Gooty	1	0·00	0·00	0·00	0·000
Cut on step	1/1	1·96	− 21·261	− 21·087	+ 0·174
Do.	1a/1	2·06	− 18·711	− 18·618	+ 0·093
Do.	1b/1	2·30	− 7·746	− 7·560	+ 0·186
Cut on embedded stone	2/1	2·80	− 31·851	− 31·665	+ 0·186
Cut on bridge parapet	2	0·83	+ 26·405	+ 26·623	+ 0·218
Cut on bridge abutment	3	2·66	− 5·490	− 5·294	+ 0·196
Do.	4	4·23	− 45·470	− 45·299	+ 0·171
Do.	5	5·34	− 81·460	− 81·294	+ 0·166
Cut on culvert	8	10·03	− 183·297	− 183·200	+ 0·097
Cut on cap of bridge	9	12·89	− 225·298	− 225·200	+ 0·098
Embedded at Rayalcheruvu ...	10	14·49	− 258·635	− 258·573	+ 0·062
Cut on railway platform	11	14·53	− 257·881	− 257·817	+ 0·064
Cut on cap of bridge	12	15·57	− 283·322	− 283·246	+ 0·076
Cut on culvert	15	20·11	− 346·096	− 346·022	+ 0·074
Cut on cap of bridge	18	24·82	− 389·378	− 389·405	− 0·027
Cut on bridge parapet	a/19	26·03	− 400·002	− 400·030	− 0·028
Cut on bridge abutment	21	28·93	− 425·342	− 425·348	− 0·006
Cut on railway platform	a/21	29·53	− 416·129	− 416·090	+ 0·039
Cut on cap of bridge	23	31·81	− 436·497	− 436·543	− 0·046
Do.	a/23	33·27	− 454·846	− 454·837	+ 0·009
Do.	24	35·03	− 461·560	− 461·539	+ 0·021
Do.	26	36·83	− 471·672	− 471·636	+ 0·036
Cut on culvert	27	38·53	− 467·019	− 466·976	+ 0·043
Cut on cap of bridge	28	39·77	− 463·599	− 463·575	+ 0·024
Do.	29	41·17	− 483·268	− 483·229	+ 0·039
Do.	30	42·30	− 491·799	− 491·793	+ 0·006
Cut on bridge parapet	31	44·10	− 499·772	− 499·742	+ 0·030
Embedded at Kondapuram ...	a/32	46·93	− 480·823	− 480·880	− 0·057
Cut on railway platform	33	46·98	− 477·197	− 477·824	− 0·627†
Cut on cap of bridge	34	47·75	− 491·562	− 491·494	+ 0·068
Cut on drain parapet	36	49·43	− 512·569	− 512·516	+ 0·053
Cut on bridge parapet	37	50·72	− 515·771	− 514·269	+ 1·502*
Do.	38	53·19	− 495·353	− 495·262	+ 0·091
Do.	39	53·79	− 481·078	− 480·981	+ 0·097
Do.	40	54·54	− 459·777	− 459·679	+ 0·098
Cut on cap of bridge	a/40	55·99	− 476·307	− 475·767	+ 0·540*
Cut on bridge abutment ...	41	57·37	− 504·834	− 504·745	+ 0·089
Do.	42	58·54	− 526·424	− 526·324	+ 0·100
Do.	44	61·01	− 573·038	− 572·942	+ 0·096

* These bench-marks appear to have been raised since they were originally erected.
† This bench-mark appears to have been lowered since it was originally erected.

Line No. 14. Gooty to Arkonam—(Continued).

Bench-marks of the original levelling that were connected during the revisionary operations — Description	Number	Distance from Gooty	Observed height above (+) or below (−) Gooty as determined in 1877-78	1906-07	Difference in height (Revised − Original). The + sign denotes that the height was *greater*, and the − sign *less* in 1906-07 than it was in 1877-78
		miles	*feet*	*feet*	*feet*
Embedded at Muddanuru... ...	$\frac{a}{44}$	61·67	− 581·844	− 581·973	− 0·129
Cut on railway platform	45	61·67	− 580·674	− 580·636	+ 0·038
Cut on bridge abutment	46	63·16	− 596·123	− 597·403	− 1·280†
Do.	50	69·56	− 648·859	− 648·838	+ 0·021
Do.	51	70·97	− 655·725	− 656·002	− 0·277
Embedded at Yerraguntla ...	$\frac{a}{51}$	71·59	− 655·835	− 655·827	+ 0·008
Cut on drain abutment	52	72·63	− 658·498	− 658·576	− 0·078
Do.	53	73·95	− 683·340	− 683·370	− 0·030
Cut on bridge abutment	54	75·35	− 708·210	− 708·233	− 0·023
Do.	55	77·41	− 725·024	− 725·085	− 0·061
Do.	56	78·42	− 729·676	− 729·710	− 0·034
Cut on bridge parapet	$\frac{a}{57}$	80·38	− 733·080	− 733·150	− 0·070
Embedded at Kamalapuram ...	$\frac{a}{58}$	81·29	− 746·050	− 746·340	− 0·290
Cut on railway platform ...	$\frac{b}{58}$	81·29	− 737·000	− 737·279	− 0·279
Cut on bridge parapet	59	83·23	− 741·845	− 741·920	− 0·075
Cut on bridge abutment	60	84·42	− 748·914	− 749·336	− 0·422†
Cut on culvert	$\frac{a}{60}$	85·27	− 752·538	− 752·570	− 0·032
Cut on bridge abutment	62	86·55	− 756·391	− 756·433	− 0·042
Cut on bridge parapet	63	88·21	− 751·440	− 751·471	− 0·031
Cut on railway platform ...	64	91·30	− 764·303	− 765·101	− 0·798†
Cut on cap of drain	65	92·00	− 769·518	− 769·557	− 0·039
Cut on bridge parapet	66	92·72	− 767·564	− 767·591	− 0·027
Cut on bridge abutment	$\frac{a}{66}$	95·03	− 748·509	− 748·510	− 0·001
Embedded at Cuddapah	67	95·91	− 748·084	− 748·124	− 0·040
Cut on stone	68	96·01	− 741·612	− 741·638	− 0·026
Cut on cap of drain	69	97·70	− 735·980	− 736·041	− 0·061
Do.	70	98·79	− 680·339	− 680·508	− 0·169
Cut on bridge parapet	$\frac{a}{70}$	99·83	− 621·659	− 621·681	− 0·022
Cut on cap of drain	71	101·25	− 538·104	− 538·152	− 0·048
Cut on bridge parapet	$\frac{a}{72}$	102·58	− 579·393	− 579·504	− 0·111
Cut on cap of drain	$\frac{b}{72}$	104·23	− 664·566	− 664·633	− 0·067
Do.	73	107·53	− 751·654	− 751·708	− 0·054
Cut on bridge parapet	74	108·88	− 765·798	− 765·835	− 0·037
Embedded at Vontimitta	75	109·69	− 776·122	− 776·170	− 0·048
Cut on cap of bridge	77	112·18	− 783·355	− 783·397	− 0·042
Cut on culvert	78	114·36	− 730·717	− 730·743	− 0·026
Do.	79	115·66	− 730·199	− 730·240	− 0·041
Cut on bridge parapet	80	119·98	− 738·747	− 728·800	− 0·053
Embedded at Nandalur	$\frac{a}{81}$	120·65	− 726·945	− 727·168	− 0·223
Cut on bridge abutment	83	121·33	− 716·825	− 716·922	− 0·097

† These bench-marks appear to have been lowered since they were originally erected.

Line No. 14. Gooty to Arkonam—(Continued).

Bench-marks of the original levelling that were connected during the revisionary operations: Description	Number	Distance from Gooty	Observed height above (+) or below (−) Gooty as determined in 1877-78	1906-07	Difference in height (Revised − Original). The + sign denotes that the height was *greater*, and the − sign *less* in 1906-07 than it was in 1877-78
		miles	*feet*	*feet*	*foot*
Cut on bridge abutment	84	121·99	− 716·877	− 716·968	− 0·091
Cut on bridge parapet	85	122·79	− 731·502	− 731·606	− 0·104
Cut on cap of bridge	$\frac{a}{86}$	124·76	− 735·640	− 735·745	− 0·105
Cut on bridge parapet	87	125·86	− 754·370	− 754·483	− 0·113
Do.	89	128·89	− 731·933	− 732·070	− 0·137
Cut on bridge abutment	90	131·60	− 699·051	− 699·192	− 0·141
Cut on bridge parapet	91	133·68	− 673·859	− 674·014	− 0·155
Embedded at Reddipalle	$\frac{a}{92}$	135·64	− 643·237	− 643·721	− 0·484
Cut on railway platform	93	135·69	− 637·947	− 638·845	− 0·898†
Cut on bridge parapet	94	136·63	− 620·115	− 620·295	− 0·180
Do.	95	138·08	− 611·349	− 611·522	− 0·173
Do.	97	141·80	− 559·702	− 559·887	− 0·185
Cut on cap of bridge	102	145·82	− 585·534	− 585·718	− 0·184
Cut on bridge parapet	103	147·65	− 569·772	− 569·951	− 0·179
Embedded at Koduru	104	148·34	− 560·027	− 560·218	− 0·191
Cut on bridge parapet	106	149·06	− 564·499	− 564·686	− 0·187
Do.	108	151·69	− 529·712	− 529·916	− 0·204
Cut on bridge abutment	109	153·27	− 511·545	− 511·771	− 0·226
Cut on bridge parapet	111	155·13	− 482·707	− 482·895	− 0·188
Cut on bridge abutment	$\frac{a}{111}$	155·94	− 460·573	− 460·756	− 0·183
Do.	113	161·84	− 539·696	− 539·876	− 0·180
Cut on cap of bridge	114	163·63	− 599·066	− 599·284	− 0·218
Embedded at Mamanduru ...	$\frac{a}{114}$	165·10	− 630·644	− 630·825	− 0·181
Cut on bridge parapet	115	166·31	− 643·172	− 643·383	− 0·211
Cut on bridge abutment	$\frac{a}{116}$	168·58	− 715·468	− 715·630	− 0·162
Cut on bridge parapet	117	170·19	− 766·871	− 767·026	− 0·155
Do.	$\frac{a}{118}$	172·94	− 840·014	− 840·174	− 0·060
Do.	119	173·22	− 840·226	− 840·395	− 0·169
Embedded at Renigunta	$\frac{a}{119}$	173·99	− 834·000	− 834·234	− 0·234
Cut on bridge parapet	120	174·17	− 829·992	− 830·157	− 0·165
Do.	$\frac{a}{120}$	175·93	− 804·800	− 804·967	− 0·167
Do.	121	177·37	− 798·860	− 799·033	− 0·173
Do.	122	179·17	− 782·880	− 783·048	− 0·168
Do.	123	180·07	− 769·580	− 769·753	− 0·173
Do.	125	181·80	− 696·215	− 696·363	− 0·148
Do.	127	184·93	− 639·956	− 640·100	− 0·144
Do.	129	186·86	− 701·180	− 701·329	− 0·149
Do.	$\frac{a}{129}$	187·89	− 724·375	− 724·506	− 0·131
Embedded at Puttur	130	188·38	− 707·811	− 707·922	− 0·111
Cut on bridge parapet	131	189·49	− 722·490	− 722·632	− 0·142
Cut on drain parapet	132	192·72	− 731·812	− 731·983	− 0·171
Cut on bridge parapet	$\frac{a}{134}$	195·43	− 767·222	− 767·409	− 0·187
Do.	136	197·89	− 804·648	− 804·882	− 0·234

† This bench-mark appears to have been lowered since it was originally erected.

Line No. 14. Gooty to Arkonam.—(Continued).

Bench-marks of the original levelling that were connected during the revisionary operations		Distance from Gooty	Observed height above (+) or below (−) Gooty as determined in		Difference in height (Revised − Original). The + sign denotes that the height was *greater*, and the − sign *less* in 1906-07 than it was in 1877-78
Description	Number		1877-78	1906-07	
		miles	*feet*	*feet*	*foot*
Cut on railway platform	$\frac{a}{136}$	198·13	− 801·593	− 801·840	− 0·247
Embedded at Nagari	137	198·14	− 805·810	− 806·038	− 0·228
Cut on bridge parapet	$\frac{a}{138}$	200·25	− 774·019	− 774·217	− 0·198
Cut on bridge abutment	$\frac{a}{139}$	205·78	− 912·626	− 912·790	− 0·164
Cut on bridge parapet	140	206·48	− 918·046	− 918·200	− 0·154
Embedded at Tiruttani	141	207·29	− 918·105	− 918·259	− 0·154
Cut on railway platform	142	207·33	− 916·045	− 916·434	− 0·389†
Cut on bridge parapet	$\frac{a}{142}$	208·71	− 921·417	− 921·570	− 0·153
Cut on bridge abutment	144	211·84	− 935·191	− 935·150	+ 0·041
Cut on railway platform	147	215·33	− 902·757	− 903·203	− 0·446†
Embedded at Arkonam	148	215·38	− 905·731	− 905·890	− 0·159

† These bench-marks appear to have been lowered since they were originally erected.

Line No. 8. Arkonam to Madras.

Bench-marks of the original levelling that were connected during the revisionary operations — Description	Number	Distance from Arkonam	Observed height above (+) or below (−) Arkonam as determined in 1880-81 (1)	1884-85 (2)	1907-08 (3)	Difference in height (Revised − Original). The + sign denotes that the height was *greater*, and the − sign *less* in 1907-08 than it was in 1880-81 and 1884-85 (2) − (1)	(3) − (1)	(3) − (2)
		miles	*feet*	*feet*	*feet*	*foot*	*foot*	*foot*
Embedded at Arkonam	1	0·00	0·000	0·000	0·000	0·000	0·000	0·000
Cut on cap of bridge	a/1	3·25	− 54·466	− 54·420	− 54·454	+ 0·046	+ 0·012	− 0·034
Cut on bridge parapet	b/1	4·29	− 74·457	− 74·407	− 74·433	+ 0·050	+ 0·024	− 0·026
Do.	2	5·06	− 87·738	...	− 87·727	...	+ 0·011	...
Cut on railway platform	3	6·54	− 94·321	− 94·264	− 94·292	+ 0·057	+ 0·029	− 0·028
Cut on bridge parapet	4	7·89	− 103·360	− 103·265	− 103·365	+ 0·095	− 0·005	− 0·100
Cut on bridge abutment	5	9·20	− 104·135	...	− 104·122	...	+ 0·013	...
Cut on bridge parapet	8	15·02	− 129·235	− 129·172	− 129·285	+ 0·063	− 0·050	− 0·113
Embedded at Tiruvallur	10	16·74	− 141·235	− 141·155	− 141·299	+ 0·080	− 0·064	− 0·144
Cut on bridge abutment	a/11	19·60	− 154·513	− 154·424	− 154·573	+ 0·089	− 0·060	− 0·149
Do.	12	20·08	− 159·612	− 159·540	− 160·492	+ 0·072	− 0·880†	− 0·952†
Cut on cap of bridge	15	24·21	− 173·507	− 173·393	− 173·556	+ 0·114	− 0·049	− 0·163
Cut on bridge abutment	17	26·50	− 191·723	− 191·619	− 191·790	+ 0·104	− 0·067	− 0·171
Embedded at Avadi	19	29·72	− 213·207	...	− 213·333	...	− 0·126	...
Cut on cap of bridge	21	33·99	− 244·343	− 244·297	− 245·023	+ 0·046	− 0·680†	− 0·726†
Embedded at verandah of Sembian Police Station.	1/24	40·86	...	− 273·279	− 273·560	...	...	− 0·281
Embedded at Perambur	1a/24	42·78	...	− 282·292	− 282·533	...	...	− 0·241
Cut on step	28	44·05	− 278·417	− 278·432	− 278·521	− 0·015	− 0·104	− 0·089
Cut on memorial stone at Madras ...	29	44·09	− 277·325	...	− 277·439	...	− 0·114	...

† These bench-marks appear to have been lowered since they were originally erected.

Line No. 17. Karwar to Hubli.

Bench-marks of the original levelling that were connected during the revisionary operations		Distance from Karwar	Observed height above (+) or below (−) Karwar as determined in		Difference in height (Revised − Original). The + sign denotes that the height was *greater*, and the − sign *less* in 1907-08 than it was in 1873-74
Description	Number		1873-74	1907-08	
		miles	*feet*	*feet*	*foot*
Embedded at Karwar	1	0·00	0·000	0·000	0·000
Cut on rock	a/1	0·14	− 1·105	− 1·156	− 0·051
Cut on mile-stone	2	0·89	+ 85·180	+ 85·152	− 0·028
Cut on rock	a/2	1·25	− 0·721	− 0·780	− 0·059
Cut on mile-stone	3	1·90	+ 3·175	+ 3·521	+ 0·346*
Cut on boulder	a/3	2·24	+ 21·546	+ 21·524	− 0·022
Cut on rock	4	3·24	+ 137·641	+ 137·538	− 0·103
Do.	a/4	6·80	− 0·318	− 0·365	− 0·047
Do.	5	10·63	+ 2·593	+ 2·575	− 0·018
Do.	a/5	12·34	+ 2·800	+ 2·790	− 0·010
Cut on bridge pier	c/5	15·08	+ 4·741	+ 4·724	− 0·017
Cut on bridge wing wall	g/5	23·55	+ 99·538	+ 99·562	+ 0·024
Cut on bridge abutment	h/5	24·53	+ 58·688	+ 58·503	− 0·185
Cut on rock	i/5	24·81	+ 55·135	+ 55·176	+ 0·041
Cut on bridge abutment	6	27·56	+ 30·788	+ 30·275	− 0·513†
Cut on bridge parapet	7	29·41	+ 80·158	+ 80·058	− 0·100
Cut on culvert	9	31·74	+ 67·675	+ 67·671	− 0·004
Cut on rock	b/11	37·94	+ 97·613	+ 97·713	+ 0·100
Cut on bridge return-wall ...	c/11	38·14	+ 101·487	+ 101·377	− 0·110
Cut on rock	d/11	38·33	+ 87·403	+ 87·507	+ 0·104
Cut on bridge abutment	b/12	42·01	+ 150·800	+ 150·811	+ 0·011
Do.	13	44·04	+ 167·906	+ 167·922	+ 0·016
Cut on bridge parapet	a/13	46·70	+ 168·578	+ 168·588	+ 0·010
Cut on culvert	19	59·88	+ 1776·398	+ 1777·079	+ 0·681
Embedded at Hubli	28	102·74	+ 2048·200	+ 2048·893	+ 0·693

* This bench-mark appears to have been raised since it was originally erected.
† This bench-mark appears to have been lowered since it was originally erected.

Line No. 16. Hubli to Bellary.

Bench-marks of the original levelling that were connected during the revisionary operations — Description	Number	Distance from Hubli	Observed height above (+) or below (−) Hubli as determined in 1873-74	1907-08	Difference in height (Revised − Original). The + sign denotes that the height was *greater*, and the − sign *less* in 1907-08 than it was in 1873-74
		miles	*feet*	*feet*	*feet*
Embedded at Hubli	1	0·00	0·000	0·000	0·000
Cut on bridge capstone	f/5	24·38	− 35·088	− 36·001	− 0·913
Cut on pillar	g/6	25·01	− 5·235	− 6·342	− 1·107
Cut on rock	i/5	31·28	+ 164·250	+ 163·436	− 0·814
Cut on bridge parapet	j/5	32·78	+ 123·425	+ 122·584	− 0·841
Do.	6	33·45	+ 112·101	+ 111·266	− 0·835
Cut on stone pillar	8	40·03	+ 228·342	+ 227·552	− 0·790†
Cut on culvert parapet	9	40·84	+ 178·707	+ 177·774	− 0·933
Do.	b/9	43·65	+ 7·133	+ 6·208	− 0·925
Cut on bridge parapet	10	44·61	− 28·213	− 29·086	− 0·873
Cut on culvert parapet	a/10	45·98	− 71·386	− 72·346	− 0·960
Cut on stone pillar	d/10	53·85	− 250·467	− 251·376	− 0·909
Cut on boundary stone	e/10	54·11	− 257·428	− 258·357	− 0·929
Cut on rock	a/11	59·30	− 339·694	− 340·648	− 0·954
Cut on boundary stone	b/11	60·96	− 349·191	− 350·173	− 0·982
Do.	c/11	63·26	− 418·745	− 419·754	− 1·009
Cut on boulder	f/11	66·30	− 389·327	− 390·317	− 0·990
Cut at base of mile-stone	12	67·66	− 423·085	− 424·622	− 1·537†
Do.	13	69·67	− 430·277	− 430·939	− 0·662†
Cut on boulder	14	70·49	− 437·806	− 438·801	− 0·995
Cut on stone pavement	15	72·12	− 428·518	− 429·487	− 0·969
Cut on stone built in masonry pillar	16	76·76	− 411·170	− 412·113	− 0·943
Cut on mile-stone	17	79·71	− 411·928	− 412·746	− 0·818
Cut on rock	a/17	80·51	− 420·905	− 421·855	− 0·950
Cut on mile-stone	18	81·71	− 419·624	− 420·654	− 1·030
Cut on culvert parapet	a/19	85·79	− 457·812	− 458·880	− 1·068
Cut on mile-stone	20	86·75	− 457·549	− 456·357	+ 1·192*
Cut on rock	a/20	89·60	− 473·363	− 474·393	− 1·030
Cut on mile-stone	21	89·75	− 463·873	− 464·870	− 0·997
Cut on boulder	a/21	90·94	− 451·976	− 452·950	− 0·974
Do.	b/21	92·05	− 455·344	− 456·305	− 0·961
Cut on mile-stone	22	92·74	− 454·936	− 455·841	− 0·905
Do.	25	96·80	− 452·813	− 454·034	− 1·221†
Do.	28	99·60	− 464·211	− 465·364	− 1·153
Cut on culvert parapet	a/28	102·16	− 339·755	− 340·808	− 1·053
Cut at base of mile-stone	29	102·60	− 323·982	− 322·141	+ 1·841*

* These bench-marks appear to have been raised since they were originally erected.
† These bench-marks appear to have been lowered since they were originally erected.

Line No. 16. Hubli to Bellary.—(Continued).

Bench-marks of the original levelling that were connected during the revisionary operations — Description	Number	Distance from Hubli	Observed height above (+) or below (−) Hubli as determined in 1873-74	1907-08	Difference in height (Revised − Original). The + sign denotes that the height was *greater*, and the − sign *less* in 1907-08 than it was in 1873-74
		miles	*feet*	*feet*	*feet*
Cut on drain abutment	30	105·52	− 238·360	− 239·349	− 0·989
Cut on mile-stone	31	105·87	− 232·145	− 232·940	− 0·795†
Cut on culvert parapet	$\frac{a}{31}$	108·61	− 331·145	− 332·184	− 1·039
Cut at base of mile-stone	32	109·87	− 379·537	− 380·728	− 1·191†
Do.	33	110·88	− 393·343	− 393·887	− 0·544†
Cut on mile-stone	34	111·89	− 430·024	− 431·048	− 1·024
Do.	35	112·90	− 457·195	− 457·924	− 0·729
Do.	36	113·90	− 485·439	− 486·767	− 1·328†
Cut at base of mile-stone	38	116·91	− 522·734	− 523·669	− 0·935
Cut on guard-stone	39	117·17	− 516·797	− 518·022	− 1·225†
Cut at base of mile-stone	40	117·91	− 518·174	− 519·143	− 0·969
Cut on rock	41	118·97	− 518·683	− 519·843	− 1·160
Cut on mile-stone	42	120·93	− 497·377	− 498·501	− 1·124
Cut on rock	$\frac{a}{42}$	123·16	− 469·495	− 470·535	− 1·040
Cut on mile-stone	43	124·96	− 483·958	− 485·162	− 1·204†
Cut on stone	44	125·16	− 482·031	− 483·072	− 1·041
Cut on rock	45	125·96	− 468·413	− 469·457	− 1·044
Do.	46	126·40	− 467·623	− 468·665	− 1·042
Cut on stone	$\frac{a}{46}$	126·99	− 479·393	− 480·478	− 1·085
Cut at base of mile-stone	48	128·99	− 483·196	− 484·654	− 1·458†
Cut on furlong-stone	49	130·39	− 498·407	− 499·995	− 1·588†
Cut at base of mile-stone	50	131·02	− 503·960	− 505·155	− 1·195
Cut on culvert parapet	$\frac{a}{50}$	132·95	− 514·697	− 515·827	− 1·130
Cut on stone	$\frac{b}{50}$	133·14	− 524·760	− 525·886	− 1·126
Do.	51	133·56	− 530·379	− 531·399	− 1·020
Cut on drain at Bellary	54	137·25	− 577·747	− 578·890	− 1·143

† These bench-marks appear to have been lowered, since they were originally erected.

Portion of Line Burma A: Pyinmana to Mandalay*.

Bench-marks of the original levelling that were connected during the revisionary operations: Description	Number	Distance from Pyinmana	Observed height above (+) or below (−) Pyinmana as determined in 1892-93	1903-04	Difference in height (Revised − Original). The + sign denotes that the height was *greater*, and the − sign *less* in 1903-04 than it was in 1892-93. On the assumption that Pyinmana bench-mark has remained unchanged	Mandalay bench-mark has remained unchanged
		miles	*feet*	*feet*	*foot*	*foot*
Embedded at Pyinmana Railway Stn.	a/243	0·00	0·000	+ 0·000	0·000	− 0·376
Cut on platform coping of Railway Stn.	243	0·04	+ 0·345	+ 0·429	+ 0·084	− 0·292
Cut on girder bridge	244	0·46	+ 4·694	+ 4·791	+ 0·097	− 0·279
Cut on drain coping	a/244	0·97	+ 19·332	+ 19·443	+ 0·111	− 0·265
G. T. S. Intersected Point, Pyinmana ...	1/244	1·25	+ 107·141	+ 107·271	+ 0·130	− 0·246
Cut on culvert parapet	245	2·97	− 9·132	− 9·044	+ 0·088	− 0·288
Do.	246	4·46	− 10·109	− 10·005	+ 0·104	− 0·272
Cut on girder bridge	247	5·89	− 0·185	− 0·102	+ 0·083	− 0·293
Do.	248	7·22	+ 29·008	+ 29·136	+ 0·128	− 0·248
Cut on culvert parapet	249	8·88	+ 64·986	+ 65·120	+ 0·134	− 0·242
Cut on railway platform coping ...	250	10·17	+ 77·731	+ 77·852	+ 0·121	− 0·255
Embedded at Kyidaunggan Railway Stn.	a/250	10·29	+ 77·587	+ 77·718	+ 0·131	− 0·245
Cut on girder bridge	251	10·49	+ 76·171	+ 76·336	+ 0·165	− 0·211
Cut on bridge	252	11·71	+ 67·142	+ 67·284	+ 0·142	− 0·234
Cut on girder bridge	253	12·77	+ 70·121	+ 70·255	+ 0·134	− 0·242
Do.	254	13·46	+ 77·462	+ 77·636	+ 0·174	− 0·202
Cut on culvert parapet	255	15·22	+ 72·594	+ 72·798	+ 0·204	− 0·172
Cut on girder bridge	256	16·52	+ 89·074	+ 89·269	+ 0·195	− 0·181
Do.	a/256	17·93	+ 95·406	+ 95·613	+ 0·207	− 0·169
Cut on culvert parapet	257	19·28	+ 92·072	+ 92·248	+ 0·176	− 0·200
Cut on girder bridge	a/257	20·20	+ 103·930	+ 104·093	+ 0·163	− 0·213
Cut on culvert parapet	258	21·24	+ 103·688	+ 103·849	+ 0·161	− 0·215
Embedded at Shwemyo Railway Stn....	259	21·75	+ 114·657	+ 114·691	+ 0·034	− 0·342
Cut on culvert parapet	260	22·58	+ 121·597	+ 121·766	+ 0·169	− 0·207
Cut on girder bridge	261	24·04	+ 136·810	+ 136·989	+ 0·179	− 0·197
Do.	a/261	25·64	+ 161·404	+ 161·641	+ 0·237	− 0·139
Do.	262	26·51	+ 164·082	+ 164·266	+ 0·184	− 0·192
Cut on the base of distant signal ...	a/262	28·00	+ 170·928	+ 171·314	+ 0·386	+ 0·010
Embedded at Tatkon Railway Stn. ...	263	28·34	+ 172·908	+ 173·345	+ 0·437	+ 0·061
Cut on railway platform coping ...	a/263	28·38	+ 173·049	+ 173·364	+ 0·315	− 0·061
Cut on culvert abutment ...	264	29·30	+ 164·517	+ 164·745	+ 0·228	− 0·148
Cut on drain	265	31·05	+ 176·932	+ 177·156	+ 0·224	− 0·152
Cut on culvert parapet	266	32·05	+ 197·569	+ 197·827	+ 0·258	− 0·118
Cut on girder bridge	a/266	33·34	+ 204·250	+ 204·477	+ 0·227	− 0·149
Do.	267	34·33	+ 226·013	+ 226·205	+ 0·192	− 0·184
Do.	268	35·58	+ 227·628	+ 227·887	+ 0·259	− 0·117
Cut on railway platform coping ...	269	36·41	+ 239·933	+ 240·219	+ 0·286	− 0·090
Embedded at Nyaunglun Railway Stn.	a/269	36·45	+ 239·428	+ 239·672	+ 0·244	− 0·132
Cut on culvert parapet	270	37·98	+ 258·452	+ 258·730	+ 0·278	− 0·098
Cut on girder bridge	271	39·14	+ 269·984	+ 270·271	+ 0·287	− 0·089

* The portion of this line between Rangoon Tidal Observatory and Pyinmana is being revised at the present time (1909-10).

Portion of Line Burma A: Pyinmana to Mandalay.—(Continued).

Bench-marks of the original levelling that were connected during the revisionary operations: Description	Number	Distance from Pyinmana	Observed height above (+) or below (−) Pyinmana as determined in 1892-93	1903-04	Difference in height (Revised − Original). The + sign denotes that the height was *greater*, and the − sign *less* in 1903-04 than it was in 1892-93. On the assumption that Pyinmana bench-mark has remained unchanged	Mandalay bench-mark has remained unchanged
		miles	*feet*	*feet*	*foot*	*foot*
Cut on culvert	a/271	40·50	+ 277·739	+ 278·065	+ 0·326	− 0·050
Do.	272	41·73	+ 288·853	+ 289·179	+ 0·326	− 0·050
Cut on girder bridge	273	42·21	+ 300·214	+ 300·543	+ 0·329	− 0·047
Cut on railway platform coping ...	274	43·06	+ 318·442	+ 318·873	+ 0·431	+ 0·055
Cut on base of Home Semaphore ...	a/274	43·28	+ 319·668	+ 320·054	+ 0·386	+ 0·010
Cut on barrel drain	275	44·24	+ 336·127	+ 336·470	+ 0·343	− 0·033
Cut on irrigation pipe	276	45·50	+ 344·787	+ 345·133	+ 0·346	− 0·030
Cut on culvert	a/276	46·96	+ 356·447	+ 356·833	+ 0·386	+ 0·010
Cut on girder bridge	277	47·58	+ 356·571	+ 356·938	+ 0·367	− 0·009
Embedded at Yamethin Railway Stn. ...	278	49·50	+ 341·798	+ 341·835	+ 0·037	− 0·339
Cut on railway platform coping ...	279	49·58	+ 341·796	+ 342·109	+ 0·313	− 0·063
Cut on girder bridge	280	50·64	+ 340·832	+ 341·280	+ 0·448	+ 0·072
Do.	a/280	51·76	+ 333·396	+ 333·818	+ 0·422	+ 0·046
Do.	b/280	56·65	+ 360·510	+ 360·840	+ 0·330	− 0·046
Cut on railway platform coping ...	281	57·25	+ 361·391	+ 361·740	+ 0·349	− 0·027
Embedded at Shweda Railway Stn. ...	a/281	57·43	+ 360·380	+ 360·717	+ 0·337	− 0·039
Cut on girder bridge	282	58·18	+ 360·190	+ 360·521	+ 0·331	− 0·045
Do.	283	59·29	+ 350·430	+ 350·756	+ 0·326	− 0·050
Do.	284	60·05	+ 343·813	+ 344·145	+ 0·332	− 0·044
Do.	a/284	60·53	+ 340·390	+ 340·682	+ 0·292	− 0·084
Embedded at Pyawbwe Railway Stn. ...	285	62·39	+ 324·113	+ 324·460	+ 0·347	− 0·029
Cut on railway platform coping ...	286	62·44	+ 324·586	+ 325·020	+ 0·434	+ 0·058
Cut on culvert	287	63·69	+ 317·789	+ 318·136	+ 0·347	− 0·029
Do.	288	64·44	+ 323·627	+ 323·987	+ 0·360	− 0·016
Cut on barrel drain	289	65·52	+ 317·884	+ 318·247	+ 0·363	− 0·013
Cut on parapet of rail opening ...	a/289	66·88	+ 305·546	+ 305·871	+ 0·325	− 0·051
Embedded at Shanywa Railway Stn. ...	290	67·78	+ 290·789	+ 291·009	+ 0·220	− 0·156
Cut on railway platform coping ...	291	67·83	+ 290·880	+ 291·335	+ 0·455	+ 0·079
Cut on barrel drain	a/291	68·09	+ 261·362	+ 261·891	+ 0·529	+ 0·153
Do.	292	70·38	+ 247·009	+ 247·378	+ 0·369	− 0·007
Do.	293	71·91	+ 234·436	+ 234·755	+ 0·319	− 0·057
Cut on girder bridge	294	73·08	+ 232·202	+ 232·452	+ 0·250	− 0·126
Embedded at Nyaungyan Railway Stn.	a/294	74·08	+ 229·193	+ 229·411	+ 0·218	− 0·158
Cut on railway platform coping ...	295	74·12	+ 229·889	+ 230·135	+ 0·246	− 0·130
Cut on girder bridge	296	75·12	+ 228·624	+ 228·913	+ 0·289	− 0·087
Do.	297	76·23	+ 220·722	+ 221·034	+ 0·312	− 0·064
Do.	298	77·84	+ 219·945	+ 220·256	+ 0·311	− 0·065
Cut on culvert parapet	299	79·50	+ 213·852	+ 214·225	+ 0·373	− 0·003
Embedded at Meiktila Road Railway Stn.	300	80·79	+ 215·808	+ 216·025	+ 0·217	− 0·159
Cut on railway platform coping ...	a/300	80·91	+ 216·221	+ 216·576	+ 0·355	− 0·021

Portion of Line Burma A: Pyinmana to Mandalay.—(Continued).

Bench-marks of the original levelling that were connected during the revisionary operations: Description	Number	Distance from Pyinmana	Observed height above (+) or below (−) Pyinmana as determined in 1892-93	1903-04	Difference in height (Revised − Original). The + sign denotes that the height was *greater*, and the − sign *less* in 1903-04 than it was in 1892-93. On the assumption that Pyinmana bench-mark has remained unchanged	Mandalay bench-mark has remained unchanged
		miles	*feet*	*feet*	*foot*	*foot*
Cut on barrel drain	301	82·48	+ 210·740	+ 211·047	+ 0·307	− 0·069
Do.	302	83·66	+ 219·511	+ 219·999	+ 0·488	+ 0·112
Cut on culvert	303	84·57	+ 213·630	+ 214·059	+ 0·429	+ 0·053
Cut on barrel drain	304	85·63	+ 213·417	+ 213·679	+ 0·262	− 0·114
Cut on girder bridge	305	86·33	+ 213·658	+ 214·002	+ 0·344	− 0·032
Cut on culvert	306	87·51	+ 211·211	+ 211·738	+ 0·527	+ 0·151
Cut on girder bridge	307	88·59	+ 209·027	+ 209·595	+ 0·568	+ 0·192
Cut on culvert	308	89·83	+ 203·324	+ 203·629	+ 0·305	− 0·071
Cut on railway platform coping ...	309	90·33	+ 203·279	+ 203·669	+ 0·390	+ 0·014
Embedded at Hanza Railway Stn. ...	a/309	90·38	+ 202·838	+ 203·224	+ 0·386	+ 0·010
Cut on girder bridge	b/309	91·68	+ 181·029	+ 181·323	+ 0·294	− 0·082
Cut on barrel drain	310	92·56	+ 164·288	+ 164·509	+ 0·221	− 0·155
Cut on irrigation pipe	a/310	93·59	+ 145·863	+ 146·146	+ 0·283	− 0·093
Cut on barrel drain	311	94·39	+ 135·242	+ 135·535	+ 0·293	− 0·083
Cut on girder bridge	a/311	95·53	+ 128·785	+ 129·151	+ 0·366	− 0·010
Embedded at Thedaw Railway Stn. ...	312	97·00	+ 129·447	+ 129·867	+ 0·420	+ 0·044
Cut on culvert	313	97·89	+ 122·375	+ 122·659	+ 0·284	− 0·092
Cut on irrigation pipe	a/313	99·29	+ 108·553	+ 108·886	+ 0·333	− 0·043
Do.	314	100·56	+ 97·150	+ 97·357	+ 0·207	− 0·169
Cut on girder bridge	315	101·73	+ 89·972	+ 90·260	+ 0·288	− 0·088
Cut on culvert	316	102·63	+ 83·474	+ 83·805	+ 0·331	− 0·045
Embedded at Samon Railway Stn. ...	a/316	103·94	+ 70·320	+ 70·772	+ 0·452	+ 0·076
Cut on girder bridge	317	104·89	+ 53·117	+ 53·386	+ 0·269	− 0·107
Cut on irrigation pipe	a/317	107·29	+ 38·822	+ 39·146	+ 0·324	− 0·052
Cut on girder bridge	318	107·97	+ 39·119	+ 39·309	+ 0·190	− 0·186
Do.	319	110·18	+ 23·718	+ 23·977	+ 0·259	− 0·117
Cut on irrigation pipe	321	113·56	+ 6·768	+ 7·444	+ 0·676*	+ 0·300
Embedded at Kume Road Railway Stn.	322	116·42	+ 4·819	+ 4·479	− 0·340	− 0·716
Cut on railway platform coping ...	323	116·46	+ 5·389	+ 5·601	+ 0·212	− 0·164
Cut on girder bridge	324	117·67	+ 0·307	+ 0·542	+ 0·235	− 0·141
Do.	325	119·60	+ 3·139	+ 3·364	+ 0·225	− 0·151
Do.	326	121·33	− 0·282	− 0·028	+ 0·254	− 0·122
Cut on base of Home Semaphore ...	a/326	122·18	− 6·598	− 6·347	+ 0·251	− 0·125
Cut on girder bridge	b/326	125·08	− 15·768	− 15·511	+ 0·257	− 0·119
Cut on base of Home Semaphore ...	327	127·48	− 19·942	− 19·689	+ 0·253	− 0·123
Embedded at Minzu Railway Stn. ...	a/327	127·54	− 20·404	− 20·175	+ 0·229	− 0·147
Cut on girder bridge	328	129·26	− 21·966	− 21·720	+ 0·246	− 0·130
Do.	329	131·76	− 24·577	− 24·322	+ 0·255	− 0·121
Do.	330	132·80	− 27·391	− 27·138	+ 0·253	− 0·123
Embedded at Kyaukse Railway Stn. ...	a/330	134·09	− 30·189	− 29·939	+ 0·250	− 0·126

* This bench-mark appears to have been raised, since it was originally erected.

Portion of Line Burma A: Pyinmana to Mandalay.—(Continued).

Bench-marks of the original levelling that were connected during the revisionary operations: Description	Number	Distance from Pyinmana	Observed height above (+) or below (−) Pyinmana as determined in 1892-93	1903-04	Difference in height (Revised − Original). The + sign denotes that the height was *greater*, and the − sign *less* in 1903-04 than it was in 1892-93. On the assumption that Pyinmana bench-mark has remained unchanged	Mandalay bench-mark has remained unchanged
		miles	*feet*	*feet*	*foot*	*foot*
Cut on base of Home Semaphore ...	331	134·09	− 29·815	− 29·558	+ 0·257	− 0·119
Cut on girder bridge	332	135·04	− 36·497	− 36·226	+ 0·271	− 0·105
Cut on base of Home Semaphore ...	334	138·33	− 43·523	− 43·258	+ 0·265	− 0·111
Embedded at Belin Railway Stn. ...	a/334	138·41	− 44·560	− 44·550	+ 0·010	− 0·366
Cut on wingwall of girder bridge ...	335	140·89	− 48·595	− 48·308	+ 0·287	− 0·089
Cut on girder bridge	336	142·74	− 55·950	− 55·741	+ 0·209	− 0·167
Cut on base of Home Semaphore ...	337	143·95	− 59·766	− 59·460	+ 0·306	− 0·070
Cut on girder bridge	338	145·01	− 62·019	− 61·700	+ 0·319	− 0·057
Cut on girder bridge over a canal ...	339	146·91	− 52·838	− 52·484	+ 0·354	− 0·022
Cut on girder bridge	340	151·09	− 66·139	− 65·830	+ 0·309	− 0·067
Do.	a/340	151·53	− 65·969	− 65·595	+ 0·374	− 0·001
Cut on base of Home Semaphore ...	341	152·28	− 61·059	− 60·673	+ 0·386	+ 0·010
Embedded at Myitnge Railway Stn. ...	a/341	152·31	− 61·858	− 61·493	+ 0·365	− 0·011
Cut on girder bridge	343	156·94	− 65·377	− 65·080	+ 0·297	− 0·079
Cut on platform coping opposite Home Semaphore	344	157·98	− 63·757	− 63·290	+ 0·467	+ 0·091
Cut on the base of Home Semaphore	345	158·00	− 63·024	− 62·585	+ 0·439	+ 0·063
Cut on return-wall of girder bridge ...	a/344	159·53	− 63·945	− 63·604	+ 0·341	− 0·035
Cut on base of water-column ...	b/344	160·43	− 64·169	− 63·714	+ 0·455	+ 0·079
Embedded at Mandalay Railway Stn.	c/344	160·74	− 62·388	− 62·012	+ 0·376	0·000
Cut on stone plinth of railway gate ...	c_1/344	161·48	− 62·395	− 62·179	+ 0·216	− 0·160
Embedded at Military Police Supply Depot., Shore	a_3/344	162·51	− 79·093	− 78·852	+ 0·241	− 0·135
P.W.D. Bench-mark at Fort Dufferin	c_2/344	162·52	− 64·721	− 64·488	+ 0·233	− 0·143
BOM embedded in masonry pillar at Fort Dufferin	c_3/344	162·57	− 66·509	− 66·173	+ 0·336	− 0·040
Cut on the plinth of revetment wall	a_2/344	162·61	− 72·734	− 72·429	+ 0·305	− 0·071
Embedded at Marine Transport office, Shore	a_1/344	162·74	− 87·399	− 87·101	+ 0·298	− 0·078

Line No. 61A. Saharanpur to Mussooree.

Bench-marks of the original levelling that were connected during the revisionary operations		Distance from Saharanpur	Observed height above (+) or below (−) Saharanpur as determined in		Difference in height (Revised − Original). The + sign denotes that the height was *greater*, and the − sign *less* in 1905-07 than it was in 1861-62 and 1903-04
Description	Number		1861-62 and 1903-04	1905-06-07	
		miles	*feet*	*feet*	*foot*
Embedded at Saharanpur ...	1	0·00	0·000	0·000	0·000
Embedded at Mohan	19	30·91	+ 582·153	+ 582·480	+ 0·327
Embedded at Mohabawala ...	37	40·96	+ 1189·311	+ 1189·674	+ 0·363
Colonel Everest's upper mark at E. End of Dehra Dún Base-line ...	2/38	43·06	+ 1051·823	+ 1052·213	+ 0·390
O on Bell platform of Trigonometrical Branch Office	1/46	47·71	+ 1323·890	+ 1324·334	+ 0·444
Iron plug at the Trigonometrical Branch Office	47	47·73	+ 1321·885	+ 1322·326	+ 0·441
Cole's Satellite Station, small solar observatory	2/46	47·80	+ 1330·105	+ 1330·548	+ 0·443
Cut on stone on Rajpur road ...	48	48·65	+ 1375·755	+ 1376·215	+ 0·460
Do.	49	49·24	+ 1431·426	+ 1431·857	+ 0·431
Do.	50	50·65	+ 1609·196	+ 1609·620	+ 0·424
Cut on mile-stone on Rajpur road ...	a/50	51·73	+ 1787·346	+ 1787·749	+ 0·403
Cut on stone on Rajpur road ...	51	52·06	+ 1842·166	+ 1842·560	+ 0·394
Cut on stone at Rajpur ...	a/51	53·05	+ 2015·560	+ 2015·926	+ 0·366
Cut on plinth of a house at Rajpur bazar	52	54·25	+ 2416·067	+ 2416·392	+ 0·325
Cut on rock at "Kolu-Khet" water works	53	57·99	+ 3295·268	+ 3295·495	+ 0·227
Do. above "Kolu-Khet" water works	a/53	58·86	+ 3519·372	+ 3519·549	+ 0·177
Do. below Bhatta village ...	54	59·10	+ 3590·955	+ 3591·125	+ 0·170
Do.	55	59·48	+ 3670·782	+ 3670·931	+ 0·149
Do.	56	59·68	+ 3724·527	+ 3724·686	+ 0·159
Do.	a/56	59·91	+ 3783·013	+ 3783·175	+ 0·162
Do.	57	60·08	+ 3833·070	+ 3833·230	+ 0·160
Do.	58	60·26	+ 3867·523	+ 3867·682	+ 0·159
Do.	59	60·50	+ 3931·305	+ 3931·456	+ 0·151
Cut on drain E. of Bhatta village ...	60	61·19	+ 4230·598	+ 4230·711	+ 0·113
Cut on rock S. of "Oakdene" ...	62	62·98	+ 4911·001	+ 4911·084	+ 0·083
Do. above "Oakdene" ...	63	63·11	+ 4964·781	+ 4964·866	+ 0·085
Do.	64	63·44	+ 5095·587	+ 5095·640	+ 0·053
Do.	65	63·80	+ 5240·135	+ 5240·197	+ 0·062
Do. below "Falcon's Nest" ...	66	64·16	+ 5375·157	+ 5375·226	+ 0·069
Do. above "Falcon's Nest" ...	67	64·59	+ 5552·361	+ 5552·415	+ 0·054
Cut on verandah of Mussooree Library	68	64·88	+ 5671·671	+ 5671·727	+ 0·056
Cut on step at Christ Church, Mussooree	69	65·15	+ 5739·656	+ 5739·707	+ 0·051
Cut on rock a little above the Church ...	a/69	65·31	+ 5834·041	+ 5834·082	+ 0·041
Do. ,"Vincent's Hill" ...	a/68	65·46	+ 6003·856	+ 6003·890	+ 0·034
Cut on "Mussooree Dome Observatory"	71	65·59	+ 6028·712	+ 6028·763	+ 0·051
Cut on "Eagles Nest"	b/68	65·61	+ 6016·914	+ 6016·944	+ 0·030
Cut on rock near "Dunseverick" ...	c/68	65·82	+ 6216·578	+ 6216·606	+ 0·028
Cut on verandah of "Dunseverick" ...	d/68	65·84	+ 6222·068	+ 6222·081	+ 0·013

A DISCUSSION OF THE RESULTS OF LEVELLING REVISIONS.

1.

The following table gives a list of the double simultaneous lines that have been revised :—

Complete line	Line numbers from Tables I (page 5) and V (page 20)	Seasons		Approximate length in miles
		Original work	Revision	
Bombay-Madras ...	32,31,25,26, 22,21,14,8.	1877-81	1906-08	881
Bellary-Karwar ...	16,17.	1873-74	1907-08	240
Karachi mean-sea-level -Tatta	78,43.	1859-60	1893-94	16
Mandalay-Pyinmana ...	Burma A.	1892-93	1903-04	161
Saharanpur-Dehra Dun ...	61 A.	1861-62	1906-07	44
Dehra Dun-Mussooree ...	61 A.	1903-04	1905-06	19

On pages 319–343 we have exhibited in a series of tables the differences between the original and revised values of height for all surviving bench-marks on the revised lines. We had at one time looked forward to deriving valuable information concerning the laws governing the errors of levelling from the comparisons of original and revised values of height, but in this research we have failed and for two reasons :—

(i). The original levellers were unaware of the advantages of having bench-marks upon ground rock, and frequently omitted to place bench-marks upon ground rock, even when rock was out-cropping on their routes. The revisionary results show that numbers of the masonry bench-marks have been raised or lowered by considerable amounts since they were first erected : this fact gives rise to doubts as to whether other masonry bench-marks may not have been moved by small amounts sufficient to vitiate scientific deductions ; in fact the stability and permanence of no masonry bench-mark can be accepted as unquestionable.

(ii). The only lines of levelling that have been revised are those, that closed with abnormally large errors,—errors so large as to arouse suspicions, that actual mistakes may possibly have been made by levellers ; it will not be from rejected lines such as these, that we shall gain information concerning the laws of error of scientific levelling. If revisions are required to throw light upon general questions of accuracy, the lines to be revised should be selected for their merits and not for their defects.

The following table was prepared, in order to show whether any connection existed between the differences, that have been discovered between original and revised values of levelling, and the differences, that appeared between the first and second levellers. For each revised line the terminal difference of height between original and revised levelling is given; and then the following data are added:—

(i). terminal differences between levellers on each original and each revised line.

(ii). maximum difference between levellers on each orginal and each revised line.

(iii). probable errors generated in the original and revised lines of levelling.

In showing the error accumulated per mile, we have merely divided the total error at the end of any line by the length in miles: this method presupposes the whole error to be systematic and to be accumulating at an uniform rate per mile. Such an assumption is known to be incorrect, but the law of accumulation of error and the relationship between error and distance are too complex to be introduced into discussions of discrepancies, and we are obliged to have recourse to rough approximations. The average systematic error may be taken to be 0·0005 per mile.

The great differences between original and revised levelling occur on the following lines:—Diksal-Gulbarga, Gulbarga-Raichur, Karwar-Hubli, Hubli-Bellary, Pyinmana-Mandalay, Saharanpur-Dehra Dun, Dehra Dun-Mussooree.

	Line	Length	Discrepancy in the values of height of terminal bench-mark (Revised levelling – Original)		Difference generated between the two levellers at the end of each line				Maximum difference between levellers		Probable error* of the difference of elevation between the terminal bench-marks	
					Original		Revised				Original line of levels	Revised line of levels
			Total	per mile	Total	per mile	Total	per mile	Original	Revised		
		miles	foot	foot	foot	foot	foot	foot	foot	foot	foot	foot
Bombay to Madras	Bombay-Kalyan ...	34·5	−0·012	−0·0003	−0·037	−0·0011	−0·032	−0·0009	−0·104	−0·032	±0·0196	±0·0090
	Kalyan-Kedgaon ...	120·0	−0·087	−0·0007	−0·034	−0·0003	−0·029	−0·0002	−0·221	+0·124	±0·0432	±0·0366
	Kedgaon-Diksal ...	30·6	−0·084	−0·0027	+0·026	+0·0008	−0·103	−0·0034	+0·050	−0·107	±0·0179	±0·0105
	Diksal-Gulbarga platform ...	170·4	−0·738	−0·0043	−0·086	−0·0005	−0·178	−0·0010	−0·128	−0·203	±0·0482	±0·0424
	Gulbarga platform-Raichur	89·9	−1·102	−0·0123	+0·017	+0·0002	+0·053	+0·0006	+0·083	−0·102	±0·0353	±0·0389
	Raichur-Gooty ...	96·5	+0·050	+0·0005	+0·070	+0·0007	+0·016	+0·0002	+0·093	+0·089	±0·0284	±0·0313
	Gooty-Arkonam ...	215·4	−0·159	−0·0007	−0·061	−0·0003	−0·011	−0·0001	−0·158	−0·089	±0·0529	±0·0311
	Arkonam-Madras ...	44·1	−0·114	−0·0026	+0·035	+0·0008	−0·003	−0·0001	+0·036	+0·020	±0·0187	±0·0161
	Totals for Bombay-Madras	801·4	−2·246	−0·0028	−0·070	−0·0001	−0·287	−0·0004				
Karwar-Bellary	Karwar-Hubli	102·7	+0·693	+0·0067	−0·004	0·0000	+0·178	+0·0017	+0·027	+0·178	±0·0293	±0·0384
	Hubli-Bellary	137·3	−1·143	−0·0083	+0·070	+0·0005	−0·101	−0·0007	+0·178	−0·149	±0·0560	±0·0389
	Pyinmana-Mandalay ...	160·7	+0·376	+0·0023	+0·055	+0·0003	+0·219	+0·0014	+0·134	+0·227	±0·0424	±0·0305
Saharanpur-Mussooree	Saharanpur-Dehra Dun ...	47·7	+0·441	+0·0092	−0·152	−0·0032	−0·065	−0·0014	−0·193	−0·086	±0·0652	±0·0164
	Dehra Dun-Mussooree ...	18·1	−0·428	−0·0236	+0·229	+0·0127	−0·196	−0·0108	+0·229	−0·196	±0·0293	±0·0133

* Probable error deduced from discrepancies (d) between the two levellers. $e_1 = 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4}}$.

We will now examine the eight main-lines, that constitute the connecting link between Bombay and Madras, and endeavour to see if any light has been thrown upon the error of 2·98 feet, that appeared in 1880 between the mean-sea-levels at Bombay and Madras.

The following considerations will help us to understand the meaning of the differences that have appeared between the revised and original levelling, the original values being always subtracted from the revised:—

(i). A large isolated negative difference denotes that the bench-mark, at which it appears, has settled or been lowered in the interval between the old and new levelling.

(ii). A large isolated *positive* difference denotes that the bench-mark has been raised.

(iii). A constant $\frac{\textit{negative}}{\textit{positive}}$ difference appearing at a number of successive bench-marks denotes *either* that the whole ground along the route has $\frac{\textit{subsided}}{\textit{risen}}$, *or* that some initial error in the old or the new levelling occurred at the first bench-mark of the series, *or* that the height of the first bench-mark of the series was altered between the dates of the arrival of the levelling and its continuation beyond.*

(iv). A difference persistently increasing and always with the same sign, whether the level-route is ascending or descending, denotes *either* that the levelling observations, original or revisionary, were being affected by systematic error, or that the earth's crust was undergoing some vertical movement or tilt during the levelling operations.

(v). A difference persistently increasing and always with the same sign, so long as the level-route continues down-hill, and which begins to decrease and change sign, when the level-route changes to up-hill, denotes that erroneous values of length have been given to the staves.

In attempting to interpret the meanings of the discrepancies we should in the first place endeavour to separate those that are due to levelling errors from those due to movements of bench-marks.

2.

Line No. 32. Bombay to Kalyan, (see *page 319*).

The values of height for the embedded bench-mark at Dadar differ by 0·077 foot and those for the embedded bench-mark at Kurla by 0·070 foot, but after Kurla the discrepancies get less, and no appreciable error was discovered at Kalyan.

3.

Line No. 31. Kalyan to Kedgaon, (see *page 320*).

In the first 37 miles the values of height were all greater in 1906-07 than in 1877-78. Beyond Kampuli they were less, except in the case of the bench-mark embedded at Kirkee, which, being in a railway station has presumably been disturbed.

In the first 37 miles the levelling-line rose 207 feet, and in the last 73 miles it fell 259 feet. But between the 37th and 47th miles it rose suddenly 1803 feet.

* When work is closed for the season some months may intervene between the connection of a bench-mark and the continuation of levelling beyond. On the return of the levellers after the interval the positions of the last bench-marks fixed should be tested. In April 1879 the levelling ended at Kem, and in the following November the relative heights of two bench-marks in the railway station were redetermined. Also when work was recommenced at Raichur in November 1880 the relative heights of two marks in the railway station were redetermined. Experience has shown, that the redetermination of two marks situated close together on a railway platform is an insufficient test of stability.

During the first 37 miles, when the rise was moderate, the original levelling appears to be too low throughout, but the difference between revised and original can hardly be said to be systematically increasing over this length, for the total difference generated in 37 miles is 0·101 foot, and half this amount occurs at the first bench-mark from Kalyan. Still the error over this length averages 0·0027 foot per mile, which is too great an average rate to be passable. In the last 73 miles the difference between revised and original values changes from − 0·074 to − 0·087——a change per mile of 0·0002——and this is within the limits of permissible error.

The chief error however on the Kalyan–Kedgaon line was accumulated between the 37th and 47th miles, when the difference (revised − original) changed from + 0·101 to − 0·074——a change of 0·175 in 9 miles, or 0·0194 a mile.

The fact, that an abnormal error appeared during the rise of 1803 feet, and that it was not visible when the levelling-line was ascending a gentle gradient, rather tends to throw suspicion on the staves. If a discrepancy of − 0·175 foot in a rise of 1803 feet is to be attributed to the staves then the adopted length of the four (ten-foot) staves must have been in 1877-78 in the mean *too small* by about 0·001 foot, *i.e.*, by 0·0001 foot per foot.

On the ascent from Kampuli to Khandala the gradient exceeded 250 feet a mile, and the difficulties of levelling were very great. We are not able therefore to ascribe discrepancies with any certainty to errors of the staves. The total error of levelling generated may well have been due to the unavoidable difficulties of observation on a mountain road.*

Between Kalyan and Kedgaon the error generated in the original levelling appears to average 0·0007 foot per mile, and at this rate the total error accumulated between Bombay and Madras would be considerably less than 1 foot.

It will thus be seen that no appreciable portion of the extraordinary error of 2·98 feet, that was accumulated between these two places in 1877, can be attributed to the Kalyan-Kedgaon line.

4.

Line No. 25. Kedgaon to Diksal, (see *page 322*).

It is difficult to understand why the first two bench-marks, like the first bench-marks on the Kalyan-Kedgaon and on other lines, should appear to have risen unless they have been actually moved. It may be that the Kedgaon bench-mark itself has sunk. The bench-marks embedded at Patas and Dhond both appear to have sunk, since they were erected: the differences obtained between the revised and the original levelling at Patas and Dhond are larger than at the embedded bench-marks of Boribyal and Diksal. Between Kedgaon and Diksal the error generated in the original levelling appears to be 0·084 foot and to average 0·0028 foot per mile. An average error of 0·0028 foot per mile is very large, and if it persisted from Bombay to Madras, it would cause a discrepancy between computed and actual values of height at Madras exceeding 2 feet. The great Bombay-Madras error may therefore be said to have *commenced* to accumulate between Kedgaon and Diksal.

5.

Line No. 26. Diksal to Gulbarga, (see *page 323*).

On the Diksal-Gulbarga line a difference of − 0·738 foot was generated in 170 miles, an average of 0·0043 foot per mile. If this rate of accumulation persisted from Bombay to Madras, a

* In 1880-81 the levelling of this steep ascent was revised, and no sensible error in the 1877-78 results was detected. The same field standard bar was used in 1880-81 as in 1877-78: the staves used in 1877-78 were Nos. 5, 6, 7, and 9, and in 1881-82 Nos. 5, 9, 10 and F.

discrepancy exceeding $3\frac{1}{2}$ feet would appear at Madras. The accumulation of the Bombay–Madras error probably commenced on the Kedgaon–Diksal line. It was undoubtedly continued on a very serious scale throughout the Diksal–Gulbarga line.

It is difficult to discuss the cause of an accumulation of error between Diksal and Gulbarga, because the bench-marks do not appear to possess adequate stability. Numbers of them have been obviously moved, and many more are under suspicion. If we examine the results obtained at the embedded bench-marks only, we see how widely the differences jump, and how irregular the accumulation of error is. At Katraj, 5 miles from Diksal, a difference of − 0·317 foot appeared: at Pomalvadi this was reduced to − 0·124. At Poplaj it was − 0·052, and at Jeur − 0·056. At Kem it was − 0·140 and at Barsi road − 0·275. At 50 miles from Diksal the difference was in fact less than it was at 5 miles.

In the 10 miles beyond Barsi road the difference jumped from 0·275 to 0·587 at Madha—the rate of accumulation being 0·03 foot per mile; but in the next 8 miles it decreased again to 0·377 at Angar, showing that the embedded bench-mark at Madha has sunk.

From Angar to Hotgi there is a continuous increase of error at the rate of 0·007 per mile. After Hotgi it decreases to Kadabgaon. At Dudhni the difference is at a maximum (for embedded marks), 0·866, and it then declines to 0·767 at Ghangapur.

The errors on the Diksal–Gulbarga line are so extraordinary, that we at first suspected the lengths of the staves.

The following table was constructed to show if the accumulation of the error of levelling varied according to whether the level-line was ascending or descending:—

Section of line	Length in miles	Average change of elevation in feet per mile	Average accumulation of error per mile
			foot
Diksal to Washimbe ...	19	− 3	− 0·0026
Washimbe to Kem ...	20	+ 9	− 0·0045
Kem to Mohol ...	40	− 7	− 0·0088
Mohol to Sholapur ...	20	flat	− 0·0068
Sholapur to Dudhni ...	40	flat	− 0·0060
Dudhni to Gulbarga ...	30	flat	+ 0·0043

The error, which is generally negative from Bombay to Madras, increased in five sections, and decreased in the last. If this negative error had been mainly due to erroneous staff-units or to erroneous staff-lengths, it should have decreased when the road *rose* from Washimbe to Kem. But on this ascending section of road the negative error continued to increase. The total fall on the line Diksal-Gulbarga is 168 feet, and if the error of 0·738 foot generated on the line is to be ascribed to the erroneous staff-lengths of 1878, then the four staves must have been on the average too long by $\frac{0 \cdot 738}{16 \cdot 8}$ foot, that is, by 0·044 foot. This amount is too gross to be admitted as possible, and though the staff-length may have been a small contributory source of error, it was obviously not the main source.

A comparison of the results of the old with the new levelling shows that no bench-marks—and certainly not the embedded—are stable or reliable. This in fact is the only conclusion, that is indisputable—no one of the bench-marks is sufficiently steady for scientific purposes. The lengths of the staves may not have been determined with sufficient frequency, but if any error has been introduced into the levelling by variations in staff-lengths, it is now completely masked by the movements of the bench-marks.

6.

Line No. 22. Gulbarga to Raichur, (see *page 326*).

The differences between the original and revised levelling for the heights of the embedded bench-marks are as follows:—

	feet
Shahabad	− 0·320
Wadi	− 0·563
Nalvar	− 0·495
Yadgiri	− 0·656
Saidapur	− 0·865
Chiksugur	− 1·422
Raichur	− 1·102

In this line there was evidently a large persistent error vitiating the original levelling. The error discovered amounts to −1·102 in 90 miles——0·0122 foot per mile. The normal accumulation of error of levelling in India works out at 0·0005 foot or 0·0006 per mile; the error on the Gulbarga-Raichur line accumulated at a rate twenty times as great as the normal rate of accumulation. At the same time the accumulation on Gulbarga-Raichur does not appear to have been uniformly steady. Between Wadi and Nalvar and between Chiksugur and Raichur the accumulated error actually decreased. As is the case on other lines, the difficulties of investigating the causes of this obscure error are greatly increased by the unreliability of the bench-marks. The bench-marks on bridges and mile-stones cannot be trusted, and some of the embedded bench-marks seem to have moved by large amounts.

The following table was constructed to show whether the error of levelling accumulated at a different rate on ascents and descents.

Section of line	Length in miles	Average change of elevation in feet per mile	Average accumulation of error per mile
			foot
Gulbarga to Shahabad ...	16	− 11	− 0·0200
Shahabad to Wadi ...	6	+ 15	− 0·0405
Wadi to Yadgiri ...	24	− 8	− 0·0039
Yadgiri to Saidapur ...	14	+ 2	− 0·0149
Saidapur to Bridge ...	15	− 6	− 0·0035
Bridge to Raichur ...	14	+ 13	− 0·0131

The error is always increasingly negative, but during ascents the rate of increase is greater than during descents. If we were to attribute the error accumulated on $\frac{\text{ascents}}{\text{descents}}$ to the adoption of erroneous lengths for the staves, we should have to assume that in the mean the four ten-foot staves were $\frac{\text{too long by } 0\cdot04 \text{ foot}}{\text{too short by } 0\cdot008 \text{ foot}}$.

The observations on ascents and on descents lead therefore to contradictory results and the deduced values for the error of the length of the mean-staff are too gross to be accepted: only one conclusion is possible——the bench-marks are not sufficiently stable. Not only is it probable that the heights of numerous bench-marks have changed between the original and revisionary operations, but there is evidence that many bench-marks were actually settling *during* the original operations, and perhaps also during the revisionary operations.

Of the whole levelling from Bombay to Madras the worst portion is between Gulbarga and Raichur; the total Bombay-Madras error amounted to 2·98 feet in 801 miles, or 0·0037 foot per mile. Between Gulbarga and Raichur an error of 1·102 feet was accumulated in 90 miles, or 0·0122 foot per mile. Whatever may have been the cause of the Bombay-Madras error, its effects are more clearly visible between Gulbarga and Raichur than on any other section of the route.

7.

Line No. 21. Raichur to Gooty, (see *page 328*).

The differences between the original and revised levelling for the heights of the embedded bench-marks are as follows:—

	foot
Matmari	− 0·062
Kosgi	+ 0·098
Adoni	− 0·140
Nancherla	+ 0·168
Timmanacherla	+ 0·345
Gooty	+ 0·050

Between Raichur and Gooty the accumulation of negative error that had previously been so persistent ceased, and a positive discrepancy began to appear.

On the Raichur-Gooty line there is some evidence forthcoming that the adopted lengths for the staves were in error.

The following table gives a summary of the evidence available:—

Section of line	Length in miles	Average change of elevation in feet per mile	Average accumulation of error per mile
Raichur to Bridge ...	21	− 11	*foot* − 0·003
Bridge to railway platform at Nancherla.	51	+ 9	+ 0·009
Nancherla platform to Gooty	24	− 15	− 0·015

We have used the bench-mark at Nancherla platform in preference to the embedded mark, because the latter seems to have moved. Several bench-marks about Nancherla show the same discrepancy as the platform mark, but no discrepancy agrees with that of the embedded mark. Whichever bench-mark we take at Nancherla, the following statements hold good—(i) in the first 21 miles from Raichur, when the line descends 228 feet, the discrepancy between old and new levelling seems to decrease in the positive direction and to increase in the negative: (ii) from the lowest point reached on the descent the line ascends 471 feet to Nancherla, and throughout this ascent the discrepancy tends to increase positively: (iii) after passing Nancherla, which is at the top of the rise, the line descends 353 feet, and the discrepancy then tends to decrease positively. The minimum and maximum values for the discrepancy occur at the points of minimum and maximum elevation on the line. These are no chance coincidences: on former lines there were reasons for suspecting the staves, but the evidence was masked by the instability of the bench-marks. On the Raichur-Gooty line the evidence against the staves is steadily corroborative. The error in the adopted length of the mean staff may be deduced as follows:—

			foot
On the first 21 miles	...	...	0·003 too long
On the next 51 miles	...	...	·010 too long
On the last 24 miles	...	...	·010 too long
	Mean	...	0·008 too long

The sole argument against the acceptance of these figures is that they are too gross. If this view is adopted, then the discrepancies must be attributed as before to movements of bench-marks.

8.

Line No. 10. Gooty to Arkonam, (see *page 330*).

The line commences with a very large initial positive discrepancy + 0·174: the discrepancy then has had a tendency to decrease, and eventually to become negative. The first discrepancy is + 0·174 and the last is − 0·159. The discrepancies immediately following the first are in sufficient accord with it to lead us to think that the embedded bench-mark at Gooty, the starting-point of the line, must have settled about 0·174 foot between 1880 and 1907. On the Raichur-Gooty line the accumulated errors of levelling in the old values of heights for the bench-marks numbered 46, 47, 50, 51, 55 and 56 made the bench-marks too low by 0·279, 0·281, 0·281, 0·254, 0·247, 0·273, respectively. The accordance of these values shows that in the original levelling an error had been generated and had affected several heights to nearly the same extent. The same discrepancy does not now appear at Gooty itself, because the embedded bench-mark has sunk since 1880, and because it has at length assumed, by the aid of settlement, a position near to the one given to it by the original levellers.

At Kondapuram the original levellers of 1880 had generated an error of about 0·030 foot, and were making their bench-marks too low. And in the first instance the height of Kondapuram was probably determined too low. But since then the bench-mark itself has subsided, and at its present position the original height for it of 480·823 feet below Gooty is actually too great. In this instance the sinking of the bench-mark has more than cancelled the original error of levelling.

The discrepancies appearing at the embedded bench-marks of the Gooty-Arkonam line are as follows:—

	foot
Rayalcheruvu	+ 0·062
Kondapuram	− 0·057
Muddanuru	− 0·129
Yerraguntla	+ 0·008
Kamalapuram	− 0·290
Cuddapah	− 0·040
Vontimitta	− 0·048
Nandalur	− 0·223
Reddipalle	− 0·484
Koduru	− 0·191
Mamanduru	− 0·181
Renigunta	− 0·234
Puttur	− 0·111
Nagari	− 0·228
Tirutani	− 0·154
Arkonam	− 0·159

There is no regularity of increase or decrease: the discrepancy at each mark is probably built up of two principal components—an error in the original determination of height, and a movement of the mark itself.

On the Gooty-Arkonam line, as on other lines, many of the railway platform bench-marks have been obviously disturbed since they were first inscribed: in certain instances the embedded and inscribed bench-marks at a railway station have been moved by the same amounts, as though the whole station had sunk. The Gooty-Arkonam line falls 769 feet in the first 92 miles; it then rises 231 feet in 9 miles, and falls again 245 feet in 11 miles; it then rises again 323 feet in 43 miles, and falls 445 feet in the last 60 miles. In these successive rises and falls we cannot trace any signs of an error in the adopted lengths of the staves; if such an error existed, its effects have been masked by those of more serious errors. During the fall of 769 feet in the first 92 miles a negative discrepancy of − 0·039 was generated, but during the fall of 445 feet in the last 60 miles a positive discrepancy was generated of + 0·024. If the lengths of the staves were the dominant cause of error, the discrepancy would persist with one sign on ascents and with the opposite sign on descents.

9.

Line No. 8. Arkonam to Madras, (see *page 334*).

This line has been revised three times. A discrepancy of 0·104 foot between the original work in 1880 and the first revision in 1884 was generated in 26 miles—at the rate of 0·0041 foot per mile. Such a high rate shows that an exceptional cause of error was affecting the results of either the one or the other series of operations. The most recent revision in 1907 leads us to think that the original levelling was superior to the work of the first revision.

10.

On the cause of the error that was generated in 1877-81 on the levelling from Bombay to Madras.

The Bombay-Madras line of levelling was observed in 1877-81 as follows:—

1877-78—Bombay to Kedgaon.

1878-79—Kedgaon to Kem.

1879-80—Kem to Raichur.

1880-81—Raichur to Madras.

The corrections adopted for 10 feet for pairs of staves were as follows:—

	Staves	Correction per pair
1877-78 Bombay to Poona ...	5 & 6 7 & 9	+ 0·001012 + 0·001425
1877-78 Poona to Kedgaon ...	5 & 6 7 & 9	− 0·001001 − 0·001212
1878-79 Kedgaon to Diksal ...	5 & 6 7 & 9	+ 0·001020 + 0·002361
1878-79 Diksal to Kem ...	5 & 6 7 & 9	+ 0·001020 + 0·002361
1879-80 Kem to Sholapur ...	5 & 6 9 & 10	+ 0·000222 + 0·000485
1879-80 Sholapur to Gulbarga ...	5 & 6 9 & 10	+ 0·000222 + 0·000485
1879-80 Gulbarga to Raichur ...	5 & 6 9 & 10	+ 0·000222 + 0·000485
1880-81 Raichur to Adoni ...	5 & F 9 & 10	+ 0·002129 + 0·002158
1880-81 Gooty to Madras ...	5 & F 9 & 10	+ 0·002186 + 0·001562
In 1880-81 between Gooty and Madras the following lengths were adopted from bench-mark 75 to Arkonam.	5 & F 9 & 10	+ 0·002129 + 0·002158

After a lapse of 30 years it is not possible to state definitely the cause of the **Bombay-Madras** levelling error, but the following memorandum contains a discussion of the question.

Memorandum by the Superintendent of Trigonometrical Surveys, dated Dehra Dun, March 17th, 1910.

(1). During the last month I have been examining the results of the levelling revisions between Bombay and Madras, and have been trying to trace the cause of the levelling error of 2·98 feet that appeared in 1880, when the levelling from Bombay connected at Madras with mean-sea-level. At the time General Walker attributed the discrepancy to observational errors, but the results of the recent revisions show, that the error accumulated at a rate greater than can be possibly attributed to observational inaccuracies. The normal rate of accumulation of systematic levelling error in India is 0·0004 foot per mile: on the Bombay-Madras line the accumulation is systematic and at the average rate of 0·0037 foot per mile.

(2). The Bombay-Madras error is however not steadily cumulative. It was mainly accumulated on the sections, Diksal-Gulbarga and Gulbarga-Raichur. The discrepancy on Diksal-Gulbarga was 0·738 foot in 170 miles,—at the rate of 0·0043 foot per mile: the discrepancy on Gulbarga-Raichur was 1·102 feet in 90 miles,—at the rate of 0·0122 foot per mile. The total systematic discrepancy, generated on the 260 miles between Diksal and Raichur, was 1·840 feet: two-thirds of the whole discrepancy therefore occur in one-third of the line.

(3). The *total* error generated in 1878 between Diksal and Raichur probably exceeded 2 feet, but as the revisionary levelling of 1907 has also generated a certain error in the same direction, the total error is not revealed in the discrepancy between original and revised results.

(4). An accumulation of systematic error at the rate of 0·0122 foot per mile is too gross to be attributed to observational inaccuracies. And as the gradient of the line from Gulbarga to Raichur is gentle, the accumulation of 0·0122 foot per mile cannot be ascribed to error in the adopted length of the mean staff.

(5). There is evidence to show that erroneous values for the lengths of the staves were adopted, and that the levellers did not determine the variations of the staff-lengths with sufficient frequency, but error of staff-length is not the cause of the Gulbarga-Raichur levelling error.

(6). At first it seemed possible, that this extraordinary error might have been caused by movements of the earth's crust. If the bench-marks connected with Bombay sea-level were affected during the levelling operations by gradual crustal subsidence, a positive closing error at Madras sea-level would have been rendered inevitable. But there has been no independent evidence of crustal movements or of seismic disturbances in the Deccan, and there has been no sign at Indian tidal observatories of any change in the relative level of land and sea, and unless the supposed movements were confined to a very small area, recent lines of level would have closed upon the older lines of Southern India with larger circuit discrepancies than have actually appeared.

(7). A consideration of the results of the revisionary levelling has led me to the conclusion, that the error of 2·98 feet at Madras was caused by the constant subsidence of bench-marks *during* the levelling operations of 1877-1880. The levellers frequently had to close work at a bench-mark, perhaps for a day or two, or perhaps for a week, or perhaps for six months. All the bench-marks were placed close to a railway line, and most of the marks were on railway platforms, bridges or culverts. Throughout every pause in the operations the bench-marks were being incessantly shaken by heavy trains, and were slowly but steadily subsiding. The levellers were assuming that their bench-marks were fixed and unalterable; this assumption was wrong. After an interval of six months the levellers did as a rule check the position of their last bench-mark by re-levelling from it to a neighbouring mark, but this relevelling was generally confined to the precincts of one railway station, and was insufficient. When a whole railway platform is supported on a made embankment and is suffering from continual subsidence, the mark cut on its edge and the mark embedded under its floor both sink together, and nothing is gained by relevelling from one to the other.

(8). The chief lessons to be learnt from the Bombay-Madras error are the following:—

(i.) Railway platforms and lines are unsuitable localities for bench-marks.

(ii.) Embedded bench-marks, though less liable to destruction by man than surface marks, are not more stable or more permanent, if placed near railways.

(iii.) No opportunity should be lost of placing bench-marks upon rock.

(iv.) The system of double simultaneous levelling, hitherto followed in India, is inferior to the system of fore-and-back double levelling, in that errors due to the subsidence of bench-marks have less tendency to cancel.

(9). The system of levelling, by which alternate sections of every line are levelled in opposite directions, one leveller always following immediately after the other, was introduced into India under the impression, that the alternation of direction on successive sections was as protective against error as the system, under which one observer levels throughout the line in one direction, and the other observer in the opposite direction*. If we consider the errors arising from the subsidence of bench-marks *during actual levelling observations*, the Indian system of levelling is as accurate as the fore-and-back system. But in the case of errors that arise from the subsidence of bench-marks *during the pauses* between periods of observation, the Indian system is inferior to the 'fore-and-back' system. The intervals between work are necessarily very much longer in the course of a year than the periods of actual work, and in considering the question of subsidence, we may omit the periods of observation and confine our attention to the intervals of rest.

(10). Bombay ——— A ——— B ——— C D ——— Madras.

If we level through from Bombay to Madras, and the bench-marks A, B, C, D are slowly sinking in the intervals, that occur between their connection by levelling from Bombay and the continuation of the levelling Madras-wards, each subsidence will introduce an error tending to make Madras too high. If for instance we make the height of A 100·471 feet, and before we have continued the levelling, the bench-mark at A subsides 0·005 foot, we ascribe to A when we recommence levelling the height of 100·471 which is too great by 0·005 foot, and this error will make our height of B too great by 0·005 foot. To counteract this evil it is of little use to level the first section from Bombay to A, and the second in the opposite direction from B to A. If the A mark has sunk in the interval between the first arrival of the levelling from Bombay, and the continuation of that levelling towards Madras, the height of B will be made too great, whether the levelling on the second section is from A to B or from B to A.

(11). Out of 66 main lines of levelling in India, 41 make the last bench-mark of the line too high, and 25 make it too low. (By the last bench-mark I mean the last that was reached by the levelling, or in other words the terminal point of the line with regard to the *direction of work*). On the 41 lines that have given heights too great, the average

* *See* last paragraph of page 78. When this paragraph was written, the results of the levelling revisions between Bombay and Madras had not been examined.

error per line as determined by the simultaneous adjustment of circuit errors is 0·206 foot: on the 25 lines that have given heights too small, the average error per line is 0·157.

(12). The average error accumulated on those lines of levelling, that have followed railway lines is considerably greater than the average error accumulated on those level-lines, that have followed roads*.

S. BURRARD.

11.

Line No. 17. Karwar to Hubli, (see *page 335.*)

This line is interesting, because several of the marks are upon rock: in these cases the discrepancies that have appeared may safely be attributed to errors of levelling, and movements of bench-marks may be disregarded. Between rock-cut mark $\frac{a}{1}$ and rock-cut mark 4, a discrepancy of $-0\cdot052$ foot was generated in 3·1 miles.

Between mark $\frac{a}{13}$ and mark 19 an immense error of $+\ 0\cdot671$ was introduced; neither of these bench-marks is however upon rock. That this discrepancy of 0·671 is not due to any recent disturbance of the bench-mark 19 is shown by the reappearance of a similar error at Hubli itself. The large error occurs during a sudden rise of road from 168 to 1776 feet in a length of only 13 miles: if it were to be attributed to error of staff-length, we should have to assume that the mean 10-foot staff in the original levelling was too long by 0·0042 foot. Studies of the staff-comparisons and of the accumulations of the levelling error on the minor ascents and descents of this same line show, that the four staves could not have had an error of 0·0042 foot in their mean length, and it is therefore out of the question to ascribe the great error of $+0\cdot671$ to staff-length. This error must be due either to some mistake made by the levellers, or to an exceptional accumulation of error on a very steep ascent, or to some bench-mark or peg between marks $\frac{a}{13}$ and 19 having risen, whilst the original operations were actually in progress.

12.

Line No. 16. Hubli to Bellary, (see *page 336.*)

On the Hubli-Bellary line too many bench-marks were placed upon mile-stones, and too few upon rock. Some of the mile-stones have been moved through several feet, and have had to be entirely rejected as bench-marks: many others have been shifted by smaller amounts. This is not the only line upon which evidence has been forthcoming, that mile-stones form very unsuitable positions for bench-marks. There were no embedded bench-marks on the original line of levelling.

The tables on pages 336 and 337 were prepared in the head-quarter office of the Trigonometrical Survey, but their correctness has been questioned by the levelling officers. The controversy has illustrated the difficulties of abstracting results from old records. The tables on pages 336 and 337 show a discrepancy of approximately a whole foot, running throughout the line, between the results of 1873-74 and those of 1907-1908; the levelling officers have maintained that this discrepancy of a foot has been incorrectly derived. The facts of the case are as follows:—

When the tables on pages 336 and 337 were being prepared, it was difficult to find a common starting-point at Hubli, from which to compare the levelling of 1873-74 with that of 1907-08. The first bench-mark on the list of page 336 was not laid down till 1878.

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* The statement in the last footnote of page 63 that several bench-marks have moved two feet is incorrect. There are instances of movements of two feet and more, but these movements have been due to the deliberate action of masons displacing the stones. Subsidences of 0·25 foot are common, and of 0·5 foot are occasionally met with.

In 1878 this bench-mark was connected by levelling with an arrow-headed bench-mark, that had been fixed and observed in 1873-74. The arrow-headed bench-mark was however not connected in 1907-08.

The first bench-mark of the list was adopted as the common starting point, and for purposes of comparison it was connected with the levelling of 1873-74 by means of the observations taken from it in 1878 to the arrow-headed mark. The tables on pages 336 and 337 are therefore in error to this extent, that the observations of 1873-74 have been supplemented by a measurement made in 1878.

The levelling officers have however pointed out, that in 1878 the arrow-headed bench-mark was found, when compared with two other bench-marks in Hubli, to be 1·153 feet higher than it was in 1873-74. The arrow-headed bench-mark had been cut on the upper surface of the upper step of the entrance to the verandah of the Travellers' Bungalow at Hubli, and it is difficult to account now for a change of 1·153 feet in its height. As this bench-mark at Hubli formed the basis of the comparisons made on pages 336 and 337, the rise in its height may be regarded as the cause of the discrepancies shown between the results of the old and new levelling. If a correction of + 1·153 feet be applied throughout the table, the discrepancies at the rock-cut marks will be:—

Bench-mark	Distance in miles	Discrepancy in foot
$\frac{i}{5}$	31	+ 0·339
$\frac{a}{11}$	59	+ 0·199
$\frac{a}{17}$	80	+ 0·203
$\frac{a}{20}$	89	+ 0·123
41	119	− 0·007
46	126	+ 0·111

13.

Line No. 43. Karachi to Tatta.

The south-end of the Karachi base-line was shown to have sunk 0·09 foot, *see* page 62.

14.

Portion of Line Burma A. Pyinmana to Mandalay, (see *page 338*).

The two terminals of the Bombay-Madras line both end at mean-sea-level, and our discussion of the discrepancies was facilitated by the certain knowledge, that mean-sea-level has not altered between 1877 and 1909. But when we come to the Burma line, we find that we have no fixed basis whatever. The line runs from Pyinmana to Mandalay: if we assume that the Pyinmana mark has remained undisturbed from 1892 to 1904, all the discrepancies become positive: if we assume that the Mandalay mark has remained undisturbed, the discrepancies become mostly negative. We have here no sea-level to start from.

The level-line from Rangoon tidal observatory to Pyinmana is actually being revised at the present time, so that any discussion of the discrepancy on the northern section, Pyinmana to Mandalay, will be premature and inconclusive.

The variations in the discrepancy between Pyinmana and Mandalay are as follows:—

		Discrepancy between original and revised levelling in foot	Change per mile *foot*
At Pyinmana	...	0·00	
			+ 0·110
At one mile	...	+ 0·11	
			+ 0·003
At 23 miles	...	+ 0·17	
			+ 0·007
At 39 miles	...	+ 0·28	
			+ 0·050
At 40 miles	...	+ 0·33	
			0·000
At 107 miles	...	+ 0·32	
			− 0·008
At 117 miles	...	+ 0·24	
			+ 0·001
At 135 miles	...	+ 0·27	
			+ 0·007
At 147 miles	...	+ 0·35	
			− 0·003
At 163 miles	...	+ 0·30	

The above values have been taken from localities, in which several discrepancies appear to be in close accord. A solitary individual discrepancy is probably due to the movement of one particular mark, but when many successive discrepancies appear constant in amount, we have to seek for some cause affecting the whole locality.

It is difficult to avoid the conclusion that the embedded bench-mark at Pyinmana has sunk from 0·150 to 0·350 foot, since it was erected. But as there is no reliable rock-cut mark in the vicinity, it will be difficult to determine the exact amount of subsidence, even when the revisionary levelling from Rangoon to Pyinmana has been completed.

The discrepancy at the embedded bench-mark at Shwemyo is out of harmony with the three preceding and the two succeeding discrepancies: the evidence goes to show that this Shwemyo mark has sunk, and our assumption, that the Pyinmana mark has sunk from 0·150 to 0·350 foot, leads to the conclusion that the Shwemyo mark has sunk from 0·116 to 0·316 foot.

The three bench-marks at Tatkon railway station all appear to have risen together; two of them are inscribed and one is embedded, and it is difficult to account for their common movement.

By rejecting exceptional movements of individual bench-marks, and by accepting only those discrepancies, that appear to be constant at successive bench-marks, we arrive at the following table:—

Bench-mark	Height above Pyinmana	Levelling discrepancy corrected by −0·150 foot for the supposed sinking of the Pyinmana bench-mark	Variation in the discrepancy	Variation in the discrepancy per foot of rise or fall
	feet	*foot*	*foot*	*foot*
Pyinmana	0	− 0·150		
			+ 0·130	+0·0012
$\frac{1}{244}$	+ 107	− 0·020		
			− 0·042	−0·0004
245	− 9	− 0·062		
			+ 0·249	+0·0006
$\frac{a}{281}$	+ 360	+ 0·187		
			− 0·039	−0·0001
$\frac{a_1}{344}$	− 87	+ 0·148		

On each occasion that the line is ascending, the levelling discrepancy increases, and on each occasion the line is descending, the levelling discrepancy decreases: the evidence is therefore strong that the discrepancies are in some measure due to errors in the adopted lengths of the staves used on either the original levelling or on the revisionary work or on both. The mean variation in the discrepancy per foot of rise or fall is 0·00055. If then we assume that the mean staff on the original levelling was too long by 0·00055 foot *per foot**, the discrepancies, that still remain unexplained, will be as shown in the following table:—

Bench-mark	Discrepancy. On the assumption that Pyinmana mark has not sunk and that staff length was correct	Discrepancy corrected by −0·350 foot for sinking of Pyinmana mark and corrected also for erroneous staff-length	Discrepancy corrected by −0·150 foot for sinking of Pyinmana mark and corrected also for erroneous staff-length
	foot	*foot*	*foot*
Pyinmana	0·000	− 0·350	− 0·150
$\frac{1}{244}$	+ 0·130	− 0·279	− 0·079
245	+ 0·088	− 0·257	− 0·057
249	+ 0·134	− 0·253	− 0·053
256	+ 0·195	− 0·204	− 0·004
265	+ 0·224	− 0·214	− 0·014
276	+ 0·346	− 0·193	+ 0·007
287	+ 0·347	− 0·162	+ 0·038
295	+ 0·246	− 0·219	− 0·019
$\frac{a}{310}$	+ 0·283	− 0·140	+ 0·060
326	+ 0·254	− 0·096	+ 0·104
337	+ 0·306	− 0·013	+ 0·187
$\frac{a_1}{344}$	+ 0·298	− 0·003	+ 0·197

One interesting fact brought to light by the Pyinmana–Mandalay revision is that the embedded bench-marks, which have hitherto been regarded as very permanent and above criticism, are even less reliable than the inscribed. All the inscribed bench-marks on both sides of Shwemyo show positive discrepancies of + 0·16 or + 0·17, and the levelling is clearly in error here by about 0·165†. But the embedded bench-mark shows a discrepancy of +0·034, which is out of accord with all the others. Within less than 7 miles there is another embedded bench-mark at Tatkon, and the discrepancy here is +0·437, also out of accord with neighbouring marks. The discrepancies at the embedded marks at Shanywa, and Meiktila show that the marks have sunk over 0·10 foot with regard to neighbouring marks: the embedded mark at Belin appears to have sunk relatively over 0·20 foot. The embedded marks at Thedaw and Samon appear now to be considerably higher than formerly.

* The results will be the same, if we assume the mean staff on the revisionary levelling to be too short by 0·00055 foot per foot.

† Pyinmana being taken as the reference datum.

As the whole Burma line is now under revision in the field, new and valuable results will shortly be at our disposal. As far as we have been able to judge from the limited data of the Pyinmana-Mandalay section of this line, the discrepancies between the old and the new Burma levelling may be attributed to four causes:—

(i). Sinking of the embedded bench-mark at Pyinmana, since the original levelling was completed.

(ii). Considerable errors in staff-lengths.

(iii). Movements of bench-marks both *during* and *after* the work of original levelling.

(iv). Errors of levelling observation.

The revision of the Burma line has shown that variations of the staff-lengths were not originally measured with sufficient frequency, and that the bench-marks were not erected with sufficient care. The level lines traverse a rocky country, and it is much to be regretted that the opportunity was not taken to cut bench-marks on the bed-rock. Railway-lines in Burma have proved unsuitable sites for permanent bench-marks, and the erection of embedded marks under railway platforms has been shown to be an useless expense. In many localities an embedded bench-mark has been the only mark erected with any consideration of permanence throughout a wide area, and this mark has been placed in the railway station, which was the worst position that could have been chosen.

Line No. 61A. Saharanpur to Mussooree, (see *page 342*).

The revisionary and the original levelling on the Saharanpur-Mussooree line give practically the same value of height to Mussooree: there has therefore been no accumulation of error generated on this line. Furthermore half the bench-marks of this line have been engraved upon rock, and there is therefore no question of local subsidence or individual disturbance. The whole level-line runs free from railways, and its embedded marks are situated in unfrequented places. A few of the marks are at the office of the Trigonometrical Survey and these have been carefully preserved. The levelling of line 61A is therefore most reliable: both the original and the revisionary operations were carried out on scientific principles: the route was favourable, and the bench-marks are trustworthy. The line crosses the Siwalik range of mountains near Mohan, and ascends the Lesser Himalaya between Rajpur and Mussooree.

The three Siwalik bench-marks at Mohan, Mohabawala and Dehra Dun base appear to have risen + 0·327, + 0·363 and + 0·390 respectively. The bench-marks in Dehra Dun appear to have risen + 0·441. The evidence tends to show that these rises are real, and that they cannot be attributed to errors of levelling, or to local disturbances of bench-marks. The discrepancies between the old and new levelling are not irregular like those on the Bombay-Madras and on the Burma lines. All the heights of the Siwalik and Dehra Dun bench-marks were uniformly greater in 1906 than they were in 1904. These changes in height have been attributed to the great earthquake of April 5th, 1905 which is supposed to have elevated the whole of the Dehra Dun region by about 0·4 foot.*

The only other explanation that we can offer of the large discrepancies in the middle of the line and of the absence of discrepancies at the two terminals, is that an error of 0·4 foot was generated between Saharanpur and Dehra Dun, either on the old or new levelling, and that a similar error but with an opposite sign was generated between Dehra Dun and Mussooree.

The rise from Saharanpur to Mussooree exceeds 6000 feet, and any error of staff-lengths would have a great cumulative effect at Mussooree; but there does not appear to be any reason for suspecting the staff-lengths in this instance. The levelling on the Saharanpur-Dehra Dun section was completed originally in 1861-62, and was revised in 1906-07. The staves used on the revisionary work were

* *Account of the Operations, G. T. Survey of India, Vol. XVIII,* preface, page V.

different from those used on the original. But on the Dehra Dun—Mussooree section the same staves, Nos. 04, 05, 01, and 03, were used in 1904 on the original work and in 1905 on the revision. If then the discrepancy at Dehra Dun of 0·4 foot is to be ascribed to an error of staff-length on the Saharanpur-Dehra Dun section, we shall have difficulty in explaining the cancelment of this error on the Dehra Dun-Mussooree section. Not only were the same staves used between Dehra Dun and Mussooree on both the original and revisionary work, but both operations were carried out in the same month of the year, the former in May 1904, the latter in May 1905. Whether the height of Mussooree has been given correct or not, is a question that we are not now considering, but the discrepancies between the original and revised results can hardly be attributed to staff-length, when the same four identical staves were used during both operations and at the same season.

As the Dehra Dun-Mussooree line is very steep, the greater portion of the line was levelled for a third time in October 1905. The maximum discrepancy at any mark between the second and third levellings was 0·06 foot.

The questions now at issue are the following:—Is the rise of 0·4 foot at Dehra Dun a real occurrence and an effect of the earthquake of 1905, or is it apparent only, and due to the unavoidable errors of levelling over steep ground? We cannot answer these questions, until we have deduced some formula to represent the probable error of levelling, and we propose to postpone consideration of the reliability of the spirit-level values of height in Dehra Dun to Part III of this volume.*

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* Part III, Chapter II.

LEVELLING OPERATIONS.

PART III.

THE SIMULTANEOUS REDUCTION OF THE LEVELLING NET-WORK.

A DISCUSSION OF THE LEVELLING ERRORS.

CHAPTER I.

THE SIMULTANEOUS REDUCTION OF THE LEVELLING NET-WORK.

The positions of the various lines, forming the level-net to be adjusted, are shown on plate XVI. These lines have been called the main-lines of levelling, (*vide* pages 5 to 12 of this volume).

On pages 20 to 24 is a list of the principal branch-lines of levelling. These emanate from main-lines and the greater number end after a short distance without having any further connection with the level-net, *vide* plate I. A few of the branch-lines, however, completely bisect main circuits and connect with bench-marks at both ends.

A comparison of plates I and XVI will show that lines 24A, 57A, and 60A divide large circuits of the level-net into smaller ones. They could not however be included among the main-lines of India, because they were not completed till 1909, and their results were not available, when the simultaneous reduction was undertaken.

The level-net is tied to sea-level at nine tidal stations, Karachi, Bombay, Karwar, Beypore, Cochin, Negapatam, Madras, Vizagapatam and False Point. The reasons for the acceptance of these nine stations and for the rejection of other tidal stations are fully explained in chapter VIII of this volume. An account of the tidal observations, from which the height of mean-sea-level at the nine accepted ports has been deduced, is also given in chapter VIII.

Before the simultaneous reduction was undertaken, the question of the weights to be assigned to the different main-lines was considered; and it was decided to make the weights of levelling results proportional to the reciprocals of the lengths of the lines. The reasons for this decision are set forth in the *Discussion of levelling errors*, in chapter II of part III of this volume. On page 114 we have shown that the probable error of a determination of mean-sea-level is 0·02 foot, and as this is small compared with the probable errors of levelling accumulated on the long main-lines of India, we have given infinite weight to the nine determinations of mean-sea-level.

In the level-net of India there are 86 main-lines of levelling, and these form 29 closed circuits. One of the circuits is necessarily redundant, for owing to the insularity of the Indian level-net the closing error of any one of the circuits is equal to the sum of the closing errors of the remaining 28 circuits.

Of the 29 circuits, 20 are inland and independent of tidal observations, and 9 are land-and-sea circuits, in which the levelling starts from one tidal observatory and ends at another.

The closing errors of circuits have been deduced on the assumption that the mean surface of the sea at Karachi, Bombay, Karwar, Beypore, Cochin, Negapatam, Madras, Vizagapatam, and False Point is at the same elevation.

The closing errors of the 29 circuits are shown in the following table:—

TABLE XXXVI.—Closing Errors of Circuits.

Circuit Number	Numbers of lines that form the circuit	Circuit	Length of circuit		Closing error of circuit	
			miles	*kilometres*	*feet*	*metre*
I	1, 2, 3, 4	Ramnad-Tanjore-Trichinopoly-Tuticorin-Ramnad	414·9	667·7	− 0·189	− 0·058
II	4, 6, 7, 8, 9, 10	Trichinopoly-Tanjore-Madras-Arkonam-Jalarpet-Erode-Trichinopoly	581·7	936·1	− 0·399	− 0·122
III	10, 14, 15, 18, 19	Jalarpet-Arkonam-Gooty-Bellary-Bangalore-Jalarpet	643·1	1035·0	− 0·625	− 0·190
IV	15, 21, 23	Bellary-Gooty-Raichur-Bellary	238·4	383·7	+ 0·086	+ 0·026
V	8, 14, 20, 21, 22, 24	Gooty-Arkonam-Madras-Bezwada-Gulbarga-Raichur-Gooty ...	1042·9	1678·4	− 0·069	− 0·021
VI	16, 22, 23, 26, 27, 29	Hubli-Bellary-Raichur-Gulbarga-Diksal-Nira-Hubli	813·2	1308·7	+ 0·416	+ 0·127
VII	25, 27, 28	Nira-Diksal-Kedgaon-Nira	115·8	186·4	+ 0·155	+ 0·047
VIII	24, 25, 26, 30, 31, 33, 35, 36, 37	Gulbarga-Bezwada-Vizagapatam-Vizianagram-Raipur-Nandgaon-Kalyan-Kedgaon-Diksal-Gulbarga.	1905·3	3066·3	− 0·267	− 0·081
IX	37, 38, 39, 40	Raipur-Vizianagram-Cuttack-Bilaspur-Raipur	1010·8	1626·7	− 0·464	− 0·141
X	34, 35, 38, 58, 60	Nandgaon-Raipur-Bilaspur-Katni-Sironj-Nandgaon	1396·9	2248·1	− 0·426	− 0·130
XI	40, 41, 58, 59, 70, 72, 74, 75	Bilaspur-Cuttack-Kendrapara-Howrah-Pirpanti-Dildarnagar-Allahabad-Katni-Bilaspur.	1673·4	2693·1	+ 0·920	+ 0·280
XII	59, 60, 63, 66, 67	Katni-Allahabad-Cawnpore-Agra-Sironj-Katni	920·0	1480·6	+ 0·098	+ 0·030
XIII	47, 48, 49, 50	Jorya-Rajkot-Viramgam-Shikarpur (Cutch)-Jorya	351·0	564·9	+ 0·521	+ 0·159
XIV	32, 33, 34, 44, 46, 50, 51, 52, 54, 57, 61, 62, 63	Bombay-Kalyan-Nandgaon-Sironj-Agra-Meerut-Ferozepore-Murghai-Shikarpur (Sind)-Sujawal-Navanar-Shikarpur (Cutch)-Viramgam-Bombay.	2758·3	4439·0	− 1·409	− 0·429
XV	45, 52, 53	Tatta-Sujawal-Shikarpur (Sind)-Tatta	613·4	987·2	+ 0·151	+ 0·046
XVI	55, 56, 57	Chach-Murghai-Ferozepore-Chach	1017·7	1637·8	+ 0·474	+ 0·144
XVII	73, 74, 76, 77	Purnea-Pirpanti-Howrah-Ramganj-Purnea	708·4	1140·0	+ 1·466	+ 0·447
XVIII	62, 64, 65, 66	Meerut-Agra-Cawnpore-Lucknow-Meerut	635·3	1022·4	+ 0·679	+ 0·207
XIX	65, 67, 68, 69, 70	Lucknow-Cawnpore-Allahabad-Dildarnagar-Gorakhpur-Lucknow ...	609·5	980·9	− 0·275	− 0·084
XX	69, 71, 72, 73	Gorakhpur-Didarnagar-Pirpanti-Purnea-Gorakhpur	815·2	1311·9	− 0·809	− 0·247
XXI	43, 44, 45, 46, 47, 48, 49, 51, 78, 79	Sea level-Bombay-Viramgam-Rajkot-Jorya-Shikarpur (Cutch)-Navanar-Sujawal-Tatta-Karachi-Sea level.	959·7	1544·5	+ 0·327	+ 0·100
XXII	17, 28, 29, 31, 32, 79, 80	Sea level-Karwar-Hubli-Nira-Kedgaon-Kalyan-Bombay-Sea level ...	561·7	904·0	− 0·078	− 0·024
XXIII	7, 11, 12, 16, 17, 18, 19, 80, 81	Sea level-Beypore-Shoranur-Erode-Jalarpet-Bangalore-Bellary-Hubli-Karwar-Sea level.	802·0	1290·7	− 0·473	− 0·144
XXIV	12, 13, 81, 82	Sea level-Cochin-Shoranur-Beypore-Sea level	113·1	182·0	+ 0·084	+ 0·026
XXV	1, 2, 3, 5, 6, 11, 13, 82, 83	Sea level-Negapatam-Tanjore-Ramnad-Tuticorin-Trichinopoly-Erode-Shoranur-Cochin-Sea level.	701·1	1128·3	− 0·425	− 0·130
XXVI	5, 9, 83, 84	Sea level-Madras-Tanjore-Negapatam-Sea level	269·2	433·2	+ 0·504	+ 0·154
XXVII	20, 30, 84, 85	Sea level-Vizagapatam-Bezwada-Madras-Sea level	508·6	818·5	− 0·044	− 0·013
XXVIII	36, 39, 41, 42, 85, 86	Sea level-False Point-Kendrapara-Cuttack-Vizianagram-Vizagapatam-Sea level.	374·9	603·3	+ 0·125	+ 0·038
XXIX	42, 43, 53, 54, 55, 56, 61, 64, 68, 71, 75, 76, 77, 78, 86	Sea level-Karachi-Tatta-Shikarpur (Sind)-Murghai-Chach-Ferozepore-Meerut-Lucknow-Gorakhpur-Purnea-Ramganj-Howrah-Kendrapara-False Point-Sea level.	3001·9	4831·0	− 0·054	− 0·016

The 29th circuit is redundant, and its closing error is equal to the sum of the 28 other closing errors.

A + sign for the closing error indicates that the elevation as computed round the circuit in a counter-clockwise direction is too great.

The lengths given for circuits, of which the sea forms one side, do not include over-sea distances.

For the simultaneous reduction of the levelling net-work by the method of minimum squares, the observed difference of elevation on each line furnishes an equation of observation: there are thus 86 equations of observation, and the elevations of the 58 junction-points of the net form the several independent unknowns.

The following table shows the equations of observation:—

TABLE XXXVII.—Equations of observation, and the corrections furnished by the simultaneous reduction.

Line Number	From	To	Page on which details of observation are given	Observed difference of dynamic height without sign	Correction by simultaneous reduction = x		Corrected difference of dynamic height, showing elevation +, or depression −.		Length of line	
				feet	*foot*	*centimetres*	*feet*	*metres*	*miles*	*kilometres*
1	Tanjore	Ramnad	137	173·418	+ 0·041	+ 1·250	− 173·459	− 52·869	114·8	184·8
2	Ramnad	Tuticorin ...	138	13·161	+ 0·026	+ 0·792	− 13·187	− 4·019	74·6	120·1
3	Tuticorin ...	Trichinopoly ...	139	267·100	− 0·069	− 2·103	+ 267·031	+ 81·390	194·4	312·8
4	Trichinopoly ...	Tanjore	142	80·332	+ 0·053	+ 1·615	− 80·385	− 24·501	31·1	50·1
5	Tanjore	Negapatam ...	143	183·513	+ 0·144	+ 4·389	− 183·657	− 55·978	48·3	77·7
6	Trichinopoly ...	Erode	144	265·253	+ 0·117	+ 3·566	+ 265·370	+ 80·883	87·0	140·0
7	Jalarpet	Erode	146	780·506	− 0·045	− 1·372	− 780·461	− 237·880	110·9	178·5
8	Arkonam ...	Madras	148	277·274	+ 0·127	+ 3·871	− 277·401	− 84·550	44·1	71·0
9	Madras	Tanjore	149	177·923	− 0·361	− 11·003	+ 177·562	+ 54·120	219·3	352·9
10	Arkonam ...	Jalarpet	153	1026·341	+ 0·036	+ 1·097	+ 1026·377	+ 312·834	89·3	143·7
11	Erode	Shoranur ...	155	441·990	− 0·202	− 6·157	− 441·788	− 134·655	116·0	186·7
12	Shoranur ...	Beypore	157	82·932	− 0·013	− 0·396	− 82·919	− 25·273	47·3	76·1
13	Shoranur ...	Cochin	158	90·762	− 0·097	− 2·957	− 90·665	− 27·634	65·7	105·7
14	Arkonam ...	Gooty	159	905·395	+ 0·531	+ 16·185	+ 905·926	+ 276·121	215·4	346·6
15	Bellary	Gooty	162	281·092	+ 0·131	+ 3·993	− 281·223	− 85·715	50·7	815·9
16	Bellary	Hubli	164	578·596	+ 0·436	+ 13·289	+ 579·032	+ 176·486	137·3	221·0
17	Hubli	Karwar	165	2047·816	− 0·296	− 9·022	− 2047·520	− 624·073	102·7	165·3
18	Jalarpet	Bangalore ...	166	1792·023	0·000	0·000	+ 1792·023	+ 546·199	85·8	138·1
19	Bangalore ...	Bellary	168	1631·252	− 0·001	− 0·030	− 1631·251	− 497·196	201·9	324·9
20	Bezwada ...	Madras	171	49·974	+ 0·166	+ 5·060	− 50·140	− 15·282	277·1	445·9
21	Raichur	Gooty	176	110·375	− 0·010	− 0·305	− 110·365	− 33·639	96·5	155·3
22	Raichur	Gulbarga ...	178	179·382	− 0·064	− 1·951	+ 179·318	+ 54·655	89·9	144·7
23	Bellary	Raichur	179	170·803	+ 0·055	+ 1·676	− 170·858	− 52·077	91·2	146·8
24	Gulbarga ...	Bezwada ...	181	1422·383	+ 0·487	+ 14·843	− 1422·870	− 433·683	319·9	514·8
25	Kedgaon ...	Diksal	186	118·224	− 0·020	− 0·610	− 118·204	− 36·028	30·6	49·2
26	Diksal	Gulbarga ...	187	168·800	+ 0·139	+ 4·237	− 168·939	− 51·492	170·6	274·5
27	Diksal	Nira	189	135·912	+ 0·078	+ 2·377	+ 135·990	+ 41·449	52·9	85·1
28	Kedgaon ...	Nira	190	17·843	− 0·057	− 1·737	+ 17·786	+ 5·421	32·3	52·0
29	Nira	Hubli	191	265·721	− 0·078	− 2·377	+ 265·643	+ 80·966	271·3	436·7
30	Bezwada ...	Vizagapatam ...	195	51·511	+ 0·212	+ 6·462	− 51·723	− 15·765	229·9	369·9
31	Kalyan	Kedgaon ...	199	1750·957	− 0·132	− 4·023	+ 1750·825	+ 533·642	120·0	193·1

TABLE XXXVII.—Equations of observation, and the corrections furnished by the simultaneous reduction.—(Continued).

Line Number	From	To	Page on which details of observation are given	Observed difference of dynamic height without sign	Correction by simultaneous reduction = x		Corrected difference of dynamic height, showing elevation +, or depression −		Length of line	
				feet	*foot*	*centimetres*	*feet*	*metres*	*miles*	*kilometres*
32	Kalyan ...	... Bombay ...	... 201	5·399	− 0·104	− 3·170	− 5·295	− 1·614	34·5	55·5
33	Kalyan ...	... Nandgaon	... 202	1529·254	− 0·279	− 8·504	+ 1528·975	+ 466·023	146·6	235·9
34	Nandgaon	... Sironj ...	... 205	75·285	+ 0·364	+ 11·095	− 75·649	− 23·057	408·8	657·9
35	Nandgaon	... Raipur ...	... 209	594·722	+ 0·538	+ 16·398	− 595·260	− 181·432	529·7	852·4
36	Vizianagram	... Vizagapatam	... 219	176·597	+ 0·067	+ 2·042	− 176·664	− 53·846	40·2	64·7
37	Vizianagram	... Raipur ...	... 220	767·629	+ 0·333	+ 10·150	+ 767·962	+ 234·071	317·8	511·4
38	Raipur ...	... Bilaspur	... 224	75·308	− 0·002	− 0·061	− 75·306	− 22·953	68·9	110·8
39	Cuttack ...	... Vizianagram	... 226	116·811	− 0·154	− 4·694	+ 116·657	+ 35·556	253·5	407·9
40	Bilaspur ...	... Cuttack ...	... 231	808·668	+ 0·645	+ 19·659	− 809·313	− 246·674	370·6	596·5
41	Kendrapara	... Cuttack ...	... 237	53·285	+ 0·047	+ 1·433	+ 53·332	+ 16·255	41·5	66·8
42	Kendrapara	... False Point	... 238	5·849	+ 0·038	+ 1·158	− 5·887	− 1·794	30·4	48·9
43	Karachi ...	... Tatta ...	... 239	29·824	− 0·007	− 0·213	+ 29·817	+ 9·088	67·7	109·0
44	Navanar ...	... Sujawal ...	... 241	19·113	− 0·189	− 5·761	+ 18·924	+ 5·768	208·5	335·5
45	Sujawal ...	... Tatta ...	... 243	10·036	− 0·003	− 0·091	+ 10·033	+ 3·058	21·1	34·0
46	Navanar ...	... Shikarpur (Cutch)	... 244	44·021	+ 0·079	+ 2·408	+ 44·100	+ 13·441	87·5	140·8
47	Shikarpur (Cutch)	... Jorya ...	... 245	34·573	+ 0·086	+ 2·621	− 34·659	− 10·564	74·8	120·4
48	Jorya ...	.. Rajkot ..	... 246	385·715	− 0·050	− 1·524	+ 385·665	+ 117·549	43·4	69·8
49	Rajkot ...	... Viramgam	... 247	315·256	+ 0·122	+ 3·719	− 315·378	− 96·125	105·2	169·3
50	Viramgam	... Shikarpur (Cutch)	... 248	35·365	+ 0·263	+ 8·016	− 35·628	− 10·859	127·6	205·4
51	Viramgam	... Bombay ...	... 249	70·118	− 0·318	− 9·693	− 69·800	− 21·275	350·6	564·2
52	Sujawal ...	... Shikarpur (Sind)	... 254	165·226	− 0·221	− 6·736	+ 165·005	+ 50·293	282·2	454·1
53	Tatta ...	... Shikarpur (Sind)	... 258	155·039	− 0·067	− 2·042	+ 154·972	+ 47·235	310·1	499·0
54	Shikarpur (Sind)	... Murghai ...	... 261	99·802	− 0·131	− 3·993	+ 99·671	+ 30·379	130·6	210·1
55	Murghai ...	... Chach ...	... 262	721·369	+ 0·068	+ 2·073	+ 721·437	+ 219·890	427·4	687·9
56	Chach ...	... Ferozepore	... 263	369·874	− 0·045	− 1·372	− 369·829	− 112·722	278·3	447·9
57	Murghai ...	... Ferozepore	... 267	351·969	− 0·361	− 11·003	+ 351·608	+ 107·168	312·0	502·1
58	Bilaspur ...	... Katni ...	... 268	369·723	+ 0·349	+ 10·637	+ 370·072	+ 112·796	196·5	316·2
59	Katni ...	... Allahabad	... 273	956·019	− 0·078	− 2·377	− 955·941	− 291·365	161·5	260·0
60	Katni ...	... Sironj ...	... 277	224·596	+ 0·249	+ 7·589	+ 224·845	+ 68·531	193·0	310·6
61	Ferozepore	... Meerut ...	... 281	93·896	− 0·268	− 8·169	+ 93·628	+ 28·537	267·8	430·9
62	Meerut ...	... Agra ...	... 282	223·110	+ 0·218	+ 6·645	− 223·328	− 68·069	133·1	214·2
63	Agra ...	... Sironj ...	... 283	963·149	− 0·108	− 3·292	+ 963·041	+ 293·530	268·5	432·1
64	Meerut ...	... Lucknow	... 284	355·763	− 0·182	− 5·547	− 355·581	− 108·379	284·8	458·4
65	Lucknow	... Cawnpore	... 289	23·443	+ 0·071	+ 2·164	+ 23·514	+ 7·167	49·4	79·5
66	Cawnpore	... Agra ...	... 290	108·531	+ 0·208	+ 6·340	+ 108·739	+ 33·143	168·0	270·3
67	Cawnpore	... Allahabad	... 292	109·033	− 0·027	− 0·823	− 109·006	− 33·224	129·0	207·6
68	Lucknow	... Gorakhpur	... 294	129·505	+ 0·130	+ 3·962	− 129·635	− 39·512	162·4	261·3

TABLE XXXVII.—Equations of observation, and the corrections furnished by the simultaneous reduction.—(Continued).

Line Number	From	To	Page on which details of observation are given	Observed difference of dynamic height without sign	Correction by simultaneous reduction = x		Corrected difference of dynamic height, showing elevation +, or depression −.		Length of line	
				feet	foot	centimetres	feet	metres	miles	kilo-metres
69	Gorakhpur ...	Dildarnagar ...	296	29·735	− 0·040	− 1·219	− 29·695	− 9·051	142·1	228·6
70	Allababad ...	Dildarnagar ...	298	73·925	− 0·087	− 2·652	− 73·838	− 22·505	126·6	203·7
71	Gorakhpur ...	Purnea	300	134·710	+ 0·391	+ 11·918	− 135·101	− 41·178	361·7	582·0
72	Dildarnagar ...	Pirpanti	303	69·977	− 0·266	− 8·108	− 69·711	− 21·248	274·6	441·8
73	Purnea	Pirpanti	305	35·807	− 0·112	− 3·414	+ 35·695	+ 10·880	36·8	59·2
74	Howrah	Pirpanti	306	135·363	+ 0·524	+ 15·971	+ 135·887	+ 41·418	251·1	404·0
75	Kendrapara ...	Howrah	308	2·688	− 0·028	− 0·853	− 2·660	− 0·811	251·0	403·9
76	Purnea	Ramganj ...	312	112·060	+ 0·136	+ 4·145	+ 112·196	+ 34·197	68·8	110·7
77	Howrah	Ramganj ...	314	213·082	− 0·694	− 21·153	+ 212·388	+ 64·735	351·7	566·0
78	Mean-sea-level ...	Karachi	317	8·949	0·000	0·000	+ 8·949	+ 2·728	0·1	0·16
79	Mean-sea-level ...	Bombay	"	19·740	− 0·003	− 0·091	+ 19·737	+ 6·016	0·8	1·29
80	Mean-sea-level ...	Karwar	"	11·766	0·000	0·000	+ 11·766	+ 3·586	0·1	0·16
81	Mean-sea-level ...	Beypore	"	14·314	0·000	0·000	+ 14·314	+ 4·363	0·02	0·03
82	Mean-sea-level ...	Cochin	"	6·568	0·000	0·000	+ 6·568	+ 2·002	0·1	0·16
83	Mean-sea-level ...	Negapatam ...	"	9·608	0·000	0·000	+ 9·608	+ 2·928	0·2	0·32
84	Mean-sea-level ...	Madras	"	15·702	+ 0·002	+ 0·061	+ 15·704	+ 4·786	1·4	2·25
85	Mean-sea-level ...	Vizagapatam ...	318	14·121	0·000	0·000	+ 14·121	+ 4·304	0·2	0·32
86	Mean-sea-level ...	False Point ...	"	14·898	+ 0·011	+ 0·335	+ 14·909	+ 4·544	9·1	14·64

A + sign affixed to a difference of height indicates that the elevation of the last bench-mark of the line is greater than that of the first.

The weights assigned to the various lines are, as mentioned above, proportional to the reciprocals of the lengths of the lines in miles.

The value of x given after each equation of observation is the correction resulting from the simultaneous adjustment; it has been shown both in decimals of a foot and in centimetres.

As the lines of level, which connect the nine tidal bench-marks with the sea, are short, it was at first intended to assign to them infinite weight in the simultaneous reduction and to accept as correct the dynamic heights given on page 117. Eventually, however, it was decided to make no difference between the treatment of these short lines and that of the long main-lines of levelling, and weights were assigned to all, proportional to the reciprocals of their lengths.

In the following table we show the heights of the tidal bench-marks, *firstly*, as observed, and *secondly*, as corrected by the simultaneous reduction. With the exception of False Point the corrections furnished by the simultaneous reduction are so minute, that the results hardly differ from what they would have been, had we assigned infinite weight to the short lines of level connecting the marks with the sea.

TABLE XXXVIII.

Tidal Station	Observed value of dynamic height from page 117	Correction furnished by the simultaneous reduction	Adopted value of dynamic height	Distance from the sea
	feet	*foot*	*feet*	*miles*
Karachi ...	8·949	0·000	8·949	0·1
Bombay ...	19·740	− 0·003	19·737	0·8
Karwar ...	11·766	0·000	11·766	0·1
Beypore ...	14·314	0·000	14·314	0·02
Cochin ...	6·568	0·000	6·568	0·1
Negapatam ...	9·608	0·000	9·608	0·2
Madras ...	15·702	+ 0·002	15·704	1·4
Vizagapatam ...	14·121	0·000	14·121	0·2
False Point ...	14·898	+ 0·011	14·909	9·1

From the simultaneous reduction of the level-net, the following values of elevation were obtained for the 49 junction points of the net, and for the 9 tidal bench-marks.

TABLE XXXIX.—Corrected elevations of 49 junction bench-marks and of 9 tidal bench-marks above mean-sea-level.

Name of the junction or tidal bench-mark, tidal marks being printed in italics	Dynamic height above mean-sea-level	Orthometric height above mean-sea-level		Name of the junction or tidal bench-mark, tidal marks being printed in italics	Dynamic height above mean-sea-level	Orthometric height above mean-sea-level	
	feet	*feet*	*metres*		*feet*	*feet*	*metres*
Agra	515·317	515·199	157·031	Kedgaon	1775·857	1776·468	541·463
Allahabad	297·572	297·542	90·690	Kendrapara	20·796	20·801	6·340
Arkonam	293·105	293·283	89·392	Lucknow	383·064	382·986	116·733
Bangalore	3111·505	3113·399	948·955	*Madras*	15·704	15·714	4·790
Bellary	1480·254	1481·016	451·410	Meerut	738·645	738·372	225·054
Beypore	14·314	14·324	4·366	Murghai	293·409	293·303	89·398
Bezwada	65·844	65·874	20·078	Nandgaon	1554·007	1554·377	473·770
Bilaspur	883·441	883·556	269·305	Navanar	9·809	9·810	2·990
Bombay	19·737	19·743	6·018	*Negapatam*	9·608	9·615	2·931
Cawnpore	406·578	406·507	123·902	Nira	1793·643	1794·300	546·898
Chach	1014·846	1014·063	309·084	Pirpanti	154·023	154·009	46·942
Cochin	6·568	6·573	2·003	Purnea	118·328	118·313	36·061
Cuttack	74·128	74·145	22·599	Raichur	1309·396	1310·005	399·286
Diksal	1657·653	1658·240	505·427	Raipur	958·747	958·920	292·276
Dildarnagar	223·734	223·712	68·187	Rajkot	404·915	404·961	123·431
Erode	539·021	539·384	164·403	Ramganj	230·524	230·486	70·252
False Point	14·909	14·913	4·545	Ramnad	19·807	19·822	6·042
Ferozepore	645·017	644·679	196·496	Shikarpur (Cutch)	53·909	53·912	16·432
Gooty	1199·031	1199·648	365·649	Shikarpur (Sind)	193·738	193·682	59·034
Gorakhpur	253·429	253·379	77·229	Shoranur	97·233	97·300	29·657
Gulbarga	1488·714	1489·322	453·941	Sironj	1478·358	1478·343	450·595
Howrah	18·136	18·138	5·528	Sujawal	28·733	28·732	8·757
Hubli	2059·286	2060·327	627·982	Tanjore	193·266	193·400	58·948
Jalarpet	1319·482	1320·308	402·426	Tatta	38·766	38·764	11·815
Jorya	19·250	19·252	5·868	Trichinopoly	273·651	273·840	83·466
Kalyan	25·032	25·040	7·632	Tuticorin	6·620	6·625	2·019
Karachi	8·949	8·949	2·728	Viramgam	89·537	89·542	27·292
Karwar	11·766	11·772	3·588	*Vizagapatam*	14·121	14·126	4·306
Katni	1253·513	1253·527	382·072	Vizianagram	190·785	190·855	58·172

On the completion of the simultaneous reduction of the levelling-net, the corrected values of dynamic elevation for all bench-marks in India were computed.

The correct elevations of the junction points and of the terminals of lines being given, the corrections to the observed heights of intermediate bench-marks on the main-lines were interpolated between the terminal points. In the interpolation on any particular line the corrections were assumed to vary at an uniform rate along the line.

For any branch-line, that terminates without a second connection with a main-line or with sea-level, a constant correction was applied throughout, equal to the correction applied to the height of its junction-point with the main-line.

For branch-lines, such as 24A and 57A, which start from and close upon a main-line, the closing error at the terminal point was distributed throughout the line, corrections to heights being made proportional to distance from starting point and being obtained by interpolation. Line 25A from Dhond to Manmad was a line of single-levelling, and as its closing error was unduly large, the results of the whole line were rejected. As there is a new standard bench-mark at Ahmednagar, line 25A will have to be revised at an early date.

The following table shows the circuit errors of those branch-lines, which have closed upon a bench-mark of the main level-net :—

TABLE XL.—The closing errors of branch-lines.

Branch-line	Point of origin	Terminal point	Length	Difference of elevation between origin and terminal	Height of terminal point according to the		Closing error of branch-line		
					simultaneous reduction	branch-line	Total	Per mile	
			miles	feet	feet	feet	feet	foot	
24A. Hyderabad-Wardha	B. M. 88 of line 24	B. M. 309 of line 35	283·7	− 846	885·616	885·681	+ 0·065	+ 0·0002	Error dispersed uniformly along the branch-line 24A.
25A. Dhond-Manmad	B. M. 8 of line 25	B. M. 123 of line 33	154·1	+ 213	1898·889	1897·816	− 1·073	− 0·0070	Owing to large closing error the branch-line 25A has been rejected
57A. Ferozepore-Ahmedabad	B. M. 27 of line 57	B. M. 22 of line 51	708·5	− 477	167·714	166·919	− 0·795	− 0·0011	Error dispersed uniformly along the branch-line 57A.
60A. Katni-Nagpur	B. M. 1 of line 60	B. M. 372 of line 35	221·6	− 241	1012·508	1012·332	− 0·176	− 0·0008	Error dispersed uniformly along the branch-line 60A.
61A. Saharanpur-Dehra Dún; 61B. Nojli-Hardwar; 61C. Hardwar-Dehra Dún	These three branch-lines form a circuit	...	115·2	...	...	...	− 0·151	− 0·0013	Error dispersed uniformly round the circuit.

The branch-lines 61A, 61B, 61C form a circuit 115·2 miles long, which is independent of the level-net, *vide* plate I. The closing error of this circuit 0·151 was distributed uniformly around the circuit, corrections being made proportional to distance.*

In addition to the nine tidal observatories, which form the base-stations of the level-net, there are 13 tidal observatories connected with the net. At four of these 13, (namely at Tuticorin, Cocanada, Navanar and Hanstal) the tidal bench-marks are bench-marks of main-lines. At Bombay (Prince's Dock) the tidal bench-mark is an extra bench-mark of line 32. At Pamban, Mormugao, Okha, Bhavnagar, Port Albert Victor, Dublat, Diamond Harbour, and Kidderpore the tidal bench-marks are connected by branch-lines.

* In the first foot-note on page 58 it was stated, that the closing error of the Hardwar-Dehra Dún-Mohan circuit was 0·847 foot, and that we were endeavouring by revisions of levelling to localise this error, which seemed unduly large. Whilst this volume has been passing through the press a mistake of a whole foot in the original computations was discovered by the levelling officers carrying out the revision. The closing error was therefore reduced from + 0·847 foot to − 0·153 foot, and this latter again has been changed to − 0·151 foot.

Tidal determinations at the ports mentioned in the following table were not allowed to influence the accepted values of heights of bench-marks*. The discrepancies between the tidal and spirit-levelled values of heights were ascribed to permanent inequalities of mean-sea-level. The correction given by interpolation on a main-line, such as 47, to the elevation of the starting-point of its branch-line 47A, has been continued throughout that branch-line. The closing error at Hanstal is only − 0·015 foot, but it was not considered advisable to accept Hanstal and to reject Okha, and both were rejected. (*See* page 126). The tidal determinations at Hanstal and Navanar were based upon one year's observations only (*see* page 110).

TABLE XLI.—Tidal determinations of mean-sea-level which were not allowed to influence the branch-lines of levelling.

Tidal observatory		How connected with level-net	Length of branch-line connecting with level-net	Dynamic height of reference bench-mark		Closing error of levelling
Position	Name			by tidal observations	by levelling observations	
			miles	*feet*	*feet*	*feet*
Gulf of Manar ...	Tuticorin ...	Reference bench-mark is bench-mark No. 40 of main-line 2, No. 1 of main-line 3, No. 1 of branch-line 3A.	0·0	6·933	6·620	− 0·313
At mouth of the Godavari.	Cocanada ...	Reference bench-mark is bench-mark No. 127 of main-line 30.	0·0	5·958	6·239	+ 0·281
Open coast, Arabian Sea.	Bombay, Prince's Dock.	Reference bench-mark is connected by a short minor branch-line to main-line 32.	0·3	19·688	19·724	+ 0·036
At entrance to the Gulf of Cutch.	Okha ...	Reference bench-mark is connected by branch-line 47A (Jorya-Okha) to level-net.	111·7	10·423	9·819	− 0·604
In the Gulf of Cutch	Navanar ...	Reference bench-mark is the initial bench-mark of the two main-lines, 44 and 46.	0·0	9·930	9·809	− 0·121
In the Gulf of Cutch	Hanstal ...	Reference bench-mark is bench-mark No. 14 of main-line 47.	0·0	9·701	9·686	− 0·015
Gulf of Cambay ...	Bhavnagar ...	Reference bench-mark is connected by branch-line 48A (Rajkot-Bhavnagar) to level-net.	109·6	20·663	20·217	− 0·446
Gulf of Cambay ...	Port Albert Victor.	Reference bench-mark is connected by a part (Rajkot-Sanoshra) of branch-line 48A (Rajkot-Bhavnagar) and by branch-line 48B (Sanoshra-Port Albert Victor) to level-net.	147·0	10·666	10·163	− 0·503
Near the mouth of the Hooghly.	Dublat ...	Reference bench-mark is connected by branch-line 74B (Kidderpore-Dublat) to level-net.	99·5	8·836	9·268	+ 0·432
Near the mouth of the Hooghly.	Diamond Harbour. ...	Reference bench-mark is connected by branch-line 74A (Kidderpore-Diamond Harbour) to level-net.	28·8	10·944	12·124	+ 1·180
On the Hooghly ...	Kidderpore ...	Reference bench-mark is connected by a minor branch-line to main-line 77.	1·1	13·003	16·173	+ 3·170

* Heights of reference bench-marks were determined from tidal observations as follows:—

	G. T. S. Vol. XVI		Dynamic correction	Dynamic height		G. T. S. Vol. XVI		Dynamic correction	Dynamic height
	Page	Height above mean-sea-level				Page	Height above mean-sea-level		
		feet		*feet*			*feet*		*feet*
Tuticorin ...	57	6·938	− 0·005	6·933	Bhavnagar ...	28	20·666	− 0·003	20·663
Cocanada ...	90	5·961	− 0·003	5·958	Port Albert Victor	25	10·668	− 0·002	10·666
Bombay (Prince's Dock) ...	37	19·694	− 0·006	19·688	Dublat ...	102	8·837	− 0·001	8·836
Okha ...	23	10·424	− 0·001	10·423	The height of the bench-mark at Dublat, as given in Vol. XVI, is too small by 4·829 feet.				
Navanar ...	19	9·931	− 0·001	9·930	Diamond Harbour	106	10·945	− 0·001	10·944
Hanstal ...	21	9·702	− 0·001	9·701	Kidderpore ...	110	13·004	− 0·001	13·003

The closing error of levelling between mean-sea-level at Okha and mean-sea-level at Hanstal is 0·604 − 0·015 = 0·589 foot, and between Navanar and Hanstal is 0·121 − 0·015 = 0·106 foot. On page 126 these closing errors were stated to be 0·571 and 0·093. The discrepancies between page 126 and table XLI are due to the fact, that the simultaneous reduction of the circuit errors has given small corrections to the levelling results. The figures of page 126 are results uncorrected for the simultaneous adjustment, those of table XLI are corrected. The discrepancies between the figures for Kidderpore, Diamond Harbour and Dublat, as given on page 126 and in table XLI, are due to the same cause.*

Mean-sea-level at Hanstal at the head of the Gulf of Cutch is 0·589 foot (= 0·180 metre) higher than at Okha at the entrance to the Gulf of Cutch. This difference of sea-level has hitherto been ascribed to a permanent elevation of the water in the gulf above the level of the open sea produced by south-west winds. Table XLI shows this explanation to be incorrect: the level of the head of the gulf at Hanstal is almost identical with the level of the open sea. Instead of the Hanstal level being too high, it now appears that the sea-level at Okha is 0·604 foot (= 0·184 metre) too low.

At Bhavnagar and Port Albert Victor the sea-level is also lower than the surface of the open sea, by 0·446 foot (= 0·136 metre) and 0·503 foot (= 0·153 metre) respectively. At Dublat, Diamond Harbour and Kidderpore the mean level of the water is higher than the surface of the open sea by 0·432 foot (= 0·132 metre) and 1·180 feet (= 0·360 metre) and 3·170 feet (= 0·966 metre) respectively.

The tidal determinations of mean-sea-level at the two following ports were accepted,† when the elevations of bench-marks over the branch-lines connecting the ports with the level-net were being deduced.

TABLE XLII.—Tidal determinations of mean-sea-level, which were accepted as correct, and which were utilised to adjust the heights on the branch-lines of levelling.

Tidal observatory		Branch-line of levelling connecting observatory with level-net	Length of branch-line connecting with level-net	Dynamic height of reference bench-mark		Closing error of levelling	
Position	Name			by tidal observations	by levelling observations	Total	Per mile of branch-line
			miles	*feet*	*feet*	*foot*	*foot*
Gulf of Manar ...	Pamban ...	1A. Ramnad − Pamban ...	27·8	7·465	7·334	− 0·131	0·0047
Open coast, Arabian Sea.	Mormugao ...	17A. Karwar-Mormugao ...	56·9	12·297	12·516	+ 0·219	0·0038

When the corrected dynamic heights of all bench-marks had been deduced, the corresponding orthometric heights were computed. Complete lists of bench-marks with descriptions and corrected elevations, both dynamic and orthometric, were then prepared, and are now being published in volumes XIXA and XIXB.

* The following table shows the discrepancies.

	Closing error as given on		Discrepancies due to simultaneous adjustment
	page 126	page 371	
	feet	*feet*	*foot*
Diamond Harbour-False Point	0·958	1·180	0·222
Diamond Harbour-Dublat ...	0·777	(1·180 − 0·432) = 0·748	0·029
Kidderpore-Diamond Harbour	1·872	(3·170 − 1·180) = 1·990	0·118
Kidderpore-False Point ...	2·830	3·170	0·340

† Heights of reference bench-marks were determined from tidal observations as follows:—

	G. T. S. Vol. XVI		Dynamic correction	Dynamic height
	Page	Height above mean-sea-level		
		feet		*feet*
Pamban ...	75	7·471	− 0·006	7·465
Mormugao ...	41	12·303	− 0·006	12·297

It was at first intended to give a complete catalogue of bench-marks with their descriptions and elevations in the present volume, but this plan had to be abandoned, when the great bulk of such a catalogue came to be realised. The total number of bench-marks exceeds 15000, and it was found more convenient to publish the descriptive lists separately.

In the present volume XIX we have shown how the levelling observations have been taken, and how the results have been computed; the final values of height resulting from these operations are about to be published in volumes XIXA and XIXB. Volume XIXA will describe the bench-marks on the southern levelling lines, 1 to 42; and volume XIXB will give details of the northern lines, 43 to 77. The few bench-marks of the nine short lines, 78 to 86, to tidal stations are common to other lines, and these nine lines have consequently been excluded from volumes XIXA and XIXB. The boundary line between volumes XIXA and XIXB will run from Bombay through Sironj, Nagpur, Bilaspur to False Point.

CHAPTER II.

A DISCUSSION OF THE LEVELLING ERRORS.

1.

The principal sources of error in levelling and the precautions taken to eliminate their effects have been already described in chapter V, Part I.

We now propose to examine the results of the levelling, and to endeavour to ascertain the forms and magnitudes of the errors that in spite of precautions have crept into the levelling work.

When the adjustment of the level-net, as described in this volume, was first taken in hand, the subject of levelling errors had not been investigated, and the relationship between accumulation of error and length of level-line had not been determined. The uncertainty, which had existed for years, is reflected, not only in the earlier survey reports and pamphlets, but in this volume itself.

In the last foot-note of page 73, errors are assumed to be accidental and to accumulate with the square root of the distance. In the first foot-note of page 74 it is suggested that errors may be systematic and may accumulate directly with the distance. On page 92 Colonel Hill's estimate of the rate of accumulation of error is given as 0·0008 foot *per mile*, and on page 93 as 0·0010 foot *per mile*. On page 114 two successive assumptions are made, when levelling and tidal results are being compared. It is, firstly, assumed that the probable error of levelling at the end of M miles is $\overset{foot}{0{\cdot}004}\sqrt{M}$, and then it is supposed that the probable error is $\overset{foot}{0{\cdot}0007}$ M.

In tables XXX and XXXI, pages 123, 124, the probable error of levelling is derived from the formula $\overset{foot}{0{\cdot}004}\sqrt{M}$, but on page 124 this formula is stated to give too small results. On page 125 the closing errors of tables XXXII and XXXIII have been treated, firstly, as if the accumulation of error were proportional to M, and, secondly, as if it were proportional to $\sqrt{M}$.

It may be argued that the preparation of this volume should have been postponed, until all uncertainties had been cleared up. But the simultaneous adjustment of the closing errors of the level-net was urgently required, and it was not practicable to postpone this work, until the law governing the accumulation of error had been discovered. The investigations, described in the present chapter, were made after the simultaneous reduction of the circuit errors had been completed, and are in fact the sequel of that reduction.

Moreover rough and ready comparisons have frequently to be made in discussions of results, and a complex formula is then not sufficiently convenient. In the examination, which was made in section (3) of Part II, pages 343-360, the discrepancies between the original and revised levelling operations were continually considered, as though they had increased directly with the distance: this may not have been strictly correct, but it was a convenient approximation, and answered its purpose.

It is very necessary, even after the simultaneous reduction has been carried out, that we should try and obtain some idea of the law of error. Before we can accept any apparent changes in the elevation of land as real, we must find the limit of accuracy, beyond which our levelling cannot be trusted. What is the probable error of the difference in height of two points one mile apart? What is the probable error of the spirit-levelled height of any bench-mark in India? These are questions we must endeavour to answer.

The aims of the discussion proposed for this chapter may then be stated as follows:—(i.) to discover the law of accumulation of error of levelling in India, (ii.) to obtain a definite numerical measure of the accuracy of spirit-levelled heights.

The data at our disposal may be classed as follows:—

(i). the discrepancies (d) between levellers at successive bench-marks;

(ii). the discrepancies (s) between levellers, as accumulated at the ends of level-lines;

(iii). the closing errors of levelling circuits.

Revisions of levelling have taught us the causes of gross errors, *vide* section (3) of Part II, pages 343-360, but they will not help us to understand the accumulation of minute errors, because in India we have so far revised only those lines, that are obviously in error by large amounts. For revisions to be instructive we must revise lines on which accumulation of error has been small.

2.

Deduction of the probable accidental error of levelling per mile from the discrepancies between levellers.

(1). At the foot of each table on pages 137-316 we have already computed for each line the probable error of one mile of levelling from the formula*—

$$e_1 = \pm\, 0{\cdot}6745 \sqrt{\frac{\Sigma d^2}{4\ \text{M}}}$$

where d is the discrepancy between levellers at any bench-mark.

Σd^2 will be too large, if there exists any systematic cause of discrepancy between levellers, such as an error in the length of one staff. On the other hand Σd^2 is generally apt to be too small on simultaneous double-levelling owing to the bias of the second leveller in favour of the first leveller's result.

The quantity e_1 is dependent *upon the assumption* that levelling error increases with the square root of the distance.

(2). We can also deduce the probable error of levelling from the discrepancy accumulated between the two levellers at the terminal bench-mark of each line: thus if s is the total discrepancy between

* Wright's Treatise on the *Adjustment of Observations*. 1st edition, page 376. We have not deduced Σd^2 strictly correctly: Σd^2 should be the summation of the discrepancies at every point for which the level was erected: we have made it the summation of discrepancies at bench-marks only. But no sensible error has been introduced, as d^2 at any bench-mark $= d_1^2 + d_2^2 + d_3^2 + \cdots$, where d_1, d_2, d_3 are the discrepancies at the pegs erected between bench-marks.

levellers at the terminal bench-mark accumulated over the whole line, the probable error* of the difference of elevation between the first and last bench-marks will be $\pm\ 0{\cdot}6745 \times \frac{s}{2}$. Then if e_2 be the probable error of one mile of levelling,

$$e_2 = \pm\ 0{\cdot}6745 \times \frac{s}{2\sqrt{M}}.$$

The quantity e_2, like e_1, is dependent upon the assumption that levelling errors are wholly accidental.

In the following table we compare e_1 and e_2 :—

TABLE XLIII.—Probable errors of levelling per mile deduced from the internal evidence furnished by the levelling observations on each line.

Line No.	Line	Length	Difference of elevation of terminal bench-marks	e_1 per mile	e_2 per mile	e_1 per kilometre	e_2 per kilometre
		miles	*feet*	*foot*	*foot*	*centimetre*	*centimetre*
1	Tanjore-Ramnad	115	− 173	± 0·0043	± 0·0028	± 0·104	± 0·067
2	Ramnad-Tuticorin	75	− 13	0·0026	0·0000	0·064	0·000
3	Tuticorin-Trichinopoly	194	+ 267	0·0043	0·0040	0·104	0·098
4	Trichinopoly-Tanjore	31	− 80	0·0050	0·0012	0·122	0·027
5	Tanjore-Negapatam	48	− 184	0·0035	0·0011	0·085	0·027
6	Trichinopoly-Erode	87	+ 265	± 0·0043	± 0·0055	± 0·104	± 0·131
7	Jalarpet-Erode	111	− 781	0·0035	0·0032	0·085	0·076
8	Arkonam-Madras	44	− 277	0·0024	0·0002	0·058	0·006
9	Madras-Tanjore	219	+ 178	0·0039	0·0019	0·095	0·046
10	Arkonam-Jalarpet	89	+ 1026	0·0036	0·0065	0·085	0·156
11	Erode-Shoranur	116	− 442	± 0·0033	± 0·0047	± 0·079	± 0·113
12	Shoranur-Beypore	47	− 83	0·0036	0·0012	0·085	0·027
13	Shoranur-Cochin	66	− 91	0·0035	0·0005	0·085	0·012
14	Arkonam-Gooty	215	+ 905	0·0021	0·0003	0·052	0·006
15	Bellary-Gooty	51	− 281	0·0061	0·0024	0·146	0·058
16	Bellary-Hubli	137	+ 579	± 0·0033	± 0·0029	± 0·079	± 0·070
17	Hubli-Karwar	103	− 2048	0·0038	0·0059	0·092	0·143
18	Jalarpet-Bangalore	86	+ 1792	0·0044	0·0141	0·107	0·339
19	Bangalore-Bellary	202	− 1631	0·0043	0·0002	0·104	0·006
20	Bezwada-Madras	277	− 50	0·0040	0·0028	0·098	0·067
21	Raichur-Gooty	97	− 110	± 0·0032	± 0·0005	± 0·076	± 0·012
22	Raichur-Gulbarga	90	+ 179	0·0041	0·0019	0·098	0·046
23	Bellary-Raichur	91	− 171	0·0032	0·0023	0·076	0·055
24	Gulbarga-Bezwada	320	− 1422	0·0048	0·0262	0·116	0·631
25	Kedgaon-Diksal	31	− 118	0·0037	0·0063	0·088	0·151
26	Diksal-Gulbarga	171	− 169	± 0·0033	± 0·0046	± 0·079	± 0·110
27	Diksal-Nira	53	+ 136	0·0047	0·0065	0·113	0·156
28	Kedgaon-Nira	32	+ 18	0·0052	0·0001	0·125	0·003
29	Nira-Hubli	271	+ 266	0·0051	0·0030	0·122	0·073
30	Bezwada-Vizagapatam	230	− 52	0·0039	0·0070	0·095	0·168
31	Kalyan-Kedgaon	120	+ 1751	± 0·0033	± 0·0009	± 0·079	± 0·022
32	Kalyan-Bombay	35	− 5	0·0015	0·0018	0·037	0·043
33	Kalyan-Nandgaon	147	+ 1529	0·0037	0·0039	0·088	0·095
34	Nandgaon-Sironj	409	− 75	0·0046	0·0022	0·110	0·053
35	Nandgaon-Raipur	530	− 595	0·0046	0·0009	0·110	0·022
36	Vizianagram-Vizagapatam ...	40	− 177	± 0·0032	± 0·0012	± 0·076	± 0·029
37	Vizianagram-Raipur	318	+ 768	0·0048	0·0039	0·116	0·095
38	Raipur-Bilaspur	69	− 75	0·0038	0·0032	0·092	0·077
39	Cuttack-Vizianagram	254	+ 117	0·0033	0·0010	0·079	0·024
40	Bilaspur-Cuttack	371	− 809	0·0042	0·0074	0·101	0·177
41	Kendrapara-Cuttack	42	+ 53	± 0·0033	± 0·0030	± 0·079	± 0·073
42	Kendrapara-False Point	30	− 6	0·0023	0·0016	0·055	0·040
43	Karachi-Tatta	68	+ 30	0·0047	0·0012	0·113	0·029
44	Navanar-Sujawal	209	+ 19	0·0043	0·0031	0·104	0·075
45	Sujawal-Tatta	21	+ 10	0·0033	0·0022	0·079	0·053

* Probable error of a mean result $= \pm\ 0{\cdot}6745\sqrt{\frac{\Sigma\, e^2}{n(n-1)}}$: in the present case $\epsilon = \frac{s}{2}$, and $n = 2$.

TABLE XLIII.—Probable errors of levelling per mile deduced from the internal evidence furnished by the levelling observations on each line.—(Continued).

Line No.	Line	Length	Difference of elevation of terminal bench-marks	e_1 per mile	e_2 per mile	e_1 per kilometre	e_2 per kilometre
		miles	*feet*	*foot*	*foot*	*centimetre*	*centimetre*
46	Navanar-Shikarpur (Cutch) ...	88	+ 44	± 0·0028	± 0·0006	± 0·067	± 0·015
47	Shikarpur (Cutch)-Jorya	75	− 35	0·0049	0·0011	0·119	0·027
48	Jorya-Rajkot	43	+ 386	0·0034	0·0019	0·082	0·046
49	Rajkot-Viramgam	105	− 315	0·0039	0·0006	0·095	0·015
50	Viramgam-Shikarpur (Cutch) ...	128	− 35	0·0062	0·0022	0·149	0·052
51	Viramgam-Bombay	351	− 70	± 0·0038	± 0·0033	± 0·092	± 0·079
52	Sujawal-Shikarpur (Sind) ...	282	+ 165	0·0020	0·0012	0·049	0·027
53	Tatta-Shikarpur (Sind)	310	+ 155	0·0046	0·0102	0·110	0·247
54	Shikarpur (Sind)-Murghai... ...	131	+ 100	0·0044	0·0060	0·107	0·143
55	Murghai-Chach	427	+ 721	0·0081	0·0007	0·195	0·018
56	Chach-Ferozepore	278	− 370	± 0·0033	± 0·0014	± 0·079	± 0·034
57	Murghai-Ferozepore	312	+ 352	0·0062	0·0108	0·149	0·259
58	Bilaspur-Katni	197	+ 370	0·0037	0·0037	0·088	0·088
59	Katni-Allahabad	162	− 956	0·0037	0·0037	0·088	0·088
60	Katni-Sironj	193	+ 225	0·0032	0·0046	0·076	0·110
61	Ferozepore-Meerut	268	+ 94	± 0·0046	± 0·0135	± 0·110	± 0·326
62	Meerut-Agra	133	− 223	0·0026	0·0055	0·064	0·131
63	Agra-Sironj	269	+ 963	0·0030	0·0050	0·073	0·122
64	Meerut-Lucknow	285	− 356	0·0041	0·0049	0·098	0·119
65	Lucknow-Cawnpore	49	+ 23	0·0028	0·0023	0·067	0·055
66	Cawnpore-Agra	168	+ 109	± 0·0022	± 0·0020	± 0·052	± 0·049
67	Cawnpore-Allahabad	129	− 109	0·0029	0·0033	0·070	0·079
68	Lucknow-Gorakhpur	162	− 130	0·0027	0·0043	0·064	0·104
69	Gorakhpur-Dildarnagar	142	− 30	0·0023	0·0021	0·055	0·052
70	Allahabad-Dildarnagar	127	− 74	0·0019	0·0010	0·046	0·024
71	Gorakhpur-Purnea	362	− 135	± 0·0039	± 0·0010	± 0·095	± 0·024
72	Dildarnagar-Pirpanti	275	− 70	0·0037	0·0063	0·088	0·153
73	Purnea-Pirpanti	37	+ 36	0·0043	0·0046	0·104	0·110
74	Howrah-Pirpanti	251	+ 135	0·0032	0·0021	0·076	0·052
75	Kendrapara-Howrah	251	− 3	0·0037	0·0043	0·088	0·104
76	Purnea-Ramganj	69	+ 112	± 0·0032	± 0·0037	± 0·076	± 0·088
77	Howrah-Ramganj	352	+ 213	0·0032	0·0024	0·076	0·058

For all India

$e_1 = \pm\ 0{\cdot}0042$ foot per mile, or $\pm\ 0{\cdot}101$ centimetre per kilometre,

$e_2 = \pm\ 0{\cdot}0062$ foot per mile, or $\pm\ 0{\cdot}149$ centimetre per kilometre.

Mean length of line = 165·6 miles = 266·5 kilometres.

The value of e_1 for all India has been derived from a combination of the values of e_1 for the several lines; thus

$$e_1 \text{ for India} = \sqrt{\frac{[e_1^2 l]}{[\ l\ ]}}$$

For each successive line the value of e_1^2 is multiplied by the length of the line, and the sum of the products is divided by the sum of the lengths of the lines.

Similarly

$$e_2 \text{ for India} = \sqrt{\frac{[e_2^2 l]}{[\ l\ ]}}$$

The value of e_1 for India is $\pm\ 0{\cdot}0042$ foot, and of e_2 is $\pm\ 0{\cdot}0062$.

3.

Deduction of the systematic error of levelling from the discrepancies generated between levellers.

If the divergence between the levellers is due to accidental errors only, e_2 will be equal to e_1, but if the divergence is due to systematic error, e_2 will be greater than e_1. If e_2 is sensibly greater than e_1, it is a proof that there was existing some systematic cause of discrepancy. From table XLIII we see that e_1 and e_2 are generally in agreement, but the following discordances are indications of the existence of systematic error :—

Line No.	Line	e_1	e_2
		foot	*foot*
18	Jalarpet-Bangalore ...	±0·0044	±0·0141
61	Ferozepore-Meerut ...	0·0046	0·0135
24	Gulbarga-Bezwada ...	0·0048	0·0262

Between Jalarpet and Bangalore the ground rises 1792 feet, and the large value of e_2, 0·0141, was probably due to errors of staff-length. As the observations on the line Jalarpet-Bangalore have been shown by the simultaneous adjustment to be free from sensible error, it appears probable, that one of the levellers adopted too small values for his staves and the other adopted too large, and that although the discrepancy between them constantly grew, their mean result continued correct. The line Ferozepore-Meerut traverses flat plains, and we cannot account for the appearance of a systematic difference between levellers. Between Gulbarga and Bezwada on line 24 (*see* pages 181 to 185) a most extraordinary divergence between levellers occurred: in the first 50 miles it had accumulated to 0·069: at 100 miles it was 0·166: at 200 miles it was 0·557: and at 319 miles it was 1·391.*

* The divergence between the levellers on the Gulbarga-Bezwada line was so extraordinary, that the original records have been recently (1910) submitted to experts for examination. The observations were taken partly in 1880, and partly in 1889. Whether the divergence attracted much attention at the time, we cannot now tell, but no reference to it is to be found in published reports. It was a question in 1909, whether the line Gulbarga-Bezwada should not be rejected and revised. It was, however, accepted eventually as one of the main-lines of the net. It formed part of the circuits V and VIII, the closing errors of which were 0·069 foot and 0·267 foot. After the simultaneous reduction had been completed, branch-line 24A closed on the Gulbarga-Bezwada line at Hyderabad (*see* plate I) with an error of 0·065 foot.

Extract from a letter from Mr. C. F. Erskine, in charge of the levelling operations, to Colonel Burrard, dated May 11th, 1910.

(1.) I do not think it possible to attribute the large closing difference on the line Gulbarga-Bezwada wholly to errors of staff comparisons. If this closing difference is to be so explained, we shall have to assume, that staff comparisons were in error by 0·01 foot, and this would mean the width of one whole graduation. The levellers moreover did not complain of their staves.

(2.) The zero of old staves was at the foot of the brass. When in use the staff rested on a small brass brad only, and therefore the entire sole of the shoe would not have been likely to wear away 0·01 foot evenly.

(3.) When the wood of staves shrinks, and a slight separation from the brass occurs, the position of the zero of the staff before separation is marked on the brass for use during the staff comparisons.

(4.) The discrepancy between levellers might have been partially, if not wholly, due to the employment of a wrong value for a level scale. On the line Gulbarga-Bezwada no attempt was made to cancel the level corrections. On all other lines precautions have been taken, in accordance with General Walker's instructions, to prevent accumulations of level error.

(5.) On the line Gulbarga-Bezwada the orders restricting the greatest permissible difference between levellers at each station to 0·005 foot appear to have been totally ignored, and this has naturally caused a large divergence. On opening the field-books at random, I find differences of 0·009 and 0·011.

Extract from a letter dated May 19th, 1910, from Captain Cowie, R.E., to Colonel Burrard.

I find the details connected with the Gulbarga-Bezwada line are as follows:—

Section	Bench-marks	Dates of observation	Staves used by		Dates of staff comparisons
			1st leveller	2nd leveller	
Gulbarga to Bider	1 to 40	Feb. 13th to March 8th, 1880	5, F	9, 10	1880, Feb. 12 and May 7
Bider to Hyderabad	40 to 99	May 6th to June 15th, 1889	4, 3	9, 10	1889, April 10 and June 18
Hyderabad to Bezwada	99 to 280	Nov. 2nd to Dec. 24th, 1889	4, 3	9, 10	1889, Nov. 1, Dec. 1, Dec. 21

I have compared the discrepancies between levellers with the changes in the height of the line. Between bench-marks 1 and 40, the discrepancies varied similarly to the height: between bench-marks 40 and 280, the discrepancies varied inversely with the height. Throughout the whole line an error of staff-length appears to have been causing the discrepancy between levellers to accumulate.

Between Gulbarga and Bider a discrepancy of 0·111 foot corresponded to a height of 575 feet. These figures would indicate the error in the relation between the two mean staves to be about 0·00193 foot.

Between Bider and Bezwada the error in the relation between the lengths of the two mean staves works out to 0·01754 and 0·01099 foot. These values are based upon the assumption, that the discrepancy between levellers was wholly due to error of staff-length. In view of the facts stated by Mr. Erskine that the levellers did not attempt to cancel errors of dislevelment, and that they habitually exceeded the limit of permissible error, we should not be justified in ascribing the whole discrepancy between levellers to errors of staves. The discrepancy was probably made up of several causes, of which error of staff-length was one.

The value of e_1 has been deduced from the formula

$$\pm 0{\cdot}6745 \sqrt{\frac{\Sigma d^2}{4\,M}}$$

and for all India it equals $\pm$ 0·0042 foot.

The value of e_2 has been deduced from the formula $\pm 0{\cdot}6745 \times \frac{s}{2\sqrt{M}}$ and for all India it equals $\pm$ 0·0062 foot.

The discordance between e_2 and e_1 for all India is due to the fact that e_2 has been more seriously affected by the systematic errors of levelling than e_1. It has been shown by Lallemand that the errors that go to produce the successive values of d, from which e_1 is derived, are *mainly* accidental, but if there are systematic errors tending to separate the results of the two levellers, they enter into e_2.*

If e_1 = probable error *per mile* = $\pm 0{\cdot}0042$ foot, then the probable error of the *terminal* result of a line of levelling = $E_1 = e_1\sqrt{M} = \pm\ 0{\cdot}0042\ \sqrt{M}$, where M = length of line in miles.

In section 2 of this chapter we regarded e_2 as accidental, but as we have now shown reasons for believing that e_2 is partly systematic, we may write
$e_2^2 = e_a^2 + e_s^2$, where e_a is the accidental component and e_s the systematic component.

For table XLIII we derived e_2, (being the probable error *per mile*), from the equation $e_2 = \pm\ 0{\cdot}6745 \times \frac{s}{2\sqrt{M}}$. If then E_2 is the probable error of the *terminal* result of a line of levelling,

$$E_2 = \pm\ 0{\cdot}6745\ \times \frac{s}{2}.$$

And E_2 (for all India) is equal to $\pm$ 0·0798 foot over a line of the average length of 165·6 miles. If E_a is the accidental component and E_s the systematic component of the probable error of the *terminal* result at the end of a line 165·6 miles long, $\sqrt{E_a^2 + E_s^2} = \pm\ 0{\cdot}0798$ foot.

As E_1 is mainly accidental, we may write $E_1 = E_a$.

We thus get two equations—

$$E_a = E_1 = \pm\ 0{\cdot}0042\sqrt{165{\cdot}6}$$

$$\sqrt{E_a^2 + E_s^2} = E_2 = \pm\ 0{\cdot}0798$$

$$E_a^2 + E_s^2 = 0{\cdot}00636804$$

$$\text{but} \quad E_a^2 = (0{\cdot}0042)^2 \times 165{\cdot}6 = 0{\cdot}00292118$$

$$\text{therefore} \quad E_s^2 = 0{\cdot}00344686.$$

$E_s = \pm\ 0{\cdot}05871$ = probable systematic error accumulated at the end of a line 165·6 miles long.

$$e_s = \frac{E_s}{M} = \frac{0{\cdot}05871}{165{\cdot}6} = \pm\ 0{\cdot}00035 \text{ foot} = \text{probable systematic error per mile of levelling.}$$

$$e_a = \pm\ 0{\cdot}0042 \text{ foot} = \text{probable accidental error per mile.}$$

The law governing the accumulation of error may thus be represented by the formula

$$\sqrt{e_a^2\,M + e_s^2\,M^2} = \sqrt{(0{\cdot}0042)^2\,M + (0{\cdot}00035)^2\,M^2}.$$

* *Nivellement de haute precision, par Charles Lallemand, 1889.*

It is hardly conceivable that all sources of systematic error are covered by the expression $\pm 0{\cdot}00035\,M$. We are justified in assuming that the systematic errors, *which tend to separate the results of levellers*, are represented in $\pm 0{\cdot}00035$ M. But there may be systematic errors, affecting the results of both levellers, and these exercise no influence upon the values of s or of e_2.

The formula for the law of error $\sqrt{(0{\cdot}0042)^2\, M + (0{\cdot}00035)^2\, M^2}$ has so far been derived from internal evidence only,— namely from the individual discrepancies and from the accumulated divergences between the two levellers. The external evidence will now be considered, but before this is done, it may not be out of place to show the relationships of E_1 and E_2 to both $\sqrt{M}$ and to M.

In the following table we show the values of E_1 and of E_2 for level-lines of various lengths.

If we calculate the probable errors of the terminal results of lines, and if we group these probable errors according to the lengths of the lines, we find that $\dfrac{E_1 \text{ for a short line}}{E_1 \text{ for a long line}} = \dfrac{\sqrt{\text{length of the short line}}}{\sqrt{\text{length of the long line}}}$, but that no such simple ratio seems applicable to E_2.

On page 379 E_1, the probable error of the terminal result of a line, was derived from the formula $E_1 = e_1 \sqrt{M}$. But E_1 can be derived directly from the discrepancies, and independently of $\sqrt{M}$. On pages 137 to 316 the value of E_1 for each line has been obtained from the formula $E_1 = \pm 0{\cdot}6745 \sqrt{\dfrac{\Sigma d^2}{4}}$.

Similarly for each line E_2 can be obtained independently of $\sqrt{M}$ from the formula $E_2 = \pm 0{\cdot}6745 \times \dfrac{s}{2}$. In the following table the average values of E_1 and E_2 are given for lines of different lengths. They are then divided in the table by $\sqrt{M}$, and finally by M. The fourth column of the table shows that E_1 is distinctly greater for long lines than for short; the sixth column shows that $\dfrac{E_1}{\sqrt{M}}$ has a fairly constant ratio for lines of all lengths; the eighth column shows that $\dfrac{E_1}{M}$ becomes smaller, as M increases. E_1 appears therefore in actual practice to vary with $\sqrt{M}$ and not with M. The last column of the table shows that the increase of E_2 is more obscure; it is in fact not clear whether in practice E_2 varies with $\sqrt{M}$ or with M.

TABLE XLIV.—Relation between the probable error of levelling and the length of line.

Lines	Number of lines	Mean Length = M	E_1	E_2	$\frac{E_1}{\sqrt{M}}$	$\frac{E_2}{\sqrt{M}}$	$\frac{E_1}{M}$	$\frac{E_2}{M}$
Under *50 miles* in length	14	37·9	·0207	·0123	·0034	·0020	·0005	·0003
Between *50 and 100 miles* in length ...	15	76·8	·0340	·0293	·0039	·0033	·0004	·0004
Between *100 and 150 miles* in length ...	14	124·5	·0393	·0360	·0035	·0032	·0003	·0003
Between *150 and 200 miles* in length ...	7	178·1	·0441	·0515	·0033	·0039	·0002	·0003
Between *200 and 250 miles* in length ...	5	215·0	·0545	·0371	·0037	·0025	·0003	·0002
Between *250 and 300 miles* in length ...	11	269·1	·0596	·0678	·0036	·0041	·0002	·0003
Between *300 and 350 miles* in length ...	4	315·0	·0906	·2270	·0051	·0128	·0003	·0007
Between *350 and 400 miles* in length ...	4	358·7	·0712	·0670	·0038	·0035	·0002	·0002
Exceeding *400 miles* in length ...	3	455·3	·1214	·0263	·0057	·0012	·0003	·0001

4.

The law of error as deduced from the closing errors of circuits.

Monsieur Lallemand in his *Nivellement de Haute Precision* attaches great weight to his deductions of the systematic error from the quantity s. We confess at first to having placed no reliance upon the quantity s.* It seemed only too probable that the value of s had been influenced by certain systematic errors only, and that other systematic errors had been affecting the results of both levellers alike. No great faith was therefore placed upon the value 0·00035 obtained for e_s on page 379, and it was considered advisable to deduce independent values for both e_a and e_s from the data furnished by the circuit errors.

The extraordinary agreement between the results obtained from the circuit errors and those obtained from the discrepancies and divergences between levellers came as a surprise; it seems to indicate that the value of s affords a better clue to systematic error than had been supposed.

In the following table we give the closing errors of the 28 circuits, and the probable accidental errors of closure calculated for the several circuits from the formula

$$E_1 = e_1 \sqrt{M} = 0{\cdot}0042 \sqrt{M}$$

TABLE XLV.—(in foot-miles.)

A comparison of the probable errors of closure, as deduced from discrepancies between levellers, with the actual closing errors.

Circuit	Length of circuit = M	Probable errors of closure = E_1 = $0{\cdot}0042\sqrt{M}$	Closing error of circuit × 0·6745 = C	C − E_1
	miles	*foot*	*foot*	*foot*
XXIV	113·1	0·0447	0·0567	+ 0·0120
VII	115·8	0·0452	0·1045	+ 0·0593
IV	238·4	0·0648	0·0580	− 0·0068
XXVI	269·2	0·0689	0·3399	+ 0·2710
XIII	351·0	0·0787	0·3514	+ 0·2727
XXVIII	374·9	0·0813	0·0843	+ 0·0030
I	414·9	0·0856	0·1275	+ 0·0419
XXVII	508·6	0·0947	0·0297	− 0·0650
XXII	561·7	0·0995	0·0526	− 0·0469
II	581·7	0·1013	0·2691	+ 0·1678
XIX	609·5	0·1037	0·1855	+ 0·0818
XV	613·4	0·1040	0·1018	− 0·0022
XVIII	635·3	0·1059	0·4580	+ 0·3521
III	643·1	0·1065	0·4216	+ 0·3151

* In the Indian levelling the two levellers work together, one immediately after the other. The value of s is therefore less useful than on the French levelling, where the levellers work in opposite directions.

TABLE XLV.—(in foot-miles).—(Continued).

A comparison of the probable errors of closure, as deduced from discrepancies between levellers, with the actual closing errors.

Circuit	Length of circuit = M	Probable errors of closure = E_1 = $0{\cdot}0042\sqrt{M}$	Closing error of circuit × 0·6745 = C	C – E_1
	miles	*foot*	*foot*	*foot*
XXV	701·1	0·1112	0·2867	+ 0·1755
XVII	708·4	0·1118	0·9888	+ 0·8770
XXIII	802·0	0·1189	0·3190	+ 0·2001
VI	813·2	0·1198	0·2806	+ 0·1608
XX	815·2	0·1199	0·5457	+ 0·4258
XII	920·0	0·1274	0·0661	− 0·0613
XXI	959·7	0·1301	0·2206	+ 0·0905
IX	1010·8	0·1335	0·3130	+ 0·1795
XVI	1017·7	0·1340	0·3197	+ 0·1857
V	1042·9	0·1356	0·0465	− 0·0891
X	1396·9	0·1570	0·2873	+ 0·1303
XI	1673·4	0·1718	0·6205	+ 0·4487
VIII	1905·3	0·1833	0·1801	− 0·0032
XIV	2758·3	0·2206	0·9504	+ 0·7298
XXIX	3001·9			

We will now repeat Table XLV substituting centimetres and kilometres for feet and miles. The probable accidental errors of closure are now calculated for the circuits from the formula $E_1 = e_1\sqrt{K}$ $= 0{\cdot}101\sqrt{K}$, where K is the length in kilometres.

TABLE XLVA.—(in metres).

A comparison of the probable errors of closure, as deduced from discrepancies between levellers, with the actual closing errors.

Circuit	Length of circuit = K	Probable errors of closure = E_1 = $0{\cdot}101\sqrt{K}$	Closing error of circuit × 0·6745 = C	C − E_1
	Kilometres	*Centimetres*	*Centimetres*	*Centimetres*
XXIV	182·0	1·3626	1·7269	+ 0·3643
VII	186·4	1·3788	3·1866	+ 1·8078
IV	383·7	1·9784	1·7680	− 0·2104
XXVI	433·2	2·1022	10·3615	+ 8·2593
XIII	564·9	2·4005	10·7110	+ 8·3105
XXVIII	603·3	2·4808	2·5698	+ 0·0890
I	667·7	2·6098	3·8856	+ 1·2758
XXVII	818·5	2·8896	0·9046	− 1·9850
XXII	904·0	3·0367	1·6036	− 1·4331
II	936·1	3·0902	8·2029	+ 5·1127
XIX	980·9	3·1633	5·6536	+ 2·4903
XV	987·2	3·1734	3·1043	− 0·0691
XVIII	1022·4	3·2295	13·9593	+ 10·7298
III	1035·0	3·2493	12·8491	+ 9·5998
XXV	1128·3	3·3926	8·7374	+ 5·3448
XVII	1140·0	3·4102	30·1389	+ 26·7287
XXIII	1290·7	3·6286	9·7242	+ 6·0956
VI	1308·7	3·6538	8·5524	+ 4·8986
XX	1311·9	3·6582	16·6319	+ 12·9737
XII	1480·6	3·8863	2·0147	− 1·8716
XXI	1544·5	3·9693	6·7227	+ 2·7534
IX	1626·7	4·0736	9·5392	+ 5·4656
XVI	1637·8	4·0874	9·7448	+ 5·6574
V	1678·4	4·1378	1·4185	− 2·7193
X	2248·1	4·7888	8·7580	+ 3·9692
XI	2693·1	5·2414	18·9139	+ 13·6725
VIII	3066·3	5·5928	5·4891	− 0·1037
XIV	4439·0	6·7292	28·9670	+ 22·2378
XXIX	4831·0			

Plate No. XVI shows that there are 29 circuits in the level-net, but as has been already explained on page 363, chapter I, Part III, one of these circuits is redundant. It is therefore necessary to reject one circuit, and we have thought it advisable to reject circuit XXIX. The closing error of this circuit is 0·054, and this is abnormally small. The length of the levelling in the circuit is 3001·9 miles; and if we regard the closing error 0·054 foot as systematic, it must have been accumulated at the rate of 0·000018 foot per mile. On the other hand if we regard the closing error as accidental, it has been accumulated at the rate of $0·001\sqrt{M}$. A systematic error of 0·000018M is one-twentieth of the normal, and an accidental error of $0·001\sqrt{M}$ is one quarter of the normal. It is evident that in circuit XXIX an extraordinary cancelment of errors must have taken place.

If E_1 was a correct measure of error, it should be less than C in as many circuits as it is more. But out of 28 circuits, there are only 7 in which E_1 is greater than C, and table XLV shows conclusively that E_1 is not a fair measure of the probable error of levelling in India. Not only does the number of positive values of $(C - E_1)$ exceed the number of negative values, but the magnitude of the positive values surpasses that of the negative. E_1 is evidently too small, and it is clear that the closures of circuits must be affected by other errors than those that tend to produce the quantity d, (*see* page 375). What are these other errors? Are they accidental, or are they systematic?

If the closing errors of circuits are mainly accidental, the probable error of one mile of levelling can be deduced from the circuits thus:

$$e_3 = \pm\, 0·6745\ \frac{\sqrt{\dfrac{c_1^{\,2}}{m_1} + \dfrac{c_2^{\,2}}{m_2} + \dfrac{c_3^{\,2}}{m_3} + \cdots}}{\sqrt{n_c}}$$

where c_1 = circuit error in feet of circuit I, c_2 of circuit II, etc.
m_1 = length in miles of circuit I, m_2 of circuit II, etc.
n_c = number of circuits.

Then $e_3 = \pm\, 0·0128$ foot.

If the closing errors of circuits are mainly systematic, the error on the line will tend to vary directly with the length of the line and not with the square root of the length, and the probable error of one mile of levelling will be

$$e_s = \pm \frac{0·6745\ \sqrt{\dfrac{c_1^{\,2}}{m_1^{\,2}} + \dfrac{c_2^{\,2}}{m_2^{\,2}} + \dfrac{c_3^{\,2}}{m_3^{\,2}}}}{\sqrt{n_c}} + \ \cdots$$

$$= \pm\, 0·00054 \text{ foot.}$$

If we adopt e_3 as the probable error, and take $0·0128\sqrt{M}$ as representing the law of accumulation, we shall find that, as a rule, it will give a larger value than the actual for the closing errors of short circuits and a smaller value than the actual for the closing errors of long circuits.

If on the other hand we adopt $e_s = \pm\, 0·00054$ as the probable error, and if we take $e_s \times M$ as the measure of accumulation of error, we shall find that the probable closing errors of long circuits will now be given larger than the actual closing errors, and that the probable closing errors of short circuits will be given too small.

The following table illustrates our meaning; the circuits have been arranged in order of their lengths, and the circuit error per mile has been shown for each circuit, firstly, on the supposition that the law of accumulation is $e \times M$, and, secondly, on the supposition that the law of accumulation is $e \times \sqrt{M}$.

TABLE XLVI.—The circuit errors exhibited according to lengths of circuits.

Circuit	Length of circuit = M	Circuit error	$\frac{\text{Circuit error}}{\text{length}}$	$\frac{\text{Circuit error}}{\sqrt{\text{length}}}$
	miles	*feet*	*foot*	*foot*
XXIV	113·1	0·084	0·00074	0·0079
VII	115·8	0·155	0·00134	0·0144
IV	238·4	0·086	0·00036	0·0056
XXVI	269·2	0·504	0·00187	0·0307
XIII	351·0	0·521	0·00148	0·0278
XXVIII	374·9	0·125	0·00033	0·0065
I	414·9	0·189	0·00046	0·0093
XXVII	508·6	0·044	0·00009	0·0020
XXII	561·7	0·078	0·00014	0·0033
II	581·7	0·399	0·00069	0·0165
XIX	609·5	0·275	0·00045	0·0111
XV	613·4	0·151	0·00025	0·0061
XVIII	635·3	0·679	0·00107	0·0269
III	643·1	0·625	0·00097	0·0247
XXV	701·1	0·425	0·00061	0·0161
XVII	708·4	1·466	0·00207	0·0551
XXIII	802·0	0·473	0·00059	0·0167
VI	813·2	0·416	0·00051	0·0146
XX	815·2	0·809	0·00099	0·0283
XII	920·0	0·098	0·00011	0·0032
XXI	959·7	0·327	0·00034	0·0106
IX	1010·8	0·464	0·00046	0·0146
XVI	1017·7	0·474	0·00047	0·0149
V	1042·9	0·069	0·00007	0·0021
X	1396·9	0·426	0·00030	0·0114
XI	1673·4	0·920	0·00055	0·0225
VIII	1905·3	0·267	0·00014	0·0061
XIV	2758·3	1·409	0·00051	0·0268
XXIX	3001·9	0·054		
Average of the 14 shorter circuits		...	0·00073	0·0138
Average of the 14 longer circuits		...	0·00055	0·0174

If we divide the circuit errors by the lengths (= M), we find that the average error per mile of the *short* circuits is 0·00073 and of the *long* circuits is 0·00055. This shows that M is too large a divisor, and that the error of levelling accumulates more slowly than M. If we divide the circuit errors by $\sqrt{M}$, the average error of the short circuits is 0·0138 and of the long circuits is 0·0174. This shows that $\sqrt{M}$ as a divisor is too small, and that the error of levelling accumulates more rapidly than $\sqrt{M}$.

In the one case the short circuits give the larger error, in the other case the long circuits give the larger error. The conclusions may be drawn, that a portion of the circuit errors is accidental and increases with $\sqrt{M}$, and that the remaining portion is systematic and increases with M.

Let it then be assumed that the probable error per mile of levelling is made up of two parts and is equal to

$$\sqrt{e_a^2 M + e_s^2 M^2},$$

where e_a and e_s are two constants to be determined.

We can determine the values of the constants e_a and e_s from the circuit errors, either by treating the latter by the method of minimum squares, or more simply by arbitrarily selecting certain of them as typical and representative. As a fair type of short circuit we can take the shortest of all, XXIV; as a type of long circuit we can select XIV. In both circuits, XXIV and XIV, the accidental and systematic errors appear to conspire, whereas the closing error of circuit XXIX is extraordinarily small and is evidently due to abnormal cancelment.

From circuit XXIV we form the following equation* :—

$$e_a^2 \times 113{\cdot}1 + e_s^2 \times (113{\cdot}1)^2 = (0{\cdot}084)^2 \times \frac{4}{9}$$

and from circuit XIV we get

$$e_a^2 \times 2758{\cdot}3 + e_s^2 \times (2758{\cdot}3)^2 = (1{\cdot}409)^2 \times \frac{4}{9}$$

$$e_a^2 + e_s^2 \times 113{\cdot}1 = \frac{4}{9} \times \frac{0{\cdot}007056}{113{\cdot}1} = 0{\cdot}0000624 \times \frac{4}{9}$$

$$e_a^2 + e_s^2 \times 2758{\cdot}3 = \frac{4}{9} \times \frac{1{\cdot}985281}{2758{\cdot}3} = 0{\cdot}0007197 \times \frac{4}{9}$$

$$e_s^2 = \frac{4}{9} \times \frac{0{\cdot}0006573}{2645{\cdot}2} = 0{\cdot}00000025 \times \frac{4}{9}$$

$$e_s = 0{\cdot}00033$$

$$\text{and } e_a = 0{\cdot}0037.$$

The values of e_a and e_s deduced from discrepancies between levellers were

$$e_a = 0{\cdot}0042$$

$$e_s = 0{\cdot}00035$$

The mean value of e_a is 0·0040 foot,—and of e_s is 0·00034 foot.

The formula expressing the relationship between the probable error of Indian levelling and the distance levelled may thus be written

$$E = \sqrt{(0{\cdot}004)^2 M + (0{\cdot}00034)^2 M^2}.$$

On page 384 we computed the probable error per mile e_3, on the supposition that the circuit errors were accumulations of accidental error, and we found that e_3 was equal to ± 0·0128. We now find that the probable accidental error per mile is equal to 0·004. The difference is due to the fact that the systematic component of the probable error was included in e_3 with the accidental component.

On page 384 we computed the probable error per mile e_s, on the supposition that the circuit errors were accumulations of systematic error only, and we found that e_s was equal to 0·00054 foot. We now find that the probable systematic error per mile is 0·00034 foot; the discrepancy is due to the inclusion of the accidental component on page 384.

* The (probable error)² is made equal to $\left(\frac{2}{3} \times \text{actual error}\right)^2$.

In the following table the actual closing errors of the circuits are compared with the probable errors of closure, deduced from the formula, which we obtained above.

TABLE XLVII.—(in foot-miles).

The probable errors of circuit-closure, deduced from the formula $\sqrt{(0.004)^2M + (0.00034)^2M^2}$, *compared with the actual closing errors of circuits.*

Circuit	Length of circuit = M	Closing error of circuit × 0·6745 = C	Probable error of levelling circuit = E = $\sqrt{(0.004)^2M+(0.00034)^2M^2}$	C − E
	miles	*foot*	*foot*	*foot*
XXIV	113·1	0·0567	0·0573	− 0·0006
VII	115·8	0·1045	0·0583	+ 0·0462
IV	238·4	0·0580	0·1019	− 0·0439
XXVI	269·2	0·3399	0·1126	+ 0·2273
XIII	351·0	0·3514	0·1409	+ 0·2105
XXVIII	374·9	0·0843	0·1492	− 0·0649
I	414·9	0·1275	0·1629	− 0·0354
XXVII	508·6	0·0297	0·1950	− 0·1653
XXII	561·7	0·0526	0·2132	− 0·1606
II	581·7	0·2691	0·2201	+ 0·0490
XIX	609·5	0·1855	0·2296	− 0·0441
XV	613·4	0·1018	0·2309	− 0·1291
XVIII	635·3	0·4580	0·2384	+ 0·2196
III	643·1	0·4216	0·2410	+ 0·1806
XXV	701·1	0·2867	0·2608	+ 0·0259
XVII	708·4	0·9888	0·2633	+ 0·7255
XXIII	802·0	0·3190	0·2953	+ 0·0237
VI	813·2	0·2806	0·2991	− 0·0185
XX	815·2	0·5457	0·2998	+ 0·2459
XII	920·0	0·0661	0·3355	− 0·2694
XXI	959·7	0·2206	0·3490	− 0·1284
IX	1010·8	0·3130	0·3664	− 0·0534
XVI	1017·7	0·3197	0·3688	− 0·0491
V	1042·9	0·0465	0·3774	− 0·3309
X	1396·9	0·2873	0·4979	− 0·2106
XI	1673·4	0·6205	0·5920	+ 0·0285
VIII	1905·3	0·1801	0·6709	− 0·4908
XIV	2758·3	0·9504	0·9611	− 0·0107

TABLE XLVIIA.—(*in metres*).

The probable errors of circuit-closure, deduced from the formula $\sqrt{(0{\cdot}004)^2 M + (0{\cdot}00034)^2 M^2}$, *compared with the actual closing errors of circuits.*

Circuit	Length of circuit = K	Closing error of circuit × 0·6745 = C	Probable error of levelling circuit = E = $\sqrt{(0{\cdot}101)^2 K + (0{\cdot}0064)^2 K^2}$	C – E
	Kilometres	*Centimetres*	*Centimetres*	*Centimetres*
XXIV	182·0	1·7269	1·7925	– 0·0656
VII	186·4	3·1866	1·8233	+ 1·3633
IV	383·7	1·7680	3·1535	– 1·3855
XXVI	433·2	10·3615	3·4793	+ 6·8822
XIII	564·9	10·7110	4·3397	+ 6·3713
XXVIII	603·3	2·5698	4·5894	– 2·0196
I	667·7	3·8856	5·0072	– 1·1216
XXVII	818·5	0·9046	5·9825	– 5·0779
XXII	904·0	1·6036	6·5341	– 4·9305
II	936·1	8·2029	6·7411	+ 1·4618
XIX	980·9	5·6536	7·0297	– 1·3761
XV	987·2	3·1043	7·0703	– 3·9660
XVIII	1022·4	13·9593	7·2970	+ 6·6623
III	1035·0	12·8491	7·3781	+ 5·4710
XXV	1128·3	8·7374	7·9784	+ 0·7590
XVII	1140·0	30·1389	8·0536	+ 22·0853
XXIII	1290·7	9·7242	9·0223	+ 0·7019
VI	1308·7	8·5524	9·1379	– 0·5855
XX	1311·9	16·6319	9·1585	+ 7·4734
XII	1480·6	2·0147	10·2418	– 8·2271
XXI	1544·5	6·7227	10·6520	– 3·9293
IX	1626·7	9·5392	11·1795	– 1·6403
XVI	1637·8	9·7448	11·2507	– 1·5059
V	1678·4	1·4185	11·5111	– 10·0926
X	2248·1	8·7580	15·1638	– 6·4058
XI	2693·1	18·9139	18·0152	+ 0·8987
VIII	3066·3	5·4891	20·4057	– 14·9166
XIV	4439·0	28·9670	29·1957	– 0·2287

Out of 28 circuits 17 show their actual closing errors (when multiplied by 0·6745) to be less than the theoretical probable errors of closure. Eleven show their closing errors (multiplied by 0·6745) to be greater than the probable errors.

If we were to reduce the value of E to $\sqrt{(0{\cdot}004)^2\,M + (0{\cdot}00030)^2M^2}$, then (C—E) would be positive in 14 circuits and negative in 14 circuits. But this reduction cannot be justified. Although the number of negative instances of (C—E) in table XLVII is 17, and of positive 11, yet the sum of the squares of the negative values of (C—E) is 0·5686, and of the positive is 0·7702. The positive though fewer in number give the larger sum.

If now we were to reduce the co-efficient of M^2 from 0·00034 to 0·00030, we should equalise the numbers of positive and negative values of (C—E), but the sum of the squares of the positive values of (C—E) would become increased to 0·8762 and that of the negative values would be decreased to 0·4070.

If we take the values of (C—E) as they stand in table XLVII the difference between the sums of the squares is 0·2016. If we were to reduce the co-efficient of M^2 from 0·00034 to 0·00030, the difference between the sums of the squares would become 0·4692.

The arguments that can be advanced in favour of the formula—

$$\text{probable error of levelling} = \sqrt{(0{\cdot}004)^2M + (0{\cdot}00034)^2M^2},$$

may be summarised as follows:—

(i). This formula is in accordance with the internal evidence derived from the discrepancies, *d* and *s*, between the two levellers.

(ii). This formula is in accordance with the external evidence, and satisfies simultaneously the closing errors of the very short circuit XXIV and of the very long circuit XIV.

(iii). This formula furnishes probable errors of closure, that agree generally with the actual errors of closure.

The evidence, supporting the formula, is therefore very strong.

On the other hand, it is hardly conceivable that all kinds of systematic errors are to be detected in the discrepancies between the two levellers. The sinking of bench-marks,—to take one instance only,—has been frequently known by experience to affect the results of both levellers similarly, when they have been working simultaneously in the same direction, and this source of systematic error affects the accuracy of the mean result of the levelling, but leaves the discrepancy between the two levellers untouched.

The deduction of the same value of systematic error from the circuit errors, as had already been derived from the discrepancies between levellers, was quite unexpected. It had been confidently predicted, that the circuit errors would display a larger accumulation of systematic error than had been found in the discrepancies.

The unexpected agreement may perhaps be explained by the following considerations:—

(i). There undoubtedly exist systematic errors which tend to increase closing errors of circuits, but which do not affect the divergence between levellers.

(ii). But there are also systematic errors which tend to increase the divergence between levellers, but which have no influence upon circuit errors.

As an example of an error affecting circuit closures, but which has no influence upon divergence between levellers, we have only to conceive that the last two or three bench-marks fixed by levelling at the close of a season suffer gradual subsidence during the summer when the operations are in abeyance.

On the return of the levellers at the commencement of the following season an error will at once creep into their work; this error will affect their circuit closures, but will cause no divergence between their results.

As an example of an error which has no effect upon circuit closures, but which would produce divergence between levellers, we have only to imagine one leveller adopting too large a value for the length of his staves and the second leveller adopting too small a value.

It may be argued, that if erroneous values for staves were adopted throughout a whole circuit, levelled continuously in one direction, the divergence between levellers, however it might increase during ascents or descents, would disappear at the closing point; but in practice circuits are not levelled continuously in one direction, and the divergence between levellers is calculated not for whole circuits, but for separate lines, which are portions of circuits.*

Although then there are systematic errors, which affect circuit closures, but which have no effect on divergences between levellers, there are also other sources of systematic error, which tend to produce divergence *on lines*, but which have no effect upon circuits.

The fact that the same formula $E = \sqrt{(0{\cdot}004)^2 M + (0{\cdot}00034)^2 M^2}$ has been derived, (1stly) from the divergence between levellers, and (2ndly) from the closing errors of circuits, is an indication that the systematic errors of levelling in India, which have tended to produce divergence between levellers without having effect on circuit closures, have on the whole been equal in magnitude to those systematic errors, which have tended to produce circuit closures, but which have been without effect on the divergence between levellers.

If the levelling circuits had all been observed continuously in the same direction many errors of levelling might have cancelled at the points of closure, and the fear might now have been entertained, that the closing errors of circuits were minima, and that greater errors were existing at intermediate points on the circuits than at the terminals. But the Indian circuits are all made up of several component lines, observed some in one direction, some in another, some in one year, some in another, some with old staves and standards, some with new; and if we take these varying conditions into consideration, we shall see, that no great tendency has existed for errors of levelling to cancel at the closing points of circuits.

Although the divergences between levellers may be unaffected by certain sources of error influencing the levelling as a whole, yet on the other hand, as we have already pointed out, divergences are apt to occur, even *when the mean levelling result is errorless.* We consider therefore that the formula

$$E = \sqrt{(0{\cdot}004)^2 M + (0{\cdot}00034)^2 M^2}$$

may be accepted as representing the relationship in India between accumulation of error and length of line, and that it gives a fair general idea of the accuracy attained by the Indian levelling during the half century, 1858 to 1908.

5.

The effect upon the probable error of changes in elevation.

In the last section we have shown the relationship between the probable error and the length of

* Let us suppose, for example, that we start from both western and eastern coasts, and level to a high point in India. As we ascend from the western coast, errors of staff-lengths cause an increasing divergence between levellers. A similar divergence is caused, as we ascend from the eastern coast. Now if we regard the two lines as one continuous line from coast to coast, the accumulated divergences will cancel and our final value of s will tend to equal nothing. But if we regard the western line as one complete line, and the eastern line as a second complete line, both of which terminate at the high point inland, a divergence between levellers will accumulate on both lines, and each of the two values of s will be a maximum.

line. We now wish to ascertain whether there is any connection between the probable error and the difference of elevation between the terminals. Will the probable error of a line of levelling, M miles in length, be the same, whether the terminal point is at the same elevation as the starting point, or 1000 feet higher?

When we measure a horizontal base-line with 10-foot compensation bars, the uncertainty of the result may be $\frac{1}{500,000}$. When we measure a vertical difference of elevation by means of ten-foot staves and a level, the method of measurement is inferior to that of the base-line, and we cannot expect to attain the same degree of accuracy.

Lallemand's formula* for the probable error of levelling is $\theta = \pm\sqrt{\eta^2 L + \frac{s^2}{9} + \lambda^2 D^2}$, in which η is the probable accidental error per kilometre, L is the length of line in kilometres, s is the accumulated discrepancy between the levellers, D is the difference in elevation in metres between the first and last bench-marks, λ is the probable error per metre of the mean length of the staves.

Lallemand has been able to calculate the value of θ for each individual line of French levelling from the internal evidence furnished by the observations.

We have only to examine pages 343 to 360 of this volume to realise that variations of staff-length may become a serious source of error in levelling.

If staves have been given erroneous lengths owing to some error of standard or of comparison, all *differences* of elevation, D, measured with them will be proportionally incorrect. The closing errors of circuits and the closing errors between sea and sea may not however be affected, because in these cases D = 0.

An endeavour was made at Dehra Dún in March 1910 to determine the probable error of the length of a staff as determined by comparison with a field standard. The results may be stated as follows:—

Probable error of length of a ten-foot staff on account of errors of observation during the comparisons = $\pm \overset{foot}{0\cdot00025}$ (= $\pm \overset{millimetre}{0\cdot0762}$).

Probable error per foot of staff on account of errors of observation during comparisons = $\pm \overset{foot}{0\cdot000025}$ (= $\pm \overset{millimetre}{0\cdot0076}$).

Probable error per foot of the mean of four staves, (on account of errors of observation during comparisons) = $\lambda_1 = \pm \overset{foot}{0\cdot0000125}$ (= $\pm \overset{millimetre}{0\cdot0038}$).†

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* Page 69, *Le Nivellement Général de la France, par Charles Lallemand.*

† The value ± 0·0000125 was deduced from considerations of numerous comparisons made in the field, and from special experiments in Dehra Dún. As doubts of its accuracy were still felt, Major Crosthwait and Captain Cowie were asked to make an independent determination; the following note shows their conclusions:—

1. From observations made in April 1910, the p.e. of the length of one edge of the field standard, derived from comparisons with a standard bar under favourable conditions of temperature, and when comparing microscopes are used, is about ± 0·0000292 foot.

2. The p.e. of the length of one face of a staff in terms of one edge of the field standard, as deduced from a consideration of p.e. of observation, p.e. of temperature, p.e. of correction for temperature, is at least ± 0·000107 foot (in this the temperature errors are put very low).

3. From above the p.e. of mean face of staff in terms of the standard bar, derived by means of comparison with mean edge of field standard will be about ± 0·00011 foot.

4. With adverse temperature condition prevailing in the field, say 10° wrong, during comparisons between field standard and staff, p.e. might be as high as ± 0·0006 without much difficulty.

5. If the comparisons of staff with standard are not made under working conditions, namely, in the sun, an error of about + 0·0006 foot may be introduced, i.e. the staff when in use may be about + 0·0006 foot longer than when the actual comparisons are made.

From the accumulated data of the Indian survey the probable error of a staff-foot due to variations in its length with time was then deduced as $\lambda_2 = \pm \overset{foot}{0.000017}\sqrt{t}$ $(= \pm \overset{millimetre}{0.0052}\sqrt{t})$, in which t = time in weeks elapsed since the comparison was made.

Then the total probable error per foot of staff-length at t weeks after comparison

$$= \lambda = \sqrt{\lambda_1^2 + \lambda_2^2}$$
$$= \sqrt{(0.0000125)^2 + (0.000017)^2 t}$$

From this formula the following values are given:—

$$\text{if } t = 1 \text{ week}, \quad \lambda = \overset{foot}{0.000021} \; (= \overset{millimetre}{0.0064})$$
$$\text{if } t = 4 \text{ weeks}, \quad \lambda = 0.000036 \; (= 0.0110)$$
$$\text{if } t = 13 \text{ weeks}, \quad \lambda = 0.000063 \; (= 0.0192)$$
$$\text{if } t = 26 \text{ weeks}, \quad \lambda = 0.000088 \; (= 0.0268)$$

The probable errors of levelling due to staff-length may then be deduced, by way of rough example, firstly, for the ascent of 2000 feet from Bombay to Lonauli, and secondly for the ascent of 4700 feet from Dehra Dún to Mussooree.

	Probable error of the levelling from Bombay to Lonauli	from Dehra Dún to Mussooree
	foot	foot
If comparisons are daily	± 0·025	± 0·059
If comparisons are weekly	0·034	0·080
If comparisons are monthly	0·048	0·113
If comparisons are quarterly	0·076	0·179
If comparisons are half-yearly	0·100	0·235

If the number of staves is multiplied, the probable error of the mean staff due to errors of comparison is decreased, but multiplication of staves does not decrease the probable error due to variation, because staves vary in length together.

In the following table we have endeavoured to see whether the values of e_1, or of e_2, or of x, for the lines of India, tend to be larger on those level-lines, which rise or fall considerably, than on those which traverse flat ground. e_1 and e_2 are the probable errors per mile deduced from the divergences between levellers; x is the correction shown to be necessary for a level line by the simultaneous reduction.

If the length of one of the first leveller's staves is in error, his results will differ constantly from those of the second leveller, whenever the route is ascending or descending. The values of d will be large and with them e_1.

But if the ascents and descents are approximately equal, the final discrepancy, s, will remain unaffected by the presence of the incorrect staff, and e_2 will not thereby have been increased.

Staves, however, may be correct at the commencement of a season, and may constantly vary together: they grow shorter when the air is dry, and they lengthen during rainy periods, *vide* Appendix No. 1. These variations may throw the levelling out, and they may produce circuit errors, although they do not increase the values of d, s, e_1 or e_2.

In table XLVIII e_1 and e_2 were classified by heights in order to show whether erroneous and discordant values for lengths of staves have been employed on Indian lines. The values of x were similarly classified in order to indicate whether atmospheric changes have tended to alter the lengths of staves during work, so that all four staves have been in error together.

$\frac{e_1}{D}$, $\frac{e_1}{\sqrt{D}}$, $\frac{e_2}{D}$, $\frac{e_2}{\sqrt{D}}$ were included in the table to furnish evidence concerning *comparisons and adopted lengths*; $\frac{x}{D}$ and $\frac{x}{\sqrt{D}}$ were included to furnish evidence concerning *changes in length during work*.

TABLE XLVIII.—The relationship between the accumulated error of levelling and the difference of elevation between the terminal points.

Lines upon which the difference of elevation of terminal bench-marks is	No. of lines	Average difference of elevation of terminal bench-marks = D	e_1	$\frac{e_1}{\sqrt{D}}$	$\frac{e_1}{D}$	e_2	$\frac{e_2}{\sqrt{D}}$	$\frac{e_2}{D}$	x	$\frac{x}{\sqrt{D}}$	$\frac{x}{D}$
			foot	*foot*	*foot*	*foot*	*foot*	*foot*	*foot*	*foot*	*foot*
Less than *50 feet*	15	24	±0·0040	0·0008	0·00017	±0·0028	0·0006	0·00012	0·085	0·0174	0·0035
Between *50 and 100 feet* ...	12	76	±0·0040	0·0005	0·00005	±0·0064	0·0007	0·00008	0·155	0·0178	0·0020
Between *100 and 150 feet* ...	10	121	±0·0033	0·0003	0·00003	±0·0027	0·0002	0·00002	0·168	0·0153	0·0014
Between *150 and 200 feet* ...	9	172	±0·0037	0·0003	0·00002	±0·0053	0·0004	0·00003	0·129	0·0098	0·0008
Between *200 and 250 feet* ...	3	220	±0·0031	0·0002	0·00001	±0·0039	0·0003	0·00002	0·387	0·0261	0·0018
Between *250 and 300 feet* ...	5	271	±0·0047	0·0003	0·00002	±0·0036	0·0002	0·00001	0·104	0·0063	0·0004
Between *300 and 400 feet* ...	6	358	±0·0045	0·0002	0·00001	±0·0062	0·0003	0·00002	0·185	0·0098	0·0005
Between *400 and 700 feet* ...	3	538	±0·0042	0·0002	0·00001	±0·0023	0·0001	0·00000	0·392	0·0169	0·0007
Between *700 and 1100 feet* ...	8	866	±0·0050	0·0002	0·00001	±0·0045	0·0002	0·00001	0·231	0·0078	0·0003
Exceeding *1100 feet*	6	1696	±0·0042	0·0001	0·00000	±0·0158	0·0004	0·00001	0·199	0·0048	0·0001

The results of this table are very peculiar. It will, firstly, be seen that neither e_1 nor e_2 tends to increase at all, either with D or with $\sqrt{D}$. The values of e_1 and e_2 are no greater on lines that rise 700 feet than on lines that traverse flat plains. Great changes in elevation have not, it appears, tended to produce larger divergences between levellers than ordinarily occur on level lines. The table shows that *erroneous values for staff-length have not been employed to any appreciable extent on Indian levelling.*

The table XLVIII further shows,—and this is more extraordinary still,—that the value of x is no greater for lines, on which D is great, than for lines, on which it is small. The value of x seems to be quite independent of D, and it would thus appear, that in spite of the probable errors of staff-comparisons, and in spite of the variations of staff-lengths, the systematic errors of Indian levelling cannot be attributed to the staves.

If it is desired to determine the probable error of levelling between two bench-marks, the distance apart of which is M miles, and between which the difference of elevation is D feet, the following formula may be used* :—

$$\sqrt{(0{\cdot}004)^2M + (0{\cdot}00034)^2M^2 + (0{\cdot}000021)^2D^2}.$$

But the inclusion of the term involving D will be an arbitrary precaution, and one that cannot be justified by experience. For mountainous country it may be advisable to include the term involving D, but as a rule the formula $\sqrt{(0{\cdot}004)^2M + (0{\cdot}00034)^2M^2}$ will suffice for the probable error.

The following table gives a numerical idea of the values of probable errors obtained from the formula $\sqrt{(0{\cdot}004)^2M + (0{\cdot}00034)^2M^2 + (0{\cdot}000021)^2D^2}$: D has been made equal to rM, where r is the average rise or fall of the line in feet per mile.

* $\lambda = 0{\cdot}000021$ foot, if $t = 1$ week, *see* page 392.

TABLE XLIX.—Value of $\sqrt{(0{\cdot}004)^2\mathrm{M} + (0{\cdot}00034)^2\mathrm{M}^2 + (0{\cdot}000021)^2\,(r\mathrm{M})^2}$.

M	$r = 0$	$r = 1$	$r = 10$	$r = 100$
miles	*foot*	*foot*	*foot*	*foot*
20	·02	·02	·02	·05
50	·03	·03	·03	·11
100	·05	·05	·06	·22
150	·07	·07	·08	·32
200	·09	·09	·10	·43
300	·12	·12	·14	
400	·16	·16	·18	
500	·19	·19	·22	
600	·23	·23	·26	
700	·26	·26	·30	
800	·29	·29	·34	
900	·33	·33	·38	
1000	·36	·36	·42	

6.

The method of computing the probable error of the adopted heights of bench-marks.

If it is required to find the probable error of the difference of elevation between two given bench-marks, the first step necessary will be to measure along the levelling lines of Plate I the distance in miles between them. If this distance is called M, and if the levelling route was over normal ground and gradients, the probable error can be computed from the formula $\sqrt{(0{\cdot}004)^2\,\mathrm{M} + (0{\cdot}00034)^2\mathrm{M}^2}$.

If the probable error of the absolute height of any particular bench-mark is required, the distance M will then have to be measured along the lines of Plate I from the nearest issue-point. The nine issue-points, at which the levelling issues from the sea, are Karachi, Bombay, Karwar, Beypore, Cochin, Negapatam, Madras, Vizagapatam, and False Point.

For example if the probable error of the height of a bench-mark in the Punjab is required, Karachi is the nearest issue-point; if by measuring along the lines of Plate I we find that this bench-mark is 800 miles from Karachi, we can calculate the probable error of its height as follows:—

$$\pm\sqrt{(0{\cdot}004)^2 \times 800 + (0{\cdot}00034)^2 \times (800)^2} = \pm\ \overset{foot}{0{\cdot}29}.$$

When attempts are being made to detect actual movements of the earth's crust, a knowledge of the accuracy of the levelling operations is very necessary. In the Dharmsala earthquake of April 5th, 1905, Dehra Dún and the Siwalik range were shown by levelling to have been upraised by 0·4 foot with reference to the two extremities of the level line, Saharanpur and Mussooree*.

Is this quantity 0·4 foot real, or is it an error of observation? These are questions, that we will now endeavour to answer.

We will begin by calculating the total probable error of the height of Dehra Dún, as determined from Saharanpur, firstly in 1862, and secondly in 1907.

* *See* pp. 359-360, Sec. 3, Part II. The discrepancies between original and revised levelling at Mussooree, as brought from Saharanpur, are + 0·051 foot, + 0·030, + 0·028, + 0·013: the mean is + 0·031. The discrepancy at Dehra Dún as calculated from Saharanpur is 0·441, and as calculated from Mussooree is 0·410.

Owing to the difficulties of levelling up steep slopes, it will be advisable, in order to arrive at as large a probability of error as possible, to include the term involving D (*vide* page 393).

Dehra Dún stands 1322 feet above Saharanpur: the value of D is equal to 1322 feet, the value of λ for the levelling operations of 1862 may be taken at 0·000063, and for the revisionary operations of 1907 at 0·000021 (*vide* page 392).

The probable error due to distance must be taken the same in both cases, and derived from the general formula $\sqrt{(0{\cdot}004)^2 M + (0{\cdot}00034)^2 M^2}$ where M = 48 miles.

We then get

probable error due to distance $= \pm$ 0·032 foot.
probable error due to height in 1862 $= \pm$ 0·083 foot.
probable error due to height in 1907 $= \pm$ 0·028 foot.

Total probable error in 1862 $= \sqrt{(0{\cdot}032)^2 + (0{\cdot}083)^2} = \pm$ 0·089 foot.

Total probable error in 1907 $= \sqrt{(0{\cdot}032)^2 + (0{\cdot}028)^2} = \pm$ 0·042 foot.

Probable error of the discrepancy between the original and the revisionary results, Saharanpur-Dehra Dún $= \sqrt{({\cdot}042)^2 + ({\cdot}089)^2} = \pm$ 0·099 foot.

This is the probable error of the discrepancy, 0·441 foot, found at Dehra Dún between the original and revised levelling from Saharanpur.

We will next deduce the probable error of the height of Dehra Dún below Mussooree as determined, firstly, in 1904, and secondly, in 1905.

In this case D = 4707 and λ = 0·000021, in both original and revisionary levelling. M = 18 miles. Then—

Probable error due to distance $= \pm$ 0·019 foot.
Probable error due to height $= \pm$ 0·099 foot.

Total probable error of the levelling, both in 1904 and in 1905 $= \sqrt{(0{\cdot}019)^2 + (0{\cdot}099)^2} = \pm 0{\cdot}101$ foot.

Probable error of the discrepancy between the two results $= 0{\cdot}101 \times \sqrt{2} = \pm$ 0·142 foot.

This is the probable error of the discrepancy, 0·410 foot, found at Dehra Dún between the original and revised levelling from Mussooree.

If now we combine both the Saharanpur-Dehra Dún and the Mussooree-Dehra Dún levellings, the probable error of the mean discrepancy 0·426 between the old and the new values for the height of Dehra Dún is

$$\sqrt{\frac{(0{\cdot}099)^2 + (0{\cdot}142)^2}{4}} = \pm 0{\cdot}087 \text{ foot.}$$

The *observed* discrepancy at Dehra Dún is 0·426, and as this is nearly five times the probable error, 0·087, of the discrepancy, it may be attributed with fair certainty to a real uplift of the earth's crust*. The rise of Dehra Dún and the Siwalik range must have occurred in the earthquake of 1905.

7.

On the weights that have been assigned to the several lines of levelling.

In the simultaneous adjustment of the circuit errors of levelling, weights were assigned to the several level-lines, inversely proportional to the lengths. If w = weight, and M = length in miles, w was taken equal to $\frac{1}{M}$.

As the weight varies inversely as the square of the probable error, the assumption

$$w = \frac{1}{M}$$

implies, that the probable error of levelling varies as $\sqrt{M}$.

In the following table the corrections furnished by the simultaneous adjustment to the results of the several lines are compared with the lengths of the lines.†

* According to the law of probability of error only one residual in a thousand is five times as great as the probable error.

† Table L furnishes a clue as to which lines of level are of a high standard and as to which are inferior. If $\frac{x^2}{M}$ is small, the level-line is reliable; if $\frac{x^2}{M}$ is large, the level-line is probably inferior. Raichur-Gooty (96·5 miles) is a first-class line, but Arkonam-Gooty (215·4 miles) is inferior. The lines Howrah-Ramganj (351·7 miles) and Howrah-Pirpanti (251·1 miles) are among the worst; as also are Bilaspur-Cuttack (370·6 miles) and Bellary-Hubli (137·3 miles). The lines Murghai-Chach (427·4 miles), Chach-Ferozepore (278·3 miles), and Tatta-Shikarpur (310·1 miles) are long lines of great accuracy. The lines Jalarpet-Bangalore (85·8 miles) and Bangalore-Bellary (201·9 miles) are amongst the best.

TABLE L.—The corrections to level-lines, furnished by the simultaneous reduction, tabulated according to the lengths of the lines.

Line No.	Line	Length of line = M	Correction furnished by the circuit adjustment = x	x^2	$\frac{x^2}{M}$
45	Sujawal-Tatta ...	21·1	− 0·003	0·0000	0·00000
42	Kendrapara-False Point	30·4	+ 0·038	0·0014	0·00005
25	Kedgaon-Diksal ...	30·6	− 0·020	0·0004	0·00001
4	Trichinopoly-Tanjore	31·1	+ 0·053	0·0028	0·00009
28	Kedgaon-Nira ...	32·3	− 0·057	0·0032	0·00010
32	Kalyan-Bombay ...	34·5	− 0·104	0·0108	0·00031
73	Purnea-Pirpanti ...	36·8	− 0·112	0·0125	0·00034
36	Vizianagram-Vizagapatam.	40·2	+ 0·067	0·0045	0·00011
41	Kendrapara-Cuttack ...	41·5	+ 0·047	0·0022	0·00005
48	Jorya-Rajkot ...	43·4	− 0·050	0·0025	0·00006
8	Arkonam-Madras ...	44·1	+ 0·127	0·0161	0·00037
12	Shoranur-Beypore ...	47·3	− 0·013	0·0002	0·00000
5	Tanjore-Negapatam ...	48·3	+ 0·144	0·0207	0·00043
65	Lucknow-Cawnpore ...	49·4	+ 0·071	0·0050	0·00010
15	Bellary-Gooty ...	50·7	+ 0·131	0·0172	0·00034
27	Diksal-Nira ...	52·9	+ 0·078	0·0061	0·00012
13	Shoranur-Cochin ...	65·7	− 0·097	0·0094	0·00014
43	Karachi-Tatta ...	67·7	− 0·007	0·0000	0·00000
76	Purnea-Ramganj ...	68·8	+ 0·136	0·0185	0·00027
38	Raipur-Bilaspur ...	68·9	− 0·002	0·0000	0·00000
2	Ramnad-Tuticorin ...	74·6	+ 0·026	0·0007	0·00001
47	Shikarpur (Cutch)-Jorya	74·8	+ 0·086	0·0074	0·00010
18	Jalarpet-Bangalore ...	85·8	0·000	0·0000	0·00000
6	Trichinopoly-Erode ...	87·0	+ 0·117	0·0137	0·00016
46	Navanar-Shikarpur (Cutch).	87·5	+ 0·079	0·0062	0·00007
10	Arkonam-Jalarpet ...	89·3	+ 0·036	0·0013	0·00001
22	Raichur-Gulbarga ...	89·9	− 0·064	0·0041	0·00005
23	Bellary-Raichur ...	91·2	+ 0·055	0·0030	0·00003
21	Raichur-Gooty ...	96·5	− 0·010	0·0001	0·00000
17	Hubli-Karwar ...	102·7	− 0·296	0·0876	0·00085
49	Rajkot-Viramgam ...	105·2	+ 0·122	0·0149	0·00014
7	Jalarpet-Erode ...	110·9	− 0·045	0·0020	0·00002
1	Tanjore-Ramnad ...	114·8	+ 0·041	0·0017	0·00001
11	Erode-Shoranur ...	116·0	− 0·202	0·0408	0·00035
31	Kalyan-Kedgaon ...	120·0	− 0·132	0·0174	0·00014
70	Allahabad-Dildarnagar	126·6	− 0·087	0·0076	0·00006
50	Viramgam-Shikarpur (Cutch).	127·6	+ 0·263	0·0692	0·00054
67	Cawnpore-Allahabad ...	129·0	− 0·027	0·0007	0·00001
54	Shikarpur (Sind)-Murghai.	130·6	− 0·131	0·0172	0·00013
62	Meerut-Agra ...	133·1	+ 0·218	0·0475	0·00036
16	Bellary-Hubli ...	137·3	+ 0·436	0·1901	0·00138
69	Gorakhpur-Dildarnagar	142·1	− 0·040	0·0016	0·00001
33	Kalyan-Nandgaon ...	146·6	− 0·279	0·0778	0·00053
59	Katni-Allahabad ...	161·5	− 0·078	0·0061	0·00004
68	Lucknow-Gorakhpur ...	162·4	+ 0·130	0·0169	0·00010
66	Cawnpore-Agra ...	168·0	+ 0·208	0·0433	0·00026
26	Diksal-Gulbarga ...	170·6	+ 0·139	0·0193	0·00011
60	Katni-Sironj ...	193·0	+ 0·249	0·0620	0·00032
3	Tuticorin-Trichinopoly	194·4	− 0·069	0·0048	0·00002
58	Bilaspur-Katni ...	196·5	+ 0·349	0·1218	0·00062
19	Bangalore-Bellary ...	201·9	− 0·001	0·0000	0·00000
44	Navanar-Sujawal ...	208·5	− 0·189	0·0357	0·00017
14	Arkonam-Gooty ...	215·4	+ 0·531	0·2820	0·00131
9	Madras-Tanjore ...	219·3	− 0·361	0·1303	0·00059
30	Bezwada-Vizagapatam	229·9	+ 0·212	0·0449	0·00020
75	Kendrapara-Howrah ...	251·0	− 0·028	0·0008	0·00000
74	Howrah-Pirpanti ...	251·1	+ 0·524	0·2746	0·00109
39	Cuttack-Vizianagram	253·5	− 0·154	0·0237	0·00009
61	Ferozepore-Meerut ...	267·8	− 0·268	0·0718	0·00027
63	Agra-Sironj ...	268·5	− 0·108	0·0117	0·00004
29	Nira-Hubli ...	271·3	− 0·078	0·0061	0·00002
72	Dildarnagar-Pirpanti	274·6	− 0·266	0·0708	0·00026
20	Bezwada-Madras ...	277·1	+ 0·166	0·0276	0·00010
56	Chach-Ferozepore ...	278·3	− 0·045	0·0020	0·00001
52	Sujawal-Shikarpur (Sind).	282·2	− 0·221	0·0488	0·00017
64	Meerut-Lucknow ...	284·8	− 0·182	0·0331	0·00012
53	Tatta-Shikarpur (Sind)	310·1	− 0·067	0·0045	0·00001
57	Murghai-Ferozepore ...	312·0	− 0·361	0·1303	0·00042
37	Vizianagram-Raipur ...	317·8	+ 0·333	0·1109	0·00035
24	Gulbarga-Bezwada ...	319·9	+ 0·487	0·2372	0·00074
51	Viramgam-Bombay ...	350·6	− 0·318	0·1011	0·00029
77	Howrah-Ramganj ...	351·7	− 0·694	0·4816	0·00137
71	Gorakhpur-Purnea ...	361·7	+ 0·391	0·1529	0·00042
40	Bilaspur-Cuttack ...	370·6	+ 0·645	0·4160	0·00112
34	Nandgaon-Sironj ...	408·8	+ 0·364	0·1325	0·00032
55	Murghai-Chach ...	427·4	+ 0·068	0·0046	0·00001
35	Nandgaon-Raipur ...	529·7	+ 0·538	0·2894	0·00055

If x_1, x_2, x_3 . . . are the corrections furnished to the several level-lines, l_1, l_2, l_3 . . . . . . , and if M_1, M_2, M_3 . . . . are the lengths in miles of the lines, then the value of wx^2 or $\frac{x^2}{M}$ should not be persistently different for long lines from what it is for short lines.

The results in table L show, however, that $\frac{x^2}{M}$ is distinctly larger for the long lines than for the short. A comparison of the first 25 lines of table L with the last 25 lines yields the following results:—

Number of values of $\frac{x^2}{M}$	First 25 lines	Last 25 lines
Exceeding 0·0010 foot	0	... 4
Between 0·0005 and 0·0010 ...	0	... 3
Between 0·0002 and 0·0005 ...	6	... 8
Less than 0·0002	19	... 10

In 19 out of the first 25 lines the value of $\frac{x^2}{M}$ is less than 0·0002, whereas it is less than 0·0002 in only 10 of the last 25 lines. In the first 25 lines the largest value of $\frac{x^2}{M}$ is 0·00043; in the last 25 lines four values of $\frac{x^2}{M}$ exceed 0·00100. This table furnishes distinct evidence that $\frac{x^2}{M}$ tends to be larger for long lines than for short. The reason of this discordance is that the equation, $w = \frac{1}{M}$, has given too large a relative weight to long lines and too small a weight to short lines.

The first result of this unfairness in the assignment of weights is, that the values of x^2 have been given slightly too small for long lines, and slightly too large for short lines. But this tendency for x^2 to be too small on long lines has been more than counteracted by the tendency of, $w = \frac{1}{M}$, to be too large, and though x^2 by itself may be slightly too small, $\frac{x^2}{M}$ is clearly too large on long lines.

Table L has in fact shown that the assumption, $w = \frac{1}{M}$, is not correct.

When the simultaneous adjustment was carried out, our knowledge of the errors of Indian levelling was less than it is now, and we followed the system that is generally recommended in treatises, and made $w = \frac{1}{M}$.

We did not then know, whether accidental or systematic errors predominated. If accidental errors were largely predominating, it would have been correct to adopt $w = \frac{1}{M}$; and if systematic errors were largely predominating, the relation between weight and distance should have been $w = \frac{1}{M^2}$.

It seemed to us that to take, $w = \frac{1}{M}$, was probably more correct than to take $w = \frac{1}{M^2}$.

From the analysis of the errors, which we made on pages 379 to 390, it would now appear that the relationship between weight and length of line could be best expressed as follows:

$$w = \frac{1}{(0{\cdot}004)^2 M + (0{\cdot}00034)^2 M^2}.$$

The question has had to be considered, whether the simultaneous adjustment should be repeated, and we have decided against repetition. We recognise that the relation, $w = \frac{1}{M}$, has given too great weights to the longer lines, but for reasons we will now explain, we doubt whether any scientific system of weights could be devised. We have therefore thought it inadvisable to go to the labour and expense of re-adjusting the closing errors, until we see our way more clearly to definite improvement and gain.

The formula, $E = \sqrt{(0{\cdot}004)^2 M + (0{\cdot}00034)^2 M^2}$, is a generalisation for the Indian levelling *as a whole*. But the level-lines of India have been observed under varying conditions, and it is doubtful if this formula could be utilised with much advantage for the derivation of weights of *single lines*. In Lallemand's formula,—probable error $= \pm\sqrt{\eta^2 L + \frac{s^2}{9} + \lambda^2 D^2}$,—the systematic error on each line is derived directly from the results of that line, and not from a wide generalisation.*

In India the subdivision of circuits into lines has been carried out somewhat arbitrarily.

Lines have been made to terminate at junction-points for the convenience of computers. From an observer's point of view a junction-point is not necessarily the line-terminal, and at times he may think it more correct to regard even a whole circuit as consisting of one line. The several sections of the circumference of a central levelling circuit enter into neighbouring circuits, and these sections have been made into separate lines. Any section, that forms part of the circumferences of two circuits, has been regarded as a separate line. If a long observed line of length L_0 is arbitrarily divided into two parts of lengths, L_1 and L_2, so that $L_0 = L_1 + L_2$, and if w_0, w_1, w_2 equal their respective weights, then $\frac{1}{w_0}$ should be equal to $\frac{1}{w_1} + \frac{1}{w_2}$; otherwise we cannot justify the arbitrary subdivision. But this relation will only hold, if the weight varies inversely as the length.

It may seem absurd to collect masses of evidence, all of which go to prove that weights do not vary inversely with the length, and then to adopt a system, under which weights are made to vary inversely with the length.

It may seem absurd to deduce a law, showing that errors accumulate both with the length and with the square root of the length, and then to base our weights on the assumption that errors accumulate with the square root of the length only. But we have to deal with accomplished facts.

If we could now commence the Indian levelling afresh, with all the knowledge we have gained from it, we should design it differently. But we have to accept the data and results that are before us, and we have to recognise, that our so-called lines are mere arbitrary lengths, determined not by observations in the field, but from the diagram of circuits; any length of levelling, that enters into two neighbouring circuits, becomes from that diagram a finite line. Though then it may not be correct to make our weights inversely proportional to lengths, such a course is an approximation to truth, and is under the circumstances the nearest approximation to truth we can make.†

In the following table LI the ratio of the adopted weights to the true weights is exhibited:—

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* Lallemand introduces a term dependent on the difference of elevation between the first and last bench-marks of each line. The results of table XLVIII on page 393 have led to the conclusion that the weights of lines in India should be independent of the difference of elevation.

† It might perhaps be argued that a nearer approximation to truth could have been attained, if weights had been arbitrarily assigned from general considerations. Such a course would have had the advantage, that we could have taken into account the chances of error at the passages of wide unbridged rivers, *see* Appendix No. 5. The large correction, $x = 0{\cdot}694$, furnished by the simultaneous reduction to the line, Howrah-Ramganj, raises doubts as to the accuracy, with which the levelling crossed the Ganges at Damukdia. The results of the simultaneous reduction tend generally, however, to show, that arbitrary weights might be very misleading. Observers are frequently mistaken as to the relative merits of different lines. Weights derived from e_i would too be most unsuitable for simultaneous double lines.

TABLE LI.—The extent to which adopted weights may be in error.

Distance in miles = M	Relative weights as adopted $W_a = \frac{1}{M}$	Relative weights as given by the formula $W_t = \frac{1}{(0{\cdot}004)^2 M + (0{\cdot}00034)^2 M^2}$	Ratio of adopted weight to true weight $\frac{W_a}{W_t}$
20	10·0	21·3	0·5
50	4·0	7·2	0·6
100	2·0	2·8	0·7
200	1·0	1·0	1·0
300	0·7	0·5	1·4
400	0·5	0·3	1·7
500	0·4	0·2	2·0

The weight of a line of 200 miles in length has been taken as unity. It will be seen from the last column that the weight assigned to a line of 20 miles is only half what it should have been, and that the weight assigned to a line of 500 miles is twice what it should have been. To this extent then our weights have been in error: our shortest line has been given a weight equal to half of what was its correct due: our longest line has been given a weight twice as great as it deserved.

We said above that the system pursued had been an approximation to truth. This is now evident, for if we had declined to assign any weights at all, we should have been giving equal weights to all lines. In that case our shortest line would have received a weight equal to $\frac{1}{20}$th of what was its correct due, and our longest line would have received a weight five times as great as it deserved. The system adopted has therefore raised the weight of the short line from $\frac{1}{20}$th to $\frac{1}{2}$ of what it should be: and it has lowered the weight of the long line from five times to twice what it should be.

We have derived the probable error of levelling, firstly, as e_1,—from discrepancies between levellers, secondly, as e_2,—from the total discrepancy accumulated on each line, and thirdly, as e_3,—from the circuit errors. We can now derive it in a fourth way, as e_4,—from the corrections x_1, x_2, x_3 . . supplied to the several lines by the simultaneous adjustment.

$$e_4 = \frac{0{\cdot}6745\sqrt{\frac{x_1^2}{M_1} + \frac{x_2^2}{M_2} + \cdots}}{\sqrt{n_l - n_s}}$$

where $x_1, x_2, \ldots$ = residual errors of lines
$M_1, M_2, \ldots$ = lengths of lines in miles
n_l = number of lines
n_s = number of stations.

Then we get

$$e_4 = \pm\, 0{\cdot}0178 \text{ foot.}$$

Summarising the four values of the probable error of levelling per mile, we get for all India

$e_1 = \pm\, 0{\cdot}0042$ foot.
$e_2 = \pm\, 0{\cdot}0062$ foot. } *vide* page 377.
$e_3 = \pm\, 0{\cdot}0128$ foot *vide* page 384.
$e_4 = \pm\, 0{\cdot}0178$ foot.

The values of e_1 and e_2 depend upon the internal evidence furnished by the level-lines, the values of e_3 and e_4 depend upon external evidence, namely, the circuit errors and the corrections given to lines by the simultaneous adjustment of circuit errors. The values of e_3 and e_4 are so much greater than those of e_1 and e_2, that internal evidence must be regarded as defective.

The values of e_3 and e_4 cannot be maintained, because they are both based upon the assumption, that errors of levelling are all accidental and increase with $\sqrt{\text{distance}}$. The excess of e_4 over e_3 is due to the fact, that the corrections to the level-lines, $x_1, x_2 \ldots$, from which e_4 is deduced, have been derived from an adjustment, in which the weights of lines have been made to vary inversely with length. Into e_3 the erroneous assumption, that probable error increases with $\sqrt{\text{distance}}$, has only entered once; into e_4 it has entered twice,—firstly, in the hypothesis that $w = \frac{1}{M}$, when the values of $x_1, x_2 \ldots$ were derived, and secondly, in the formula by which e_4 itself was derived.

8.

The tendency of levelling is to make elevations too great.

There is a tendency in levelling to make elevations too great. If we level from A to B, the chances are almost two to one, that the height of B with regard to A will be given too great. If B is higher than A, the difference of elevation will probably be given too great: if B is lower than A, the difference of elevation will probably be given too small: in each case B will probably be placed too high.

Let us consider the main level-lines of India, and divide them into two classes:—

(i.) those on which the final bench-mark of the line was placed by levelling observations too high.

(ii.) those on which the final bench-mark of the line was placed by levelling observations too low.

In deciding whether the terminal bench-mark of any line has been given too great or too small a height by the observations on that line, we accept as our tests the corrections to the lines furnished by the simultaneous adjustment of the closing errors of circuits.

Of the 86 main-lines of India, lines 78 to 86 may be omitted as being too short; of the remaining 77 the following may be omitted as having been levelled partially in one direction and partially in the other:—

Nos. 14, 15, 43, 53, 70.

The following lines may also be omitted as having been revised, the original and revisionary results being contradictory:—

Nos. 8, 21, 22, 25.

The following lines may be omitted, as the simultaneous adjustment has furnished them with corrections less than 0·005 foot (*see* tables XXXVII and L), and no conclusion can be drawn from such small quantities:—

Nos. 18, 19, 38, 45.

We have now left 64 lines, which are available for our investigation of the general tendency of levelling. We do not expect to prove that levelling invariably makes all bench-marks too high; the operation of levelling is liable to many kinds of errors, and when any particular error,—let us say for instance that arising from staff-length,—is allowed to become exceptionally large, it may mask, for the time, any smaller though persistent tendency. Proof of a persistent tendency cannot thus be based upon a few lines, but a large number, such as 64, may be expected to furnish evidence.

The simultaneous adjustment of closing errors shows that on the following lines the levelling observations made the final bench-mark too high :—

Nos. 1, 2, 3, 4, 5, 9, 23, 24, 26, 28, 29, 30, 31 (twice), 32 (twice), 33, 34, 35, 36, 37, 39, 40, 41, 44, 47, 48, 49, 52, 54, 56, 57, 61, 62, 63, 66, 68, 71, 72, 73, 77.

On the following lines the levelling observations made the final bench-mark too low :—

Nos. 6, 7, 10, 11, 12, 13, 16, 17, 20, 27, 42, 46, 50, 51, 55, 58, 59, 60, 64, 65, 67, 69, 74, 75, 76.

On 25 lines the final bench-mark has been made too low : on 39 lines, or rather on 41, if we include the two measurements of lines 31 and 32, the final bench-mark has been made too high.

For those lines, on which the final bench-mark has been given too high, the aggregate of the errors determined by the simultaneous adjustment is 7·985 feet,—and this aggregate excludes the errors of the original measurements of lines 31 and 32. For those lines on which the final bench-mark has been given too low, the aggregate of the errors is 3·936 feet.

For those lines, on which the final bench-mark has been found to be too high, the average correction furnished by the simultaneous adjustment is 0·205 foot: and for those lines, on which the final bench-mark was too low, the average correction is 0·157.

The evidence may be summed up as follows :—

	Lines tending too high	Lines tending too low
Number	41	25
Average length of line ...	193 miles	154 miles
Sum of the errors = $\Sigma[x]$ ...	7·985 feet	3·936 feet
Average error per line (x) ...	0·205 foot	0·157 foot

These figures show that there has been a persistent tendency throughout the levelling operations of India to make elevations too great. In all probability this tendency arises from the gradual sinking of bench-marks during levelling work*. The fact that the average length of those lines, which make heights too high, is 193 miles and that the average length of those, which make heights too low is 154, indicates that the tendency, though persistent, is more likely to be masked on short lines than on long, and that it requires a certain length to make its influence apparent.

9.

The comparative suitability of railways and roads as levelling routes.

Of the 77 main-lines of India, 43 were levelled either wholly or partially along railway lines : 34 lines have been levelled along roads and have had no contact with railways†.

* Page 353.

† The following level-lines passed along railways :—
Nos. 3 to 12 inclusive, 14 to 18, 21 to 23, 25, 26, 31 to 36, 38 to 40, 43, 49 to 52, 56, 58 to 60, 66, 67, 72, 74, 77.
The following level-lines adhered to roads :—
Nos. 1, 2, 13, 19, 20, 24, 27 to 30, 37, 41, 42, 44 to 48, 53 to 55, 57, 61 to 65, 68 to 71, 73, 75, 76.

On the 43 level-lines that followed railways, the average error per line allotted by the simultaneous adjustment was $\overset{foot}{0 \cdot 198}$: on the 34 level-lines that adhered to roads the average error per line was $\overset{foot}{0 \cdot 131}$.

The average length of the 43 railway-level-lines was 162 miles, and of the 34 road-level-lines was 171 miles.

In the simultaneous adjustment of circuit errors railway-lines and road-lines received on the average approximately the same weight.* The results of the adjustment show that *a road-line of levels deserves twice the weight of a railway-line of levels.*

The following table shows the values of x, of e_1 and of e_2 for the railway-lines and the road-lines:—

TABLE LII.

Level-lines	Average length of line	Mean correction by simultaneous reduction $= x$	Probable error per mile: deduced from mark to mark differences between levellers $= e_1$	Probable error per mile: deduced from final differences between levellers accumulated $= e_2$
	miles	*foot*	*foot*	*foot*
43 railway-lines ...	162	0·198	± 0·0037	± 0·0037
34 road-lines ...	171	0·131	± 0·0046	± 0·0083

The results of this table are of considerable interest.

The mean value of x for the railway-lines is distinctly greater than for the road-lines, and its marked excess warrants the inference that the levelling along railways has persistently generated greater errors than along roads. On the other hand the values of e_1 and of e_2 are smaller for railways than for roads, and this shows that the *discrepancies* between levellers tend to be less on railways than on roads. Although then the *results* of levelling over railways are inferior to those over roads, the *accordance* between the levellers is superior. Whatever then may be the cause of the inferiority of levelling along railways, it is a cause that does not tend to separate the results of the two levellers.

One other point in table LII is deserving of notice. In the case of railway-lines the values of e_1 and e_2 are the same: in the case of road-lines e_2 is almost twice as great as e_1. This difference denotes that on railway-lines any existing cause of systematic error is affecting both levellers in exactly the same way, but that on road-lines the systematic error is affecting the two levellers unequally.

If we take the law of error for levelling to be generally $\sqrt{(0 \cdot 004)^2 M + (0 \cdot 00034)^2 M^2}$, and if we assume that accidental errors are similar on railways and roads, and that the difference in the value of x for railways and roads is due to the systematic errors, we find that the accumulation of error on roads may be represented by the formula

$$\sqrt{(0 \cdot 004)^2 M + (0 \cdot 00028)^2 M^2}$$

and that the accumulation on railways requires the formula

$$\sqrt{(0 \cdot 004) M + (0 \cdot 00041)^2 M^2}.$$

* Average weight of a railway-line $= \frac{1}{162}$; average weight of a road-line $= \frac{1}{171}$. The railway-line was therefore given a higher weight than the road-line.

In the general formula $\sqrt{e_a^2 M + e_s^2 M^2}$ it would indeed appear, that the co-efficient of M^2 in the second term is dependent more upon the character of the ground, over which the levelling passes, than upon anything else: over solid rock the co-efficient may fall below 0·0002, and on a hard road it will not be as high as 0·0003. But on a made embankment or over loose soil or swamps it may rise to 0·0005.

The simultaneous adjustment has shown that roads have proved more suitable routes for levelling than railways, so far as accuracy is concerned. But we ought not on this account to abandon all railways in future. A railway may be the easiest, the straightest and the cheapest route, and these advantages cannot be wholly disregarded. And as for accuracy the difference may be simply this, that levelling along a railway requires *more care and greater precautions* than levelling along a road, owing to the instability of railway embankments and to the vibrations caused by trains.

Although railway level-lines do not on the whole compare favourably with road level-lines, yet there are a few instances of railway lines yielding excellent results. The line from Jalarpet to Bangalore is 86 miles in length, and followed a railway the whole way. Between Jalarpet and Bangalore the line rose 1792 feet, and the simultaneous reduction of closing errors showed no correction to be required to the Jalarpet-Bangalore line.

In discussing the relative merits of railways and roads we have also to take into account the requirements of the country traversed. As a rule the levels of a railway have been already determined, and to carry levelling along it enables us only to correct heights previously measured: but when we leave the railway-lines, we gain the opportunity of erecting bench-marks in unsurveyed localities and of fixing heights, where none are known.

10.

On the differences between the elevations of mean-sea-level at different places.

In chapter VIII Part I, we gave a complete account of the determinations of mean-sea-level, and we explained, how nine tidal observatories had been selected as the base-stations of the level-net, and how other tidal observatories had been rejected. To that chapter we have but little to add; we can, however, now that the simultaneous adjustment of circuit errors has been effected, show the apparent variations in mean-sea-level round the whole coast of India. And we can examine again, whether the discrepancies between determinations of mean-sea-level are real and due to actual variations of sea-level, or whether they are unreal and due only to errors of levelling. In chapter VIII, pages 126 and 127, we calculated the errors of levelling from two rough approximate formulæ,—

(i.) Probable error $= 0·004 \sqrt{M}$

and (ii.) Probable error $= 0·0007\ M$

We can now utilise the formula which we have deduced on pages 377 to 390,

$$\sqrt{(0·004)^2 M + (0·00034)^2 M^2}.$$

In the following table LIII we have shown the variations of mean-sea-level, as found from levelling operations,—firstly, with regard to the mean-sea-surface adopted for the adjusted level-net, and secondly, with regard to mean-sea-level at Bombay (Apollo Bandar). We also give in table LIII the probable errors of the levelling.

TABLE LIII.—The elevation of mean-sea-level at different points of the coast of India.

Tidal observatory: Position	Tidal observatory: Name	Distance from level-net	Branch-line connecting with level-net	Probable error of connecting branch-line	The nearest tidal base-station of the level-net	Distance as levelled from nearest base-station	Probable error of the levelling connecting with nearest base-station	Distance as levelled from Bombay (Apollo Bandar)	Probable error of the levelling connecting with Bombay	Elevation of mean-sea-level with regard to the datum of the level-net*	Elevation of mean-sea-level with regard to the mean-sea-level at Bombay†
1	2	3	4	5	6	7	8	9	10	11	12
		miles		*foot*		*miles*	*foot*	*miles*	*foot*	*feet*	*feet*
Open-coast Arabian Sea.	Karachi ...	0·0	Main-line ...	...	A base-station ...	0·0	...	864	±0·3164	0·000	+0·848
In the Gulf of Cutch.	Hanstal ...	0·0	Main-line ...	...	Karachi ...	443·9	±0·1729	514	0·1969	−0·015	+0·116
	Navanar ...	0·0	Main-line ...	...	Karachi ...	297·3	0·1224	566	0·2147	−0·121	+0·541
At mouth of the Gulf of Cutch.	Okha ...	111·7	47A. Jorya-Okha	±0·0568	Karachi ...	571·3	0·2165	611	0·2301	−0·604	−0·455
In the Gulf of Cambay.	Port Albert Victor.	147·0	48B Sanoshra-Port Albert Victor & 48A (Part).	0·0696	Bombay (Apollo Bandar).	602·8	0·2273	603	0·2273	−0·503	−0·304
	Bhavnagar ...	109·6	48A Rajkot-Bhavnagar.	0·0561	Bombay (Apollo Bandar).	565·4	0·2145	565	0·2143	−0·446	−0·147
Open-coast Arabian Sea.	Bombay (Apollo Bandar).	0·0	Main-line ...	...	A base-station ...	0·0	...	0	...	0·000	0·000
	Bombay (Prince's Dock).	0·3	Minor branch-line	0·0022	Bombay (Apollo Bandar).	3·0	0·0070	3	0·0070	+0·036	+0·036
	Mormugao ...	56·9	17A. Karwar-Mormugao.	0·0358	Karwar ...	56·9	0·0358	619	0·2328	+0·219	+0·078
	Karwar ...	0·0	Main-line ...	...	A base-station ...	0·0	...	562	0·2133	0·000	+0·078
	Beypore ...	0·0	Main-line ...	...	A base-station ...	0·0	...	1157	0·4162	0·000	+0·551
	Cochin ...	0·0	Main-line ...	...	A base-station ...	0·0	...	1176	0·4227	0·000	+0·467
Gulf of Manar ...	Tuticorin ...	0·0	Main-line ...	...	Negapatam ...	237·7	0·1017	1275	0·4564	−0·313	+0·814
	Pamban ...	27·8	1A. Ramnad-Pamban.	0·0231	Negapatam ...	190·9	0·0852	1255	0·4496	−0·131	+0·977
Open-coast Bay of Bengal.	Negapatam ...	0·0	Main-line ...	...	A base-station ...	0·0	...	1069	0·3863	0·000	+1·448
	Madras ...	0·0	Main-line ...	...	A base-station ...	0·0	...	801	0·2949	0·000	+0·944
Near the mouths of the Godavari.	Cocanada ...	0·0	Main-line ...	...	Vizagapatam ...	105·9	0·0547	800	0·2946	+0·281	+1·240
Open-coast Bay of Bengal.	Vizagapatam ...	0·0	Main-line ...	...	A base-station ...	0·0	...	907	0·3311	0·000	+1·057
Open-coast Bay of Bengal.	False Point ...	0·0	Main-line ...	...	A base-station ...	0·0	...	1222	0·4384	0·000	+1·663
In the delta of the river Ganges.	Dublat ...	99·5	74B Kidderpore-Dublat.	0·0523	False Point ...	377·3	0·1500	1530	0·5432	+0·432	+1·986
	Diamond Harbour.	28·8	74A Kidderpore-Diamond Harbour.	0·0236	False Point ...	323·9	0·1316	1476	0·5248	+1·180	+2·756
On the river Hooghly.	Kidderpore ...	1·1	Minor branch-line	0·0042	False Point ...	295·7	0·1218	1448	0·5153	+3·170	+4·764

Column 11 shows the variations of mean-sea-level, with regard to the mean-sea-surface adopted as the basis of the level-net. The basis of the level-net was the mean-sea-level at Karachi, Bombay (Apollo Bandar), Karwar, Beypore, Cochin, Negapatam, Madras, Vizagapatam, False Point. At these 9 ports the mean-sea-level was assumed to be at the same elevation. The levelling errors on the network, connecting these ports, were then adjusted and distributed, and the results in column 11 have been derived from the adjusted net. Certain tidal stations, such as Tuticorin, Cocanada, Hanstal, Navanar, were tied directly to main-lines of the level-net: other tidal stations, such as Okha, Mormugao, Pamban, were connected to the level-net by special branch-lines of levelling.

Column 12 shows the variations of mean-sea-level with regard to mean-sea-level at Bombay. The numbers in this column have been derived from the unadjusted levelling; no assumption concerning mean-sea-level has here been made, and no levelling errors have been distributed or eliminated.

* As derived from levelling results, which have been adjusted by the simultaneous reduction, *vide* pages 365-372.

† As derived from levelling results, which have not been adjusted, *vide* pages 365-372.

The essential difference then between columns 11 and 12 is that the former has been founded upon the nine base-stations and the adjusted levelling, and the latter upon a single tidal station and upon the unadjusted levelling. We have now to consider,—to what extent are the variations, as shown in columns 11 and 12, due to real changes in the elevations of the sea, and to what extent are they due to errors of levelling?

In order to enable these questions to be answered, the numbers in columns 3 to 10 have been compiled.

Columns 3, 4, 5 deal with the probable errors of the branch-levelling, which connects any tidal observatory with the level-net. If the probable error of the branch-levelling is required for comparison with the figures in column 11, — for the purpose of testing whether the figures of column 11 are real or unreal, — it will be found in column 5, having been derived from the formula,

$$E = \sqrt{(0{\cdot}004)^2\,M + (0{\cdot}00034)^2 M^2},\quad M \text{ being given in column 3.}$$

This method of deriving the probable error of the levelling is based upon the assumptions, that the level-net, *as adjusted*, is errorless, and that the only levelling errors remaining are those on the short branch-lines connecting the level-net with mean-sea-level. As these assumptions are not clearly justified, we have added columns 6, 7 and 8. In column 8, the probable error of the connecting levelling is exhibited, having been derived from the same formula as before, $E = \sqrt{(0{\cdot}004)^2 M + (0{\cdot}00034)^2 M^2}$, but with a different value of M. The value of M now adopted, is that given in column 7.

Columns 5 and 8 both contain estimates of the probability of error, and these estimates are intended to be tests of the reality or unreality of the figures in column 11. The difference between columns 5 and 8 is this:—the figures of column 5 are dependent upon the assumption that the simultaneous reduction of the level-net renders the levelling results of the net free from error. The figures of column 8 are dependent upon the assumption, that the simultaneous reduction of the level-net introduces no improvement into the accuracy of the levelling results. These assumptions are two extremes, and neither is correct. The truth lies between the two. The simultaneous reduction undoubtedly increases the accuracy of results, but it does not render results errorless.

The probable errors, as shown in column 5, are too small; but, as shown in column 8, they are too large. Column 8 is nearer to the truth than column 5, and it will be advisable to adopt the probable errors from column 8 as the tests of column 11.

Columns 9 and 10 have been added, in order that the reality or unreality of the figures of column 12 may be tested.

Column 8 is therefore the test for column 11, and column 10 for column 12.

Karachi.—From column 11 the sea-level at Karachi appears to be 0·848 foot higher than at Bombay. The probable error of the levelling is shown in column 10 to be ±0·3164 foot. The observed discrepancy of 0·848 is thus only twice the probable error, and we are consequently not able to state with any certainty that the mean-sea-level at Karachi is actually higher than at Bombay. On page 124 we showed that if we follow an alternative line of levelling, the discrepancy of 0·848 becomes reduced to 0·327. We attribute the discrepancy of 0·848 foot to errors of levelling.

Hanstal *Navanar* *Okha*	The discrepancies at Hanstal and Navanar are clearly due to errors of levelling; the mean-sea-level at Okha may possibly be slightly lower than at Bombay or Karachi, but we are unable to state definitely that it is so. The discrepancy of — 0·604 foot may be due to errors of levelling. (In this connection read page 372).

Port Albert Victor *Bhavnagar*	The discrepancies at the Cambay ports are chiefly due to errors of levelling.
Bombay (*Prince's Dock*)	There may be a very slight difference in the elevation of mean-sea-level at the two Bombay tidal stations, as the observatory at Prince's Dock is sheltered, but the discrepancy shown in table LIII is mainly due to errors of levelling.
Mormugao (*Goa*) *Karwar* *Beypore* *Cochin*	The discrepancies at these open coast stations may safely be ascribed to errors of levelling.
Tuticorin *Pamban*	The probable error of the levelling from Bombay to the two Manar ports exceeds 0·4 foot, and the observed discrepancies of 0·814 and 0·977 foot are almost entirely the results of levelling errors.
Negapatam *Madras* *Cocanada* *Vizagapatam* *False Point*	The average discrepancy between sea-level at these five stations in the Bay of Bengal and sea-level at Bombay exceeds a whole foot, and there appear, at first sight, some grounds for concluding that the mean surface of the Bay of Bengal is nearly a foot higher than the mean surface of the Arabian Sea. But, as we have already pointed out on page 123, this conclusion cannot be upheld. The discrepancy of a foot is due to the errors of levelling accumulated on long lines, *vide* section 8, chapter II of Part III.
Dublat (*Saugor Island*) *Diamond Harbour*	Dublat and Diamond Harbour are situated in the delta of the Ganges, and are under the influence of the river Hooghly. It would not therefore be surprising to find, that the mean-sea-level at both places is slightly too high. The probability of the error of levelling is 0·1500 foot at Dublat, and this prevents us from ascribing the observed discrepancy of 0·432 foot to actual rise of sea-level. At Diamond Harbour the probable error of levelling is 0·1316 foot; the observed difference of 1·180 feet, being eight times larger, must be considered as real.*
Kidderpore	Kidderpore is on the Hooghly, and there is no doubt at all that the observed difference of 3·170 feet is due to the mean level of the river at Kidderpore being actually higher than the mean level of the sea.* The difference, given in the last column of table LIII, (namely 4·764 feet) between the mean water levels at Bombay and Kidderpore is due partly to errors of levelling, but mainly to the river water at Kidderpore being higher than the mean sea surface in Bombay harbour.

Diamond Harbour and Kidderpore are the only two tidal observatories in India, at which we have proved that the mean water level is higher than the mean level of the sea. The observed discrepancies at all other tidal stations have to be attributed to errors of levelling.

* Read page 372.

11.

The values of height of certain inland points, as derived from different tidal base-stations.

In this section we have taken three points near the central back-bone of India, and have computed their heights through level-lines connecting them with the sea.

We have not, however, complicated the matter by introducing any disturbed elevations of mean-sea-level, such as have been suspected in the Gulf of Cutch and found in the Hooghly. If the levelling computations had been made to start from sea-surfaces differing in elevation, the several values of height of the central points would have necessarily been discordant. But the discordances would not have been instructive; they would merely have reflected the discrepancies between the different sea-surfaces, from which the levelling took off.

We have, therefore, in calculating the heights of the central points, followed only those lines of level, which emanate from reliable tidal stations, at which the mean-sea-level appears without any doubt to be at the same elevation as the mean surface of the open seas surrounding India.

TABLE LIV.—The height of Sirônj.

(*Latitude 24°, Longitude 77°;* vide *Plates I and XVI*).

Final corrected value of dynamic height, derived from the simultaneous reduction,
= 1478·358 feet = 450·599 metres.

Starting point of levelling	Route followed by levelling	Length of line		Probable error of levelling*		Height of Sironj		Discrepancy from	
= mean-sea-level at	level-lines	miles	kilometres	foot	metre	feet	metres	1478·358 feet	450·599 metres
								feet	foot
Karachi ...	78,43,45,52, 54,57,61, 62,63.	1483	2386·6	±0·528	±0·161	1479·669	450·999	+1·311	+0·400
Bombay ...	79,32,33, 34.	591	951·1	±0·225	±0·069	1479·108	450·828	+0·750	+0·229
False Point...	86,42,41, 40,58,60.	841	1353·4	±0·310	±0·094	1477·019	450·191	−1·339	−0·408
Vizagapatam	85,36,37, 58,60,38.	817	1314·8	±0·302	±0·092	1477·358	450·295	−1·000	−0·305

* p. e. = $\sqrt{(0·004)^2 M + (0·00034)^2 M^2 + (0·000021)^2 D^2}$, *vide* page 393. The probability of error should be compared against two-thirds of the actual discrepancy.

TABLE LV.—The height of Gulbarga.

(*Latitude 17°, Longitude 77°*, vide *Plates I and XVI*).

Final corrected value of dynamic height derived from the simultaneous reduction = 1488·714 feet = 453·756 metres.

Starting point of levelling	Route followed by levelling	Length of line		Probable error of levelling*		Height of Gulbarga		Discrepancy from	
= mean-sea-level at	level-lines	miles	kilometres	foot	metre	feet	metres	1488·714 feet	453·756 metres
								foot	*foot*
Bombay ...	79, 32, 31, 25, 26.	356	572·9	±0·146	±0·045	1489·072	453·865	+0·358	+0·109
Karwar ...	80, 17, 16, 23, 22.	421	677·5	±0·168	±0·051	1489·565	454·015	+0·851	+0·259
Vizagapatam	85, 30, 24	550	885·1	±0·212	±0·065	1488·015	453·543	−0·699	−0·213
Madras ...	84, 8, 14, 21, 22.	447	719·4	±0·177	±0·054	1488·128	453·577	−0·586	−0·179

TABLE LVI.—The height of Bangalore.

(*Latitude 13°, Longitude 78°*, vide *Plates I and XVI*).

Final corrected value of dynamic height derived from the simultaneous reduction = 3111·505 feet = 948·378 metres.

Starting point of levelling	Route followed by levelling	Length of line		Probable error of levelling*		Height of Bangalore		Discrepancy from	
= mean-sea-level at	level-lines	miles	kilometres	foot	metre	feet	metres	3111·505 feet	948·378 metres
								foot	*foot*
Karwar ...	80,17,16,19	442	711·3	±0·184	±0·056	3112·238	948·601	+0·733	+0·223
Beypore ...	81,12,11,7, 18.	360	579·4	±0·158	±0·048	3111·765	948·457	+0·260	+0·079
Cochin ...	82,13,11,7, 18.	378	608·3	±0·164	±0·050	3111·849	948·483	+0·344	+0·105
Negapatam	83,5,4,6,7, 18.	363	584·2	±0·159	±0·048	3111·235	948·296	−0·270	−0·082
Madras ...	84,8,10,18.	221	355·7	±0·116	±0·035	3111·340	948·327	−0·165	−0·050

* p. e. = $\sqrt{(0.004)^2M + (0.00034)^2M^2 + (0.000021)^2D^2}$, *vide* page 393. The probability of error should be compared against two-thirds of the actual discrepancy.

In all the thirteen cases the probable error of levelling is less than the discrepancy met with at the central station, but the discrepancies are, nevertheless, almost certainly due to errors of levelling. It will be noticed that the seven operations of levelling, which connect the central stations with the west coast of India, all make the central stations too high, whilst the six operations of levelling, which connect the central stations with the east coast, all make the central stations too low. This difference is, perhaps, partly due to the tendency, which Indian levelling has, to produce too high values of elevation (*vide* section 8, pages 400-401). The lines of level joining the west and east coasts were mainly levelled through from west to east, and their tendency was to make the centre of India too high with regard to the west coast, and to make the east coast too high with regard to the centre. But we do not regard this explanation as complete. The lines connecting Bangalore with the west coast were run from east to west, and yet they make Bangalore too high. It is certainly peculiar that out of 13 lines of levelling, the seven from the west coast all make the centre of India too high, and the six from the east coast all make the centre of India too low. From this general accordance of results it might be argued, that the mean surface of the Bay of Bengal is about a foot higher than the mean surface of the Arabian Sea. On the other hand, as we have repeatedly stated before, it is very doubtful, if the levelling is sufficiently accurate to bring to light an average difference of one foot between the two seas. If there had been a persistent difference of 2 feet, we should have been able to pronounce it to be real, but one foot is very near the border-line of the possibility of error. We are not now discussing short level-lines, of 40 or 50 miles, as we did in the case of Dehra Dún on page 395; the line from Karachi to Sironj exceeds 1400 miles, that from Sironj to False Point exceeds 800 miles, and on these very long lines considerable levelling errors may accumulate.

Whilst therefore the levelling operations of 1858-1909 have proved that the mean surfaces of the Arabian Sea and of the Bay of Bengal are very nearly at the same elevation, they have also given rise to a suspicion, that the Bay of Bengal may be perhaps slightly the higher of the two. It is but a suspicion: the accuracy of the levelling does not warrant us in pronouncing the divergence to be proved. It will be for our successors to show by means of future lines, whether the suspicion is well-founded, or whether the divergence is a result of levelling errors.

APPENDICES.

APPENDIX.

No. 1.

EXPERIMENT TO TEST THE CHANGES, DUE TO MOISTURE AND TEMPERATURE, IN THE LENGTH OF A LEVELLING STAFF.

BY J. ECCLES, ESQ., M.A.,

In charge of the Computing Office.

The staff selected for the experiment was No. 11 of the ordinary pattern staff used in the levelling of precision. It is a built-up staff consisting of seven strips of teak and two of some soft wood which looks like pine. It was not treated in any way to make it impervious to moisture. Two fine dots were engraved on its brass terminals approximately 10 feet apart.

The experiment was commenced on 30th November 1899 and was carried on till 7th December 1900, but unfortunately the record was broken for two months, April and May 1900, owing to the necessity for removing the microscopes used in the experiment, as they were required with the Jäderin base-line apparatus. Incomplete as it is, the record is of great interest and is sufficient to show the need of frequent comparisons of staves with standards.

The staff was placed on two "camels" on the table used for bar comparisons and the standard 10-foot steel bar I_S was placed on two other "camels" beside it. The staff and the bar were brought alternately under the microscopes G and H of the base-line apparatus and the differences of the distances between the two engraved dots on the staff and the corresponding graduations of the bar were measured in micrometer divisions and afterwards converted into decimals of a foot.

The comparisons were made approximately once a week.

A wet and a dry bulb thermometers were placed close to where the comparisons were made and were read at the time of the comparison. The relative humidity was computed by the usual formula:—

$$\text{Relative Humidity} = \frac{f''}{\text{Tension of vapour at temperature of dry bulb}},$$

where f'', the tension of vapour at the temperature of dew point, is given by

$$f'' = f' - \frac{d}{88} \cdot \frac{h}{30},$$

f' being the tension of vapour at the temperature of evaporation as given in Guyot's Meteorological and Physical Tables,

d the difference of the readings in degrees Fahrenheit between the dry and wet bulb thermometers, and h the height of the barometer in inches.

The following table gives the comparison and its results in the variation of the staff and also the relative humidity and temperature of the air:—

Comparisons of Levelling Staff No. 11 with 10-Ft. Steel Standard Bar I_S.*

Date	End at which reading is taken	Temperature of Standard Bar: Observed	Temperature of Standard Bar: Correction	Temperature of Standard Bar: Corrected mean temperature	Standard Bar: Micrometer reading	Standard Bar: Sum of readings (in terms of microscope G)	Standard Bar: Correction for expansion (in terms of microscope G)	Standard Bar: Excess above datum at 62° F.	Staff: Micrometer reading	Staff: Sum of readings in terms of mic: G	Staff: Excess above Standard at 62° F.	Staff: Value of excess in decimals of a foot	Staff: Length in Feet	Air temperature in Fahr.: Dry bulb	Air temperature in Fahr.: Wet bulb	Relative Humidity	Barometer
30th Nov. 1899	G	° 64·8	−0·62	° 64·33	365·9	642·7	− 42·9	599·8	121·8	506·0	− 93·8	−0·0003244	9·9998797	° 66·5	° 56·3	0·533	Inches 27·86
	H	65·0	−0·53		388·1				399·8			Mean	9·9998645				
	G	...	...	...	215·0	648·8	− 42·9	605·9	205·9	503·3	−102·6	−0·0003548	9·9998493				
	H	...	...	...	451·5				309·5								
8th Dec. 1899	G	59·8	−0·67	59·26	252·3	573·8	+ 50·4	624·2	124·8	480·8	−143·4	−0·0004959	9·9997082	61·6	51·4	0·499	27·69
	H	60·0	−0·62		334·6				370·5			Mean	9·9997049				
	G	...	...	...	263·3	574·1	+ 50·4	624·5	212·8	479·2	−145·3	−0·0005025	9·9997016				
	H	...	...	...	323·5				277·3								
15th Dec. 1899	G	58·0	−0·70	57·49	163·8	573·2	+ 83·0	656·2	212·2	509·1	−147·1	−0·0005087	9·9996954	59·8	51·8	0·587	27·61
	H	58·3	−0·63		426·1				309·0			Mean	9·9996949				
	G	...	...	...	194·9	574·0	+ 83·0	657·0	235·8	509·6	−147·4	−0·0005097	9·9996944				
	H	...	...	...	394·5				285·0								
22nd Dec. 1899	G	58·5	−0·69	57·94	263·2	595·3	+ 74·8	670·1	106·8	491·2	−178·9	−0·0006187	9·9995854	61·2	51·0	0·496	27·68
	H	58·7	−0·63		345·6				400·1			Mean	9·9995747				
	G	...	...	...	310·5	595·7	+ 74·8	670·5	185·6	485·4	−185·1	−0·0006401	9·9995640				
	H	...	...	...	296·8				312·0								
29th Dec. 1899	G	59·0	−0·69	58·45	377·6	584·2	+ 65·4	649·6	248·2	575·5	− 74·1	−0·0002562	9·9999479	61·6	54·2	0·626	27·71
	H	59·2	−0·62		215·0				340·6			Mean	9·9999306				
	G	...	...	...	309·6	589·1	+ 65·4	654·5	328·3	570·4	− 84·1	−0·0002908	9·9999133				
	H	...	...	...	290·9				252·0								
5th Jan. 1900	G	57·7	−0·69	57·19	291·6	557·6	+ 88·6	646·2	364·5	553·8	− 92·4	−0·0003195	9·9998846	59·0	50·1	0·539	27·56
	H	58·0	−0·63		276·8				197·0			Mean	9·9998902				
	G	...	...	...	324·1	555·7	+ 88·6	644·3	257·4	555·1	− 89·2	−0·0003084	9·9998957				
	H	...	...	...	241·0				309·8								
12th Jan. 1900	G	56·5	−0·66	55·90	279·6	542·8	+112·3	655·1	361·7	534·7	−120·4	−0·0004163	9·9997878	60·1	48·3	0·414	27·74
	H	56·6	−0·64		273·9				180·0			Mean	9·9997807				
	G	...	...	...	217·1	548·9	+112·3	661·2	219·8	536·7	−124·5	−0·0004305	9·9997736				
	H	...	...	...	345·3				329·8								
19th Jan. 1900	G	54·9	−0·66	54·37	416·5	617·3	+140·5	757·8	402·7	749·7	− 8·1	−0·0000280	10·0001761	57·1	50·5	0·638	27·83
	H	55·1	−0·61		209·0				361·1			Mean	10·0001749				
	G	...	...	...	386·6	619·2	+140·5	759·7	495·3	750·9	− 8·8	−0·0000304	10·0001737				
	H	...	...	...	242·1				266·0								

* Length of I_S = 10·00020414 feet. Prof. Vol. I. p. (28).
The value of 1 division of Micrometer G = 0·0000034584 foot.
1 division of Micrometer H = 0·96086 division of Micrometer G.
Expansion of the Standard for 1°F. = 18·411693 divisions of Micrometer G.

***Comparisons of Levelling Staff No. 11 with 10-Ft. Steel Standard Bar Is.*—(Continued).**

Date	End at which reading is taken	Temperature of Standard Bar: Observed	Temperature of Standard Bar: Correction	Temperature of Standard Bar: Corrected mean temperature	Standard Bar: Micrometer reading	Standard Bar: Sum of readings (in terms of microscope G)	Standard Bar: Correction for expansion (in terms of microscope G)	Standard Bar: Excess above datum at 62° F.	Staff: Micrometer reading	Staff: Sum of readings in terms of mic: G	Staff: Excess above Standard at 62° F.	Staff: Value of excess in decimals of a foot	Staff: Length in Feet	Air temperature in Fahr.: Dry bulb	Air temperature in Fahr.: Wet bulb	Relative Humidity	Barometer
		°		°										°	°		Inches
26th Jan. 1900	G	54·8	−0·66	54·32	369·2	619·1	+141·4	760·5	628·4	913·8	+153·3	+0·0005302	10·0007343	56·7	52·4	0·758	27·68
	H	55·1	−0·61		260·1				297·0			Mean	10·0007331				
	G	...	...	...	274·1	621·7	+141·4	763·1	545·8	915·7	+152·6	+0·0005278	10·0007319				
	H	...	...	...	361·8				385·0								
6th Feb. 1900	G	56·5	−0·66	55·95	489·9	855·8	+111·4	967·2	708·6	1236·0	+268·8	+0·0009297	10·0011338	58·8	51·7	0·623	27·82
	H	56·7	−0·64		380·8				548·9			Mean	10·0011426				
	G	...	...	...	537·4	854·5	+111·4	965·9	654·6	1239·8	+273·9	+0·0009473	10·0011514				
	H	...	...	...	330·0				609·0								
9th Feb. 1900	G	57·8	−0·69	57·19	127·7	261·5	+ 88·6	350·1	406·8	685·9	+335·8	+0·0011614	10·0013655	61·3	55·2	0·687	27·69
	H	57·9	−0·63		139·3				290·5			Mean	10·0013738				
	G	...	...	...	45·0	259·4	+ 88·6	348·0	561·8	688·6	+340·6	+0·0011780	10·0013821				
	H	...	...	...	223·1				132·0								
16th Feb. 1900	G	60·5	−0·66	59·92	108·2	281·2	+ 38·3	319·5	270·8	661·0	+341·5	+0·0011811	10·0013852	63·8	55·1	0·581	27·62
	H	60·6	−0·60		180·1				406·1			Mean	10·0013787				
	G	...	...	...	55·8	280·6	+ 38·3	318·9	380·1	657·2	+338·3	+0·0011700	10·0013741				
	H	...	...	...	234·0				288·4								
23rd Feb. 1900	G	62·0	−0·63	61·31	108·1	283·8	+ 12·7	296·5	373·1	613·7	+317·2	+0·0010970	10·0013011	65·8	56·8	0·580	27·69
	H	61·8	−0·56		182·9				250·4			Mean	10·0013013				
	G	...	...	...	...	...	...	...	313·3	613·8	+317·3	+0·0010974	10·0013015				
	H	...	...	...	...	...	...	...	312·7								
2nd Mar. 1900	G	63·8	−0·63	63·23	249·2	307·5	− 22·6	284·9	412·8	617·5	+332·6	+0·0011503	10·0013544	67·0	57·4	0·563	27·58
	H	63·8	−0·51		60·7				213·0			Mean	10·0013658				
	G	...	...	...	135·8	309·3	− 22·6	286·7	159·3	625·9	+339·2	+0·0011731	10·0013772				
	H	...	...	...	180·6				485·6								
9th Mar. 1900	G	65·8	−0·60	65·23	185·3	315·6	− 59·5	256·1	188·9	419·5	+163·4	+0·0005653	10·0007694	69·2	57·0	0·474	27·71
	H	65·8	−0·54		135·6				240·0			Mean	10·0007640				
	G	...	...	...	187·8	318·4	− 59·5	258·9	259·9	419·2	+160·3	+0·0005544	10·0007585				
	H	...	...	...	135·9				165·8								
15th Mar. 1900	G	72·6	−0·65	71·97	245·4	413·6	−183·6	230·0	230·8	352·0	+122·0	+0·0004220	10·0006261	76·7	62·6	0·459	27·58
	H	72·5	−0·52		175·0				126·1			Mean	10·0006254				
	G	...	...	...	277·3	413·7	−183·6	230·1	191·2	351·7	+121·6	+0·0004206	10·0006247				
	H	...	...	...	142·0				167·0								

Comparisons of Levelling Staff No. 11 with 10-Ft. Steel Standard Bar Is.—(Continued).

Date	End at which reading is taken	Temperature of Standard Bar: Observed	Temperature of Standard Bar: Correction	Temperature of Standard Bar: Corrected mean temperature	Standard Bar: Micrometer reading	Standard Bar: Sum of readings (in terms of microscope G)	Standard Bar: Correction for expansion (in terms of microscope G)	Standard Bar: Excess above datum at 62° F.	Staff: Micrometer reading	Staff: Sum of readings in terms of mic: G	Staff: Excess above Standard at 62° F.	Staff: Value of excess in decimals of a foot	Staff: Length in Feet	Air temperature in Fahr.: Dry bulb	Air temperature in Fahr.: Wet bulb	Relative Humidity	Barometer
		°		°										°	°		Inches
26th Mar. 1900	G	72·6	−0·65	71·97	92·5	257·4	−183·6	73·8	0·9	0·9	−72·9	−0·0002521	9·9999520	75·8	61·3	0·439	27·70
	H	72·5	−0·52		171·6				0·0			Mean	9·9999510				
	G	...	...	...	92·3	258·0	−183·6	74·4	...	...	−73·5	−0·0002541	9·9999500				
	H	...	...	...	172·5				...								
28th May 1900	G	84·4	−0·59	83·70	584·9	980·0	−399·5	580·5	10·8	181·3	−399·2	−0·0013805	9·9988236	87·2	67·8	0·371	27·53
	H	84·2	−0·62		411·2				177·4			Mean	9·9988238				
	G	...	...	...	403·7	980·2	−399·5	580·7	83·8	181·6	−399·1	−0·0013802	9·9988239				
	H	...	...	...	600·0				101·8								
6th June 1900	G	86·2	−0·61	85·58	437·8	1007·6	−434·1	573·5	6·7	91·3	−482·2	−0·0016676	9·9985365	88·3	72·8	0·483	27·53
	H	86·2	−0·63		593·0				88·0			Mean	9·9985331				
	G	...	...	...	580·9	1008·7	−434·1	574·6	52·8	90·4	−484·2	−0·0016745	9·9985296				
	H	...	...	...	445·2				39·1								
22nd June 1900	G	90·4	−0·70	89·80	610·1	1051·9	−511·8	540·1	21·2	223·8	−316·3	−0·0010938	9·9991103	91·2	80·1	0·623	27·40
	H	90·4	−0·50		459·8				210·9			Mean	9·9990930				
	G	...	...	...	620·2	1055·3	−511·8	543·5	32·9	217·2	−326·3	−0·0011284	9·9990757				
	H	...	...	...	452·8				191·8								
29th June 1900	G	89·3	−0·70	88·65	642·1	1023·9	−490·7	533·2	201·2	427·3	−105·9	−0·0003662	9·9998379	90·0	80·2	0·659	27·35
	H	89·2	−0·50		397·4				235·3			Mean	9·9998270				
	G	...	...	...	462·9	1027·8	−490·7	537·1	146·9	424·9	−112·2	−0·0003880	9·9998161				
	H	...	...	...	587·9				289·3								
11th July 1900	G	84·8	−0·59	84·19	515·0	934·3	−408·6	525·7	327·0	712·8	+187·1	+0·0006471	10·0008512	85·3	79·8	0·790	27·40
	H	84·8	−0·63		436·4				401·5			Mean	10·0008566				
	G	...	...	...	515·7	930·3	−408·6	521·7	455·1	711·8	+190·1	+0·0006578	10·0008619				
	H	...	...	...	431·5				267·2								
30th July 1900	G	83·4	−0·60	82·75	285·7	888·1	−382·0	506·1	264·7	1158·2	+652·1	+0·0022553	10·0024594	84·1	79·5	0·811	27·40
	H	83·3	−0·61		626·9				929·9			Mean	10·0024644				
	G	...	...	...	449·9	891·7	−382·0	509·7	498·3	1164·7	+655·0	+0·0022653	10·0024694				
	H	...	...	...	459·8				693·5								
8th Aug. 1900	G	83·8	−0·59	83·20	471·8	896·5	−390·3	506·2	493·7	1226·2	+720·0	+0·0024901	10·0026942	84·9	79·1	0·778	27·40
	H	83·8	−0·62		442·0				762·3			Mean	10·0026951				
	G	...	...	...	550·9	897·3	−390·3	507·0	231·2	1227·5	+720·5	+0·0024918	10·0026959				
	H	...	...	...	360·5				1036·9								

Comparisons of Levelling Staff No. 11 with 10-Ft. Steel Standard Bar Is.—(Continued).

Date	End at which reading is taken	Temperature of Standard Bar: Observed	Temperature of Standard Bar: Correction	Temperature of Standard Bar: Corrected mean temperature	Standard Bar: Micrometer reading	Standard Bar: Sum of readings (in terms of microscope G)	Standard Bar: Correction for expansion (in terms of microscope G)	Standard Bar: Excess above datum at 62° F.	Staff: Micrometer reading	Staff: Sum of readings in terms of mic: G	Staff: Excess above Standard at 62° F.	Staff: Value of excess in decimals of a foot	Staff: Length in Feet	Air temperature in Fahr.: Dry bulb	Air temperature in Fahr.: Wet bulb	Relative Humidity	Barometer
		°		°										°	°		Inches
16th Aug. 1900	G	83·6	−0·60	83·00	515·8	885·7	−386·6	499·1	422·6	1285·3	+786·2	+0·0027191	10·0029232	84·1	79·0	0·802	27·35
	H	83·6	−0·61		385·0				897·8			Mean	10·0029343				
	G	...	...	...	564·6	886·7	−386·6	500·1	174·1	1292·7	+792·6	+0·0027412	10·0029453				
	H	...	...	...	335·2				1164·2								
24th Aug. 1900	G	81·0	−0.64	80·40	557·4	831·5	−338·8	492·7	637·5	1380·8	+888·1	+0·0030714	10·0032755	82·1	78·1	0·840	27·36
	H	81·0	−0·57		285·3				773·6			Mean	10·0032762				
	G	...	...	...	575·2	834·2	−338·8	495·4	803·3	1383·9	+888·5	+0·0030728	10·0032769				
	H	...	...	...	269·5				604·3								
31st Aug. 1900	G	79·8	−0·64	79·21	531·9	816·8	−316·9	499·9	605·9	1457·1	+957·2	+0·0033104	10·0035145	80·1	76·2	0·840	27·50
	H	79·8	−0·54		296·5				885·9			Mean	10·0035074				
	G	...	...	...	571·2	818·2	−316·9	501·3	300·9	1454·4	+953·1	+0·0032962	10·0035003				
	H	...	...	...	257·1				1200·5								
7th Sep. 1900	G	80·8	−0·64	80·20	579·6	831·8	−335·1	496·7	749·9	1480·7	+984·0	+0·0034031	10·0036072	81·6	77·9	0·850	27·52
	H	80·8	−0·57		262·5				760·6			Mean	10·0035842				
	G	...	...	...	643·4	838·4	−335·1	503·3	634·8	1474·0	+970·7	+0·0033571	10·0035612				
	H	...	...	...	202·9				873·4								
7th Sep. 1900	G	81·2	−0·63	80·55	644·8	843·6	−341·5	502·1	484·2	1484·6	+982·5	Mean of Means	10·0036061			0·825	
	H	81·1	−0·57		206·9				1041·2			+0·0033979	10·0036020	83·2	78·1	0·800	27·52
	G	...	...	...	646·2	840·5	−341·5	499·0	732·8	1496·5	+997·5	Mean	10·0036280				
	H	...	...	...	202·2				794·8			+0·0034498	10·0036539				
14th Sep. 1900	G	79·6	−0·63	79·07	573·9	829·7	−314·3	515·4	753·8	1471·8	+956·4	+0·0033077	10·0035118	80·2	76·0	0·829	27·53
	H	79·7	−0·54		266·2				747·2			Mean	10·0035134				
	G	...	...	...	255·9	814·2	−314·3	499·9	509·5	1457·2	+957·3	+0·0033108	10·0035149				
	H	...	...	...	581·0				986·3								
21st Sep. 1900	G	78·5	−0·61	77·99	265·1	818·6	−294·4	524·2	599·1	1506·4	+982·2	+0·0033969	10·0036010	79·5	75·1	0·819	27·60
	H	78·6	−0·51		576·0				944·3			Mean	10·0036008				
	G	...	...	...	502·6	821·1	−294·4	526·7	478·8	1508·8	+982·1	+0·0033965	10·0036006				
	H	...	...	...	331·5				1072·0								
28th Sep. 1900	G	77·1	−0·63	76·48	319·7	795·5	−266·6	528·9	252·6	1487·4	+958·5	+0·0033149	10·0035190	79·3	71·0	0·671	27·60
	H	77·0	−0·52		495·2				1285·1			Mean	10·0035341				
	G	...	...	...	292·2	796·5	−266·6	529·9	392·9	1497·1	+967·2	+0·0033450	10·0035491				
	H	...	...	...	524·8				1149·2								

Comparisons of Levelling Staff No. 11 with 10-Ft. Steel Standard Bar Is.—(Continued).

Date	End at which reading is taken	Temperature of Standard Bar: Observed	Temperature of Standard Bar: Correction	Temperature of Standard Bar: Corrected mean temperature	Standard Bar: Micrometer reading	Standard Bar: Sum of readings (in terms of microscope G)	Standard Bar: Correction for expansion (in terms of microscope G)	Standard Bar: Excess above datum at 62° F.	Staff: Micrometer reading	Staff: Sum of readings in terms of mic: G	Staff: Excess above Standard at 62° F.	Staff: Value of excess in decimals of a foot	Staff: Length in Feet	Air temperature in Fahr.: Dry bulb	Air temperature in Fahr.: Wet bulb	Relative Humidity	Barometer
		°		°										°	°		Inches
5th Oct. 1900	G	77·7	−0·61	77·15	319·2	822·4	−278·9	543·5	591·1	1350·4	+806·9	+0·0027906	10·0029947	80·0	69·6	0·601	27·63
	H	77·7	−0·50		523·7				790·2			Mean	10·0029977				
	G	...	...	...	527·2	825·6	−278·9	546·7	501·2	1355·3	+808·6	+0·0027965	10·0030006				
	H	...	...	...	310·6				888·9								
12th Oct. 1900	G	78·2	−0·60	77·61	431·9	851·9	−287·4	564·5	698·8	1208·2	+643·7	+0·0022262	10·0024303	81·1	70·0	0·582	27·66
	H	78·1	−0·49		437·1				530·1			Mean	10·0024326				
	G	...	...	...	399·2	850·0	−287·4	562·6	520·1	1207·6	+645·0	+0·0022307	10·0024348				
	H	...	...	...	469·2				715·5								
19th Oct. 1900	G	74·4	−0·68	73·82	308·8	799·4	−217·6	581·8	627·3	1054·7	+472·9	+0·0016355	10·0018396	77·3	66·3	0·567	27·67
	H	74·5	−0·59		510·6				444·8			Mean	10·0018132				
	G	...	...	...	256·2	803·5	−217·6	585·9	353·2	1043·5	+457·6	+0·0015826	10·0017867				
	H	...	...	...	569·6				718·4								
26th Oct. 1900	G	71·8	−0·64	71·29	257·4	791·3	−171·0	620·3	450·9	985·3	+365·0	+0·0012624	10·0014665	74·0	62·0	0·513	27·81
	H	71·9	−0·49		555·6				556·2			Mean	10·0014670				
	G	...	...	...	354·2	794·9	−171·0	623·9	384·1	989·2	+365·3	+0·0012634	10·0014675				
	H	...	...	...	458·7				629·8								
2nd Nov. 1900	G	71·1	−0·64	70·52	541·2	792·3	−156·9	635·4	435·7	988·8	+353·4	+0·0012222	10·0014263	74·1	64·0	0·582	27·79
	H	71·1	−0·52		261·3				575·6			Mean	10·0014217				
	G	...	...	...	428·9	795·8	−156·9	638·9	518·8	989·6	+350·7	+0·0012129	10·0014170				
	H	...	...	...	381·8				490·0								
9th Nov. 1900	G	71·8	−0·64	71·18	272·3	803·6	−169·0	634·6	535·1	1020·4	+385·8	+0·0013343	10·0015384	74·9	65·0	0·595	27·59
	H	71·7	−0·50		552·9				505·1			Mean	10·0015322				
	G	...	...	...	329·6	801·6	−169·0	632·6	362·4	1014·8	+382·2	+0·0013218	10·0015259				
	H	...	...	...	491·2				679·0								
16th Nov. 1900	G	69·2	−0·63	68·56	555·3	762·2	−120·8	641·4	528·6	990·0	+348·6	+0·0012056	10·0014097	71·0	63·2	0·657	27·76
	H	69·1	−0·56		215·3				480·2			Mean	10·0014219				
	G	...	...	...	478·8	763·0	−120·8	642·2	594·2	997·8	+355·6	+0·0012299	10·0014340				
	H	...	...	...	295·8				420·0								
23rd Nov. 1900	G	67·0	−0·58	66·50	474·8	738·6	−82·9	655·7	652·1	934·8	+279·1	+0·0009653	10·0011694	70·0	58·0	0·488	27·69
	H	67·1	−0·52		274·5				294·2			Mean	10·0011772				
	G	...	...	...	364·1	738·6	−82·9	655·7	603·6	939·3	+283·6	+0·0009808	10·0011849				
	H	...	...	...	389·8				349·4								

Comparisons of Levelling Staff No. 11 with 10-Ft. Steel Standard Bar Is.—(Continued).

Date	End at which reading is taken	Temperature of Standard Bar: Observed	Temperature of Standard Bar: Correction	Temperature of Standard Bar: Corrected mean temperature	Standard Bar: Micrometer reading	Standard Bar: Sum of readings (in terms of microscope G)	Standard Bar: Correction for expansion (in terms of microscope G)	Standard Bar: Excess above datum at 62° F.	Staff: Micrometer reading	Staff: Sum of readings in terms of mic: G	Staff: Excess above Standard at 62° F.	Staff: Value of excess in decimals of a foot	Staff: Length in Feet	Air temperature in Fahr.: Dry bulb	Air temperature in Fahr.: Wet bulb	Relative Humidity	Barometer
30th Nov. 1900	G	64·0°	−0·63	63·53°	125·2	526·7	−28·2	498·5	576·8	751·9	+253·4	+0·0008764	10·0010805	66·4°	57·8°	0·600	Inches 27·70
	H	64·2	−0·51		417·9				182·2			Mean	10·0010828				
	G	...	...	...	182·1	527·0	−28·2	498·8	460·2	753·5	+254·7	+0·0008809	10·0010850				
	H	...	...	...	359·0				305·2								
7th Dec. 1900	G	59·5	−0·68	59·00	156·8	464·9	+55·2	520·1	313·9	714·6	+194·5	+0·0006727	10·0008768	62·5	52·8	0·527	27·74
	H	59·8	−0·62		320·6				417·0			Mean	10·0008722				
	G	...	...	...	245·7	466·3	+55·2	521·5	195·7	713·3	+191·8	+0·0006634	10·0008675				
	H	...	...	...	229·6				538·7								

The results have been plotted in the first three diagrams in Plate XIV, and a casual glance will show that the variation in the length of the staff follows pretty closely on the change of humidity, but does not seem to have much connection with the change of temperature.

The greatest variation in length is about 0·005 of a foot: it occurs between June and September, and corresponds to a change of 0·45 in humidity: the other great change between February and June is about 0·003 of a foot and corresponds to a change of humidity of 0·30.

From this it appears that the numbers representing the change in length of the staff in feet and the change in the relative humidity are roughly in the ratio of 1 to 100. Accordingly the values of the relative humidity have been reduced in this ratio and plotted side by side with the variations in the length of the staff.

The result is exhibited in the fourth diagram of Plate XIV and appears to show that change of temperature has little effect in the alteration of the length of this particular staff.

This is not in accordance with the experiments of Colonel Goulier mentioned by M. Lallemand at page 112 of his "*Nivellements de Haute Precision*", but it is a matter for congratulation that it is so, since in India the humidity and the temperature effects do not always tend to cancel, the greatest humidity occurring at a time when the temperature is very high.

During the working part of the year; November to April, the greatest possible error which could be introduced at one station of observation from the expansion of two such staves would be 0·003 of a foot, that is if the top of one staff and the bottom of the other were read, while if work were carried on during the rains an error of 0·005 of a foot might be introduced. Generally speaking errors half the size of the above might be expected, as it is seldom that the whole length of the staff is used.

It must however be remembered that these errors are to a great extent guarded against by the system of comparing the staves against standard steel bars, but as the total correction for the variation in the lengths of the staves depends on the algebraical sum of the rises and falls, it follows that in a long line of levels, or even in a short one in hilly country, a very appreciable error may be introduced unless careful comparisons are frequently made. An example of this occurs in the line from Bangalore to Mangalore which is 224 miles long with a difference of level of about 3000 feet: it was found that the total correction for the expansion of the staves was as much as 0·588 of a foot. It is to be feared that in the older lines of levelling the necessity for frequent comparison was to some extent overlooked, and that the comparisons were not as carefully conducted as they might have been, but of late years great attention has been paid to this point.

It cannot be too strongly impressed on levellers that they ought to compare their staves against standard bars very frequently and very carefully, and further, in view of the investigation under discussion, that an extra comparison should be made not more than a week after any great change in the weather either from dry to wet or from wet to dry.

Dehra Dún
May, 1910.

J. ECCLES.

APPENDIX.

No. 2.

ON THE ERECTION OF STANDARD BENCH-MARKS IN INDIA DURING THE YEARS 1904-1910.

BY C. F. ERSKINE, ESQ.,

In charge of the Tidal and Levelling Operations.

In 1901 the Superintendent Trigonometrical Surveys brought to the notice of the Surveyor General of India, that owing to the great and unforeseen loss of bench-marks which had been gradually going on for over 40 years, indeed ever since levelling operations were first commenced in India, there were reasons to fear that a very large proportion of what were intended to be substantial and enduring records had been either lost or disturbed from causes which were beyond the power of the department to prevent, such as the expansion of cantonments and cities, the duplication of railway lines, the widening of roads, the extension of railway stations and platforms, the renewal of culverts and bridges etc. In most cases bench-marks had been cut on bridges, culverts, railway platfoms and mile-stones, and it was believed that almost all those inscribed on mile-stones, numbering in the aggregate about 3,000, had been displaced. Colonel Burrard proposed, that standard bench-marks of a new pattern should be erected in all parts of India, and this proposal was accepted.

The urgency of the subject being thus recognised, the question arose as to the ways and means of securing their preservation. And, after due deliberation, it was decided that new bench-marks of some distinctly defined and prominent design should be erected all over India, and connected with existing bench-marks that had been previously levelled to, such to be considered as standard bench-marks, bearing the following characteristic features:—

(1) Architectural design.

(2) Sites for them carefully chosen in public places, having due regard to certain conditions mentioned elsewhere under the heading "Sites for standard bench-marks".

(3) Solidity of construction ensuring comparative indestructibility.

In order to advance the scheme, the various Governments had to be consulted.

The idea was to gradually erect permanent standard bench-marks in all the principal towns in India, those of one province being completed before those of another province were commenced, and that a commencement should be made in the United Provinces of Agra and Oudh.

A specimen bench-mark was erected at Dehra Dún, complete with slab (on which is to be inscribed the height of the bench-mark) and railings.

The local Governments were requested to sanction the erection of the standard bench-marks and to invite the co-operation of municipalities and district authorities, who were asked to provide sites, to undertake the preservation of the marks, and to bear the cost of repairs.

The Government of the United Provinces of Agra and Oudh was first approached. A programme was submitted by Major Burn, R.E., officer in charge of the Tidal and Levelling, to Colonel Burrard, who then addressed the Government on behalf of the scheme.

The following are a few extracts from the letter to the Government of the United Provinces of Agra and Oudh:—

"For nearly half a century the Trigonometrical Survey has been running lines of level of great accuracy across India and "connecting with tidal stations at many points of the coast. Of recent years it has been brought home to us that we are gradually "losing our bench-marks all over the country, and that unless we take some steps, nine-tenths of them will soon have disappeared "or have been disturbed". * * *

"Having fixed these bench-marks at great cost, we feel that it is incumbent upon us to adopt measures for their "preservation, both for the use of engineers and for the scientific purposes of posterity, who will in future ages desire to ascertain "the vertical movements of the earth's crust". * * * *

"The large towns derive considerable permanent benefit from the possession of accurately fixed bench-marks".

The proposals set forth in the application here referred to were readily sanctioned by the Government, who expressed warm approval of the scheme.

It now became the duty of the officer in charge of the Tidal and Levelling Party to arrange with local officials and engineers, for the erection of the standard bench-marks. They were consulted as to the most suitable sites for them, attention being drawn to the main points to be considered in the selection of sites, namely, that the localities chosen, should be as little liable to interruption and to subsidence as possible. A plan and elevation of approved design was enclosed with this communication. If stone suitable for the monoliths was not procurable locally, the officer in charge of the party would arrange to send the monoliths direct from a selected quarry to the officers concerned in the erection of the bench-marks. The officers addressed were informed that though the Survey of India would pay for the erection of the bench-marks, their future maintenance would rest with the local authorities. Site plans and estimates of cost were called for and on their receipt the officer in charge decided upon the most suitable sites. He then communicated his approval to the local engineers, and requested that the work of construction might be immediately taken in hand, at the same time pointing out the importance of having the work completed well before levelling operations were undertaken, so that the bench-marks might fully settle into a permanent position before being connected with the adjacent lines of levelling.

In like manner other provinces were communicated with, and bench-marks were erected, as opportunities arose, and as finances permitted. The operations were gradually extended, until the whole of India and part of Burma have been provided for.

In the case of cantonments, arrangements were made through the Director General of Military Works, Simla, for the erection of the bench-marks.

The selection of a suitable stone was a very important matter. Marble, granite or some hard sandstone were thought of as being the best available stone from which to choose a suitable one. It was ascertained that in Jubbulpore, specimens of all three were to be seen, and Major Burn went there to investigate the subject. He soon found ample evidence of the kind of stone that would best suit the purpose. The marble weathered badly; the granite was out of the question, as the cost was prohibitive, and it was difficult to procure blocks of the dimensions required; but a stone was found which was used for innumerable building purposes, and which would answer all our requirements; this was the Chunar sandstone, obtained from the quarries in the Mirzapur district, being outlying crops of the solid rock which forms a portion of the great Vindhyan range.

Before deciding finally upon the acceptance of a choice of stone for the bench-marks, Major Burn sought the opinion of Sir Thomas Holland, Director of the Geological Survey. Sir Thomas Holland wrote as follows:—"after further examination "of the samples of building stone in our collection, and after consultation with my colleagues, I am of opinion that your selec-"tion of Chunar sandstone for the monoliths required in Northern India appears to be the best that could be made. The posi-"tion of the quarries permits of easy distribution, and the remarkable uniformity of the stone will ensure the production of "monoliths whose stability can be relied on without expert inspection of each stone. The use of similar stone for delicate car-"vings on the exposed parts of many buildings in Central and Northern India is an illustration of the general confidence in its "durability, and the freshness of carvings on the old Buddhist *stupas*, like those of Sanchi and Barhut, shows that, after an "exposure of 2,000 years, these sandstones are practically unaffected by the weather."

On receiving this expert evidence of the imperishable nature and ornamental properties of Chunar sandstone, Major Burn at once decided to utilize it for all the standard bench-marks in the United Provinces.

In dealing with the question of sites for standard bench-marks in towns and cantonments, it was considered that the most favourable localities would be public gardens, gardens of law courts, post and telegraph offices, or of churches. It was obviously desirable to obtain sites, which were not likely to be built over when offices were extended.

In expressing his opinion as to the kind of site which should be selected, Colonel Burrard wrote:—

"As to the most suitable site for a bench-mark, it should be chosen where it is least likely to suffer (1stly) from natural "movements, (2ndly) from disturbance by living creatures. The most natural movement that takes place is subsidence, and rock "is consequently a safer basis than alluvium. The other natural movements, that we have to guard against, arise from tree-"growth, from floods and defective drainage."

"It is very difficult to say what sites are likely to be most undisturbed by men and animals: roads and railways are "constantly being widened, and offices enlarged, so that any bench-marks in their vicinity are sure in time to be swept away. "The ground level of churchyards is liable to subsidence. Public gardens and gardens surrounding churches are perhaps "favourable positions."

The design for the standard bench-marks was not an easy one to frame. The question was very fully gone into, and many opinions were called for from various executive officers before finality could be obtained.

The following is a description of the design finally approved and adopted for all the standard bench-marks:—

"The bench-mark will consist of a monolith 2 feet square at base and 3 feet high, 2 feet of the upper portion being "dressed, the remaining lower portion of one foot being left undressed. The upper four inches of the stone is shaped to the "form of a frustrum of a pyramid, terminating at the top in a square of 3-inch sides. On one face of the monolith the words "$\boxed{\text{G.T.S. Standard Bench-Mark}}$ and the year of construction are engraved. The stone rests on a bed of concrete, $6\frac{1}{2}$ feet "square and $2\frac{1}{2}$ feet in depth, the upper surface of the stone being 2 feet above ground level. A space is left in the brick work "surrounding the monolith, for a stone slab on which the height of the bench-mark above mean-sea-level will hereafter be inscribed, "and which will be laid in cement with a slight slope to allow the rain to drain off."

The inscription on the monolith is engraved at the quarry, before the stone is placed in position. It would be inadvisable to postpone the engraving, until after the monolith had been erected.

The structure is enclosed by iron railings.

For the bench-marks constructed in 1904-05, the monolith was dressed to a depth of 14 inches below the top; so that when the block was erected, a large portion of the undressed stone was left exposed. In 1905-06 an alteration in this feature of the design was made, and the dressed portion increased to a depth of 2 feet below the top: consequently, when the monolith is placed in position, only the dressed portion is now left exposed.

Twenty-seven bench-marks of the former description have been erected, mostly in the United Provinces.

The weight of a monolith is about 2,000 lbs.

The cost of a monolith, dressed and inscribed after the latest approved design is Rs. 16 and annas 8, at Chunar Railway Station.

The cost of erection of standard bench-marks varies considerably in different parts of India, and it is not possible to give any accurate estimate of the *average* cost of construction of a single bench-mark.

The slab, referred to above, is a piece of Agra stone of the dimensions, 2 feet × 1 foot × 2 inches, on which is cut an inscription indicating the height above sea-level of the standard bench-mark. The inscription is arranged in the manner shown below:—

THE HEIGHT OF THE TOP

OF THIS PILLAR IS

FEET

ABOVE THE MEAN LEVEL

OF THE SEA.

On the back of each slab is engraved the name of the place, where the bench-mark, to which the height refers, has been erected. The slabs will be forwarded to their respective destinations, and the local engineers will have them embedded in masonry at the foot of the monoliths.

The slabs have been prepared by the Tidal and Levelling Party and the greatest care will be taken that the proper stones are sent to the correct sites.

The height inscribed on the slab is not the height of the bench-mark as deduced directly from observations in the field, but is the height assigned to it after all circuit errors have been eliminated in the process of grinding.

The standard bench-marks have been connected either with existing bench-marks on the main-lines previously executed, or with new levelling, in which latter case they have been connected *pari passu* with the levelling.

The top of the monolith is in every case the point of reference. The levelling to the bench-marks has in all cases been executed by two levellers working independently with first-class instruments, and the methods employed were in every sense the same as those adopted for the main-lines of levelling.

Complete list of standard bench-marks connected by levelling up to date :—

Number	Name of town	Bench-marks	Year in which connected	Number	Name of town	Bench-marks	Year in which connected
1	Bombay ...	2	old	35	Ahmednagar ...	1	1906-07†
2	Calcutta ...	1	old	36	Kirkee ...	1	1906-07
3	Madras ...	1	old	37	Poona ...	2	1906-07
4	Karachi ...	1	old	38	Sholapur ...	1	1906-07
5	Rangoon ...	1	old	39	Multan ...	1	1907-08
6	Dehra Dún ...	2	1905-06	40	Dera Ismail Khan ...	1	1907-08
7	Saharanpur ...	1	1905-06	41	Raichur ...	1	1907-08
8	Muzaffarnagar ...	1	1905-06	42	Bellary ...	1	1907-08
9	Meerut ...	2	1905-06	43	Cuddapah ...	1	1907-08
10	Aligarh ...	1	1905-06	44	Madras ...	1	1907-08
11	Bareilly ...	1	1905-06	45	Bikaner ...	1	1907-08
12	Shahjahanpur ...	1	1905-06	46	Satara ...	1	1908-09
13	Lucknow ...	1	1905-06*	47	Belgaum ...	1	1908-09
14	Sitapur ...	1	1905-06	48	Saugor ...	1	1908-09
15	Fyzabad ...	1	1905-06	49	Bangalore ...	1	1908-09
16	Allahabad ...	2	1905-06	50	Jodhpur ...	1	1908-09
17	Mirzapur ...	1	1905-06	51	Calicut ...	1	1908-09
18	Benares ...	1	1905-06	52	Jubbulpore ...	1	1908-09
19	Ghazipur ...	1	1905-06	53	Negapatam ...	1	1908-09
20	Gorakhpur ...	1	1905-06	54	Madura ...	1	1908-09
21	Muttra ...	1	1905-06	55	Trichinopoly ...	1	1908-09
22	Agra ...	1	1905-06	56	Secunderabad ...	3	1908-09
23	Gwalior ...	1	1905-06	57	Salem ...	1	1908-09
24	Lahore ...	1	1906-07	58	Tinnevelly ...	1	1908-09
25	Rawalpindi ...	1	1906-07	59	Bijapur ...	1	1908-09
26	Jhansi ...	1	1906-07	60	Deesa ...	1	1908-09
27	Delhi ...	1	1906-07	61	Nagpur ...	1	1908-09
28	Ambala ...	1	1906-07	62	Hinganghat ...	1	1908-09
29	Ludhiana ...	1	1906-07	63	Akola ...	1	1908-09
30	Ferozepore ...	1	1906-07	64	Raipur ...	1	1908-09
31	Jhelum ...	1	1906-07	65	Bilaspur ...	1	1908-09
32	Atttock ...	1	1906-07	66	Sambalpur ...	1	1908-09
33	Peshawar ...	1	1906-07	67	Ahmedabad ...	1	1908-09
34	Devlali ...	1	1906-07	68	Roorkee ...	1	1908-09

* This bench-mark was originally connected in 1905-06, but was subsequently removed to another site, and reconnected in 1909-10.

† This bench-mark was originally connected in 1606-07, but owing to the rejection of the line Dhond to Manmad, will be reconnected in 1910-11.

Complete list of standard bench-marks connected by levelling up to date.—(*Contd.*).

Number	Name of town	Standard bench-marks	Year in which connected	Number	Name of town	Standard bench-marks	Year in which connected
69	Mussooree ...	1	1908-09	89	Bezwada ...	1	1909-10
70	Sukkur ...	1	1909-10	90	Nellore ...	1	1909-10
71	Hyderabad ...	1	1909-10	91	Motihari ...	1	1909-10
72	Karachi ...	1	1909-10	92	Bhagalpur ...	1	1909-10
73	Mhow ...	1	1909-10	93	Burdwan ...	1	1909-10
74	Jacobabad ...	1	1909-10	94	Purnea ...	1	1909-10
75	Surat ...	1	1909-10	95	Dinajpur ...	1	1909-10
76	Godhra ...	1	1909-10	96	Cuttack ...	1	1909-10
77	Dhulia ...	1	1909-10	97	Balasore ...	1	1909-10
78	Bahawalpur ...	1	1909-10	98	Rangoon ...	1	1909-10
79	Rajkot ...	1	1909-10	99	Pegu ...	1	1909-10
80	Khanpur ...	1	1909-10	100	Toungoo ...	1	1909-10
81	Sadikganj ...	1	1909-10	101	Mandalay ...	1	1909-10
82	Baroda ...	1	1909-10	102	Shwebo ...	1	1909-10
83	Muzuffernagar ...	1	1909-10	103	Meiktila ...	1	1909-10
84	Rewah ...	1	1909-10	104	Magwe ...	1	1909-10
85	Bankipore ...	1	1909-10	105	Myitkyina ...	1	1909-10
86	Berhampore (Madras)	1	1909-10	106	Wuntho ...	1	1909-10
87	Vizagapatam ...	1	1909-10	107	Bhopal ...	2	1909-10
88	Cocanada ...	1	1909-10				

List of standard bench-marks erected but not yet connected by levelling.

Number	Name of town
1	Ahmednagar ...
2	Barisal ...
3	Dacca ...
4	Comilla ...
5	Chittagong ...
6	Dhubri ...
7	Gauhati ...

List of standard bench-marks under construction.

Number	Name of town
1	Mymensingh ...
2	Sylhet ...
3	Silchar ...
4	Dibrugarh ...

The Governments of Eastern Bengal and Assam, and of Burma have suggested that standard bench-marks should be erected in the following towns:—

Number	Town	Circle	Number	Town	Circle
	EASTERN BENGAL AND ASSAM.			BURMA.—(*Continued*).	
1	Silchar		21	Thaton	Toungoo.
2	Sylhet		22	Pa-an (Thaton District)	Toungoo.
3	Dibrugarh ...		23	Kyaikto	Toungoo.
			24	Moulmein ...	Toungoo.
	BURMA.		25	Kalaw	Toungoo.
4	Bhamo	Mandalay.	26	Taunggyi	Toungoo.
5	Thabeitkyin ...	Mandalay.	27	Loilem	Toungoo.
6	Sagaing	Mandalay.	28	Insein	Rangoon.
7	Maymyo	Mandalay.	29	Taikkyi	Rangoon.
8	Hsipaw	Mandalay.	30	Kyauktan ...	Rangoon.
9	Lashio	Mandalay.	31	Twante	Rangoon.
10	Akyab	Maritime.	32	Tharrawaddy ...	Rangoon.
11	Tavoy	Maritime.	33	Zigon	Rangoon.
12	Mergui	Maritime.	34	Prome	Rangoon.
13	Sandoway ...	Maritime.	35	Henzada	Rangoon.
14	Yamethin ...	Chindwin.	36	Myanaung ...	Rangoon.
15	Thazi	Chindwin.	37	Danubyu	Rangoon.
16	Kyaukse	Chindwin.	38	Myaungmya ...	Rangoon.
17	Myingyan ...	Chindwin.	39	Ma-ubin	Rangoon.
18	Pakokku	Chindwin.			
19	Monywa	Chindwin.			
20	Thayetmyo ...	Chindwin.			

The cordiality with which the standard bench-mark scheme has been received by the various local Governments is evidence of its popularity. Everywhere the demands for these bench-marks have been in excess of the original programme proposed; as a unique instance it may be mentioned that the Government of Burma has asked for no less than 36 standard bench-marks in excess of the number originally provided for by the Tidal and Levelling Party.

Apart from the results to be naturally expected from a well appointed system, the friendly attitude and ready assistance accorded by officials with whom it has been necessary to have dealings, have been a most helpful means of bringing to a successful culmination a project of very great utility to the public, and one which is highly conducive to the advancement of the science of Geodesy.

The executive officers in charge of the Levelling Operations, who have taken part in the origin, the development and the extensions of the standard bench-mark scheme, have been:—

Major J. M. Burn, R. E., for one year, 1904-05.

Mr. C. F. Erskine, for five years, 1905-10.

Many years before the present scheme of erecting standard bench-marks in all parts of India had been evolved, marks, recognised as standard bench-marks had been constructed at the ports of Karachi, Bombay, Madras, Calcutta and Rangoon. The object being to have reliable bench-marks of tidal reference at those Indian ports where tidal operations were to be carried on permanently. They were so constructed and placed as to render them practically imperishable. They are not of uniform design, and are unlike the pattern that has now been adopted. They have all been connected by double levelling of precision.

The following are descriptions of the old standard bench-marks of tidal reference:—

Karachi.

This bench-mark was accepted by Colonel G. A. Laughton, I.A., of the Bombay Revenue Survey, as defining the datum of his survey of Karachi made in 1874-75 and all levels in Karachi are referred to it.

It is situated in the south corner of the compound of Holy Trinity Church and consists of a circular masonry pillar, 2 feet 2 inches in diameter, rising 2 feet 9 inches above ground level. It is plastered with Portland cement, and its top is capped by a thick horizontal slate. An iron pin 2 inches in diameter, fixed in the pillar, passes through a perforation at the centre of the slate, and projects slightly above its surface, the top of the pin being the point of reference. The slate is inscribed as follows:—

G. T. S.
BENCH MARK
ACCEPTED HEIGHT ABOVE
MEAN SEA LEVEL 27·55
A.D. 1862.

This pillar is protected by a substantial iron railing.

Bombay.

(1). *At Public Works Secretariat.*

This bench-mark consists of a block of granite, 3 feet cube, resting on a masonry foundation. The top surface of this block is on exactly the same level as the bench-mark on the Town Hall steps. The following inscriptions have been cut on this stone:—

North face—

"Standard Bench Mark
for
Bombay
Erected 1885"

"The top surface of this stone is 19·773 feet above the mean level of the sea as marked on the granite stone let into the south side of the north entrance to the Prince's Dock."

East face—

"The top surface of this stone is 19·773 feet above the mean level of the sea as determined by Major A. W. Baird, R.E., in charge Tidal and Levelling Operations, Survey of India, from observations with a self-registering tide-gauge at Apollo Bandar, extending from January 1878 to January 1885. During this period the highest recorded high water was 10·71 feet, and the lowest recorded low water was 29·39 feet."

West face—

"The top surface of this stone is 100 feet above the plane of reference hitherto known as Town Hall Datum."

Bombay.

(2). *At Prince's Dock.*

This bench-mark consists of a notch cut in a large block of granite let into the south side of the north entrance to the dock. The bottom surface of the notch corresponds to mean-sea-level, and is 19·773 feet below the standard bench-mark opposite the Public Works Secretariat, or 80·227 feet above the Town Hall Datum. The following inscription has been cut on the block:—

"The bottom surface of this notch
80·227 above T. H. D.
Mean Level of the Sea
1885"

Note.—The Town Hall Datum, which is an imaginary line 100 feet below the bench-mark on the Town Hall steps, is the datum to which levels of local surveys in Bombay for many years, have been referred.

The bench-mark on the Town Hall steps is an inscription G. T. S. O B. M. cut on the bottom step on the north side of the main entrance to the Town Hall at Bombay. It is a few inches south of the iron railing and immediately above the arrow head which was the original bench-mark.

Madras.

This bench-mark is an inscription G. T. S. O B. M. cut on the north-east corner of the plinth of the old light-house and is the standard bench-mark for Madras as accepted by the Government of Madras in their Resolution No. 737 in the Public Works Department, dated 24th March 1885.

The point of reference is within the circle.

Calcutta.

This bench-mark consists of a solid block of Chunar sandstone embedded 6 inches in a masonry foundation, the portion of the block exposed being a 3-foot cube: the foundation is 5 feet deep and 4 feet 7 inches square, having its top surface a few inches above the ground so as to form a plinth or step round the block.

It was originally placed in the compound of the Mathematical Instrument office (Survey of India), Wood Street, in front of the centre of the outer wall of the portico; but in 1909 the M.I.O. buildings were extended and the bench-mark was removed and re-erected in the compound of the Surveyor General's office in the angle between Wood Street and Short Street.

The following inscriptions were originally cut on metal plates let into stone:—

"Standard Bench Mark
for
Calcutta
1895."

"The level surface enclosed within the circle engraved on the metal plate inserted in the upper face of this stone is in the plane of reference, and is 18·89 feet above mean-sea-level at False Point, as determined by spirit-levelling and automatic tidal observations, the latter extending continuously from May 1881 to May 1885, and both undertaken in the course of the Tidal and Levelling operations of the Survey of India Department."

"The plane of reference is 26·83 feet above the level of the sill of Kidderpore old Dock, the datum adopted by the Survey of India Department for the Kidderpore Tide Tables and by the Marine Survey of India and the River Surveyors for their charts of Kidderpore and Diamond Harbour. It is also 15·85 feet above mean water-level at Kidderpore, as determined by the Survey of India Department Spirit-Levelling and Automatic Tidal Observations, the latter extending continuously from March 1881 to December 1894, during which period the highest recorded High Water at Kidderpore was 2·7 feet, and the lowest recorded Low Water was 24·6 feet below the plane of reference."

"The plane of reference is 18·69 feet above mean-sea-level at Dublat, Saugor Island, as determined by the Survey of India Department Spirit Levelling and Automatic Tidal Observations, the latter extending continuously from April 1881 to April 1886. It is also 9·85 feet above a bench-mark embedded in masonry, about 630 feet south of the site of the Dublat Tidal Observatory at the foot of the main embankment".

After the re-erection of the bench-mark in 1909, the old inscriptions were removed, and the date engraved on the metal plate altered to 1910.

Rangoon.

This bench-mark consists of a 3-foot cube of polished granite, resting on a masonry foundation, erected in the Custom House flag-staff enclosure, a few feet away from the time gun. The top surface of the stone is the plane of reference.

The following inscriptions have been cut on the stone:—

North side—

"Standard
Bench-mark
for
Rangoon."

South side—

"The top surface of the stone is 16·69 feet above mean water-level at Latter Street and Brooking Street Wharves, as determined by Spirit Levelling, and Automatic Tidal Observations, the latter extending continuously from 1880 to 1892, and both undertaken in the course of the Tidal and Levelling Operations of the Survey of India Department: during this period the highest recorded High Water was 5·68 feet, and the lowest recorded Low Water was 27·05 feet below the top surface of this stone."

East side—

"The top surface of this stone is 26·97 feet above Graham Smith's Datum. The datum adopted by the Survey of India Department for the Rangoon Tide Tables and by the Marine Survey of India, and the River Surveyors for their charts of Rangoon. The zero of the Tidal graduated staff at Brooking Street Wharf also corresponds with Graham Smith's datum."

West side—

"The top surface of this stone is 2·90 feet above the bench-mark inscribed on the base of the Obelisk at Elephant Point, and 232·43 feet below the permanent bench-mark embedded at Mandalay Railway Station, as determined by the Levelling Operations of the Survey of India Department."

Debra Dún, 1st June, 1910.

C. F. Erskine.

APPENDIX.

No. 3.

MEMORANDUM ON THE STEPS TAKEN IN 1905-1910 TO ENABLE MOVEMENTS OF THE EARTH'S CRUST TO BE DETECTED.

BY COLONEL S. G. BURRARD, R.E., F.R.S.,

Superintendent of Trigonometrical Surveys.

The rate, at which mountains rise in altitude, is generally considered to be too slow to be observed, but this view rests upon no sound basis. Tidal measurements in India have not, it is true, brought to light any decided relative movements of land and sea,* but reliable observations have been made during short periods only, and have not been sufficient to warrant any conclusion upon the question at issue. It would moreover be unsafe to assume that no movements of the earth's crust had occurred in the interior of continents, because none had been detected at tidal observatories. Slow movements, persistent but imperceptible to man, may be taking place, and may be altering the relative levels of different places in India.

In the Kangra (Dharmsala) earthquake of 1905, the Siwalik range was apparently raised 0·4 foot in a few seconds.† This earthquake had disastrous effects over a wide Himalayan area. Middlemiss states that the shock was due to a sudden rupture among the Sub-Himalayan formations, "where the strain was specially great owing to resistances to the well established forward "march of the overthrusting foot of the Himalayan range."‡ In this case therefore it was the shock, that alarmed the population; the rise of the Siwalik range was an unnoticed effect of the shock and would have remained unnoticed, had it not been subsequently brought to light by levelling observations.

If we assume that the Himalaya have been upheaved by successions of severe earthquakes, and if we take 0·4 foot to be the average rise, produced by a single severe Himalayan earthquake, then a mountain, like Everest, 29,002 feet high, must have experienced some 70,000 such earthquakes, since it first emerged from the sea. Severe shocks are experienced in the Himalaya about two or three times in a century. The effects however of a single shock are confined to a small area, and if the elevation of the whole Himalaya is to be attributed to the lifting force of earthquakes, we shall have to assume the occurrence not of 70,000 severe shocks but of 70,000,000. We are not able to disprove this theory, but it does not appear to accord with the observed facts of geology; those facts lead us to believe that the rise of mountains is due, more to the continual pressure of a horizontal force acting upon the outer crust, than to the periodic ruptures caused by the force. Experience in mines shows that the rocks of the earth's crust will change their shape under constant pressure; and a horizontal force, that is sufficient to produce occasional fractures of the crust, is sufficient to overcome its rigidity, and gradually and imperceptibly to create folds in its surface.

In the Himalaya mountains India possesses a series of ranges of comparatively recent growth, and in the Siwalik mountains we have the most recent range on the face of the earth. No rises of the Himalayan or Siwalik ranges have so far been noticed by man, and it may be conceded that the growth of these mountains is not progressing at a sufficiently rapid rate to attract the attention of residents. But what rate of growth would attract the attention of agricultural and pastoral populations? Would the growth of a foot in 100 years be perceived without the aid of instruments and marks? We are convinced that it would not be. A growth of even 1 foot in 10 years might pass unnoticed, if it took place gradually, and if it affected a wide area. The walls of houses would be cracked occasionally, roads and pipe-lines would be found to require periodic repairs; but the damage would be attributed to subsidence or rainfall.

If the Himalaya are growing at the rate of 1 foot in 100 years, it will take less than three million years for a peak to rise from sea-level to the height of Mount Everest. Provided reliable marks are now placed upon rock in Himalayan localities accessible to levelling operations, an average rise at the rate of 1 foot in 100 years will be detected by levellers before the lapse of a century.

The heights of peaks at Mussooree and visible from Mussooree, were first determined trigonometrically between 1830 and 1850. In 1903 I thought that it might prove of interest, if a redetermination were made. But it at once became evident that no comparisons of results would be obtainable. The trigonometrical determinations, made between 1830 and 1850, were sufficiently accurate to give values of height within probably 30 or 50 feet of the truth for snow-peaks, and within 5 or 10 feet of the truth for peaks on the outer ranges, but they were not sufficiently accurate to enable variations in height to be detected. It is possible that the degree of accuracy, necessary for the detection of variations, is unattainable in trigonometrical observations;

* Page 120 of this volume.

† Pages 63, 359 and 395 of this volume.

‡ *The Kangra Earthquake of 4th April, 1905*, by Middlemiss, page 348. *Memoirs Geological Survey of India*, Vol. XXXVIII, 1910.

whether this may prove to be the case or not, we cannot at present tell. What we do know is that trigonometrical observations of the highest attainable accuracy were not taken between 1830 and 1850, and until such measurements (combined wherever possible with spirit-levelling) have been made and repeated at long intervals of time, we shall possess no grounds upon which to base discussions of variations of height.

For the detection of changes in the outer mountains spirit-levelling operations are evidently required, and in the case of snow-peaks, inaccessible to levellers, long series of trigonometrical observations are necessary. If a trigonometrical value of height for a distant snow-peak were all that we were seeking, it would be best to observe it from 10 or 12 different stations, devoting two days to each. The chances of constant error and the effects of abnormal refraction become cancelled, if stations of observation are multiplied; a good mean value of height is then obtained. But when *variations* in height are the aim of our researches, we need not endeavour to cancel stational errors, for we are no longer seeking an exact absolute value. The best plan now is to make a long series of observations from one fixed point throughout different seasons and different years; we thereby attain a continuous record, and if the observations be repeated 100 years hence, data will be obtained upon which discussions of variations may be based.

We have then at present no data for such discussions. We can make observations, but we have no earlier observations with which to compare. The only course open to us is to take such steps now, as will possibly enable our successors to detect variations in height.

The steps, that have been lately taken, and that are still in progress, may be classified under three heads:—

(i.) The determination by spirit-levelling of heights of rock-cut marks in all parts of India.

(ii.) The observation of several Himalayan lines of spirit-levelling.

(iii.) The series of trigonometrical observations to Himalayan stations and peaks carried out by Mr. H. G. Shaw.*

I will now give a short account of these three classes of observations.

(i). *The determination by spirit-levelling of the heights of rock-cut marks over India.*

Unconsolidated ground is useless as a foundation for bench-marks that are intended to be perpetual. A bench-mark erected on alluvium may settle and sink into the ground; a change in its height does not necessarily denote a movement of the crust.

The extensive plains of Northern India, consisting of alluvium deposited by the Himalayan rivers, possess no outcrops of rock except along their borders. The peninsula of India exhibits numerous outcrops of rock, and offers suitable sites for rock-cut bench-marks in all directions, but even in the peninsula, rocky though it be, there are large areas of riverain alluvium, upon which no perpetual marks can be founded.

The Indian railway-lines have as a rule been carried along the flat alluvial tracts, and have only been taken over mountainous areas, where the latter were unavoidable. The lines of spirit-levelling have to a considerable extent followed the lines of railway.

The spirit-levelling operations were originally intended to be of use to engineers, and the work of engineers is mainly confined to the regions of population and fertility.

When therefore in 1903 the lists of bench-marks came to be examined, the number of marks that had been engraved upon ground-rock was found to be extremely small. During certain periods of levelling the present and practical uses of bench-marks appear to have been regarded to the entire exclusion of the future and scientific uses. In many instances marks have been inscribed on unstable culverts, bridges and railway platforms in preference to ground-rock in the vicinity.† For scientific purposes marks on culverts, bridges and platforms are useless.

Since 1908 the levelling officers have been devoting much attention to the question of rock-cut marks, and have been making every endeavour to obtain perpetual records of height in all parts of the country. ‡

On page 68 the question of a fundamental bench-mark was discussed, and five bench-marks were mentioned, any one of which would have been suitable to be a permanent bench-mark of reference for India. It would be easy to supplement these

* For Mr. Shaw's heights of snow-peaks, *see* preface to Synoptical volume XXXV, G. T. Survey of India.

† Two lines of level ascend the ghauts from Bombay, the southern leading to Poona, the northern to Nasik. For many miles both lines traverse solid rock. In 1877-78 the levellers from Bombay to Poona, (119 miles) placed no mark upon this rock: in the same year the levellers from Bombay to Nasik (121 miles) placed four marks upon rock; these four marks were too few, but they have sufficed to make the Nasik line superior as a scientific operation to the Poona line. Fresh marks upon rock are about to be added to these two lines.

‡ The following few instances may be quoted to serve as illustrations of rock-cut marks:—

Vol. XIXA, page 17, bench-mark $\frac{5}{17}$; pages 125-141, Karwar-Bellary. *See* also Mhow, Bhopal, Dhulia on line 34, and level-lines, Hyderabad (Deccan) to Wardha, Kalyan to Kedgaon, Diksal to Gulbarga, Gooty to Arkonam, on which rock-cut marks have been erected.

Vol. XIXB, *See* Karachi, Sukkur, Rajkot, Godhra, Hyderabad (Sind); see also level-lines Ferozepore to Chach, Katni to Bilaspur, Dhubri to Gauhati.

five by many other equally suitable marks, but nothing would be gained by the inclusion of such a list here, as all the rock-cut bench-marks of India will be found fully described in volumes XIXA and XIXB. These two volumes are sequels of the present volume XIX; they have been bound separately in order to limit the bulk of the latter. *

Many principal stations of the triangulation consist of marks engraved upon rock, and several of these have been connected by levelling.† But principal stations, even when their marks are upon ground-rock, cannot be accepted as primary standards of height without examination of the field-books. Many of these stations are on precipitous hills, unsuited for levelling operations, and the determinations of height are consequently not always reliable. In certain cases, too, the heights of the rock-cut marks have not been determined, the levelling having closed upon the upper surfaces of the brick pillars built over the marks.

The principal station of Sanichari may be quoted as an instance of a satisfactory rock-cut mark, the height of which was determined by spirit-levelling.

At the principal stations of Gurramkonda, Thikri, Ongole, and Bor the elevations of the upper mark-stones were determined by levelling; but as the heights of the pillars above the rock-cut marks were also recorded, the elevations of the rock-cut marks themselves are deducible.

Gidgarh, Nialamari and Haltibetta are instances of stations, where the pillars were connected by spirit-levelling, but at which the heights of the rock-cut marks themselves cannot be deduced with certainty.

It is intended to engrave many more bench-marks on ground-rock in different parts of India within the next few years; and in order to ensure that these marks are not all obliterated by chemical change or by growth of vegetation, some of them will be protected by pillars. ‡

(ii). *The Himalayan lines of spirit-levelling.* *

Seven scientific lines of simultaneous double-levelling have been recently carried, or are about to be carried into the Himalaya. These lines all follow main roads suitable for levelling, and all will have many bench-marks engraved upon ground-rock. §

The Himalayan lines of level are :—

Mountain line	Length in miles	Number of rock-cut bench-marks		Connecting link with level-net	Date of observation	Observers
		Total	Protected by pillars			
Rajpur to Mussooree, Lal-Tibba, Banog.	22	43	15	Saharanpur-Rajpur ...	1905-09	‖
Siliguri to Tindharia ...	19	8	2	connected at Siliguri ...	1909-10	O. N. Pushong T. F. Kitchen
Kathgodam to Naini Tal ...	11	14	2	Bareilly-Kathgodam ...	1909-10	O. N. Pushong T. F. Kitchen
Kotdwara to Lansdowne ...	28	26	5	Hardwar-Kotdwara ...	1909-10	O. N. Pushong T. F. Kitchen
Pathankot to Dharmkot ...	55	48	11	Lahore-Pathankot ...	1909-10	A. M. Talati O. D. Jackson
Kalka to Solon	36	not yet complete	6	Ambala-Kalka	1910-11	
Rawalpindi to Murree ...	39	about to be completed	at every 5 miles	connected at Rawalpindi ...	1910-11	
Murree to Kashmir ...	the proposal to extend from Murree into Kashmir is under consideration.				1910-11	

* When volume XIX was first undertaken, the intention was to make it include all lists of bench-marks. These lists however proved longer than had been anticipated, and it was found necessary to devote a separate volume to them; the latter was in the first instance numbered XX, *vide* pages 85 and 101. But even this volume proved to be too bulky, and its further sub-division into two parts became desirable. Instead then of numbering the Levelling volume XIX, and the two volumes containing lists of bench-marks XX and XXI, we have now decided to number them respectively XIX, XIXA and XIXB.

† The principal stations will be found enumerated in appendix 6 of this volume. They will be found described in volumes XIXA and XIXB.

‡ A protecting pillar for rock-cut bench-marks was introduced by Mr. Erskine in 1909. The pillar is of masonry, 2 feet square, with a hollow centre 6 inches square. The hollow at the top of the pillar is closed by a stone-slab, which bears the inscription

G. T. Survey
O
Upper mark

The slab is so fixed, that the circle inscribed on it is vertically above the circle cut on the rock *in situ*.

In 1909-10 forty-nine such pillars were built over rock-cut bench-marks, after the marks had been connected by levelling. Two of these pillars are at Karachi, two at Sukkur, one at Rajkot, one at Dhulia, one at Vizagapatam, one at Hyderabad (Sind): there are 41 of these pillars on the Himalayan lines of level.

§ *See* page 342.

‖ *See* lines 61 A, 61 B, 61 C, 61 D, on page 22: *see* also pages 342, 359, and 395.

The results of the levelling from Saharanpur to Mussooree, Lal Tibba and Banog will be published in volume XIXB*; the results on the other Himalayan level-lines will not be available in time for inclusion in volume XIXB, which is already in the printer's hands.

Other branch-lines of level are being projected into the mountains, south of Allahabad and Bengal, and west of Dera Ismail Khan, so that the rock of the Vindhyas and of the Suliman ranges may be tied by levelling to that of the Himalaya.

(iii). *The trigonometrical observations by Mr. H. G. Shaw, 1905-1909.*

Mr. Shaw had five stations of observation :—

Station I Mussooree (Shaw's Station).
" II Dehra Dún (Shaw's Station).
" III Nojli (Shaw's Station).
" IV Nojli Tower Station, upper mark.
" V Nag Tibba hill station.

Two stations were purposely introduced at Nojli, one 50 feet higher than the other, as we wished to compare the effects of atmospheric refraction at ground-level with its effects at an altitude of 50 feet above the ground.

Mr. Shaw's trigonometrical observations consisted of the following series :—

	Observations of vertical angles
First Series	From I to II, and from II to I
Second Series	From I to III, and from III to I
Third Series	From I to IV, and from IV to I
Fourth Series	From I to V, and from V to I
Fifth Series	From I to the Himalayan peaks of Bandarpunch, Srikanta, Jaonli and Kedarnath.
Sixth Series	From III to the Himalayan peaks of Bandarpunch, Srikanta, Jaonli and Kedarnath.
Seventh Series	From V to the Himalayan peaks of Bandarpunch, Srikanta, Jaonli and Kedarnath.

The following descriptions of Mr. Shaw's five stations will, it is hoped, enable the sites to be identified a hundred years hence. The stations are at present being carefully preserved.

Station I. Mussooree (Shaw's Station) is 25 feet east, and 17½ feet south or 30 feet S. E. of Mussooree Dome Observatory Station (Evelyn Hall) (*vide* Synoptical volume of the Great Arc Meridional Series—Section 24°-30°, page 86*—A). It is a pakka pillar 3 feet in diameter and 1 foot 9 inches in height, upper surface being flush with ground level, with an annulus 4 inches in width. The spirit-levelled orthometric height of Mussooree, Shaw's Station, is 6929·9 feet and of Mussooree Dome Observatory (G. T. S. Hill Station) is 6935·0 feet, the difference between the two stations being 5·1 feet.

* Many rock-cut marks will be found in volume XIXB on line 61A between Rajpur and Mussooree, four in Mussooree itself, three in Landour, seven between Mussooree and Banog.

In 1908 Lieut. Morshead, R.E., levelled to the canal bench-marks at Hardwar, which are situated in the gorge cut by the Ganges through the Siwalik range. As these marks were masonry erections, Lieutenants Bell and Mason, R.E., levelled to a rock-cut bench-mark at Hardwar in 1910. The Ganges is cutting across the axis of the Siwalik range at Hardwar, and it will be of interest to observe, whether the future growth of the range will cause a decrease in the river's gradient above Hardwar, and an increase of gradient below. The erosive power of the Ganges is so great, that the river will probably be able to maintain its course across the range, however rapidly the latter may grow. We have no grounds for believing, that the rise of the Siwalik range has ever been sufficiently rapid to dam the Ganges, but it has probably at times been a serious obstacle to the less powerful river, the Jumna.

Station II. Dehra Dún (Shaw's Station) is 10 feet west and 21½ feet south of the Dehra Dún (Haig Observatory) Latitude station (Cowie's Station) (*vide* G. T. S. Vol. XVIII page (59)). It is 79 feet 8 inches east of the Dehra Dún Longitude Station (Strahan and Burrard's Station of 1885) (*vide* G. T. S. Vol. XV Appendix page (5) and Vol. XVIII, page (59)). It is a pakka pillar 3 feet in diameter and 2 feet 6 inches in height, the upper surface being flush with ground level with an annulus 3 inches in width. The spirit-levelled orthometric height is 2234·3 feet.

Station III. Nojli (Shaw's Station) is 7 feet east and 19 feet south or 20 feet S. E. of Colonel Campbell's Latitude Station, 63 feet from S. E. corner and 68 feet from N. E. corner of Nojli T. S. It is a pakka pillar 3 feet in diameter and 2¼ feet in height upper surface of which is flush with ground level, with an annulus 3 inches in width. A stone 6 × 6 × 9 with the letters G.T.S. O B.M. inscribed on it has been embedded in the centre of the pillar, upper surface of which is on a level with top of the pillar. The spirit-levelled orthometric height of Nojli (Shaw's Station) is 886·7 feet and of Nojli Tower Station upper mark 937·0 feet, the difference being 50·3 feet between the two stations.

Station IV. Nojli Tower Station, upper-mark, is a principal station of the Great Arc Meridional Series of triangulation, *section 24° to 30.°* It is situated about half a mile S. of the village of the same name and about 3 miles S. E. of Baliakheri Railway Station, O and R. Railway.

Station V. Nag Tibba h.s. A circle and dot inscribed on the upper surface of a stone embedded centrally in a circular masonry pillar 40 inches in diameter and 2 feet in height. Vertically below this upper mark, 2 other stones similarly inscribed are embedded in the centre and in the foundation of the pillar respectively. Around this pillar, a circular masonry ring has been built one foot thick and of the same height as the pillar leaving a concentric space 3 inches wide, and surrounding this a platform of earth and stones 14 feet square has been built. It is on the summit of the highest of three peaks locally known as Nag Tibba. The hill can be approached from Mussooree in 2 marches by several different paths all of which are very steep in places. There is a site for good camping ground on the spur running north from the station, and water is found on the north side of the main ridge to the east.

A pillar of stone covering a mark-stone sunk in the ground was found on this point, the mark-stone was not disturbed and it formed the lower mark-stone over which the pillar was built.

The following table shows the distances in miles of station I from Mr. Shaw's other stations.

From	Distance of I
	miles
II	9·454
III	45·927
IV	45·931
V	9·886

The following table shows the distances in miles of the four snow-peaks from Mr. Shaw's stations.

From	Distance of			
	Bandarpunch	Srikanta	Jaonli	Kedarnath
	miles	*miles*	*miles*	*miles*
I	47·129	55·474	54·062	63·759
III	92·923	99·800	96·961	104·148
V	37·370	46·495	45·814	56·438

Mr. Shaw's observations have been considered from three different aspects :—

(i.) As furnishing determinations of the heights of snow-peaks, *vide* preface to Synoptical volume XXXV of the G. T. Survey of India.

(ii.) As furnishing information concerning atmospheric refraction, which will be dealt with in a separate publication.

(iii.) As indicating the relative heights of stations and peaks in 1905-1909.

In this appendix we are only concerned with the third aspect,—the relative heights of various points in 1905-1909. We wish now to record the relative heights, as determined in 1905-1909, in order that they may be available for comparison with future measurements.

As records of relative heights, the observed vertical angles are more useful and furnish simpler data than absolute differences of height in feet. The vertical angles are derived directly from observation, and they can be repeated and tested on the ground at any time. Differences of height in feet have to be deduced from the vertical angles by the aid of some assumed co-efficient of refraction. As permanent records of data, obtained in 1905-1909, the observed vertical angles have therefore been entered in the following tables.

First Series.

Vertical angles between Stations I and II.

Hour of observation	From Station I to Station II (angle of depression)															
	Nov. 6th to 13th 1905	No. of days	April 10th to 26th 1906	No. of days	Oct. 6th to Nov. 7th 1906	No. of days	April 8th to 23rd 1907	No. of days	Oct. 21st to 31st 1907	No. of days	Mar. 9th to 20th 1908	No. of days	Oct. 22nd to 31st 1908*	No. of days	April 6th to 16th 1909	No. of days
	5° 26′ +		5° 26′ +		5° 26′ +		5° 26′ +		5° 26′ +		5° 26′ +		5° 26′ +		5° 26′ +	
	″		″		″		″		″		″		″		″	
8 a. m. ...	10·90	3	16·80	12	15·57	15	14·00	10	16·65	9	13·25	7	6·74	7	13·81	9
10 a. m. ...	17·00	3	17·50	3	18·41	11	17·12	8	17·50	8	17·58	6	9·94	7	16·39	7
Noon ...	19·50	3	20·82	3	21·33	8	20·53	8	21·30	7	19·43	5	11·72	7	18·45	6
Minimum refraction	20·55	6	21·78	12	21·17	12	21·14	7	22·30	10	19·68	6	12·36	9	18·46	8
4. 30 p. m. ...	18·27	3	21·82	3	21·71	4	20·75	5	20·72	4	20·34	3	10·95	7	17·32	4
	feet		*feet*		*feet*		*feet*		*feet*		*feet*		*feet*		*feet*	
Height of instrument at I.	4·9		4·9		4·9		4·6		4·6		4·9		4·9		4·9	
Height of instrument at II.	4·9		4·9		4·9		4·6		4·6		4·9		5·0		4·9	
Height of signal at I	2·5		2·5		2·5		2·5		2·5		2·5		1·6		2·5	
Height of signal at II	2·5		2·5		2·5		2·5		2·5		2·5		3·1		2·5	

Hour of observation	From Station II to Station I (angle of elevation).															
	Oct. 28th to Nov. 3rd 1905	No. of days	Mar. 1st to 5th 1906	No. of days	Oct. 24th to 29th 1906	No. of days	Mar. 4th to 9th 1907	No. of days	Nov. 7th to 14th 1907	No. of days	Mar. 30th to April 3rd 1908	No. of days	Oct. 22nd to 31st 1908*	No. of days	Mar. 22nd to 29th 1909	No. of days
	5° 18′ +		5° 18′ +		5° 18′ +		5° 18′ +		5° 18′ +		5° 18′ +		5° 18′ +		5° 18′ +	
	″		″		″		″		″		″		″		″	
8 a. m. ...	55·90	3	60·19	3	51·48	5	57·41	4	56·16	3	55·37	4	53·10	7	58·59	7
10 a. m. ...	47·86	3	50·19	3	44·95	5	50·49	4	47·74	3	46·68	4	45·38	7	48·38	5
Noon ...	45·23	3	44·49	3	41·80	5	47·02	4	42·88	3	43·14	4	43·35	7	47·06	5
Minimum refraction	43·90	6	44·21	5	42·74	6	45·76	4	43·31	6	43·30	5	43·29	9	46·58	6
4. 30 p. m. ...	50·26	3	46·29	3	46·66	4	48·49	3	45·96	3	46·47	3	47·21	7	48·58	4

* Simultaneous reciprocal observations.

Second Series.

Vertical angles between Stations I and III.

Hour of observation	From Station I to Station III (angle of depression)									
	Nov. 11th to 15th 1905	No. of days	April 19th to 25th 1906	No. of days	Oct. 31st to Nov. 8th 1906	No. of days	April 8th to 23rd 1907	No. of days	April 6th to 16th 1909	No. of days
	1° 42′ +		1° 42′ +		1° 42′ +		1° 42′ +		1° 42′ +	
	″		″		″		″		″	
8 a. m.	34·09	5	46·18	3	38·62	6	41·41	8	45·04	8
10 a. m.	40·34	5	61·83	3	37·41	4	45·56	8	56·24	6
Noon	47·30	3	65·24	3	46·91	5	58·35	4	59·74	5
Minimum refraction ...	53·95	1	65·50	3	54·25	4	63·41	5	61·87	6
4. 30 p. m.	*no observations*		66·03	3	52·86	2	62·57	4	61·50	1
	feet		*feet*		*feet*		*feet*		*feet*	
Height of instrument at I ...	4·9		4·9		4·9		4·6		4·9	
Height of instrument at III ...	4·9		4·9		4·9		4·6		4·9	
Height of signal I ...	1·6		1·6		1·6		1·6		1·6	
Height of signal III ...	1·6		1·6		1·6		1·6		1·6	

Hour of observation	From Station III to Station I (angle of elevation)									
	Dec. 1st to 9th 1905	No. of days	Mar. 8th to 16th 1906	No. of days	Nov. 22nd to Dec. 5th 1906	No. of days	Mar. 18th to 23rd 1907	No. of days	Mar. 8th to 12th 1909	No. of days
	1° 8′ +		1° 8′ +		1° 8′ +		1° 8′ +		1° 8′ +	
	″		″		″		″		″	
8 a. m.	168·61	8	100·53	6	150·21	2	96·74	4	112·87	3
10 a. m.	82·47	8	51·31	7	63·94	5	44·85	4	54·19	4
Noon	40·22	7	32·89	5	32·15	3	25·96	3	23·07	4
Minimum refraction ...	29·84	7	26·90	4	25·38	4	23·92	2	19·94	3
4. 30 p. m.	*no observations*		39·47	4	38·80	3	39·74	2	27·51	2

Third Series.

Vertical angles between Stations I and IV.

Hour of observation	From Station I to Station IV (angle of depression)					
	April 19th to 25th 1906	No. of days	April 8th to 23rd 1907	No. of days	April 6th to 16th 1909	No. of days
	1° 41′ +		1° 41′ +		1° 41′ +	
8 a. m.	63″·49	3	60″·33	7	58″·38	8
10 a. m.	78·21	3	62·18	8	70·28	7
Noon	81·47	2	75·53	5	75·30	4
Minimum refraction ...	83·75	3	80·41	5	76·68	7
4. 30 p. m.	82·99	3	80·59	4	78·63	3
	feet		*feet*		*feet*	
Height of instrument at I ...	4·9		4·6		4·9	
Height of instrument at IV ...	4·9		4·6		4·9	
Height of signal at I ...	1·6		1·6		1·6	
Height of signal at IV ...	2·4		3·2		3·2	

Hour of observation	From Station IV to Station I (angle of elevation)					
	March 17th to 22nd 1906	No. of days	March 25th to 28th 1907	No. of days	March 13th to 16th 1909	No. of days
	1° 7′ +		1° 7′ +		1° 7′ +	
8 a. m.	112″·37	2	120″·78	4	143″·63	2
10 a. m.	64·69	3	74·79	4	78·65	3
Noon	47·47	4	48·99	4	50·90	3
Minimum refraction ...	45·44	4	45·97	3	44·83	3
4. 30 p. m.	46·62	2	47·11	3	46·48	3

Fourth Series.

Vertical angles between Stations I and V.

Hour of observation	From Station I to Station V (angle of elevation)									
	April 14th to 19th 1906	No. of days	April 8th to 23rd 1907	No. of days	Mar. 9th to April 21st 1908	No. of days	Oct. 21st to 31st 1908	No. of days	April 6th to 29th 1909	No. of days
	3° 12′ +		3° 12′ +		3° 12′ +		3° 12′ +		3° 12′ +	
	″		″		″		″		″	
8 a. m.	7·68	5	14·71	11	12·75	13	48·16	7	14·16	13
10 a. m.	8·00	4	13·42	8	12·48	7	44·25	7	10·83	9
Noon	8·25	3	12·44	6	13·75	4	43·54	7	11·90	7
Minimum refraction ...	5·07	4	12·48	8	12·52	8	43·42	10	11·68	9
4. 30 p. m.	7·37	2	14·87	4	16·19	3	44·39	7	17·38	4
	feet		*feet*		*feet*		*feet*		*feet*	
Height of instrument at I ...	4·9		4·6		4·9		4·9		4·9	
Height of instrument at V ...	4·9		4·9		4·9		4·9		4·9	
Height of signal at I ...	2·5		2·5		2·5		2·5		2·5	
Height of signal at V ...	4·2		5·0		5·0		10·5		5·0	

Hour of observation	From Station V to Station I (angle of depression)									
	May 1st to 7th 1906	No. of days	May 10th to 15th 1907	No. of days	April 27th to May 1st 1908	No. of days	Oct. 5th to 14th 1908	No. of days	May 6th to 11th 1909	No. of days
	3° 19′ +		3° 19′ +		3° 19′ +		3° 19′ +		3° 19′ +	
	″		″		″		″		″	
8 a. m.	63·72	6	62·17	5	62·33	4	48·62	6	59·92	5
10 a. m.	65·35	3	63·76	5	63·53	4	50·67	8	60·60	5
Noon	65·66	3	62·57	5	64·74	4	52·43	8	61·48	5
Minimum refraction ...	65·95	7	63·60	5	64·40	5	50·97	7	62·54	5
4. 30 p. m.	65·18	3	63·22	5	64·66	3	48·06	4	62·47	4

Fifth Series.

Vertical angles from Station I to four snow-peaks; taken in the afternoon at the time of minimum refraction: (height of instrument = 5 feet).

	Bandarpunch		Srikanta		Jaonli		Kedarnath	
	Elevation	Number of days on which observed	Elevation	Number of days on which observed	Elevation	Number of days on which observed	Elevation	Number of days on which observed
	° ′ ″		° ′ ″		° ′ ″		° ′ ″	
November 6th to 14th, 1905 ...	2 52 20	6	2 13 24	9	2 37 26	5	2 18 10	2
April 12th and 18th, 1906 ...	2 52 5	2	2 13 6	1	2 37 9	1	...	0
October 31st to November 8th, 1906	2 52 14	7	2 13 21	8	2 37 20	8	2 18 0	5
April 8th to 23rd, 1907 ...	2 52 5	1	2 13 15	5	2 37 16	3	2 17 53	1
October 24th to November 22nd, 1907	2 52 18	10	2 13 30	11	2 37 23	12	2 18 6	9
March 10th to April 18th, 1908 ...	2 52 7	6	2 13 15	5	2 37 14	6	2 17 51	2
October 21st to 31st, 1908 ...	2 52 27	8	2 13 39	9	2 37 39	9	2 18 21	6
April 8th to 29th, 1909 ...	2 52 12	1	2 13 19	2	2 37 20	1	2 17 59	1

Sixth Series.

Vertical angles from Station III to four snow-peaks; taken in the afternoon at the time of minimum refraction: (height of instrument = 5 feet).

	Bandarpunch		Srikanta		Jaonli		Kedarnath	
	Elevation	Number of days on which observed	Elevation	Number of days on which observed	Elevation	Number of days on which observed	Elevation	Number of days on which observed
	° ′ ″		° ′ ″		° ′ ″		° ′ ″	
December 7th, 1905 ...	1 44 9	1	...	...	...	...	...	...
March 16th, 1906 ...	1 43 48	1	...	...	1 43 16	1	...	...
December 4th and 5th, 1906 ...	1 44 19	2	...	...	1 43 34	1	1 38 23	1
March 23rd, 1907 ...	...	...	1 28 30	1	...	...	...	...
January 14th to 26th, 1909 ...	1 44 24	3	1 28 24	3	1 43 56	3	1 38 41	3

Seventh Series.

Vertical angles from Station V to four snow-peaks; taken in the afternoon at the time of minimum refraction: (height of instrument = 5 feet).

	Bandarpunch		Srikanta		Jaonli		Kedarnath	
	Elevation	Number of days on which observed	Elevation	Number of days on which observed	Elevation	Number of days on which observed	Elevation	Number of days on which observed
	° ′ ″		° ′ ″		° ′ ″		° ′ ″	
October 9th to 15th, 1908 ...	2 54 4	1	2 5 21	3	2 30 36	4	2 7 55	2
May 5th to 10th, 1909 ...	2 53 46	2	2 4 56	3	2 30 13	1	2 7 30	1

The horizontal angles between the four snow-peaks of Bandarpunch, Srikanta, Jaonli and Kedarnath observed at various times are as follows.

Horizontal angles between the four snow-peaks.

Station of observation		Date	Between the peaks of	Observed horizontal angles
				° ′ ″
Birond	H.S.	1851	Kedarnath ... Jaonli ...	4 55 31
Ghungti	H.S.	1850	Kedarnath ... Jaonli ...	9 52 47
			Kedarnath ... Bandarpunch ...	21 13 6
			Jaonli ... Bandarpunch ...	11 20 19
Mabegarh	H.S.	1850	Kedarnath ... Jaonli ...	10 21 44
			Jaonli ... Bandarpunch ...	15 9 59
Ghandial	H.S.	1842	Kedarnath ... Jaonli ...	13 25 19
			Kedarnath ... Srikanta ...	19 50 54
			Kedarnath ... Bandarpunch ...	35 47 59
			Jaonli ... Srikanta ...	6 25 35
			Jaonli ... Bandarpunch ...	22 22 40
			Srikanta ... Bandarpunch ...	15 57 5

Horizontal angles between the four snow-peaks.—(Continued).

Station of observation		Date	Between the peaks of	Observed horizontal angles
				° ′ ″
Banog	H.S.	1842	Kedarnath ... Jaonli ...	7 58 52
			Kedarnath ... Srikanta ...	15 36 33
			Kedarnath ... Bandarpunch ...	28 56 52
			Jaonli ... Srikanta ...	7 37 41
			Jaonli ... Bandarpunch ...	20 58 0
			Srikanta ... Bandarpunch ...	13 20 19
Ranigarh	H.S.	1842	Kedarnath ... Srikanta ...	17 37 26
			Kedarnath ... Bandarpunch ...	31 3 55
			Srikanta ... Bandarpunch ...	13 26 29
Nag Tibba	h.s.	October 1908 by B. R. Hughes and H. G. Shaw	Kedarnath ... Jaonli ...	8 47 1
			Kedarnath ... Srikanta ...	18 15 42
			Kedarnath ... Bandarpunch ...	35 7 28
			Jaonli ... Srikanta ...	9 28 41
			Jaonli ... Bandarpunch ...	26 20 27
			Srikanta ... Bandarpunch ...	16 51 46

Debra Dún,
July 22nd 1910.

S. G. Burrard.

APPENDIX.

No. 4.

DYNAMIC AND ORTHOMETRIC CORRECTIONS TO THE HIMALAYAN LEVELLING LINES AND CIRCUIT; AND A CONSIDERATION OF THE ORDER OF MAGNITUDE OF POSSIBLE REFRACTION ERRORS.

BY J. DE GRAAFF HUNTER, M.A.,

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In the following pages the first ten sections are taken up with an investigation of the corrections, due to the lack of parallelism of the level surfaces at and above mean-sea-level, which should be applied to certain Himalayan level lines where gravity is greatly perturbed from normal value. Sections 11 to 17 deal with errors in levelling up a steady slope which are due to refraction.

Orthometric and Dynamic corrections.

1.

The lines of levelling here under consideration are shown on Plate XVIII, and are as follows :—

(1) Saharanpur via Dehra Dun to Mussooree, with a branch line to Nojli.

(2) Dehra Dun to Hardwar.

(3) Hardwar to Nojli.

They have especial interest as regards the dynamic and orthometric corrections as they run where gravity is much disturbed by the closely adjacent Himalaya. The values of gravity have been observed at eight stations close to the levelling lines. A second point of interest is that heights of points at Mussooree have been computed from vertical angles observed both at Nojli and at Dehra Dun; and so for the consideration of atmospheric refraction it is important to know with as much accuracy as possible the orthometric heights of Mussooree above both Nojli and Dehra Dun.

Further, the relative heights of points on the lines under consideration appear to be changing, possibly on account of geological upheavals and depressions*. To investigate this in the case of a circuit, it is necessary to previously rid the circuit of any error due to the convergence of the successive level surfaces. It then remains to consider whether the residual error is probably accounted for merely by errors of observation, and other causes, or whether actual changes in the heights of the various points, with time, have taken place.

2.

The dates at which the sections of the circuit were levelled are :—

(1). From Nojli 18th April 1907 reaching Dehra Dun 15th May 1907.

(2). From Nojli 20th January 1908 reaching Hardwar 6th March 1908.

(3). From Hardwar 24th March 1909 reaching Dehra Dun 9th April 1909.

It will be seen that Nojli, Dehra Dun and Hardwar each were visited on two occasions at intervals of 9, 23 and 12½ months respectively. A question yet to be answered is, has the level of one or more of the stations Nojli, Dehra Dun or Hardwar appreciably changed in these intervals?

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* The height of Dehra Dun deduced from levelling to both Saharanpur and Mussooree apparently changed by 5¼ inches as a result of the earthquake of 1905.

3.

The height of Dehra Dun * above Nojli was found by line (1) of section 2 to be 1341·956 feet. Hardwar above Nojli by line (2) 58·849 feet. Dehra Dun above Hardwar by line (3) 1282·955 feet. Thus from the latter two heights we deduce that Dehra Dun is 1341·804 feet above Nojli. This value differs from the other by 0·152 foot. Now the length of the circuit is 115·2 miles. Accordingly the closing error is larger than the probable error of observation leads us to expect (see section 9 below). All the circuit was double-levelled and the discrepancies between the two lines according to the two sets of observations were between Nojli, B.M. 9†, Dehra Dun*, Hardwar‡, Nojli 0·029, 0·058, 0·023, 0·003 foot respectively. Taking these all of the same sign we get the total discrepancy between the two sets of observations to be 0·113 foot—smaller than the closing error.

4.

The stations near the levelling lines where gravity has been observed are Nojli, Mohan, Asarori, Dehra Dun, Rajpur, Mussooree, Hardwar and Roorkee. The particulars of values obtained are given in Table 1 of Appendix No. 7. For values at intermediate points on the levelling lines the method of simple linear interpolation has been followed. In Appendix No. 7 section 6 reference is made as to the justifiability of this method.

5.

The dynamic correction may be conveniently divided into two parts; first, the correction due to the regular change of g with latitude, as given by the formula $g = 978{\cdot}00\,(1 + 0{\cdot}005310 \sin^2 l)$: and second, the correction due to irregular change of g, that is, the discrepancy between the formula value of g and the observed value multiplied by the quantity $(1 + \frac{2h}{R})$, where h is the approximate height of the station, to reduce to sea level value (see Appendix No. 7 section 3). This discrepancy is denoted by dg. The first correction is easily got by use of the tables for F prepared for the purpose and given on pages 103 to 106 of this volume. The second correction is $dg \,.\, \frac{dh}{g_{24}}$, where g_{24} denotes the standard value of g in latitude 24°, and dh is the rise in height in the neighbourhood to which dg applies. Denoting $\frac{1000\, dg}{g_{24}}$ by F^1 we find the following values for F^1 (Table 1).

Table 1.

Place	F^1	Place	F^1
Nojli ...	− 0·066	Mussooree ... (Mean of Camel's Back and Dunseverick)	+ 0·109
Mohan ...	− 0·050	Rajpur ...	− 0·017
Asarori ...	− 0·028	Hardwar ...	− 0·085
Dehra Dun ...	− 0·052	Roorkee ...	− 0·080

6.

We proceed now to the computations. As we have divided up the circuit into latitude-intervals of $\frac{1}{20}$th of a degree, it is necessary to interpolate between the values of F. In Table 2 we give five columns, headed dh, F, F^1, C, C^1 respectively: dh is the rise in height in any latitude-interval, and C, C^1 are the two corrections, and are $\frac{F.\, dh}{1000}$ and $\frac{F^1.\, dh}{1000}$ respectively. In most cases the intervals have been chosen according to latitude, but two intervals are those between Dehra Dun, Rajpur and Mussooree. In the same way Nojli has been chosen as the end of an interval.

* The actual point at Dehra Dun is an iron plug let into the north wall of the G. T. Office main building. Nojli refers to Shaw's Refraction Station.

† B. M. 9 is the junction of the Nojli branch line with the Saharanpur-Mussooree line.

‡ This line Hardwar-Nojli was observed backward and forward by one observer and by same instrument. The figure 0·003 refers to the total discrepancy between the two sets of observations.

Table 2.

	Station or Latitude	*dh*	*F*	*F*¹	$C = \frac{F.dh}{1000}$	$C^1 = \frac{F^1.dh}{1000}$
		feet			*feet*	*foot*
Via Mohan	Nojli	+ 42	+ 0·4426	− 0·064	+ 0·0186	− 0·0028
	B. M. 9	+ 7	+ 0·4477	− 0·062	+ 0·0031	− 0·0004
	Latitude 30°·00	+ 50	+ 0·4507	− 0·060	+ 0·0225	− 0·0030
	" 30·05	+ 67	+ 0·4547	− 0·057	+ 0·0304	− 0·0038
	" 30·10	+ 203	+ 0·4587	− 0·054	+ 0·0931	− 0·0110
	" 30·15	+ 471	+ 0·4627	− 0·050	+ 0·2180	− 0·0236
	" 30·20	+ 508	+ 0·4667	− 0·038	+ 0·2371	− 0·0193
	" 30·25	− 192	+ 0·4707	− 0·039	− 0·0904	+ 0·0075
	" 30·30	+ 186	+ 0·4733	− 0·050	+ 0·0880	− 0·0093
	Dehra Dun	+ 1094	+ 0·4780	− 0·035	+ 0·5229	− 0·0383
	Rajpur	+ 3256	+ 0·4829	+ 0·046	+ 1·5723	+ 0·1498
	Mussooree Library ...	+ 851	+ 0·4855	+ 0·109	+ 0·4132	+ 0·0927
	Banog	+ 30	+ 0·4855	+ 0·109	+ 0·0146	+ 0·0033
	Lal Tibba	+ 352	+ 0·4855	+ 0·109	+ 0·1708	+ 0·0383
	Shaw's Refraction Station from Mussooree Library					
Via Hardwar	Nojli	− 15	+ 0·4376	− 0·068	− 0·0066	+ 0·0010
	Latitude 29°·85	+ 11	+ 0·4346	− 0·074	+ 0·0048	− 0·0008
	" 29·85	− 8	+ 0·4386	− 0·080	− 0·0035	+ 0·0006
	" 29·90	+ 71	+ 0·4426	− 0·083	+ 0·0314	− 0·0059
	Hardwar (B. M. Mayapur canal bungalow compound).	+ 35	+ 0·4467	− 0·083	+ 0·0156	− 0·0029
	Latitude 30°·00	+ 176	+ 0·4507	− 0·079	+ 0·0794	− 0·0139
	" 30·05	+ 208	+ 0·4547	− 0·074	+ 0·0945	− 0·0153
	" 30·10	+ 143	+ 0·4587	− 0·069	+ 0·0655	− 0·0099
	" 30·15	+ 101	+ 0·4627	− 0·066	+ 0·0467	− 0·0067
	" 30·20	+ 354	+ 0·4667	− 0·061	+ 0·1653	− 0·0216
	" 30·25	+ 145	+ 0·4707	− 0·057	+ 0·0683	− 0·0083
	" 30·30	+ 121	+ 0·4738	− 0·053	+ 0·0574	− 0·0064
	Dehra Dun					

7.

From Table 2 we get by simple addition the two corrections (regular and irregular) to the observed heights above Nojli to reduce them to dynamic heights above the level surface through Nojli. These are given in Table 3 under headings ΣC, ΣC^1 and $\Sigma C + \Sigma C^1$. In this table are also given the observed heights and the dynamic heights.

Table 3.

Place	Observed height above Nojli	ΣC	ΣC^1	Correction $= \Sigma C + \Sigma C^1$	Dynamic height
	feet	*feet*	*foot*	*feet*	*feet*
Nojli	0·000	...	...	...	...
Dehra Dun	1341·956	+ 0·6204*	− 0·0657	+ 0·555	1342·511
Rajpur	2436·022	+ 1·1433	− 0·1040	+ 1·039	2437·061
Mussooree Library	5691·357	+ 2·7156	+ 0·0458	+ 2.761	5694·118
Banog	6542·676	+ 3·1288	+ 0·1385	+ 3·267	6545·943
Lal Tibba	6572·284	+ 3·1434	+ 0·1418	+ 3·285	6575·569
Shaw's Refraction Station (Mussooree).	6043·360	+ 2·8864	+ 0·0841	+ 2·970	6046·330
Nojli	0·000	...	...	...	...
Hardwar	58·849	+ 0·0261*	− 0·0051	+ 0·021	58·870
Dehra Dun	1341·804	+ 0·6188*	− 0·0901	+ 0·529	1342·333

8.

In Table 3 it will be noticed that two dynamic heights are given for Dehra Dun. These correspond to the two ways of approaching Dehra Dun; either directly from Nojli along the Saharanpur road, or *viâ* Hardwar. In Section 3 it was pointed out that the levelled heights failed to agree by 0·152 foot. We now see that the dynamic heights do not agree so well, differing by 0·178 foot; and that this change is chiefly due to the correction for irregularity of g.

9.

Now the differences d between levellers on the level lines of India have been taken out, and from these it has been deduced that the probable error e_1, of the mean result of the double-levelling on a line whose length is M miles is $0·004\sqrt{M}$ foot. Here M = 115·2 so that the probable error is $\pm 0·043$ foot. It has been remarked above that the discrepancy between two sets of levels in this circuit is only 0·113 foot. No account hitherto has been taken of the possible effects of refraction in this circuit. One would naturally expect the refraction effects to cancel in a circuit like this in which (roughly speaking) the mean gradient is nil, when we consider both upward and downward slopes. It has not been possible to apply any refraction correction to this case as temperature readings were not taken. In Sections 11 to 17 an estimate has been made of the probable magnitude of the refraction correction in the line from Dehra Dun to Mussooree: and the result is found to be less than one quarter of the orthometric correction.

We may fairly certainly conclude in the case of this circuit Nojli—Dehra Dun—Hardwar—Nojli that the refraction correction will be smaller than the orthometric correction.

Accordingly we conclude that the closing error of this circuit cannot be accounted for by the dynamic correction or the refraction correction.

The quantities involved, however, are too small to show without doubt any *change* in level of any parts of the circuit.

10.

We now give in Table 4 the orthometric heights for comparison with the uncorrected levelled heights for a number of points on the circuit and the Mussooree branches. Here again we have to apply to the dynamic height both the regular and irregular corrections; but this is done in one operation. Failing more observed values of g at different points at Mussooree, we have considered dg to be constant there (from Banog to Lal Tibba). Accordingly there is no correction from the levelled heights of the several points near Mussooree above the Library to obtain the orthometric heights above the Library. The correction is $\frac{g_{34} - g}{g}$ times the dynamic height: and at Mussooree $g = 979·443$ also $g_{34} = 978·859$, so factor is $-\frac{0·597}{1000}$

* A more detailed determination of the quantity $\Sigma\frac{F.\,dh}{1000}$ has been made by Lieuts. Bell and Mason, R. E., who find the following values for the dynamic correction:—

Nojli to Dehra Dun *via* Mohan + 0·6185 foot.
Nojli to Hardwar + 0·0257 foot.
Nojli to Dehra Dun *via* Hardwar + 0·6193 foot.

which give a closing correction to the circuit of −0·0008 foot against the quantity + 0·0016 foot found above. The discrepancy is accordingly 0·002 foot, which is of small account.

Table 4.

Height of Mussooree Library above	Dynamic	Correction	Orthometric	Levelled
	feet	*feet*	*feet*	*feet*
(1) Nojli*	5694·118	− 3·399	5690·719	5691·357
(2) Dehra Dun (Iron plug) ...	4351·607	− 2·598	4349·009	4349·401

We thus see that correction to levelled heights of points at Mussooree above Dehra Dun and Nojli are − 0·392 and − 0·638 foot respectively. These corrections are to be applied to all levelled points at Mussooree. We accordingly get Table 5, giving the corrected orthometric heights above Dehra Dun and Nojli of the several Mussooree points.

Table 5.

Point	Orthometric height above	
	(1) Nojli*	(2) Dehra Dún†
	feet	*feet*
Library	5690·719	4343·238
Dome Observatory H.S. ...	6047·755	4700·274
Shaw's Refraction station ...	6042·722	4695·241
Lal Tibba	6571·646	5224·165
Banog H.S.	6542·038	5194·557

The heights given in Table 5 are directly comparable with those deduced from vertical angles at Nojli and Dehra Dun, as the computation form for vertical angles gives the *orthometric* height of the observed point above the level surface through the point of observation. As the line from Nojli to Dehra Dun was levelled two years later than that from Dehra Dun to Mussooree there is a possibility of a variation in the height of Dehra Dun during this interval, partly vitiating the results.

Refraction Correction.

11.

Now briefly consider the question of refraction as it applies to levelling up a slope, where the slope persists in the same direction. M. Ch. Lallemand has investigated formulae for refaction (see *Comptes-Rendus des Séances de la Commission permanente de L'Association Géodésique Internationale, 1896*). His fundamental formula has been criticised on the ground that in the limiting case of a ray starting horizontally in air arranged in horizontal layers of equal density (and consequently equal refractive power) a finite amount of refraction is obtained; which at first sight may appear unnatural. The reason of this may be most easily understood by considering what occurs to light which grazes a glass-air surface. If r, r^1 are the angles at which a ray meets and leaves a glass surface, the ordinary law of refraction gives $\cos r = \mu \cos r^1$. When the light grazes, $r = o$, so that $\cos r^1 = \frac{1}{\mu}$, and r^1 is an angle of finite size. This is the case in which the direction of the incident light is *absolutely* parallel to the layers of equal refractive power; and yet the light is refracted by a definite amount towards the medium of greater refractive power. Also here there is a sudden change of refractive power and only a portion of the incident light is refracted, the remainder being reflected. In the case where the change of refractive power is gradual, the whole of the light is refracted and none is reflected. This latter is the case of light passing through air arranged in plane strata, such that each stratum is of one density throughout, and the change of density from one stratum to another is continuous.

I have worked out a formula for refraction quite independently, and by a different method; and this agrees with M. Lallemand's formula.

* The heights above Nojli are from Shaw's Refraction Station and are taken from the levelling line from Nojli along the Saharanpur road. From Dehra Dun to Mussooree was levelled between April 28, 1905 and May 29, 1905.

† The heights above Dehra Dun here are from Shaw's Refraction Station, which is 5·771 feet higher than the "iron plug" from which the other heights in this appendix are measured.

12.

For the case when the level is placed half way between the two levelling staves M. Lallemand obtains

$$E = -0^{mm}00108 \frac{B}{0^{m}76} \frac{t_3 - t_1}{(1 + \alpha\theta)^2} \frac{L^2}{D} \phi(\delta)$$

where E is the error

B is the barometric pressure in metres of mercury

t_1, t_2, t_3 are the temperatures in degrees centigrade of the air at points on the ray where it meets the front staff, telescope and back staff respectively

D is the difference in reading on the back and front staff

L is the distance between the staves

α is the co-efficient of expansion of air = 0·00366

θ is the mean of the three temperatures t_1, t_2, t_3.

$$\phi(\delta) = \frac{\mu - \frac{1}{2}\log(1-\delta^2)}{\log\frac{1+\delta}{1-\delta}} - \frac{1}{2\delta}$$

where $\mu = 0·434$ (modulus for converting Naperian to ordinary logarithms)

and $$\tau = \frac{t_3 - t_2}{t_2 - t_1} = -\frac{\log(1+\delta)}{\log(1-\delta)}.$$

The last equation defines δ in terms of the three temperatures t_1, t_2, t_3.

This formula is based on the ordinary physical laws and the assumption that the temperature of the air is constant at a given height h above the ground, and is given by the formula $t = a + b. \log(h + c)$ which, M. Lallemand states, is the most suitable empirical relation between t and h. The co-efficients a, b, c are to be determined by observations of temperature at three levels. The quantity $\phi(\delta)$ ranges in value from zero when $\tau = o$, to a maximum value 0·066 when $\tau = 0·27$, and then to zero again when $\tau = 1$. Other values are given in Table 6.

Table 6.

τ	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
$\phi(\delta)$	0·040	0·063	0·065	0·059	0·049	0·038	0·028	0·017	0·007

13.

M. Lallemand shows that

$$t_3 - t_2 = C. \log(1 + \delta)$$
and
$$t_2 - t_1 = -C. \log(1 - \delta)$$

where $\delta = \frac{D}{2h}$, and h is the height of the instrument above some plane parallel to and below the surface of the ground: the position of this plane depends on the temperature conditions. Taking the temperature conditions the same as considered by M. Lallemand in Section 11 of his article referred to above (Section 11), the data are $D = 2^{\cdot m}2$, $L = 150^{m}$, $t_2 - t_1 = 0°·75$, $t_3 - t_2 = 0°·35$. We have to find the corresponding values for $t_2 - t_1$ and $t_3 - t_2$ for different values of D and L, say D^1 and L^1 remembering that C and h are the same in both cases.

14.

Solving $$\tau = -\frac{\log(1+\delta)}{\log(1-\delta)}$$

we find with $\delta = 0·66$ $\tau = 0·470$

and with $\delta = 0·65$ $\tau = 0·477$

so that for $\tau = \frac{35}{75} = 0·467$

we may take δ as approximately 0·66.

Hence $$\delta^1 = \frac{D^1}{2h} = \frac{D^1\delta}{D}.$$

Therefore $\delta^1 = D^1 \frac{0 \cdot 66}{2 \cdot 2} = 0 \cdot 3D^1$

whence we can find τ^1 from

$$\tau^1 = -\frac{\log(1 + \delta^1)}{\log(1 - \delta^1)},$$

and then $\phi(\delta^1)$ from Table 6.

$$\text{Also } C = \frac{t_3 - t_2}{\log(1 + \delta)} = \frac{0^\circ \cdot 35}{0 \cdot 22} = 1 \cdot 59.$$

15.

Now consider the Dehra Dun—Mussooree line, dividing it into two portions Dehra Dun—Rajpur and Rajpur—Mussooree (Library) in each of which the slope may be considered more or less uniform. The computations of the refraction errors are performed in Table 7, which requires no explanation further than that average values of some of the quantities are taken out, which is merely treating the lines as of uniform slope and the successive intervals between the staves as equal; also a mean value for the whole line is deduced for the factor which contains the barometric pressure and temperature. Heights and distances have been turned into their metre-equivalents to suit the formula.

Table 7.

	Dehra Dun (Iron plug) to Rajpur	Rajpur to Mussooree Library
Length of line = A	10515 metres	17088 metres
Rise = C	333 m	992 m
Number of spans = n	150	458
Average $D = \frac{C}{n} = D^1$	$2^m \cdot 22$	$2^m \cdot 17$
Average $L = \frac{A}{n} = L^1$	$70^m \cdot 1$	$37^m \cdot 3$
Average value of K or $0^{mm} \cdot 00108 \frac{B}{0^m \cdot 76(1 + a\,\theta)^2}$	0·0008	0·0008
$\delta^1 = 0 \cdot 3D^1$	0·666	0·651
$\tau^1 = -\frac{\log(1+\delta^1)}{\log(1-\delta^1)}$	0·47	0·48
$\phi(\delta^1)$ from Table 6	0·052	0·051
$t^1_3 - t^1_1 = 1 \cdot 59\{(\log(1+\delta^1) - \log(1-\delta^1)\}$	1·11	1·07
$-E = K(t^1_3 - t^1_1)\,\phi(\delta^1)\,\frac{L^{1^2}}{D^1}$	$0^{mm} \cdot 102$	$0^{mm} \cdot 028$
nE	$-15^{mm} \cdot 3 = -0 \cdot 050$ foot	$-12^{mm} \cdot 8 = -0 \cdot 042$ foot
Error per metre	$-10^{-3} \times 1^{mm} \cdot 46$	$-10^{-4} \times 7^{mm} \cdot 49$

It is instructive here to note that, for the two lines in which the slopes are 1 in 31·6 and 1 in 17·2, the error per metre is practically twice as great in the line of smaller slope as in the other. The reason is that though the refraction would naturally be greater for the greater slope, other things being equal, it is counteracted by the necessary intervals between the level staves being shorter on the steeper line than on the other.

16.

Now the time at which temperature conditions are similar to those taken above is in the early morning; and probably these conditions only extend through half of an ordinary levelling day. During the other half of the day it is probable that the correction has the opposite sign to that found above; and it is doubtless of smaller amount. For this reason the values of E found above would doubtless be too large, were it not for the fact that possibly both t_3-t_1 and ϕ (δ) have larger values than we have taken. On the whole there seems little doubt that the values found above are certainly not less than the true corrections. Taking them to be correct, we see that the total correction for refraction between Dehra Dun and Mussooree is $-0·092$ foot. The orthometric correction on the same line is $-0·392$ foot. The ratio of the refraction correction to orthometric correction accordingly is less than one-fourth.

17.

As regards the ordinary circuits of India in which a line, sometimes rising, sometimes falling, is followed, it seems practically certain that the refraction correction is extremely small; and it may be expected to be about of the same order, in the general case, as that part of the dynamic correction not taken account of when formula values of g are used.

Dehra Dun,
February, 1910.

J. de G. Hunter.

APPENDIX.

No. 5.

THE PASSAGE OF RIVERS BY THE LEVELLING OPERATIONS.

BY O. C. OLLENBACH, ESQ.,

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During the course of levelling operations the lines of levels have had to be taken across many of the large rivers, which when unbridged, presented formidable obstacles, as ordinary levelling could not be adhered to, owing to the depth and great expanse of water. In all these cases the levellers have had to resort to special methods, a brief account of which is given in the table that follows.

Though a wide unbridged river is a formidable obstacle to levelling, yet extraordinary precautions are taken to effect a crossing without appreciable error, and Colonel Burrard decided to make no reduction, on account of river passages, in the weights assigned to the several level-lines in the simultaneous reduction.

Line No.	River crossed	Method adopted	Greatest length of shot	Names of Levellers and season
20	Kistna at Bezwada	Ordinary levelling along the anicut. Level equidistant from staves.	*chains** 8·00	G. D. Cusson Narsing Dass 1887-88
30	Godavari at Baber-Lanka village.	Ordinary levelling along anicuts. Level equidistant from staves.	10·00	G. D. Cusson Narsing Dass 1887-88
43	Manora ...	As the distance was too great to read a staff with any degree of accuracy, two indicator clamps, painted white, were attached to the staves. These clamps were moved up and down, according to pre-arranged signals, till the wire of the telescope of the level came on a level with their upper surfaces, when they were clamped and their readings recorded. Each reading was marked on the staves and verified after the observations were completed. The observations lasted two days, five sets of readings being taken each day, and the mean of the ten sets being accepted as the difference in height, which worked out to + 0·438 foot. The back staff was on Humby's Pier and the forward staff on Kimari Groyne.	36·00	G. Belcham 1893-94
55	Indus near Dera Ghazi Khan.	The ordinary method of levelling was adopted. As the river was split up into several channels, the instrument had to be set up nine times. These nine stations were observed forward and back and the mean of each pair of observations accepted. The width of the main channel was found to be 17·47 chains and that of the river about $1\frac{1}{2}$ miles. During these observations the staves were always equidistant from the instrument.	17·47	Capt. Walker C. J. Carty 1859-60

* 1 chain = 66 feet = 20·117 metres.

Line No.	River crossed	Method adopted	Greatest length of shot	Names of Levellers and season
			*chains**	
55	Indus between Darya Khan and Dera Ismail Khan.	Ordinary method adopted. The instrument being set up on long pegs driven firmly into the sand on islands at convenient distances apart. Five stations were observed at in crossing the river, the longest shot being 7·47 chains and the terminal difference between the two levellers was 0·004 foot. Previous to this the crossing was made by the "Tide-pole" and "Vertical angles" methods, the results showing the difference of height between the two banks being as follows:— By Levelling ... 0·926 foot. By "Tide-pole" ... 1·197 feet. By "Vertical angle" ... 0·919 foot.	7·47	Zille Hasnain D. H. Luxa 1906-07
57	Indus near Mithankot.	Method of crossing main channel not known, the distance being 28·20 chains. Five sets of observations were made and the mean accepted.	28·20	Capt. Branfill C. J. Carty 1860-61
64	Ganges between Meerut and Moradabad.	Ordinary method adopted, the longest shot being 11·75 chains. Sixteen sets of observations were made and the mean accepted. Level equidistant from staves.	11·75	C. Lane H. L. Clarke 1867-68
67	Ganges at Malakka Junction, Allahabad.	Ordinary method adopted, the longest shot being 13·31 chains. The mean of two sets of observations was accepted. Level equidistant from staves.	13·31	H. Trotter Ramchand 1863-64.
69	Gogra ...	Ordinary method adopted, the longest shot being 21·35 chains. The mean of ten sets of observations accepted. Level equidistant from staves.	21·35	C. Lane A. W. Donnelly 1869-70.
69	Ganges at Dildarnagar.	Ordinary method adopted. The longest shot was 16·60 chains. The mean of eight sets of observations accepted. Instrument equidistant from staves.	16·60	C. Lane A. W. Donnelly 1869-70.
70	Ganges at Mirzapur.	Ordinary method adopted, the longest shot being 15·20 chains. The mean of two sets of observations accepted. Instrument equidistant from staves.	15·20	H. Trotter Ramchand 1864-65.
70	Ganges at Balwah Ghat.	Ordinary method adopted, the longest shot being 19·02 chains. Six sets of observations were made and the mean accepted. Instrument and back staff on same bank and forward staff across river. Instrument equidistant from staves.	19·02	H. Trotter Ramchand 1864-65.
70	Ganges at Jusi Parao, Allahabad.	Ordinary method adopted. Instrument equidistant from staves.	7·82	H. Trotter Ramchand 1864-65.
71	Gandak at Balwa, between Gorakhpur and Bettiah.	Ordinary method adopted, the longest shot being 15·79 chains Eighteen sets of observations were made and the mean accepted. Instrument equidistant from staves.	15·79	C. Lane A. W. Donnelly 1869-70.

* 1 chain = 66 feet = 20·117 metres.

Line No.	River crossed	Method adopted	Greatest length of shot	Names of Levellers and season
			*chains**	
73	Ganges at Karagola Ghat.	The distance being too great for an ordinary staff to be read, a foot, measured on paper and divided into tenths and half tenths, was attached to the staves, but even these divisions could with difficulty be read with any degree of accuracy, except in the early morning and towards sundown, at which times the refraction is greatest. By multiplying the number of observations and taking morning and evening sets on two consecutive days, alternating the order of observations on the second day, the difference of level between the banks was found to be, by Capt. Carter (mean of 54 observations) 3·380 feet by Mr. Donnelly (mean of 54 observations) 3·338 feet. The distance across the river was 30·83 chains.	30·83	Captain Carter A. W. Donnelly 1871-72
74B	Hooghly river at Samalbaria village.	The levels were taken across by simultaneous tidal observations on either bank. Pegs 6 feet long were driven into the bank, on either side, about 10 feet below high-water mark. These were connected to other pegs higher up on the shores to test if any settlement took place during observations. Gauges were erected on the pegs capable of being read to 0·01 of a foot, and simultaneous observations were taken at both gauges by means of pre-arranged signals, and the time of each noted by watches, set just before observations commenced. Six sets of observations were taken at different times, two at rising tide, two at falling tide and two at high tide, giving a total of 370 readings for each gauge. The means of these readings were accepted and a difference of 1·823 feet deduced. The N. bank was found to be higher than the S. bank. In this case the distance across the river was not found by measuring a base and by observing the angles as is usually done, but it appears to be considerably over a mile.	...	T. H. Rendell Narsing Dass 1882-83
75	Rasulpur river near Contai.	The ordinary method was adopted, but the staves used were graduated on one side only, the value of each division being 0·020 foot. The instrument was placed midway between the staves, and on the same bank on which the forward staff was, while the back staff was on the opposite or W. bank. The mean of 26 sets of observations was accepted.	23·00	T. H. Rendell Narsing Dass 1881-82
75A	Haldi river at Basuli chak.	In this case the ordinary method was adopted, but the staves used were those of Colonel Strange's pattern, graduated to tenths and two hundredths of a foot. The instrument and forward staff were on a sand island and back staff on left bank, the distance between level and staves being equal. Sixteen sets of observations were taken and the mean accepted. The distance from level to back staff was found by triangulation. From the sand island to the right bank, another channel 14·00 chains wide, had to be negotiated, but it did not appear to offer any difficulties, as G. T. pattern staves were used.	32·00	T. H. Rendell Narsing Dass 1882-83
75A	Rupnarain river near Gewankhali.	The method adopted for crossing this river was the same as that for the Hooghly river, in line 74B, the staves used being Colonel Strange's pattern, graduated to tenths and two hundredths of a foot. The observations were carried out on five consecutive days, 3rd to 7th March 1883, during which period 483 observations were taken on either bank, the greatest difference between the several results obtained from different states of the tide being about $\frac{1}{10}$ of a foot. The distance across from bank to bank was found to be 48 chains.	48·00	T. H. Rendell Narsing Dass 1882-83

* 1 chain = 66 feet = 20·117 metres.

Line No.	River crossed	Method adopted	Greatest length of shot	Names of Levellers and season
75A	Damodar river	Ordinary method adopted. The level was placed midway between the staves on a sand island. The length of shot was 14 chains.	*chains** 14·00	T. H. Rendell Narsing Dass 1882-83.
77	Ganges river at Damukdia.	Some doubt having been cast on the "Tide-pole" method of crossing large rivers, the experiments at Damukdia Ghat were carried out in order to prove which method was the best, and at the same time to test, whether the supposition, that the heights of the surface water at two banks were identical, is correct. For this purpose three different methods were adopted viz: (a) By "Vertical angles". (b) By Levelling. (c) By "Tide-pole". (a) Vertical angles were taken with two 24-inch theodolites, placed on isolated masonry pillars, and the signals observed to were discs on similar pillars and firmly clamped at a known height. Observations were conducted on three different days, at time of minimum refraction and undertaken simultaneously on both banks by means of pre-arranged signals. The results were in very good accordance. (b) For this method the levels were placed on isolated masonry pillars. The framework which held the discs was erected on the same pillars which held the discs for the vertical angles observations. These discs were about 102·5 chains from the levels, the back staves being 6 chains distant from the instruments. When the telescope was brought on to the disc, the latter was lowered below the line of sight and then slowly raised till the white line painted on it was intersected by the horizontal wire of the level. So soon as this was effected the disc operator received a signal and immediately clamped it. The height of the centre of the disc was measured and recorded. The same observation was repeated, the disc being lowered to the intersecting point this time. Observations were conducted on four days, giving a total of 114 observations on each bank, and the mean difference deduced was 2·132 feet, the Sara side being higher. This difference is very near that given by the vertical angles method, though the results varied considerably on different days without any apparent reason. (c) "Tide-pole" method. Two old staves were bolted to piles driven into the bed of the river just below water level, and simultaneous readings were taken on either side on two calm days. The zeros of the staves were connected with the two bench-marks on the pillars on which the discs were erected. The results obtained by the three different methods are as follows:— (a) By "Vertical angles" ... 2·139 feet (b) By Levelling ... 2·132 „ (c) By "Tide-pole" ... 2·212 „ With regard to the results Captain H. L. Crosthwait R.E., remarks:— "These experiments seem to me to prove that "in the case of a well selected site, where current "and channel are fairly symmetrical, there exists no "great difference of level between the water on the "two sides of a river. In this case the difference of "level between the bench-marks as obtained by the "Tide-pole' method and the mean of the other two "methods, amounts to only 0·080 of a foot or 0·912 "of an inch".†	102·50	Captain H. L. Crosthwait R. E. J. P. Barker 1900-01

* 1 chain = 66 feet = 20·117 metres.

† Prof. papers 1903, serial No. 7, page 11.

Line No.	River crossed	Method adopted	Greatest length of shot	Names of Levellers and season
77 A	Brahmaputra at Dhubri.	The "Tide-pole" method was adopted, the channel being 31 chains wide. Simultaneous readings of the water on the graduated poles were taken on three days and the height of the referring pile on the opposite (Fakirganj) bank deduced.	*chains** 31·00	E. H. Corridon O. N. Pushong 1905-06
Burma A	Rangoon river ...	Ordinary method adopted. Instrument equidistant from staves. Five sets of readings taken and the mean accepted. Back staff on left bank, instrument and forward staff on right bank.	22·20	J. Bond Vinayak Narain 1892-93
Burma A	Irrawaddy at Sagaing	Here the "Vertical angles" method was adopted. Two 12-inch theodolites were set up on isolated masonry pillars, the objects observed to being the object glasses of the telescopes. Observations were carried on for four days, the observers changing places on the 3rd day. The distance across was found by triangulation to be 48·34 chains.	48·34	Lieut. H. Wood R. E. Lieut. F. B. Tillard 1902-03
Burma B	Irrawaddy at Magwe	The ordinary method of levelling was adopted. The two levellers set up their instruments on an island in mid-stream, the staves being on piles driven into the two banks. Sixty-four sets of observations were taken, 30 sets by the 1st leveller and 34 sets by the 2nd, the general means of the results obtained by both levellers differed only by 0·004 of a foot. The levels were placed midway between the staves, the distance being 26 chains either way.	52·00	E. H. Corridon M. Zille Hasnain 1902-03

In 1856 the Chenab river was crossed at three points in order to determine the amount of error to which one is liable in referring to the surface of a river, at the opposite extremities of a section across, when the breadth is too great for a staff on one bank, to be read from the other. Sections were selected at right angles to the stream, and pools were dug in the sand on each side, to obtain an unagitated surface of water for reference.

The results, by direct levelling, differed from those referred to the margin of the stream by 0·032, 0·039, 0·074 foot respectively, in the three instances, giving an average error of 0·048 foot, the average width of the river being 12 chains.

The values of the difference of height obtained by the three methods at the crossings of the Indus at Dera Ismail Khan and those of the Ganges at Damukdia Ghat are:—

Indus—By "Tide-pole"	...	...	1·197 feet
By "Vertical angles"	...	...	0·919 foot
By Levelling	...	...	0·926 „
Ganges—By "Tide-pole"	...	...	2·212 feet
By "Vertical angles"	...	...	2·139 „
By Levelling	...	...	2·132 „

Chenab—crossed by means of tide-poles and by direct levelling, the difference being 0·048 of a foot.

The difference between results by "Tide-pole" and by levelling is thus:—

On Chenab (1856) 0·048 of a foot
„ Ganges (1900) 0·080 „ „
„ Indus (1906) 0·272 „ „

while the difference between the results by levelling and by "Vertical angles" is:—

On Ganges + 0·007 of a foot
„ Indus − 0·007 „ „

* 1 chain = 66 feet = 20·117 metres.

The above figures would seem to establish the superiority of the "Vertical angles" method over the "Tide-pole" method.

As regards the best method of carrying levels of precision across a wide river, Captain H. L. Crosthwait remarks "I "think the method of vertical angles is far preferable to that of levelling . . . . . it is very difficult to make a satisfactory "intersection of a distant object when the object itself has to be moved. The operation is very trying to the eyes, and tedious as "well as uncertain. In the case of vertical angles, where the telescope is moved, it is comparatively simple to get a good inter- "section. Taking into consideration the facts that there is no great difference between the results by the three methods and "that there is nearly always a great difficulty in getting a suitable site for observations with water gauges, I would recommend "for future work the employment of two 12-inch theodolites with good levels, as being the best and most expeditious method of "carrying lines of levels across large rivers." (*Vide Prof. papers 1903, Serial No. 7, page* 11).

Dehra Dún,
August 6th, 1910.

O. C. Ollenbach.

APPENDIX.

No. 6.

THE ERRORS OF THE TRIGONOMETRICAL VALUES OF HEIGHTS OF STATIONS OF THE PRINCIPAL TRIANGULATION.

BY O. C. OLLENBACH, ESQ.,

Survey of India.

The trigonometrical difference of height between any two stations of triangulation, the height of one above mean-sea-level being known, is determined by a well-known formula, first introduced by Colonel Everest, from simultaneous mutual vertical observations of the stations; but owing to the complex distribution of heat in the lower strata of the earth's atmosphere this method, which presupposes that both of the angles are equally refracted at the time of observation and that this refraction is consequently eliminated in deducing the angle subtended by the excess of the higher station over the lower,* does not often yield satisfactory results. In hilly or mountainous regions results of a high degree of accuracy may be obtained by this procedure, but in the plains the rays of light passing from the object to the observer undergo considerable refraction before reaching their final destination. Much reliance cannot therefore be placed upon the heights thus obtained. The following extract is taken from Volume II, *Account of the Operations of the Great Trigonometrical Survey of India*, page 154, by General J. T. Walker, C. B., R.E., F.R.S.:—

"In a country where the trigonometrical stations can be erected on hills, or on points of sufficient command to permit "the mutual rays of light to pass freely through the air, at some distance above the surface of the ground, the method of vertical "angles is susceptible of a high degree of accuracy, provided the observations are taken during the time of the day when the "refraction is a minimum. In a hilly country determinations of height may probably be thus made with a degree of accuracy "which will not fall far short of that of good spirit-levelling in the plains, and will be superior to what could be expected from "the laborious process of levelling over the steep slopes and rugged ground which are met with at every step in a mountainous "region. But in a very flat country the trigonometrical method is beset with many difficulties from which that of spirit-levelling "is comparatively free; the rays of light mutually passing between the stations frequently graze the surface of the ground, and "always traverse the lowest strata of the atmospere, which are occasionally dense and heavy with moisture, and at other times "rarefied by the heat which is radiated from the surface of the ground whenever the sun shines out powerfully".

By spirit-levelling on the other hand the final height of a station is determined by a series of peg stations whose differential elevations are obtained by placing the instrument midway between stations and by taking the readings of back and forward staves simultaneously. Spirit-level values of height are therefore quite independent of refraction and their reliability is without question. This constitutes the principal reason why trigonometrical measurements of height are inferior to those of spirit-levelling. The errors of trigonometrical values of height can be determined by means of comparisons with spirit-level values.

The following table shows the errors of the trigonometrical values of height of several of the principal stations of triangulation of India:—

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* *Vide* page 8 of this volume.

Series of Principal Triangulation	Number of Synoptical Volume	Names and distinguishing numbers of Principal Stations of Triangulation which are also Spirit-level bench-marks	Geodetic numbers assigned to the stations as levelling bench-marks	Error of Trigonometrical height = Trig. value – Spirit-level value
				feet
The Great Indus Series	Vol. I	Abbaswala, CVIII	$\frac{b}{9}$ of Line 55	+ 1
		Ahmad Sindi, CXXXVI	$\frac{i}{10}$ of Line 55	+ 1
		Bakar, CXXXII	$\frac{g}{10}$ of Line 55	– 1
		Chandia Khan, XXIX	3 of Line 53	+ 2
		Dera Din Panah, CXII	$\frac{c}{9}$ of Line 55	– 1
		Dorata, C	$\frac{1}{8}$ of Line 55	– 3
		Farowala, CXVII	$\frac{a}{10}$ of Line 55	+ 1
		Gola, LXXV	2 of Line 57	0
		Hairo, XIV	4 of Line 53	+ 1
		Hatidara, XLII	$\frac{a}{1}$ of Line 54	0
		Jalbani, XXXII	$\frac{c}{2}$ of Line 53	– 4
		Jangal-pahora, XLV	2 of Line 54	+ 3
		Jharkil, CXXVII	$\frac{e}{10}$ of Line 55	0
		Kandkot, XLIX	$\frac{a}{3}$ of Line 54	– 5
		Karohar, XXI	$\frac{1}{3}$ of Line 53	+ 3
		Kasain, CXXX	$\frac{f}{10}$ of Line 55	– 1
		Kasmor, LVIII	$\frac{1}{4}$ of Line 54	0
		Khemwala, CIV	9 of Line 55	+ 2
		Lakha, XXVI	$\frac{a}{3}$ of Line 53	– 3
		Laluwali, LXXXIV	$\frac{2}{3}$ of Line 57	– 3
		Lanjiwar, LXXXI	$\frac{1}{3}$ of Line 57	+ 2
		Litan, XLVII	3 of Line 54	+ 1
		Mahiwala, CVII	$\frac{a}{9}$ of Line 55	– 2
		Mari, XXXVIII	$\frac{a}{2}$ of Line 53	0
		Maru Pir, XX	$\frac{c}{3}$ of Line 53	– 2
		Mir-ka-kuba, XVI	$\frac{e}{3}$ of Line 53	– 2
		Mir Khan, XII	$\frac{a}{4}$ of Line 53	– 3
		Mohammad Shah, CXXV	$\frac{d}{10}$ of Line 55	+ 1
		Pari, CXLVIII	$\frac{a}{18}$ of Line 55	– 1
		Sabar Khan, XVIII	$\frac{d}{3}$ of Line 53	+ 3

Series of Principal Triangulation	Number of Synoptical Volume	Names and distinguishing numbers of Principal Stations of Triangulation which are also Spirit-level bench-marks	Geodetic numbers assigned to the stations as levelling bench-marks	Error of Trigonometrical height = Trig. value − Spirit-level value
				feet
The Great Indus Series (*Contd.*)	Vol. I	Sakwala, CXV	10 of Line 55	0
		Sandi, CXXXVII	$\frac{j}{10}$ of Line 55	0
		Segra, CXXXIV	$\frac{h}{10}$ of Line 55	0
		Shahpur, LXXIII	$\frac{1a}{3}$ of Line 57	+ 1
		Shahpur, CXXII	$\frac{c}{10}$ of Line 55	+ 1
		Sojra, XXIV	$\frac{b}{3}$ of Line 53	0
		Sukhiwala, CXX	$\frac{b}{10}$ of Line 55	− 1
		Taman, CXLV	$\frac{1}{17}$ of Line 55	+ 1
		Yusuf, XXXVI	$\frac{b}{2}$ of Line 53	+ 4
The Great Arc Meridional Series—Section 24° to 30°.	Vol. II	Begarazpur, XLVII	$\frac{d}{26}$ of Line 61	− 3
		Boolandshahar, XXXVII	$\frac{1}{8}$ of Line 62	− 9
		Dholpur, XX	$\frac{1}{6}$ of Line 63	− 6
		Nojli, LIII	$\frac{5}{9}$ of Line 61A	− 8
The Karachi Longitudinal Series.	Vol. III	Kanad, CI	$\frac{2}{15}$ of Line 52	+ 4
The Gurhagarh Meridional Series.	Vol. IV	There are no bench-marks	...	...
The Rahun Meridional Series.	Vol. V	Kado, LXXXV	$\frac{a}{11}$ of Line 61	+ 1
The Jogi-Tila Meridional Series.	Vol. VI	Akbar-da-Bunga, VII	$\frac{1}{17}$ of Line 57	0
		Koar, XLIX	$\frac{2}{104}$ of Line 56	+ 7
The Sutlej Series	Vol. VI	Chanikhan, V	$\frac{1}{5}$ of Line 57	0
		Datekhan, XI	$\frac{1c}{5}$ of Line 57	+ 1
		Kandani, I	$\frac{2a}{3}$ of Line 57	− 4
		Khanbela, II	$\frac{1}{4}$ of Line 57	− 1
		Magreja, III	$\frac{2b}{3}$ of Line 57	− 4
		Nurkanch, IX	$\frac{1b}{5}$ of Line 57	+ 2
		Paphra, IV	$\frac{1a}{4}$ of Line 57	0
		Pirhar, VII	$\frac{1a}{5}$ of Line 57	+ 2
The North-West Himalaya Series.	Vol. VII	Jaoli, XXXVIII	$\frac{3}{158}$ of Line 56	+ 3

Series of Principal Triangulation	Number of Synoptical Volume	Names and distinguishing numbers of Principal Stations of Triangulation which are also Spirit-level bench-marks	Geodetic numbers assigned to the stations as levelling bench-marks	Error of Trigonometrical height = Trig. value − Spirit-level value
				feet
The Great Arc Meridional Series—Section 18° to 24°.	Vol. VIII	Badali, XX	$\frac{7}{237}$ of Line 35	+ 5
		Bider base-line, E. End, XLV	$\frac{2c}{40}$ of Line 24	− 3
		" " W. End, XLIII	$\frac{3}{40}$ of Line 24	− 4
		Gidgarh, IV	$\frac{a}{220}$ of Line 34	− 3
		Shilapali, XLVII	$\frac{1}{44}$ of Line 24	− 2
		Wirur, XXI	$\frac{1}{266}$ of Line 35	+ 2
The Jabalpur Meridional Series.	Vol. IX	Khara, XIX	$\frac{2}{453}$ of Line 35	− 2
		Lapeta, IV	$\frac{1}{40}$ of Line 60A	− 6
		Sitapar, XX	$\frac{2}{470}$ of Line 35	+ 1
The Bider Longitudinal Series.	Vol. X	Bora Gattu, III	$\frac{2}{34}$ of Line 24A	+ 6
		Yarada, XLV	$\frac{1}{229}$ of Line 30	0
The Bilaspur Meridional Series.	Vol. XI	Bhalua, II	$\frac{1a}{104}$ of Line 58	− 10
		Bodri, XV	$\frac{a}{62}$ of Line 38	+ 1
		Dalea, XII	$\frac{1}{20}$ of Line 58	+ 7
		Gathaura, XIV	8 of Line 40	− 1
		Hathbena, XLIII	$\frac{1}{157}$ of Line 37	+ 8
		Hirapur, XLV	$\frac{3}{149}$ of Line 37	+ 1
		Kotgarh, XVI	$\frac{1}{19}$ of Line 40	− 4
		Sirsi, LII	$\frac{1a}{144}$ of Line 37	− 2
The Calcutta Longitudinal Series.	Vol. XII	Amua, XVII	$\frac{1}{16}$ of Line 59	− 5
		Chinsura, LXXXI	$\frac{b}{75}$ of Line 74	− 2
		Lora, XVI	$\frac{1}{16}$ of Line 60A	− 6
		Salaia, XIV	$\frac{1}{50}$ of Line 60	0
		Saugor, V	$\frac{7}{155}$ of Line 60	+ 2
The East Coast Series	Vol. XIII	Barnai, XXXVII	$\frac{3}{37}$ of Line 39	0
		Bor, LXIII	$\frac{13}{51}$ of Line 36	− 1
		Chandikho, XLIII	$\frac{1}{85}$ of Line 39	0

Series of Principal Triangulation	Number of Synoptical Volume	Names and distinguishing numbers of Principal Stations of Triangulation which are also Spirit-level bench-marks	Geodetic numbers assigned to the stations as levelling bench-marks	Error of Trigonometrical height = Trig. value − Spirit-level value
				feet
The East Coast Series (*Contd.*)	Vol. XIII	Chandipur, XXII	$\frac{6}{83}$ of Line 75	− 1
		Cuttack, XXXV	$\frac{1}{339}$ of Line 40	+ 1
		Kudi, XI	$\frac{a}{133}$ of Line 75	− 4
		Mal, LI	$\frac{1}{171}$ of Line 39	− 1
		Mirzapur, I	$\frac{1}{177}$ of Line 75	− 1
		Patna, XV	$\frac{a}{116}$ of Line 75	− 4
		Pindi, LX	$\frac{1}{243}$ of Line 39	+ 2
		Ramnagar, IV	$\frac{18a}{159}$ of Line 75	+ 6
		Sarisa, II	$\frac{a}{45}$ of Line 74A	+ 1
		Sautia, XIII	$\frac{1}{124}$ of Line 75	+ 2
		Vizagapatam base-line, N. End, LXVIII ...	$\frac{1}{37}$ of Line 36	− 1
		Vizagapatam base-line, S. End, LXX ...	$\frac{1}{28}$ of Line 36	0
The Budhon Meridional Series.	Vol. XIV	Baragaon, XXIII	$\frac{1g}{25}$ of Line 66	+12
		Bhatauli, XLII	$\frac{30}{100}$ of Line 64	− 1
		Firozabad, XXII	$\frac{1}{10}$ of Line 66	+11
		Sirsa, XL	$\frac{1a}{77}$ of Line 64	+ 3
The Rangir Meridional Series.	Vol. XV	Bisungarh, XX	$\frac{1}{49}$ of Line 66	− 8
		Fatehganj, XXXI	$\frac{1}{148}$ of Line 64	−25
		Kalsan, XIX	$\frac{1}{61}$ of Line 66	−31
The Amua Meridional Series.	Vol. XVI	Darawal, XXVIII	$\frac{a}{224}$ of Line 64	−14
		Jajmao, XVIII	$\frac{1}{9}$ of Line 67	+ 1
		Maihar, I	$\frac{2}{50}$ of Line 59	−10
		Parser, XXX	$\frac{3}{224}$ of Line 64	0
		Sirwaia, XXIX	$\frac{1}{228}$ of Line 64	0
The Karara Meridional Series.	Vol. XVI	Burwa, V	$\frac{1a}{108}$ of Line 59	−12
		Karra, XVI	$\frac{2}{63}$ of Line 67	−10
		Majilgaon, XVII	$\frac{1}{55}$ of Line 67	− 3
		Pesar, XXX	$\frac{2}{17}$ of Line 68	+ 2
		Turkani, XXXI	$\frac{1}{30}$ of Line 68	+12
		Utiamao, XXXII	$\frac{2}{19}$ of Line 68	0

Series of Principal Triangulation	Number of Synoptical Volume	Names and distinguishing numbers of Principal Stations of Triangulation which are also Spirit-level bench-marks	Geodetic numbers assigned to the stations as levelling bench-marks	Error of Trigonometrical height = Trig. value − Spirit-level value
				feet
The Gurwani Meridional Series.	Vol. XVII	Baripur, VII	$\frac{1}{31}$ of Line 70	− 10
		Ganespur, VIII	$\frac{1}{18}$ of Line 70	− 7
		Kumeria, XXV	$\frac{1}{77}$ of Line 68	− 3
		Orajar, XXIV	$\frac{1}{70}$ of Line 68	+ 2
		Rahet, XXII	$\frac{5}{69}$ of Line 68	− 2
The Gora Meridional Series.	Vol. XVII	Balariaganj, XVII	$\frac{1a}{20}$ of Line 69	+ 4
		Baniapar, XVIII	$\frac{1}{17}$ of Line 69	− 2
		Barhani, VIII	$\frac{3a}{74}$ of Line 69	− 6
		Barhanpur, X	$\frac{a}{71}$ of Line 69	− 2
		Chit Bisram, XIV	$\frac{1}{42}$ of Line 69	+ 3
		Hirdepur, IX	$\frac{1}{85}$ of Line 70	− 6
		Kanaon, XII	$\frac{1}{51}$ of Line 69	− 1
		Katwar, XXII	$\frac{1}{8}$ of Line 69	− 2
		Rajabari, XXVI	$\frac{1}{5}$ of Line 69 A	+ 3
		Rajgarh, XX	$\frac{1a}{8}$ of Line 69	+ 3
		Samenda, XV	$\frac{1}{35}$ of Line 69	− 2
		Saraia, XXIV	$\frac{1}{105}$ of Line 68	− 3
The Hurilaong Meridional Series.	Vol. XVIII	Nuaon, XV	$\frac{1}{11}$ of Line 72	− 1
		Patjirwa, XXVIII	$\frac{2}{20}$ of Line 71	+ 8
The Chendwar Meridional Series.	Vol. XVIII	Harpur, XXII	$\frac{1}{38}$ of Line 71	− 3
		Paladpur, XXI	$\frac{5}{41}$ of Line 71	− 5
		Phulwaria (Fulbaria), XIV	$\frac{1}{80}$ of Line 72	0
		Sawajpur, XXIII	$\frac{a}{40}$ of Line 71	− 3
The North Parasnath Meridional Series.	Vol. XIX	Basantpur, XV	$\frac{2a}{66}$ of Line 71	− 5
		Chotaipati, XVII	$\frac{1}{68}$ of Line 71	+ 2
		Harpur, XVIII	$\frac{1}{78}$ of Line 71	− 3
The North Maluncha Meridional Series.	Vol. XIX	Barari, XII	$\frac{1}{47}$ of Line 72	− 4
		Dighi, XX	$\frac{9}{105}$ of Line 71	+ 6

Series of Principal Triangulation	Number of Synoptical Volume	Names and distinguishing numbers of Principal Stations of Triangulation which are also Spirit-level bench-marks	Geodetic numbers assigned to the stations as levelling bench-marks	Error of Trigonometrical height = Trig. value − Spirit-level value
				feet
The Calcutta Meridional Series.	Vol. XX	Nial, II	$\frac{1}{65}$ of Line 74	+ 1
		Ramchandpur, XXXVII	$\frac{1}{23}$ of Line 77B	+ 18
The Brahmaputra Meridional Series.	Vol. XX	Khankhanapur, VIII	$\frac{1}{28}$ of Line 77D	+ 4
The East Calcutta Longitudinal Series and the Eastern Frontier Series, Section 23° to 26°.	Vol. XXI	There are no bench-marks	...	...
The Assam Longitudinal Series.	Vol. XXII	Chilahati, IV	$\frac{1}{148}$ of Line 77	+ 3
		Dhubri, XXIV	$\frac{1a}{43}$ of Line 77A	− 2
The South Konkan Coast Series.	Vol. XXIII	Pil, XV	$\frac{2}{18}$ of Line 17A	+ 2
The Mangalore Meridional Series.	Vol. XXIV	Aundh, VI	$\frac{4}{78}$ of Line 29	− 3
		Kalas, I	$\frac{1}{7}$ of Line 27	− 3
The South-East Coast Series.	Vol. XXV	Kakkrakota, XXXII	$\frac{1}{5}$ of Line 1	0
		Kallakota, XXXV	$\frac{2}{6}$ of Line 1	+ 1
		Kallapat, VI	$\frac{1}{96}$ of Line 9	+ 3
		Kanad, XLIV	$\frac{2}{26}$ of Line 1	+ 3
		Karakkurchi, XXXVII	10 of Line 1	0
		Kulamangalam, XL	$\frac{2}{12}$ of Line 1	0
		Kumbakonam, XXIII	$\frac{2}{180}$ of Line 9	− 2
		Nambudalai, XLIX	43 of Line 1	+ 1
		Pallathivayal, XLII	$\frac{1}{14}$ of Line 1	0
		Poragudi, LIV	45 of Line 1	− 3
		Ramnad, LVI	$\frac{a}{2}$ of Line 2	− 1
		Saramutiraikota, XXX	$\frac{a}{3}$ of Line 5	+ 1
		Tanichanthai, LXI	$\frac{1}{7}$ of Line 2	+ 2
		Urannankudi, LI	$\frac{1}{44}$ of Line 1	− 2
		Uttarakoshamangai, LVIII	5 of Line 2	+ 1
The Ceylon Branch Series of the South-East Coast Series.	Vol. XXV	Gandhamana, LXXXIII	$\frac{5}{17}$ of Line 1 A	− 2
		Marakayarpatnam, LXXXI	$\frac{a}{11}$ of Line 1 A	0
		Ramaswami Madam, LXXIX	$\frac{1}{8}$ of Line 1 A	0

Series of Principal Triangulation	Number of Synoptical Volume	Names and distinguishing numbers of Principal Stations of Triangulation which are also Spirit-level bench-marks	Geodetic numbers assigned to the stations as levelling bench-marks	Error of Trigonometrical height = Trig. value − Spirit-level value
				feet
The Bombay Longitudinal Series.	Vol. XXVI	Bori, XXII	$\frac{1a}{12}$ of Line 25	− 1
		Kem, XVII	$\frac{1}{26}$ of Line 26	− 7
		Wapla, XVI	$\frac{2}{42}$ of Line 26	0
The Madras Longitudinal Series.	Vol. XXVII	Anandalamalai, XXXI	$\frac{1}{18}$ of Line 10	− 3
		Ballamale, IV	$\frac{1}{185}$ of Line 18A	− 2
		Haltibetta, XV	$\frac{3}{50}$ of Line 18A	− 3
		Kurumkota, XXXII	$\frac{1}{2}$ of Line 8	+ 2
		Mangalore, II	$\frac{1}{203}$ of Line 18A	+ 2
		St. Thomas's Mount, XLIV	$\frac{1}{11}$ of Line 9	0
		Tirumani, XXXVIII	$\frac{1}{39}$ of Line 9	0
		Yerrakonda, XX	$\frac{1}{26}$ of Line 18	+ 1
The Madras Meridional and Coast Series.	Vol. XXVIII	Anantagiri, I	$\frac{1}{216}$ of Line 24	− 3
		Aupad, LVIII	$\frac{2}{54}$ of Line 30	+ 3
		Bandalduru, XXXIV	$\frac{2}{190}$ of Line 20	+ 5
		Chintalapad, LXXII	$\frac{1}{252}$ of Line 24	+ 2
		Gurramkonda, XXXVII	$\frac{1}{216}$ of Line 20	+ 1
		Kappakonda, XLVI	$\frac{1}{166}$ of Line 30	− 1
		Nialamari, II	$\frac{1}{199}$ of Line 24	− 2
		Ongole, XVIII	$\frac{1}{99}$ of Line 20	− 1
		Palaparu, XII	$\frac{2}{52}$ of Line 20	0
		Rettambedu, XLIV	$\frac{1}{262}$ of Line 20	+ 2
The Great Arc Meridional Series—Section 8° to 18°.	Vol. XXIX	Adoni, XXII	$\frac{1c}{22}$ of Line 21	+ 1
		Bangalore base-line, N. E. End, LIII ...	$\frac{1}{70}$ of Line 18	+ 1
		Bangalore base-line, S. W. End, LII ...	78 of Line 18	+ 1
		Cape Comorin base-line, N. End, C ...	55 of Line 3A	0
		Cape Comorin base-line, S. End, CI ...	56 of Line 3A	+ 1
		Chennimalai, LXIX	$\frac{2}{10}$ of Line 11	− 1
		Gooty, XXV	$\frac{a}{1}$ of Line 14	− 4
		Goraigat, I	$\frac{1}{48}$ of Line 24	+ 4
		Honnur, XXIX	$\frac{2}{138}$ of Line 19	0

Series of Principal Triangulation	Number of Synoptical Volume	Names and distinguishing numbers of Principal Stations of Triangulation which are also Spirit-level bench-marks	Geodetic numbers assigned to the stations as levelling bench-marks	Error of Trigonometrical height = Trig. value − Spirit-level value
				feet
The Great Arc Meridional Series—Section 8° to 18°. (*Contd.*)	Vol. XXIX	Koilpati, LXXXIII	$\frac{1}{36}$ of Line 3	− 2
		Kottapalle, XV	$\frac{1b}{41}$ of Line 22	0
		Kutiparai, LXXXI	$\frac{1}{59}$ of Line 3	−10
		Maliabad, XIX	$\frac{1a}{6}$ of Line 21	0
		Morur, LXVII	$\frac{1}{80}$ of Line 7	− 2
		Naikal, XVII	$\frac{1}{28}$ of Line 22	− 1
		Rangaswamibetta, XLIII	$\frac{1}{35}$ of Line 18A	− 1
		Tirthapalli, XLVI	$\frac{1}{55}$ of Line 18	0
		Yettimalai, LXX	$\frac{3}{55}$ of Line 6	+ 1
The Gujarat Longitudinal Series.	Vol. XXX	Hasalpur, XXVI	$\frac{1}{3}$ of Line 51	+ 1
		Ingrodi, XXX	$\frac{2}{32}$ of Line 49	0
		Jinjhar, XVII	$\frac{1}{31}$ of Line 51	+ 2
		Khoraj, XXIV	$\frac{1}{8}$ of Line 51	+ 1
		Sanand, XXII	$\frac{1}{10}$ of Line 51	+ 1
		Sola, XXI	$\frac{1}{17}$ of Line 51	+ 1
		Vastral, XVIII	$\frac{a}{22}$ of Line 51	+ 3
The Khanpisura Meridional Series.	Vol. XXXI	Anakvadi, XXV	$\frac{1}{23}$ of Line 34	+13
		Dhanvar, XXIV	$\frac{2}{61}$ of Line 35	+13
		Singarchori, XV	$\frac{1}{149}$ of Line 34	− 4
		Thikri, XVII	$\frac{1}{122}$ of Line 34	− 2
		Valvadi, XXIII	$\frac{6}{41}$ of Line 35	+14
The Singi Meridional Series	Vol. XXXII	Parnera, XXXIII	$\frac{1}{188}$ of Line 51	0
		Sidhpur, XXIII	$\frac{b}{18}$ of Line 51D	+ 4
		Sinnar, XXXVII	$\frac{11}{90}$ of Line 33	− 4
The Cutch Coast Series	Vol. XXXIII	Bhachau, I	$\frac{1}{16}$ of Line 46	− 2
		Charakda, VIII	$\frac{1}{11}$ of Line 46	0
		Domani, XLIV	$\frac{a}{3}$ of Line 45	− 3
		Gada, XXXIX	$\frac{1}{77}$ of Line 44	− 2
		Guni, XXVIII	$\frac{b}{65}$ of Line 44	− 1

Series of Principal Triangulation	Number of Synoptical Volume	Names and distinguishing numbers of Principal Stations of Triangulation which are also Spirit-level bench-marks	Geodetic numbers assigned to the stations as levelling bench-marks	Error of Trigonometrical height = Trig. value − Spirit-level value
				feet
The Cutch Coast Series (*Contd.*)	Vol. XXXIII	Hathria, XVI	$\frac{1}{50}$ of Line 44	+ 2
		Lakhpat, XXV	$\frac{a}{62}$ of Line 44	+ 2
		Mod, XXXI	$\frac{1}{66}$ of Line 44	0
		Moghul Bhin, XXXVII	$\frac{a}{68}$ of Line 44	+ 1
		Saiyid Ali, XXVII	$\frac{a}{65}$ of Line 44	+11
		Sugandia, XXVI	$\frac{1b}{65}$ of Line 44	0
		Sukhpur, VI	$\frac{1}{15}$ of Line 46	0
		Vikia, XLIII	$\frac{7}{16}$ of Line 45	− 1
The Kathiawar Meridional Series.	Vol. XXXIV	Chitalia, XXIX	$\frac{1}{38}$ of Line 48	+ 1
		Kanmer, X	$\frac{1}{2}$ of Line 50	+ 1
		Khakhana, XXVI	$\frac{1}{7}$ of Line 49	− 1
		Malia, XVI	$\frac{1}{6}$ of Line 47	0
		Manaba, XII	$\frac{1}{1}$ of Line 50	0
		Pata-i-Shah, VIII	$\frac{1}{6}$ of Line 50	− 2
		Tarkia, XXV	$\frac{1}{13}$ of Line 49	+ 2
		Vandhia, XIV	$\frac{1}{20}$ of Line 46	0
The North-East Longitudinal Series.	Vol. XXXV	Ataria, XI	$\frac{1}{41}$ of Line 64A	+ 8
		Bakwa, LXIX	$\frac{1}{18}$ of Line 71	−12
		Bharmi, LVII	15 of Line 69A	−11
		Diwanganj, CII	$\frac{1}{108}$ of Line 71	− 1
		Gharbaria, LVIII	$\frac{1}{7}$ of Line 69A	− 9
		Ghiba, CIX	$\frac{2b}{112}$ of Line 71	− 2
		Kalianpur, XIII	$\frac{1}{43}$ of Line 64A	+ 4
		Latona, CIII	$\frac{1}{106}$ of Line 71	− 2
		Purena, LV	$\frac{2}{13}$ of Line 69A	−10
		Ramganj, CXXII	69 of Line 76	+ 6
		Ramnagar, CVII	$\frac{6b}{105}$ of Line 71	+ 5
		Rupdi, LXXIX	$\frac{1}{30}$ of Line 71	− 1
		Sonakhoda, CXXI	$\frac{1}{59}$ of Line 76	+ 3
		Umra, XV	$\frac{6}{51}$ of Line 64A	+ 3

Series of Principal Triangulation	Number of Synoptical Volume	Names and distinguishing numbers of Principal Stations of Triangulation which are also Spirit-level bench-marks	Geodetic numbers assigned to the stations as levelling bench-marks	Error of Trigonometrical height = Trig. value − Spirit-level value
				feet
The Base-line figures	...	Banog, (X)	$\frac{8b}{68}$ of Line 61A	+ 3
		Bhaorasa, (V)	$\frac{1}{224}$ of Line 60	− 4
		Chach base-line, S.W. End, (XIII) ...	209 of Line 56	− 1
		Dehra Dun base-line, E. End, (IX) ...	$\frac{2}{38}$ of Line 61A	− 3
		Kamkhera, (IV)	$\frac{1}{232}$ of Line 34	+ 2
		Karachi base-line, S. End, (XX) ...	12 of Line 43	0
		Sironj base-line, N.E. End, (II) ...	237 of Line 34	+ 3
		Surantal, (III)	$\frac{3a}{234}$ of Line 34	− 2
The Burma Coast Series	...	Myayabengkyo		+ 4
The Mandalay Meridional Series.	...	Sheinmaga		+ 9
		Taungpila		+ 6
		Toungoo		+ 10

Wherever lines of levels are connected with the triangulation, the spirit-level values of height for the stations connected are adopted; the trigonometrical heights of unconnected stations are determined by referring the differential heights, derived from the triangulation, to the stations whose heights have been fixed by the levelling operations.

Trigonometrical values of height have repeatedly emanated from spirit-level values in all parts of India. It is therefore impossible now to discover what errors in trigonometrical heights would have been generated, if triangulation had been kept always independent of levelling, and if no connections between the two had been instituted.

Dehra Dun,
August 6th, 1910.

O. C. Ollenbach.

APPENDIX.

No. 7

THE EFFECT ON THE SPHEROIDAL CORRECTION OF EMPLOYING THEORETICAL INSTEAD OF OBSERVED VALUES OF GRAVITY AND A DISCUSSION OF DIFFERENT FORMULÆ GIVING VARIATION OF GRAVITY WITH LATITUDE AND HEIGHT.

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1.

In introducing corrections to observed heights in levelling operations, to take account of the spheroidal form of the sea-level surface and the whole series of outer level surfaces, it is possible to proceed in either of two ways :—

(1) To introduce corrections such that the corrected value of the height of a point is the ***actual distance*** measured along a vertical between the point and the sea-level surface; this quantity being called the "*orthometric height*".

(2) To introduce corrections such that the corrected value of the height of a point is the distance measured along a vertical at some *standard latitude* between the level surface through the point and the sea-level surface; the derived quantity being called by its original investigator M. Lallemand the "côte dynamique", which perhaps may be translated "*dynamic equivalent height*" or more briefly, though less explicitly, simply "*dynamic height*".

In adopting the second of these methods (which has great advantages in the actual computations, as well as being scientifically preferable) it is necessary to still further define gravity at our standard latitude. We take it to be an ideal value at sea-level, and to vary with height according to the quantity $\left(1 - \frac{2H}{R}\right)$, where H is the height above sea level and R is the mean radius of the earth.

2.

One of the first points of difference that arises between the use of observed values of gravity and of the theoretical values is, that, as we level along any parallel of latitude rising to a height h, with theoretical values there is a correction proportional to h to get the dynamic height; and no correction at all to get the orthometric height. On the other hand, with observed values of g corrections to both dynamic and orthometric heights will in general exist. This is merely because the sea-level surface differs from a true surface of revolution about the polar axis.

3.

Let us now consider strictly the formulæ which occur.

Let P_h (*see* figure 1, plate XVII) be any point on the earth's surface, P_o the point on the sea-level surface on the vertical curve* through P_h; then $P_h\ P_o\ (= h)$ is the orthometric height of P_h. Let values of gravity at P_h and P_o be ${}_pg_h$ and ${}_pg_o$ respectively. Further let S_o be the ideal reference point on standard latitude at sea-level; and let level surface through P_h cut vertical curve through S_o at S_H. Then $S_H\ S_o\ (= H)$ is the dynamic height of P_h. Let the ideal gravity at S_o be G_o and that at S_H be G_H.

---

* The vertical cannot be considered as a straight line. It is a curve cutting the successive level surfaces orthogonally.

Taking adjacent level surfaces we have

$$_{\mathrm{P}}g_{\mathrm{h}}\, dh = G_{\mathrm{H}}\, dH$$

$$\text{dynamic height of } P_{\mathrm{h}} = \int dH = \int \frac{_{\mathrm{P}}g_{\mathrm{h}}}{G_0} \cdot \frac{dh}{1 - \frac{2H}{R}}$$

$$\text{since} \quad G_{\mathrm{H}} = \left(1 - \frac{2H}{R}\right) G_0.$$

Now $_{\mathrm{P}}g_{\mathrm{h}}$ is strictly speaking the observed value of gravity at the point P_{h}. If then we take the observed value and multiply it by the factor $\left(1 - \frac{2h}{R}\right)^{-1}$ to reduce it to sea-level,

since
$$\frac{1 - \frac{2h}{R}}{1 - \frac{2H}{R}} = 1 + \frac{2}{R}(H - h) + \frac{4H(H-h)}{R^2} + \ldots.$$

and since $(H - h)$ is small and can be neglected compared with R, we get

$$\text{dynamic height of } P_{\mathrm{h}} = \int \frac{g_{\mathrm{P}}}{G_0} dh.$$

$$\text{where} \quad g_{\mathrm{P}} = \left(1 - \frac{2h}{R}\right)^{-1} \cdot {_{\mathrm{P}}g_{\mathrm{h}}} = \left(1 + \frac{2h}{R}\right)\left(\text{observed value of } g\right).$$

It is to be noted that in making use of the *observed* value of g, it is *positively incorrect* to make use of any reduction other than that for height as above—the Bouguer term and orographic term do not come into the expression at all. On the other hand, when making use of a theoretical sea-level value these corrections might be employed (if practicable) to make the theoretical value accord more closely with the value taken above. It would be feasible to apply the Bouguer correction to theoretical values of g; the orographical correction could hardly be dealt with except in very special cases. In such cases where the orographical correction is large it is accordingly preferable in practice to make use of observed values rather than theoretical values of g, if such values are available. An example of this has been given in Appendix 4.

4.

It is of interest at this point to enquire whether the Bouguer or any other correction for height does improve the accordance between values of g given by the best available formula and values given by observation. Professor Helmert's formula of 1884, $g = 978\,(1 + 0{\cdot}005310 \sin^2 l)$, is found to suit India better than his new formula of 1901 $g = 978{\cdot}03\,(1 + 0{\cdot}005302 \sin^2 l - 0{\cdot}000007 \sin^2 2l)$.

As the object is to fit the actual values of g as well as possible, there is no doubt that the first formula should be used for levelling corrections. In the next section the two formulæ are compared in relation to the levelling correction.

Table 1, at the end of this section, has been prepared to exhibit the differences between the values of g by the 1884 formula and those found by actual observation with the new half-seconds pendulums brought out by Major Lenox Conyngham. In this table the following quantities are given:—

(1) Name of station.

(2) Latitude.

(3) Approximate height above sea-level $= h$.

(4) Observed value of gravity corrected to sea-level $= g\,(1 + 2h/R)$.

(5) Theoretical value of gravity $= 978\,(1 + 0{\cdot}005310 \sin^2 l) = \gamma$.

(6) Discrepancy $= g\,(1 + 2h/R) - \gamma = \delta g$.

(7) Difference between theoretical value and theoretical value at latitude 24°, $\Delta g = \gamma - \gamma_{24}$.

Now if a chart is prepared in which δg is plotted against height, we find that the points lie below and above the zero line to a fairly equal extent, suggesting that there is no relation between g and h. An inspection of the table of values of δg leads to the same conclusion. This seems to be sufficient reason for neglecting the Bouguer term in the theoretical values of g, at least so far as levelling corrections are concerned.

Table 1.

Arranged in order of absolute value of δg.

$\gamma_{24} = 978 \cdot 859$

Name of Station	Latitude	Approximate height	$g\left(1+\frac{2h}{R}\right)$	γ	$\delta g = g\left(1+\frac{2h}{R}\right)-\gamma$	$\Delta g = \gamma - \gamma_{24}$
	° ′	feet				
Mach	29 52	3522	979·288	979·288	0·000	+ 0·429
Meerut	29 0	734	979·220	979·221	− 0·001	+ 0·362
Muktlara	22 24	926	978·750	978·753	− 0·003	− 0·106
Gesupur	28 33	691	979·190	979·186	+ 0·004	+ 0·327
Ramchandpur	25 41	132	978·981	978·975	+ 0·006	+ 0·116
Salem	11 40	948	978·204	978·212	− 0·008	− 0·647
Chatra	24 13	64	978·884	978·873	+ 0·011	+ 0·014
Kalka	30 50	2202	979·352	979·364	− 0·012	+ 0·505
Mortakka	22 13	576	978·757	978·743	+ 0·014	− 0·116
Madras	13 4	20	978·281	978·266	+ 0·015	− 0·593
Rajpur	30 24	3321	979·313	979·330	− 0·017	+ 0·471
Ludhiana	30 55	835	979·352	979·371	− 0·019	+ 0·512
Montgomery	30 40	557	979·373	979·351	+ 0·022	+ 0·492
Kurseong	26 53	4913	979·086	979·062	+ 0·024	+ 0·203
Ujjain	23 11	1612	978·827	978·802	+ 0·025	− 0·057
Asarori	30 14	2467	979·290	979·317	− 0·027	+ 0·458
Mian Mir	31 32	708	979·449	979·420	+ 0·029	+ 0·561
Ferozepore	30 56	647	979·401	979·372	+ 0·029	+ 0·513
Kaliana	29 31	810	979·230	979·260	− 0·030	+ 0·401
Multan	30 11	404	979·281	979·312	− 0·031	+ 0·453
Cuttack	20 29	92	978·668	978·636	+ 0·032	− 0·223
Mhow	22 33	1903	978·797	978·763	+ 0·034	− 0·096
Kesarbari	26 8	204	978·971	979·007	− 0·036	+ 0·148
Kisnapur	25 2	113	978·967	978·930	+ 0·037	+ 0·071
Jacobabad	28 17	183	979·203	979·166	+ 0·037	+ 0·307
Jalgaon	21 0	760	978·704	978·665	+ 0·039	− 0·194
Hoshangabad ...	22 45	1002	978·812	978·773	+ 0·039	− 0·086
Shahpur	22 12	1286	978·783	978·743	+ 0·040	− 0·116
Mysore	12 19	2501	978·278	978·236	+ 0·042	− 0·623
Mohan	30 11	1660	979·264	979·313	− 0·049	+ 0·454
Amraoti	20 56	1123	978·714	978·665	+ 0·049	− 0·194
Kalsi	30 31	1684	979·289	979·339	− 0·050	+ 0·480

Table 1.—(Continued).

$\gamma_{34} = 978 \cdot 859$

Name of Station	Latitude ° ′	Approximate height (feet)	$g\left(1 + \frac{2h}{R}\right)$	γ	$\delta g = g\left(1 + \frac{2h}{R}\right) - \gamma$	$\Delta g = \gamma - \gamma_{34}$
Dehra Dun	30 19	2239	979·273	979·324	− 0·051	+ 0·465
Quetta	30 12	5520	979·366	979·314	+ 0·052	+ 0·455
Bangalore	13 1	3118	978·316	978·263	+ 0·053	− 0·596
Fatehpur	30 26	1434	979·279	979·333	− 0·054	+ 0·474
Ellichpur	21 18	1314	978·740	978·685	+ 0·055	− 0·174
Nojli	29 53	879	979·225	979·290	− 0·065	+ 0·431
Khandwa	21 50	1014	978·787	978·714	+ 0·073	− 0·145
Darjeeling	27 3	6966	979·147	979·074	+ 0·073	+ 0·215
Dera Ghazi Khan	30 4	397	979·229	979·303	− 0·074	+ 0·444
Roorkee	29 52	867	979·210	979·288	− 0·078	+ 0·429
Badnur	21 54	2103	978·803	978·724	+ 0·079	− 0·135
Hardwar	29 56	949	979·211	979·294	− 0·083	+ 0·435
Asirgarh	21 28	2077	978·778	978·694	+ 0·084	− 0·165
Jalpaiguri	26 31	268	978·947	979·035	− 0·088	+ 0·176
Colaba	18 54	34	978·634	978·545	+ 0·089	− 0·314
Edgar Shaft	12 56	2945	978·351	978·260	+ 0·091	− 0·599
Sibi	29 33	434	979·159	979·262	− 0·103	+ 0·403
Mussooree (Camel's Back) ...	30 28	6924	979·442	979·335	+ 0·107	+ 0·476
Yercaud	11 47	4493	978·326	978·217	+ 0·109	− 0·642
Mussooree (Dunseverick) ...	30 27	7129	979·444	979·334	+ 0·110	+ 0·475
Simla	31 6	7043	979·497	979·386	+ 0·111	+ 0·527
Siliguri	26 42	387	978·923	979·048	− 0·125	+ 0·189
Pathankot	32 17	1088	979·338	979·481	− 0·143	+ 0·622
Kodaikanal	10 14	7665	978·358	978·164	+ 0·194	− 0·695
Sandakphu	27 6	11766	979·286	979·078	+ 0·208	+ 0·219
Ootacamund	11 25	7395	978·424	978·203	+ 0·221	− 0·656

5.

We now turn to consider the different effects on levelling results according as we use the 1884 or 1907 formula for g. Dealing only with sea-level values, if g is the value of gravity at any latitude and g_{24} the value at the standard latitude 24°, the dynamic correction per foot rise along a line of levelling is $E = \frac{g - g_{24}}{g_{24}}$, g being given the value appropriate to the latitude where the rise takes place. Let suffixes 84 and 07 denote values obtained from the two formulæ.

$$\text{Then} \quad E_{84} = \frac{0{\cdot}005310\,(\sin^2 l - \sin^2 24^\circ)}{1 + 0{\cdot}005310\,\sin^2 24^\circ}$$

$$E_{07} = \frac{0{\cdot}005302\ (\sin^2 l - \sin^2 24^\circ) - 0{\cdot}000007\,(\sin^2 2l - \sin^2 48^\circ)}{1 + 0{\cdot}005302\,\sin^2 24^\circ - 0{\cdot}000007\,\sin^2 48^\circ}$$

$$E_{07} - E_{84} = 0{\cdot}005310\,(\sin^2 l - \sin^2 24^\circ)\left\{\frac{1}{1+0{\cdot}005302\,\sin^2 24^\circ - 0{\cdot}000007\,\sin^2 48^\circ} - \frac{1}{1+0{\cdot}005310\,\sin^2 24^\circ}\right\}$$

$$- \frac{0{\cdot}000008\,(\sin^2 l - \sin^2 24^\circ) + 0{\cdot}000007\,(\sin^2 2l - \sin^2 48^\circ)}{1 + 0{\cdot}005302\,\sin^2 24^\circ - 0{\cdot}000007\,\sin^2 48^\circ}$$

$$= \quad A - B \text{ (say).}$$

Now A is obviously less than

$$0{\cdot}005310\,(\sin^2 l - \sin^2 24^\circ)\{0{\cdot}000008\sin^2 24^\circ + 0{\cdot}000007\,\sin^2 48^\circ\}$$

$$\text{which is less than} \quad 0{\cdot}005310\,\cos^2 24^\circ\,(0{\cdot}000002 + 0{\cdot}000004)$$

$$\text{or} \quad 0{\cdot}26 \times 10^{-7},$$

which corresponds to a correction of 0·001 foot in a rise of 40,000 feet. This is quite negligible.

Again B is numerically slightly less than, but is practically equal to

$$0{\cdot}000008\,(\sin^2 l - \sin^2 24^\circ) + 0{\cdot}000007\,(\sin^2 2l - \sin^2 48^\circ)$$
$$= 0{\cdot}000004\,(\cos 48^\circ - \cos 2l) + 0{\cdot}0000035\,(\cos 96^\circ - \cos 4l).$$

As l increases from zero this expression decreases to its absolute minimum, when $l = 45^0$. Accordingly its extreme values in India are at the extreme Indian latitudes.

Taking these as 8° and 32° respectively, we find

$$B_8 = 0{\cdot}000004 \times 0{\cdot}2922 + 0{\cdot}0000035 \times 0{\cdot}9526$$
$$= 0{\cdot}0000045.$$

$$\text{Similarly } B_{32} = 0{\cdot}0000027.$$

Hence greatest discrepancy is at latitude 8°; and at this point it is less than 0·0045 foot per thousand feet of rise. This is of no practical importance.

6.

As soon as one contemplates abandoning the theoretical values of g in favour of locally observed values, one is faced with one considerable difficulty. If g was known at all points along a level line the difficulty would disappear. But as g has been observed at a comparatively small number of places only in India, these places are usually at considerable distances apart. The question then arises, how can values be assigned to points intermediate to those at which g has been observed? Unless the points are fairly close together, and there are no big local irregularities in the values of g, any method of interpolation is subject to considerable criticism.

7.

As a test case to get some idea of the order of the corrections, which are taken no account of in any formula giving g in terms of the latitude as the only variable, three lines of levels meeting in a central point (Jalarpet) have been selected in South India. The other extremities of the lines are Madras, Bangalore and Salem respectively (*see* figure 2, plate XVII). Gravity has been observed at four stations on or close to these lines; namely at Bangalore, Edgar Shaft (surface station, Kolar Gold Fields), Madras, Salem; and the observed differ from theoretical values, according to the 1884 formula, by amounts +0·053, +0·091, +0·015, −0·008 respectively. The dynamic correction has already been applied to these lines, so far as the theoretical value of g permit; it remains to consider the residual corrections due to the discrepancies of observed g from the formula values.

8.

The lines selected have several special features:—

(1) One starts from sea-level at Madras.

(2) This with another goes to a height of over 3000 feet, running practically along a parallel of latitude.

(3) The third line runs due south through normal country to a height of 919 feet.

(4) The irregularity of g is exceptionally large at Edgar Shaft; in fact it is larger than at any other place so far observed at in India, excepting a few hill stations and stations close to the foot of big mountains.

9.

First we must somehow get a hypothetical value of g for Jalarpet; and to do this an entirely arbitrary method has been used. If A, B, C are the values of δg at Edgar Shaft, Madras, Salem, and the direct distances from these places to Jalarpet are a, b, c, the value for Jalarpet has been taken to be

$$\frac{1}{3}\left(\frac{Ab + Ba}{a + b} + \frac{Bc + Cb}{b + c} + \frac{Ca + Ac}{c + a}\right).$$

In the case under consideration

$A = +0{\cdot}091$

$B = +0{\cdot}015$ and $a : b : c = 3{\cdot}4 : 12{\cdot}3 : 7{\cdot}1$

$C = -0{\cdot}008$

so that the above expression is found to be $0{\cdot}044$. For intermediate points along the three lines from this common point we assign values as follows: from Salem to Jalarpet δg changes from $-0{\cdot}008$ to $+0{\cdot}044$. At a point distant α from Salem and β from Jalarpet on this line, we take the value of δg as $\dfrac{-0{\cdot}008\,\beta + 0{\cdot}044\,\alpha}{\alpha + \beta}$; and similarly for the other lines.

10.

Having thus arrived at values for δg, the appropriate corrections are easily found. The correction to a rise in height dh in the neighbourhood of a point is $\dfrac{\delta g}{978{\cdot}0}\ dh$ as accurately as we require. Thus the multipliers of dh at the several points Madras, Salem, Jalarpet, Edgar Shaft, Bangalore are $+0{\cdot}015$, $-0{\cdot}008$, $+0{\cdot}046$, $+0{\cdot}093$, $+0{\cdot}054$ feet respectively per thousand feet rise.

11.

The lines are now divided into convenient intervals, as shown in figure 2, plate XVII; the mean value of the multiplier of dh is interpolated from values given in Section 10, and the values of dh taken from the levelling books. The figures are given below:—

Madras to Jalarpet.

		foot
10^{-6}	$+ 16 \times 102$	$= +0{\cdot}0016$
	$+ 19 \times 53$	$0{\cdot}0010$
	$+ 23 \times 123$	$0{\cdot}0028$
	$+ 26 \times 125$	$0{\cdot}0033$
	$+ 29 \times 215$	$0{\cdot}0062$
	$+ 34 \times 158$	$0{\cdot}0054$
	$+ 38 \times 160$	$0{\cdot}0061$
	$+ 40 \times 114$	$0{\cdot}0046$
	$+ 43 \times 87$	$0{\cdot}0037$
	$+ 46 \times 168$	$0{\cdot}0077$
	Total ...	$+0{\cdot}0424$

Jalarpet to Edgar Shaft.

		foot
10^{-6}	$+ 54 \times 709$	$= +0{\cdot}0384$
	$+ 65 \times 211$	$0{\cdot}0137$
	$+ 86 \times 416$	$0{\cdot}0358$
	Total ...	$+0{\cdot}0879$

Edgar Shaft to Bangalore.		
10^{-6}	$+86 \times 171 =$	$+0{\cdot}0148$
	$+80 \times 130$	$+0{\cdot}0104$
	$+69 \times 15$	$+0{\cdot}0010$
	$+58 \times 49$	$+0{\cdot}0028$
	Total	$+0{\cdot}0290$

Salem to Jalarpet.			
10^{-6}	$-2 \times 327 =$	$-0{\cdot}0007$	
	$+9 \times 186$		$+0{\cdot}0017$
	$+24 \times (-170)$	$-0{\cdot}0041$	
	$+38 \times 9$		$+0{\cdot}0003$
	$+46 \times 49$		$+0{\cdot}0023$
	Total $=$	$-0{\cdot}0005$	

12.

The corrections to bring observed height to dynamic height, using only the formula for g, are now given with the values found in last section owing to δg.

Table 2.

Line	Correction for Δg ($\Delta g = \gamma - \gamma_{24}$)	Correction for δg ($\delta g = g - \gamma$)
	feet	*foot*
Madras to Jalarpet ...	$-0{\cdot}792$	$+0{\cdot}042$
Jalarpet to Edgar Shaft ...	$-0{\cdot}838$	$+0{\cdot}088$
Edgar Shaft to Bangalore	$-0{\cdot}277$	$+0{\cdot}029$
Jalarpet to Salem ...	$+0{\cdot}304$	$+0{\cdot}001$
Madras to Bangalore ...	$-1{\cdot}907$	$+0{\cdot}159$
Madras to Salem ...	$-0{\cdot}488$	$+0{\cdot}043$
Salem to Bangalore ...	$-1{\cdot}419$	$+0{\cdot}116$

(Note that sign of correction must always be changed if we go along a line in the opposite direction. For in this case we change increase of height into decrease).

The above figures show that by far the most important part of the correction had been taken account of by using simply the formula for g. The uncorrected part is some 10°/₀ of the complete correction.

13.

As mentioned above the interpolation of values for g is open to criticism. This is clearly seen if we try to deduce the value at Edgar Shaft from the values at Bangalore, Madras and Salem. However there is an immediate reason for the large value at Edgar Shaft. The density beneath this place is abnormally high. This is not the case at Jalarpet, so that one has a fair chance of getting a fairly near value by the method of interpolation employed. At all events, it may be safely assumed that the corrections obtained above are not very far from the truth.

14.

We have so far considered the effect of the irregularity of gravity on a special line of levels. In Appendix 4 another actual line, ascending to the remarkable height of over 7400 feet above sea-level has been considered. This latter is a most unusual case, and at present we are concerned with forming an estimate of the uncorrected errors in levelling due to irregularity of gravity, in ordinary country where levelling operations are ordinarily carried on. Let us now consider the whole of India in a general way. Denoting $g^{\circ} - g^{\circ}_{24}$ by Δg, we may consider $\frac{\delta g}{\Delta g}$ as giving a good idea of the relative values of the levelling corrections due to the irregular and regular changes of g; that is, of the portion of the correction taken no account of to that taken full account of when we use the formula for g. As a mean for India therefore consider the ratio, $\delta g/\Delta g$ for all the points at which gravity has been observed in India, with the exception of the following places omitted on account of their being hill stations or stations close to the foot of big ranges; Rajpur, Darjeeling, Sibi, Mussooree, Yercaud, Simla, Siliguri, Pathankot, Kodaikanal, Sandakphu, Ootacamund.

The values of Δg and δg can be taken from the table and taking the sums for the 46 remaining stations we find $\Sigma\Delta g = 15 \cdot 294$, $\Sigma\delta g = 1 \cdot 755$; and the ratio of these quantities gives $\Sigma\delta g = 11 \cdot 47°/_{o}$ of $\Sigma\Delta g$.

15.

An alternative way of evaluating the mean Δg is to take the formula $978 \times 0 \cdot 005310 (\sin^2 l - \sin^2 24°)$ and find the mean value, irrespective of sign, between latitudes 8° and 32°. This is done as follows:—

$$\text{Mean value of } \sin^2 l \text{ between limits } 24° \text{ and } 32° = \frac{\int_{24}^{32} \sin^2 l \, dl}{\int_{24}^{32} dl} \times 9 \cdot 78 \times 0 \cdot 531$$

where 24° and 32° are given their values in radians.

$$\text{Now } \frac{\int_{l_1}^{l_2} \sin^2 l \, dl}{\int_{l_1}^{l_2} dl} = \frac{\frac{1}{2}\int_{l_1}^{l_2} (1 - \cos 2l) dl}{\int_{l_1}^{l_2} dl}$$

$$= \frac{\frac{1}{2} \cdot (l - \frac{1}{2} \sin 2l)\Big]_{l_1}^{l_2}}{l\Big]_{l_1}^{l_2}}$$

$$= \frac{1}{2} - \frac{1}{4} \; \frac{\sin 2l_2 - \sin 2l_1}{l_2 - l_1}.$$

Now $l_2 - l_1 = 8° = 0 \cdot 1395$ radians, and $\sin 64° - \sin 48° = 0 \cdot 15565$; and from 8° to 24° $l_2 - l_1 = 16° = 0 \cdot 2780$ radians and $\sin 48° - \sin 16° = 0 \cdot 46750$.

Hence mean from 24° to 32° is $0 \cdot 221$, and from 24° to 8° is $0 \cdot 080$; also $\sin^2 24° = 0 \cdot 166$. Therefore the mean of $\sin^2 l - \sin^2 24°$ between 24° and 32° is $0 \cdot 055$, and between 24° and 8° is $-0 \cdot 086$; and of these two numbers the arithmetic mean is $0 \cdot 071$.

Then mean Δg is $978 \times 0 \cdot 00531 \times 0 \cdot 071 = 0 \cdot 369$, and mean δg is $1 \cdot 755/46$. The ratio required is accordingly $1 \cdot 755/0 \cdot 369 \times 46 = 0 \cdot 1035$. That is, mean δg is $10 \cdot 35°/_{o}$ of mean Δg.

16.

In conclusion taking into account the several determinations of this ratio we may suppose its value to be under 12½°/ₒ or one-eighth. That is to say, if we correct level lines for gravity, using the theoretical value of g (1884 or 1907 formula) we may fully expect to have introduced at least seven-eighths of the true correction.

Note.—The computations have been made chiefly by means of a 50 cm. slide rule, and accordingly slight errors will occur in the last place of decimals in some cases. These errors are too small to be of appreciable amount in the final results obtained.

Dehra Dun,
January, 1910.

J. de G. Hunter.

APPENDIX.

No. 8.

ON THE DISCREPANCY BETWEEN THE TRIGONOMETRICAL AND SPIRIT-LEVEL VALUES OF THE DIFFERENCE OF HEIGHT BETWEEN DEHRA DUN AND MUSSOOREE.

BY COLONEL S. G. BURRARD, R.E., F.R.S.,

Superintendent of Trigonometrical Surveys.

One curious fact brought to light by Mr. Shaw's observations between Dehra Dun and Mussooree is that the trigonometrical difference of height, determined from reciprocal vertical angles, is systematically larger than the spirit-level value of the difference. The orthometric difference of height determined by spirit-levelling is 4695·6 feet (= 1431·2 metres): the trigonometrical determination always exceeds 4698·0 feet (= 1431·9 metres).

Table showing excess in feet of the trigonometrical determination of the height of Mussooree above Dehra Dun over the spirit-level determination.

	October November 1905	March April 1906	October November 1906	March April 1907	October November 1907	March April 1908	October 1908	March April 1909	Mean
	feet	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*
8 a. m.	3·0	4·3	3·2	3·7	3·8	3·2	3·1	3·8	3·5
10 a. m.	2·8	3·2	2·7	3·1	2·9	2·8	2·5	2·8	2·9
Noon	2·8	2·9	2·6	3·1	2·8	2·6	2·4	2·9	2·8
3 p. m., time of minimum refraction ...	2·8	3·0	2·7	3·1	2·9	2·6	2·5	2·8	2·8
4-30 p. m.	3·2	3·2	3·2	3·3	3·0	3·0	2·8	3·0	3·1

The mean excess of the trigonometrical determination is 3·0 feet (= 0·9 metre).

I do not think that the difference between the trigonometrical and spirit-level values can be attributed to errors of observation. As the above table shows, trigonometrical observations have been carried out for years at different times of day and during different seasons, and have always given accordant results, whatever instrument has been employed. If any one is unwilling to accept the levelling results, he should study pages 342, 359 and 395 of this volume, and he will realise how unjustifiable it would be to attribute an error of even one foot to the levelling.

The diurnal variation of the difference is small, and seems to denote that the difference is not a phenomenon of refraction. Detailed calculations support this view, and show that refraction is not the primary cause. Let us, for instance, suppose that Mussooree is raised by refraction, when viewed from Dehra Dun, through x feet; and that Dehra Dun is raised by refraction, when viewed from Mussooree, through y feet. Then the discrepancy between the trigonometrical and spirit-level values will be $\frac{x-y}{2}$ feet. We have therefore to put $\frac{x-y}{2}$ equal to 3 feet, and $x - y = 6$ feet (= 1·8 metres).

Now let r_1 be the co-efficient of refraction at Dehra Dun and r_2 at Mussooree: then from Mr. Shaw's observations we have the mean refraction $= \frac{r_1 + r_2}{2} = 0{\cdot}056$. And we have to assume that the difference $(r_1 - r_2)$ is such, that Mussooree is raised by refraction 6 feet higher when viewed from Dehra Dun, than Dehra Dun is raised, when viewed from Mussooree. We can then deduce

$$r_1 = 0{\cdot}081,$$
$$r_2 = 0{\cdot}031.$$

But these values are contrary to all experience; and in the face of numerous independent determinations of refraction we should not be justified in accepting such a large co-efficient as 0·081 for Dehra Dun or such a small co-efficient as 0·031 for Mussooree.

The effects of refraction upon the levelling between Dehra Dun and Mussooree may be neglected; in Appendix No. 4 Mr. Hunter has shown that the total correction for refraction to spirit-levelling between Dehra Dun and Mussooree is only − 0·092 foot.

The discrepancy between the trigonometrical and spirit-level values of height cannot be attributed to our employment of erroneous values of g in the formulæ for deriving the orthometric corrections for spirit-level heights, (page 100). In Appendix No. 4 of this volume, Mr. Hunter has shown that if observed values of g, (corrected for height only), are used for the deduction of the orthometric correction from the formulæ of chapter VII, the observed value of the spirit-level height of Mussooree above Dehra Dun will receive a correction of only − 0·392 foot.

Great differences of opinion at present prevail amongst geologists and geodesists on the subject of the Bouguer term in the reduction of pendulum observations. Professor Suess has recently expressed distrust of the results of pendulum observations, and of the theory of isostasy*. Mr. Tittmann and Mr. Hayford have recently questioned the correctness of our orographical corrections for pendulum observations, and have put forward a theory of complete isostasy†.

But I do not think that our neglect of the Bouguer term in the deduction of the orthometric correction for spirit-levelled heights (*see* page 101) can be the cause of the discrepancy between the trigonometrical and spirit-level determinations of the Himalayan difference of height. The following are the several values of gravity :—

	at Dehra Dun	at Mussooree (Camel's Back)	difference (Dehra Dun—Mussooree)
	cm.	*cm.*	*cm.*
Observed values	979·063	978·793	+ 0·270
Observed values corrected for height only	979·273	979·442	− 0·169
Observed values corrected for height, and for mass (Bouguer)	979·194	979·199	− 0·005
Observed values corrected for height, and for mass (Bouguer) and for orography	979·198	979·225	− 0·027
Theoretical values from Helmert's formula	979·324	979·335	− 0·011

It is difficult to see how any theory of isostatic compensation can so modify the adopted values of g, as to bring about an additional correction of + 3 feet to the spirit-levelled height of Mussooree‡. If observed values of gravity are used, without any correction at all for height or mass, the correction to the spirit-levelled height will be less than + 0·7 foot.

The only explanation that I can offer of the discrepancy of 3 feet between the trigonometrical and spirit-level values of the height of Mussooree above Dehra Dun is the following :—

(i.) The plumb-line is deflected at Dehra Dun about 30″ towards the north: the observed angle of elevation of Mussooree from Dehra Dun is thus about 30″ too small§.

(ii.) The plumb-line is deflected at Mussooree also about 30″ towards the north; and the observed angle of depression of Dehra Dun from Mussooree is thus also 30″ too small.

(iii.) Both the back and forward vertical angles being 30″ too small, and the horizontal distance between Dehra Dun and Mussooree being 9·5 miles, the trigonometrical value of the difference of height has been given about 7 feet too small.

(iv.) But the spirit-level value of this difference of height is 3 feet smaller than the trigonometrical value, and as the latter is 7 feet too small, the spirit-level value must be 10 feet too small.

(v.) Calculations of trigonometrical heights are based upon a spheroidal figure for the earth; the spirit-levelling follows the surface of the geoid. The surface of the geoid must be, I think, 10 feet higher at Mussooree above the spheroidal surface than it is at Dehra Dun. This separation of the two surfaces would affect the levelling to the extent of 10 feet.

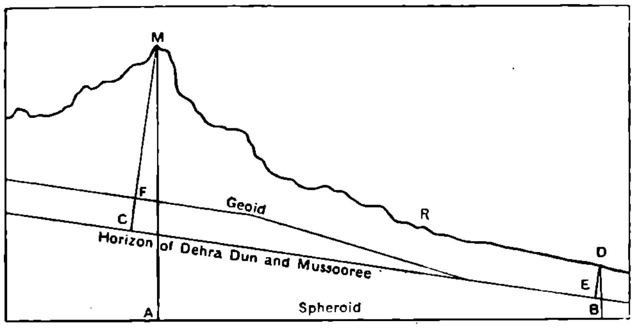
* *Vide, The Face of the Earth,* Volume IV, page 610, Sollas's translation of *Das Antlitz der Erde.*

† *Report Coast and Geodetic Survey, U. S. A., 1909. Report International Geodetic Conference, Budapest, 1906. Report International Geodetic Conference, London, 1909*

‡ The mountain line of levelling from Dehra Dun to Mussooree is the only line in India, upon which the neglect of the Bouguer term might affect the orthometric values of height in the first place of decimals of a foot.

§ For deflections see *Philosophical Transactions of the Royal Society, Vol. 205, 1905, p. 308.*

(vi.) If the deflection of the plumb-line is 30″ both at Mussooree and Dehra Dun, it may be argued that this represents the inclination of the geoidal to the spheroidal surface, and in 9·5 miles this inclination would only produce a separation of 7 feet. This argument would be correct, if the deflection of the plumb-line *continued to be 30″ throughout the line* from Dehra Dun to Mussooree. But at Rajpur, midway between Dehra Dun and Mussooree, the deflection of the plumb-line is 10″ greater than at Dehra Dun or Mussooree. The surface of the geoid is therefore not rising at an uniform angle of 30″ throughout the line. At the two extremities of the line it is inclined 30″ to the spheroid; at the centre of the line its inclination exceeds 40″.*



M = Mussooree ; R = Rajpur ; D = Dehra Dun.
Difference of height between Mussooree and Dehra Dun :—
Above Spheroid . . . . = H_1 = MA − DB.
As determined trigonometrically = H_2 = MC − DE.
,, by spirit levelling = H_3 = MF − DE.
$H_1 - H_2 = + 7$ feet.
$H_1 - H_3 = + 10$,,
$H_2 - H_3 = + 3$,,

Dehra Dun,
July 15th, 1910.

S. G. Burrard.

* The adopted deflections of the plumb-line are those, which have been determined in the plane of the meridian. The line joining Dehra Dun and Mussooree is some 6 degrees in azimuth east of north. In the vertical plane, passing through Dehra Dun and Mussooree, the deflections are probably 2″ greater at both places than in the meridional plane. The course moreover of the spirit-levelling does not follow the straight line, but zig-zags to the east and to the west of it. These considerations prevent us from claiming any high degree of accuracy for our estimate of the departure of the geoidal from the spheroidal surface, but they do not affect the general principles underlying the explanation. See preface to *Synoptical Volume XXXV, G. T. Survey of India.*

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* Out of print.

Vol. III. *The Principal Triangulation—the Base-Line Figures, the Karáchi Longitudinal, N.W. Himalaya, and Great Indus Series of the North-West Quadrilateral. Dehra Doon, 1873*.*

Vol. IV. *The Principal Triangulation—the Great Arc (Section 24°-30°), Rahún, Gurhágarh and Jogí-Tíla Meridional Series and the Sutlej Series of the North-West Quadrilateral. Dehra Dún, 1876.*

Vol. IVA. *General Description of the Principal Triangulation of the Jodhpore and the Eastern Sind Meridional Series of the North-West Quadrilateral, with the Details of their Reduction and the Final Results. Dehra Dún, 1886.*

Vol. V. *Details of the Pendulum Operations and of their Reduction. Dehra Dún and Calcutta, 1879.*

Appendix No. 1. Account of the Remeasurement of the Length of Kater's Pendulum at the Ordnance Survey Office, Southampton.

Appendix No. 2. On the Relation between the Indian Pendulum Operations, and those which have been conducted elsewhere.

1. General Considerations on Pendulum Operations.
2. General Considerations on the Reduction of Pendulum Observations.
3. On a proposed Method of treatment of the Results of Pendulum Operations, with a view to facilitating the Solution of the General Problem of Local Variation.
4. Sketch of the Method of Solution from the Data as proposed in foregoing Sections.
5. Notes for a History of the Use of Invariable Pendulums.
6. On the Estimation of the Provisional Equatorial Numbers of different Pendulums.
7. Account and Explanation of the Table of Provisional Equatorial Vibration-numbers of Invariable Pendulums.
8. General Synopsis of Determinations.

Appendix No. 3. On the Theory, Use and History of the Convertible Pendulum.

1. The Convertible Pendulum as used by Kater.
2. The Theory of the Convertible Pendulum.
3. Application of the Theory in the case of Kater's and Sabine's Experiments.
4. Application of the Theory to the use of the Reversible Pendulum.
5. On the Constancy or otherwise of the Difference *A—B*.
6. Relation of the Subject to the Use of Invariable Pendulums.

Appendix No. 4. On the Length of the Seconds Pendulum determinable from Materials now existing.

1. Review of the Operations with Kater's Convertible Pendulum.
2. Final Comparison of Experiments with Kater's Convertible Pendulum.
3. Other Values of the Length of the Seconds Pendulum.

Appendix No. 5. A Bibliographical List of Works relating to Pendulum Operations in connection with the Problem of the Figure of the Earth.

Vol. VI. *The Principal Triangulation of the South-East Quadrilateral, including the Great Arc—Section 18° to 24°, the East Coast Series, the Calcutta and the Bider Longitudinal Series, the Jabalpur and the Bilâspur Meridional Series, and the Details of their Simultaneous Reduction. Dehra Dún, 1880.**

* Out of print.

Vol. VII. General Description of the Principal Triangulation of the North-East Quadrilateral, including the Simultaneous Reduction and the Details of five of the component Series, the North-East Longitudinal, the Budhon Meridional, the Rangir Meridional, the Amua Meridional, and the Karára Meridional. Dehra Dún, 1882.

Appendix No. 1. The Details of the Separate Reduction of the Budhon Meridional Series, or Series J of the North-East Quadrilateral.

Appendix No. 2. Reduction of the North-East Quadrilateral. The Non-circuit Triangles and their Final Figural Adjustments.

Appendix No. 3. On the Theoretical Errors Generated Respectively in Side, Azimuth, Latitude and Longitude in a Chain of Triangles.

Appendix No. 4. On the Dispersion of the Residual Errors of a Simultaneous Reduction of Several Chains of Triangles.

Vol. VIII. Details of the Principal Triangulation of eleven of the component Series of the North-East Quadrilateral, including the following Series; the Gurwáni Meridional, the Gora Meridional, the Huriláong Meridional, the Chendwár Meridional, the North Parasnáth Meridional, the North Malúncha Meridional, the Calcutta Meridional, the East Calcutta Longitudinal, the Brahmaputra Meridional, the Eastern Frontier—Section 23° to 26°, and the Assam Longitudinal. Dehra Dún, 1882.

Vol. IX. Electro-Telegraphic Longitude Operations executed during the years 1875-77 and 1880-81. Dehra Dún, 1883.

Appendix to Part I.
1. Determination of the Geodetic Elements of Longitude Stations.
2. Descriptions of Points used for Longitude Stations.
3. Comparison of Geodetic with Electro-Telegraphic Arcs of Longitude.
4. Circuit Errors of Observed Arcs of Longitude.
5. Results of Idiometer Observations made during Season 1880-81.

Appendix to Part II.
1. Situations of the Longitude Stations at Bombay, Aden and Suez.
2. Survey Operations at Aden.
3. Results of the Triangulation.
4. Right Ascensions of Clock Stars.

Vol. X. Electro-Telegraphic Longitude Operations executed during the years 1881-82, 1882-83 and 1883-84. Dehra Dún, 1887.

Appendix to Part I.
1. Determination of the Geodetic Elements of the Longitude Stations.
2. Descriptions of Stations of the Connecting Triangulation and of those at which the Longitude Observations were taken.
3. On the Errors in ΔL caused by Armature-time and the Retardation of the Electric Current.
4. On the Rejection of some doubtful Arcs of Season 1881-82.
5. On the probable Causes of the Errors of Arc-measurements, and on the Nature of the Defects in the Transit Instruments which might produce them.

Vol. XI. Astronomical Observations for Latitude made during the period 1805 to 1885, with a General Description of the Operations and Final Results. Dehra Dún, 1890.

Vol. XII. General Description of the Principal Triangulation of the Southern Trigon, including the Simultaneous Reduction, and the Details of two of the component Series, the Great Arc Meridional—Section 8° to 18°, and the Bombay Longitudinal. Dehra Dún, 1890.

Vol. XIII. Details of the Principal Triangulation of five of the component Series of the Southern Trigon, including the following Series; the South Konkan Coast, the Mangalore Meridional, the Madras Meridional and Coast, the South-East Coast, and the Madras Longitudinal. Dehra Dún, 1890.

Vol. XIV. ***General Description of the Principal Triangulation of the South-West Quadrilateral, including the Simultaneous Reduction and the Details of its component Series. Dehra Dún, 1890.***

Vol. XV. *Electro-Telegraphic Longitude Operations executed during the years 1885-86, 1887-88, 1889-90 and 1891-92, and the Revised Results of Arcs contained in Volumes IX and X; also the Simultaneous Reduction and the Final Results of the whole of the Operations. Dehra Dún, 1893.*

Appendix No. **1.** Determination of the Geodetic Elements of the Longitude Stations.

Appendix No. **2.** On Retardation (a numerical mistake was made in this appendix in the conversion of a formula from kilometres to miles: the conclusions drawn cannot therefore be upheld).

Vol. XVI. *Details of the Tidal Observations taken during the period from 1873 to 1892 and a Description of the Methods of Reduction. Dehra Dún, 1901.*

Vol. XVII. *Electro-Telegraphic Longitude Operations executed during the years 1894-95-96. The Indo-European Arcs from Karachi to Greenwich. Dehra Dún, 1901.*

Appendix No. **1.** Descriptions of Points used for Longitude Stations.

Appendix No. **2.** The Longitude of Madras.

Vol. XVIII. *Astronomical Observations for Latitude made during the period 1885 to 1905 and the Deduced Values of the Deflections of the Plumb-line. Dehra Dún, 1906.*

Appendix No. **1.** On Deflections of the Plumb-line in India.

Appendix No. **2.** Determination of the Geodetic Elements of the Latitude Stations of Bajamara, Bahak, Lambatach and Kidarkanta.

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Appendix No. **4.** On the Value of the Micrometer of the Zenith Telescope.

Appendix No. **5.** On the Azimuth Observations of the Great Trigonometrical Survey of India.

Appendix No. **6.** A Catalogue of the Publications of the Great Trigonometrical Survey of India.

Vol. XIX. *Levelling of Precision in India (1858 to 1909). Dehra Dún, 1910.*

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Appendix No. **3.** Memorandum on the steps taken in 1905-10 to enable movements of the Earth's Crust to be detected.

i. The determination by spirit-levelling of the heights of rock-cut marks over India.

ii. The Himalayan lines of spirit-levelling.

iii. The Trigonometrical observations by Mr. H. G. Shaw, 1905-09.

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Appendix No. **5.** The passage of rivers by the levelling operations.

Appendix No. **6.** The errors of the Trigonometrical values of heights of stations of the Principal Triangulation.

Appendix No. **7.** The effect on the spheroidal correction of employing theoretical instead of observed values of gravity and a discussion of different formulæ giving variation of gravity with latitude and height.

Appendix No. **8.** On the discrepancy between the Trigonometrical and Spirit-level values of the difference of height between Dehra Dun and Mussooree.

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Synopses of the Results of the Operations of the Great Trigonometrical Survey of India, comprising Descriptions, Co-ordinates, &c., of the Principal and Secondary Stations and other Fixed Points of the Several Series of Triangles. For the use of Surveyors in the field. Price Rs. 2 per volume.

Vol. I. *The Great Indus Series, or Series D of the North-West Quadrilateral. Dehra Doon, 1874.*

Vol. II. *The Great Arc—Section 24° to 30°, or Series A of the North-West Quadrilateral. Dehra Doon, 1874.*

Vol. III. *The Karáchi Longitudinal Series, or Series B of the North-West Quadrilateral. Dehra Doon, 1874.*

Vol. IV. *The Gurhágarh Meridional Series, or Series F of the North-West Quadrilateral. Dehra Dún, 1875.*

Vol. V. *The Rahún Meridional Series, or Series E of the North-West Quadrilateral. Dehra Dún, 1875.*

Vol. VI. *The Jogí-Tíla Meridional Series, or Series G, and the Sutlej Series, or Series H of the North-West Quadrilateral. Dehra Dún, 1875.*

Vol. VII. *The North-West Himalaya Series, or Series C of the North-West Quadrilateral, and the Triangulation of the Kashmir Survey. Dehra Dún, 1879.* (Vol. VII is of great use to mountaineers).

Vol. VIIA. *The Jodhpore Meridional Series and the Eastern Sind Meridional Series of the North-West Quadrilateral. Dehra Dún, 1887.*

Vol. VIII. *The Great Arc—Section 18° to 24°, or Series A of the South-East Quadrilateral. Dehra Dún, 1878.*

Vol. IX. *The Jabalpur Meridional Series, or Series E of the South-East Quadrilateral. Dehra Dún, 1878.*

Vol. X. *The Bider Longitudinal Series, or Series D of the South-East Quadrilateral. Dehra Dún, 1880.*

Vol. XI. *The Bilaspur Meridional Series, or Series F of the South-East Quadrilateral. Dehra Dún, 1880.*

Vol. XII. *The Calcutta Longitudinal Series, or Series B of the South-East Quadrilateral. Dehra Dún, 1880.*

Vol. XIII. *The East Coast Series, or Series C of the South-East Quadrilateral. Dehra Dún, 1880.*

Vol. XIIIA. *The South Párasnáth Meridional Series and the South Malúncha Meridional Series of the South-East Quadrilateral. Dehra Dún, 1885.*

Vol. XIV. *The Budhon Meridional Series, or Series J of the North-East Quadrilateral. Dehra Dún, 1883.*

Vol. XV. *The Rangír Meridional Series, or Series K of the North-East Quadrilateral. Dehra Dún, 1883.*

Vol. XVI. The Amua Meridional Series, or Series L, and the Karára Meridional Series, or Series M of the North-East Quadrilateral. Dehra Dún, 1883.

Vol. XVII. The Gurwáni Meridional Series, or Series N, and the Gora Meridional Series, or Series O of the North-East Quadrilateral. Dehra Dún, 1883.

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Vol. XX. The Calcutta Meridional Series or Series T, and the Brahmaputra Meridional Series, or Series V of the North-East Quadrilateral. Dehra Dún, 1883.

Vol. XXI. The East Calcutta Longitudinal Series, or Series U, and the Eastern Frontier Series—Section 23° to 26°, or Series W of the North-East Quadrilateral. Dehra Dún, 1883.

Vol. XXII. The Assam Valley Triangulation, E. of Meridian 92°, emanating from the Assam Longitudinal Series, or Series X of the North-East Quadrilateral. Preliminary Issue. Dehra Dún, 1891.

Vol. XXIII. The South Konkan Coast Series, or Series C of the Southern Trigon. Dehra Dún, 1891.

Vol. XXIV. The Mangalore Meridional Series, or Series D of the Southern Trigon. Dehra Dún, 1891.

Vol. XXV. The South-East Coast Series, or Series F of the Southern Trigon. Dehra Dún, 1891.

Vol. XXVI. The Bombay Longitudinal Series, or Series B of the Southern Trigon. Dehra Dún, 1892.

Vol. XXVII. The Madras Longitudinal Series, or Series G of the Southern Trigon. Dehra Dún, 1892.

Vol. XXVIII. The Madras Meridional and Coast Series, or Series E of the Southern Trigon. Dehra Dún, 1892.

Vol. XXIX. The Great Arc Meridional Series—Section 8° to 18°, or Series A of the Southern Trigon. Dehra Dún, 1899.

Vol. XXX. The Abu Meridional Series, or Series I, and the Gujarát Longitudinal Series, or Series K of the South-West Quadrilateral. Dehra Dún, 1892.

Vol. XXXI. The Khánpisura Meridional Series, or Series G of the South-West Quadrilateral. Dehra Dún, 1893.

Vol. XXXII. The Singi Meridional Series, or Series H of the South-West Quadrilateral. Dehra Dún, 1893.

Vol. XXXIII. The Cutch Coast Series, or Series L of the South-West Quadrilateral. Dehra Dún, 1893.

Vol. XXXIV. The Káthiáwár Meridional Series, or Series J of the South-West Quadrilateral. Dehra Dún, 1894.

Vol. XXXV. The North-East Longitudinal Series, or Series I of the North-East Quadrilateral. Dehra Dún, 1909. Price five rupees.

Descriptions and heights of all the bench-marks falling within the following sheets will be published in pamphlet form in the course of the year 1911.

Sheet No.	Limits	Sheet No.	Limits	Sheet No.	Limits	Sheet No.	Limits
35	Lat. 24° - 28° Long. 64° - 68°	45	Lat. 24° - 28° Long. 72° - 76°	55	Lat. 20° - 24° Long. 76° - 80°	66	Lat. 12° - 16° Long. 80° - 84°
38	Lat. 32° - 36° Long. 68° - 72°	46	Lat. 20° - 24° Long. 72° - 76°	56	Lat. 16° - 20° Long. 76° - 80°	72	Lat. 24° - 28° Long. 84° - 88°
39	Lat. 28° - 32° Long. 68° - 72°	47	Lat. 16° - 20° Long. 72° - 76°	57	Lat. 12° - 16° Long. 76° - 80°	73	Lat. 20° - 24° Long. 84° - 88°
40	Lat. 24° - 28° Long. 68° - 72°	48	Lat. 12° - 16° Long. 72° - 76°	58	Lat. 8° - 12° Long. 76° - 80°	74	Lat. 16° - 20° Long. 84° - 88°
41	Lat. 20° - 24° Long. 68° - 72°	49	Lat. 8° - 12° Long. 72° - 76°	63	Lat. 24° - 28° Long. 80° - 84°	78	Lat. 24° - 28° Long. 88° - 92°
43	Lat. 32° - 36° Long. 72° - 76°	53	Lat. 28° - 32° Long. 76° - 80°	64	Lat. 20° - 24° Long. 80° - 84°	79	Lat. 20° - 24° Long. 88° - 92°
44	Lat. 28° - 32° Long. 72° - 76°	54	Lat. 24° - 28° Long. 76° - 80°	65	Lat. 16° - 20° Long. 80° - 84°		

Professional Papers of the Survey of India.

Professional Paper No. 1. *On the projection for a Map of India and Adjacent Countries on the Scale of 1 : 1000000. Second Edition, Dehra Dún, 1903.*

" " *No. 2.* *Method of measuring Geodetic Bases by means of Metallic Wires by M. Jäderin. (Translated from Mémoires Présentés Par Divers Savants Á L'académie Des Sciences De L'institut De France). Dehra Dún, 1899.*

" " *No. 3.* *Method of measuring Geodetic Bases by means of Colby's Compensated Bars. Dehra Dún, 1900.*

" " *No. 4.* *Notes on the Calibration of Levels. Dehra Dún, 1900.*

" " *No. 5.* *The Attraction of the Himalaya Mountains upon the Plumb-Line in India*. Considerations of recent data. Dehra Dún, 1901. Price Two Rupees.*

" " *No. 6.* *Account of a Determination of the Co-efficients of Expansion of the wires of the Jäderin Base-Line Apparatus. Dehra Dún, 1902.*

" " *No. 7.* *Miscellaneous. Calcutta, 1903 :—*

Price one Rupee, or one Shilling Six Pence.

(1) *On the values af Longitude employed in maps of the Survey of India.*
(2) *Levelling across the Ganges at Damukdia.*
(3) *Experiment to test the increase in the length of a Levelling Staff due to moisture and temperature.*
(4) *Description of a Sun-dial designed for use with tide gauges.*
(5) *Nickel-Steel alloys and their application to Geodesy (Translated from the French).*
(6) *Theory of electric projectors (Translated from the French).*

* *Vide* Nature, Vol 66, No. 1699 of May 22, 1902.

Professional Paper No. 8. Experiments made to determine the Temperature Co-efficients of Watson's Magnetographs. Calcutta, 1905. Price one Rupee or one Shilling six Pence.

" " No. 9. An Account of the Scientific work of the Survey of India and a Comparison of its progress with that of Foreign Surveys. Prepared for the use of the Survey Committee, 1905. Calcutta, 1905. Price one Rupee or one Shilling six Pence.*

" " No. 10. The Pendulum operations in India, 1903 to 1907, by Major G.P. Lenox Conyngham, R.E. Dehra Dún, 1908. Price Two Rupees Eight Annas.

Hand-books for the use of Surveyors.

Hand-book of General Instructions for the Survey of India Department. Third Edition. Calcutta, 1907. Price Three Rupees or 4s. 6d.

Hand-book of Professional Instructions for the Trigonometrical Branch, Survey of India Department. Second Edition. Calcutta, 1902. Price Three Rupees.

Hand-book of Professional Instructions for the Topographical Branch, Survey of India. Third Edition. Calcutta 1905. Price Three Rupees.

Auxiliary Tables to facilitate the calculations of the Survey of India. Fourth Edition. Revised and extended. Dehra Dún, 1906. Price Two Rupees.

Special Publications on Scientific subjects.

Report on the Explorations in Great Tibet and Mongolia made by A–K in 1879-82. Dehra Dún, 1891.

Catalogue of 249 Stars for the epoch January 1, 1892, from observations by the Great Trigonometrical Survey of India. Dehra Dún, 1893. Price Two Rupees.

Report on the Recent Determination of the Longitude of Madras. Calcutta, 1897.

Report on the Trigonometrical Results of the Earthquake in Assam. Calcutta, 1898.

The Total Solar Eclipse, January 22nd, 1898. Dehra Dún, 1898.

(1) *Report on the observations at Dumraon.*
(2) *Report on the observations at Pulgaon.*
(3) *Report on the observations at Sahdol.*

Report on the Identification and Nomenclature of the Himalayan Peaks as seen from Katmandu, Nepal.† Calcutta, 1904.

A Sketch of the Geography and Geology of the Himalaya Mountains and Tibet by Colonel S. G. Burrard, R.E., F.R.S., Superintendent, Trigonometrical Surveys and Mr. H. H. Hayden, B.A., F.G.S., Superintendent, Geological Survey of India. Calcutta, 1907-08.

Part I.—The high Peaks of Asia.
Part II.—The Principal Mountain ranges of Asia.
Part III.—The Rivers of the Himalaya and Tibet.
Part IV.—The Geology of the Himalaya.

Price Rs. 2 per part.

* *Vide* Nature Vol. 74, No. 1917 of July 26, 1906.
† *Vide* Nature Vol. 71, Nos. 1828 and 1830 of November 10th and 24th, 1904.

General Reports on The Operations of the Great Trigonometrical Survey of India from 1861 to 1877.
General Reports on the Operations of the Survey of India from 1878 to 1909.

Extracts from Narrative Reports of the Survey of India. Price Rs. 1-8 or Two Shillings and three pence.

1900-01. Recent improvements in Photo-Zincography. G. T. Triangulation, Upper Burma. Latitude Operations, 1900-01. Experimental Base Measurement with Jäderin Apparatus. Magnetic Survey. Tidal and Levelling Report for 1900-01. Topography, Upper Burma. Calcutta, 1903.

1901-02. G. T. Triangulation, Upper Burma. Latitude Operations, 1901-02. Magnetic Survey. Tidal and Levelling Report for 1901-02. Topography in Upper Burma. Topography in Sind. Topography in the Punjab. Calcutta, 1904.

1902-03. Principal Triangulation, Upper Burma. Topography, Upper Burma. Topography, Shan States. Survey of the Sámbhar Lake. Latitude Operations. Tidal and Levelling Operations. Magnetic Survey. Introduction of the Contract System of payment in Traverse Surveys. Traversing with the Subtense Bar. Compilation and Reproduction of Thána maps. Calcutta, 1905.

1903-04. The Magnetic Survey of India. Pendulum Operations. Tidal and Levelling Operations. Astronomical Azimuths. Utilisation of old Traverse data for modern Surveys in the United Provinces of Agra and Oudh. Identification of Snow Peaks in Nepal. Topographical Surveys in Sind. Notes on Town and Municipal Surveys. Notes on Riverain Surveys in the Punjab. Calcutta, 1906.

1904-05. The Magnetic Survey of India. Pendulum operations. Tidal and Levelling operations. Triangulation in Baluchistan. Survey operations with the Somaliland field force. Calcutta, 1907.

1905-06. The Magnetic Survey of India. Pendulum operations. Tidal and Levelling operations. Extract from Narrative Report of No. 11 Party. Calcutta, 1908.

1906-07. The Magnetic Survey of India. Pendulum operations. Tidal and Levelling operations. Triangulation in Baluchistan. Astronomical Latitudes. Topographical Surveys in Karenni. Extracts from the Narrative Report of No. 11 Party. Calcutta, 1909.

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Accounts of the progress of Indian Geodesy were submitted to the International Geodetic Conferences that met at

Stuttgart in 1898,

Paris in 1900,

Copenhagen in 1903,

Buda Pesth in 1906,

London and Cambridge in 1909,

and were published in the reports of the Conferences.

Accounts of the progress of Geodesy and Geography in India were published in the Annual Reports of the Board of Scientific Advice from 1905 to date.

A paper on Himalayan Attractian was published in the Monthly Notices of the Royal Astronomical Society, January 1902.

Summaries of the progress of Geodesy in India were published in the following numbers of the Philosophical Transactions of the Royal Society of London:—

Series A, Vol. 186 (1895) pp. 754–816.

Series A, Vol. 205 (1905) pp. 289–318.

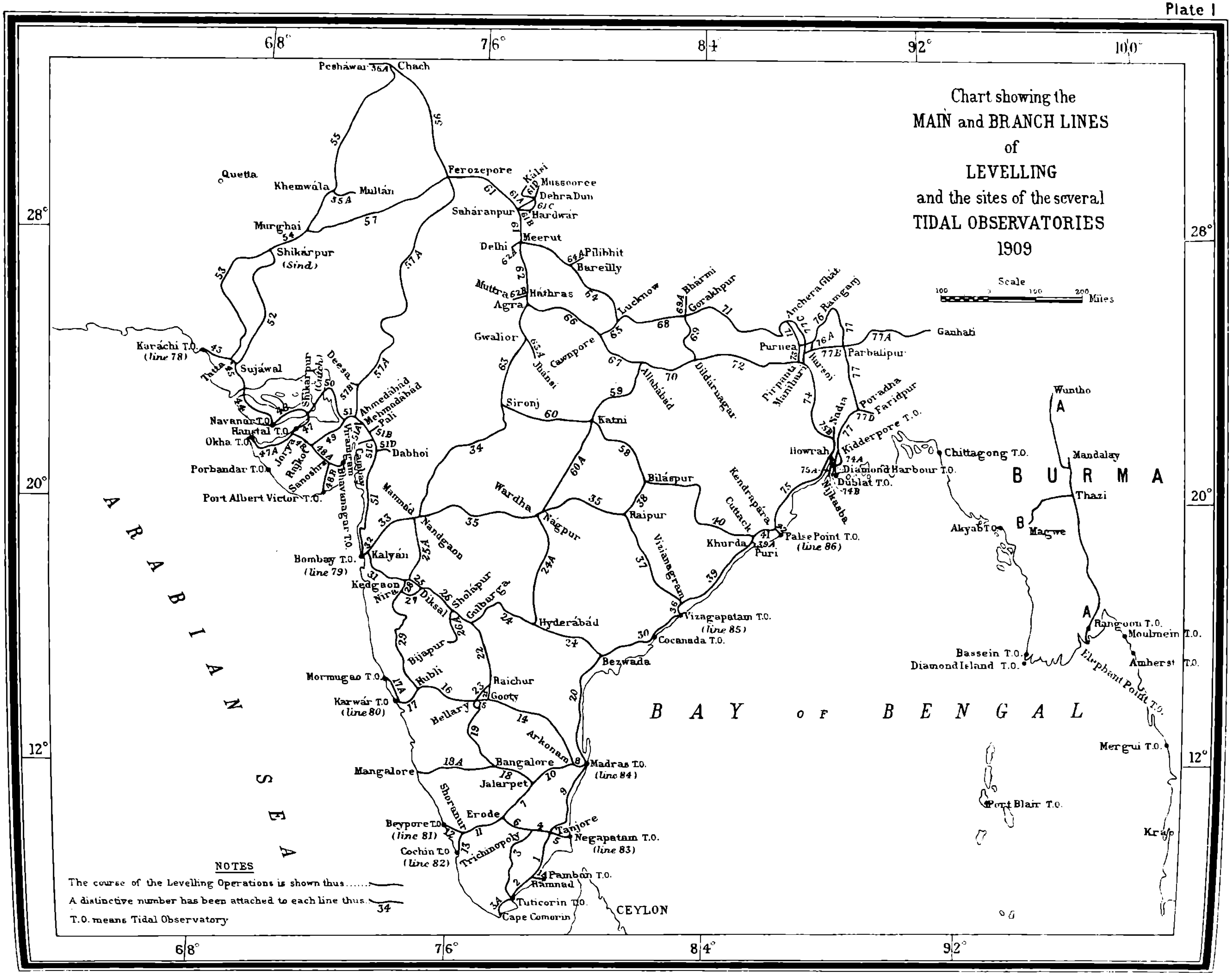
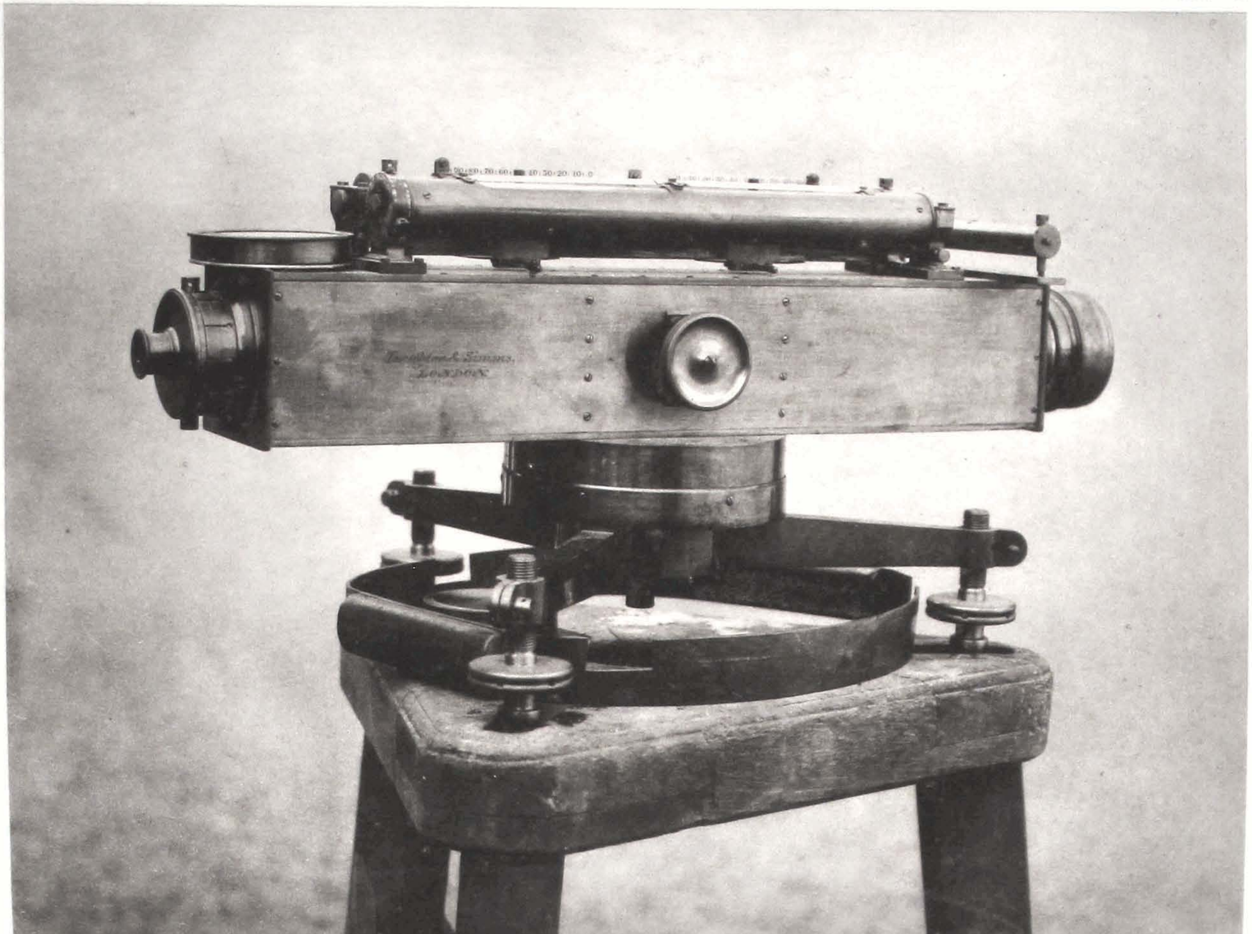


Chart showing the
MAIN and BRANCH LINES
of
LEVELLING
and the sites of the several
TIDAL OBSERVATORIES
1909
Scale
Miles
NOTES
The course of the Levelling Operations is shown thus
A distinctive number has been attached to each line thus
34
T.O. means Tidal Observatory
68°
76°
84°
92°
100°
28°
20°
12°
ARABIAN SEA
BAY OF BENGAL
BURMA
CEYLON
Peshawar
Chach
Quetta
Khemwála
Multán
Murghai
Shikárpur (Sind)
Ferozepore
Kalsi
Mussooree
Dehra Dun
Hardwár
Sahāranpur
Meerut
Delhi
Pilibhit
Bareilly
Muttra
Hathras
Agra
Gwalior
Jhánsi
Cawnpore
Lucknow
Bhármi
Gorakhpur
Karáchi T.O. (line 78)
Tatta
Sujáwal
Deesa
Ahmedábád
Mehmadábád
Pali
Navanar T.O.
Hanstal T.O.
Okha T.O.
Porbandar T.O.
Port Albert Victor T.O.
Rajkot
Sanoshra
Dabhoi
Bhavnagar T.O.
Sironj
Katni
Allahábád
Dildárnagar
Purnea
Ganhati
Parbatipur
Anchera Ghat
Ramganj
Hurseni
Pirpainti
Manihari
Nadia
Poradha
Faridpur
Howrah
Kidderpore T.O.
Chittagong T.O.
Diamond Harbour T.O.
Dublat T.O.
Nijkasba
Bilaspur
Raipur
Wardha
Nagpur
Manmád
Nandgaon
Bombay T.O. (line 79)
Kalyán
Kedgaon
Nira
Diksal
Sholápur
Gulbarga
Hyderábád
Vizianagram
Kendrapára
Cuttack
Khurda
Puri
False Point T.O. (line 86)
Vizagapatam T.O. (line 85)
Cocanada T.O.
Bezwada
Bijapur
Hubli
Mormugao T.O.
Karwár T.O. (line 80)
Raichur
Gooty
Bellary
Arkonam
Madras T.O. (line 84)
Bangalore
Jalarpet
Mangalore
Shoranur
Erode
Beypore T.O. (line 81)
Cochin T.O. (line 82)
Trichinopoly
Tanjore
Negapatam T.O. (line 83)
Pamban T.O.
Ramnad
Tuticorin T.O.
Cape Comorin
Wuntho
Mandalay
Thazi
Akyab T.O.
Magwe
Rangoon T.O.
Moulmein T.O.
Amherst T.O.
Bassein T.O.
Diamond Island T.O.
Elephant Point T.O.
Mergui T.O.
Port Blair T.O.
Kraw

PLATE II.

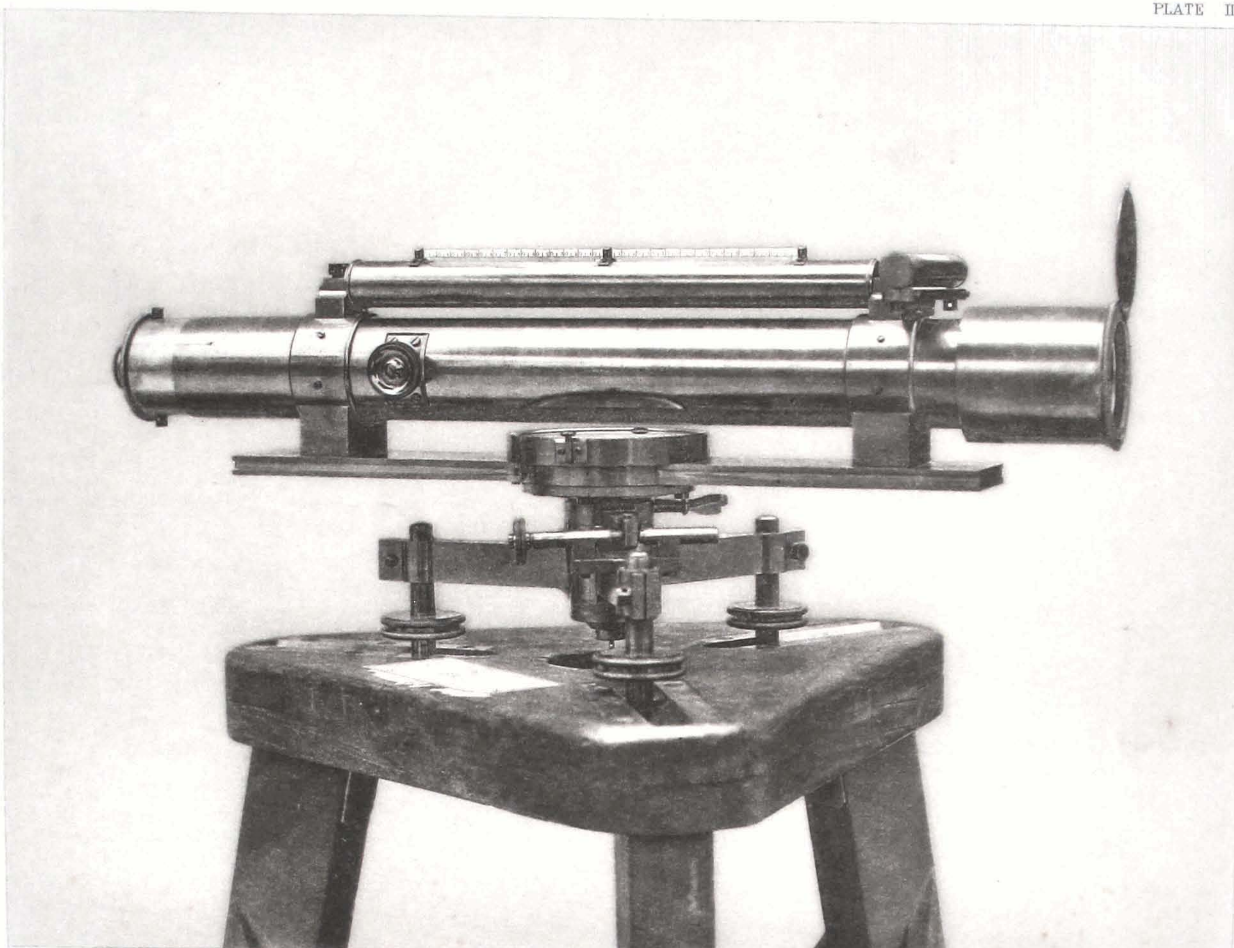


Photogravure

Survey of India Offices, Calcutta, December 1909.

THE RECTANGULAR LEVEL

PLATE III.

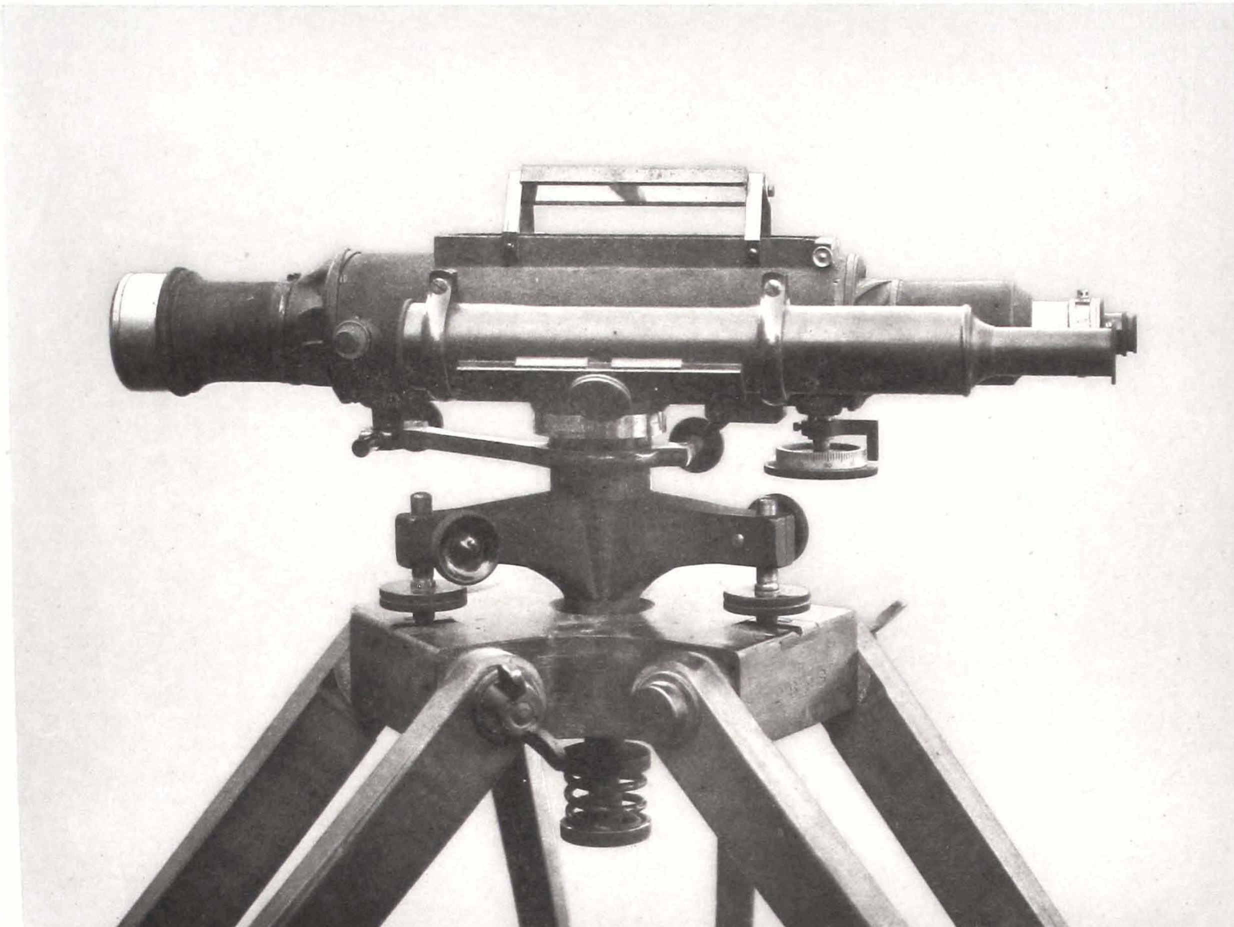


Photogravure

Survey of India Offices, Calcutta, November 1909.

THE CYLINDRICAL LEVEL

PLATE IV.

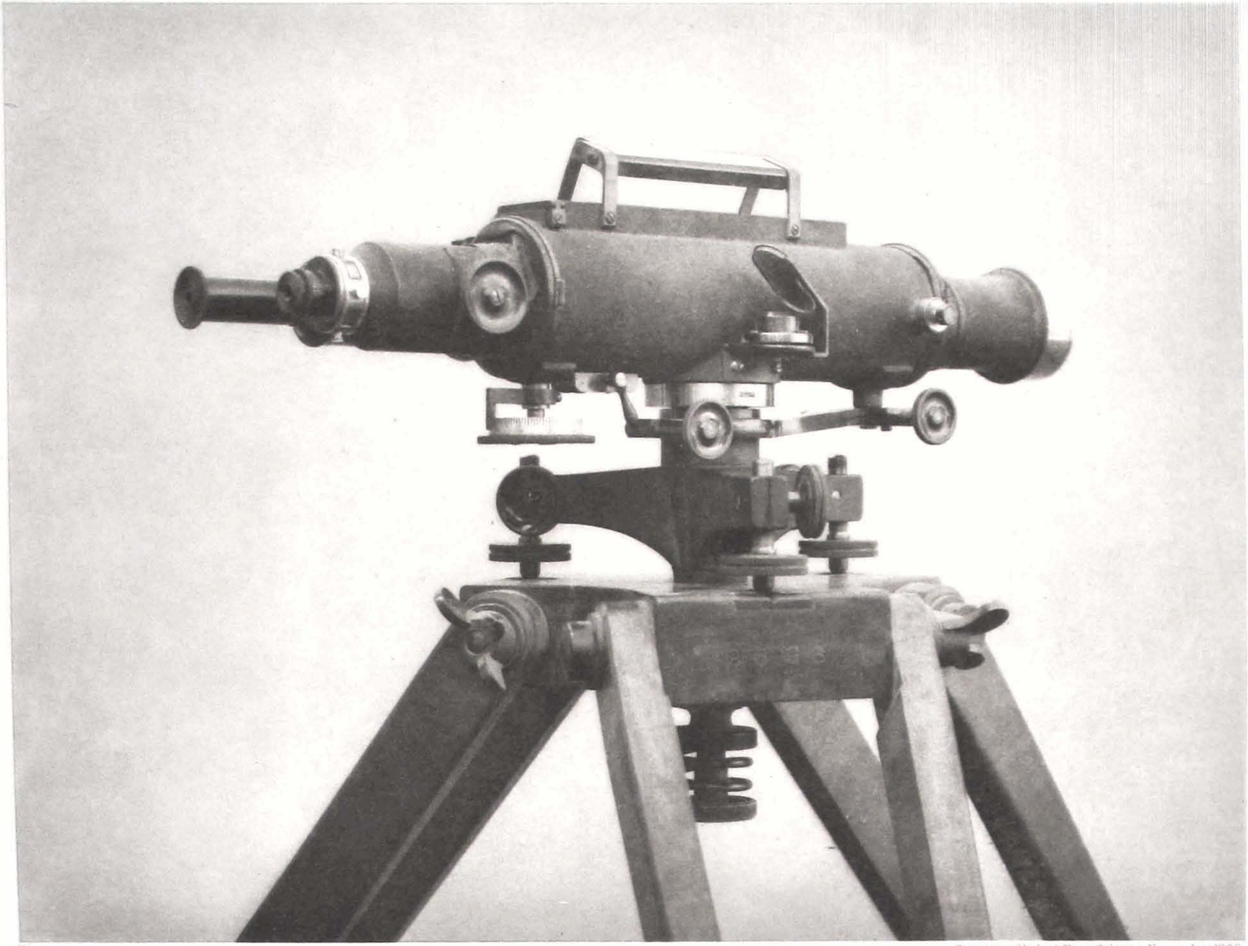


Photogravure

Survey of India Offices, Calcutta, November 1909.

THE AMERICAN BINOCULAR LEVEL

PLATE V.



Photogravure

Survey of India Offices, Calcutta, November 1909.

THE AMERICAN BINOCULAR LEVEL

PLATE VI.

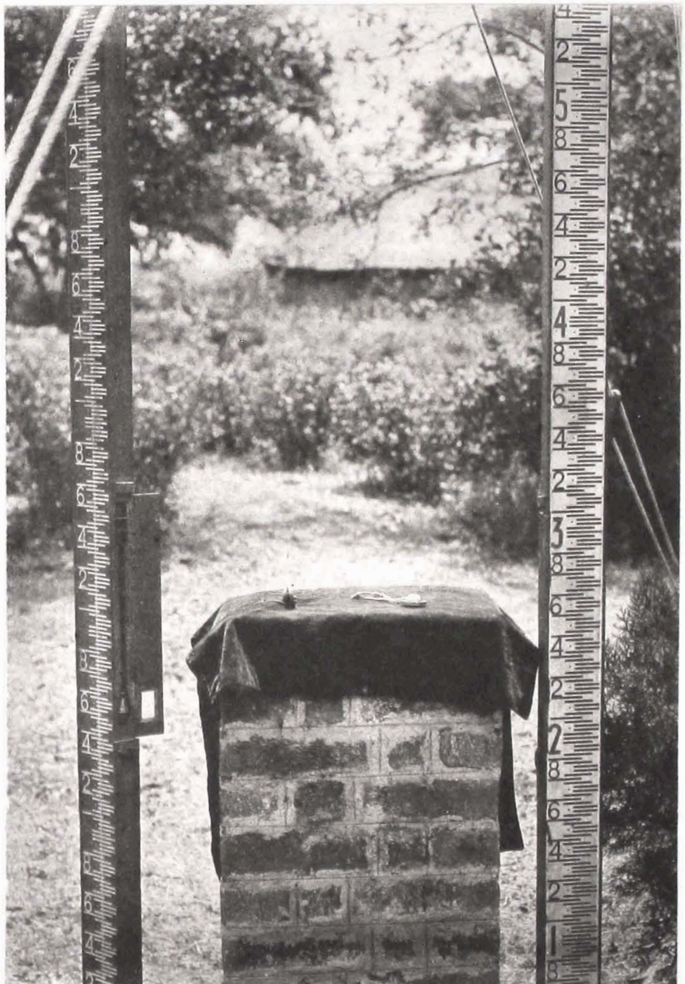
Photogravure.

Survey of India Offices, Calcutta, November 1909.

OBSERVER WITH CYLINDRICAL LEVEL AND RECORDER.

Photogravure. Survey of India Offices, Calcutta, November 1903.

GENERAL WALKER'S STAVES ERECTED UPON PEGS.



Photogravure

Survey of India Offices, Calcutta, November 1909.

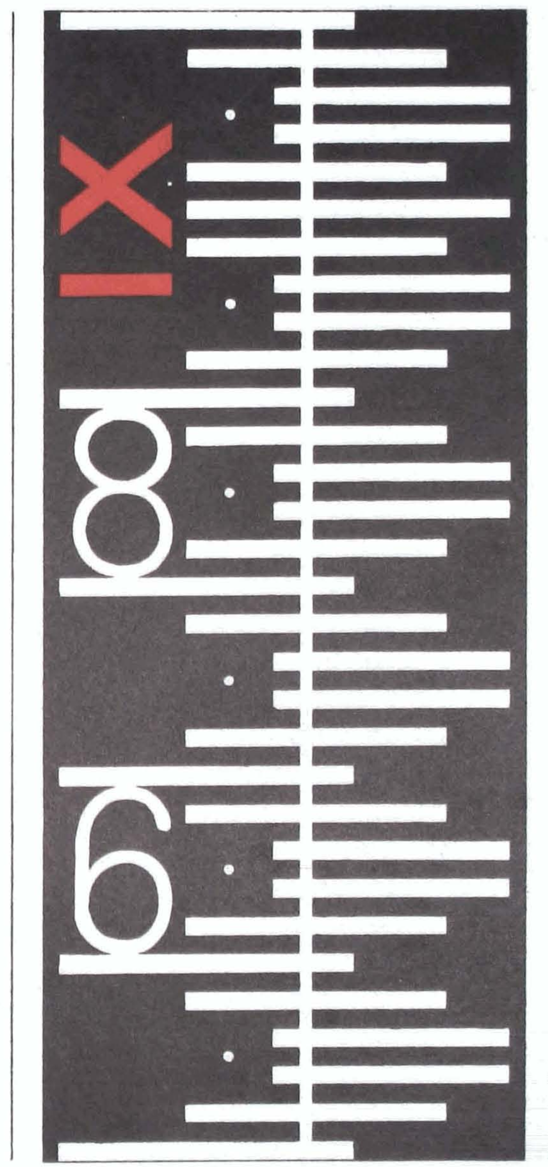
GENERAL WALKER'S STAVES, THEIR GRADUATION AND THE POSITION OF THE PLUMMET.

Method of graduation adopted for

GENERAL WALKER'S STAFF

White Face

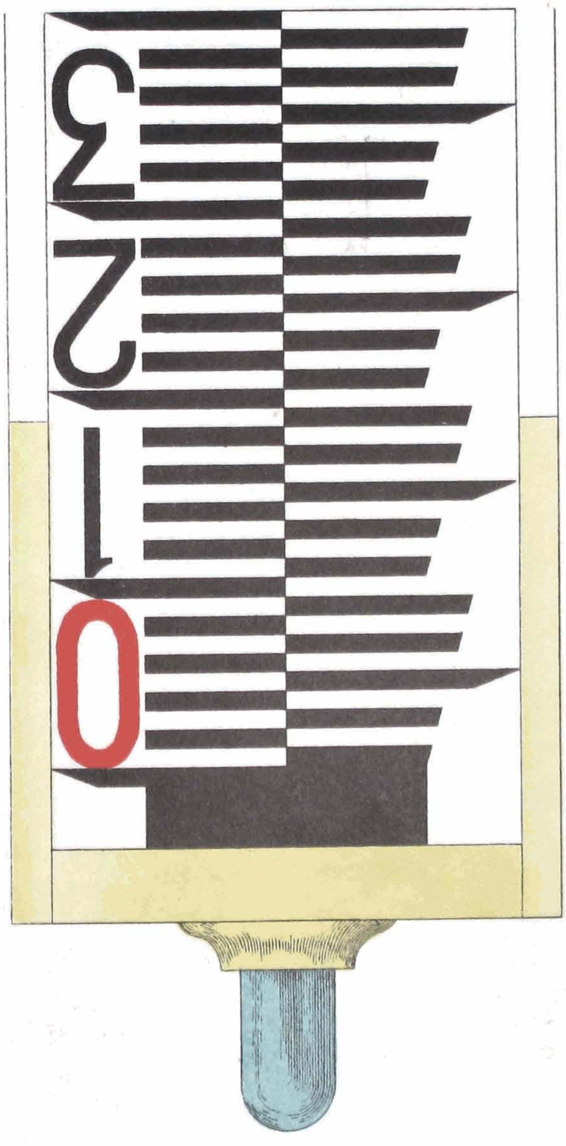
Black Face



Full Size

Original Method of graduation adopted for
CAPTAIN COWIE'S STAFF

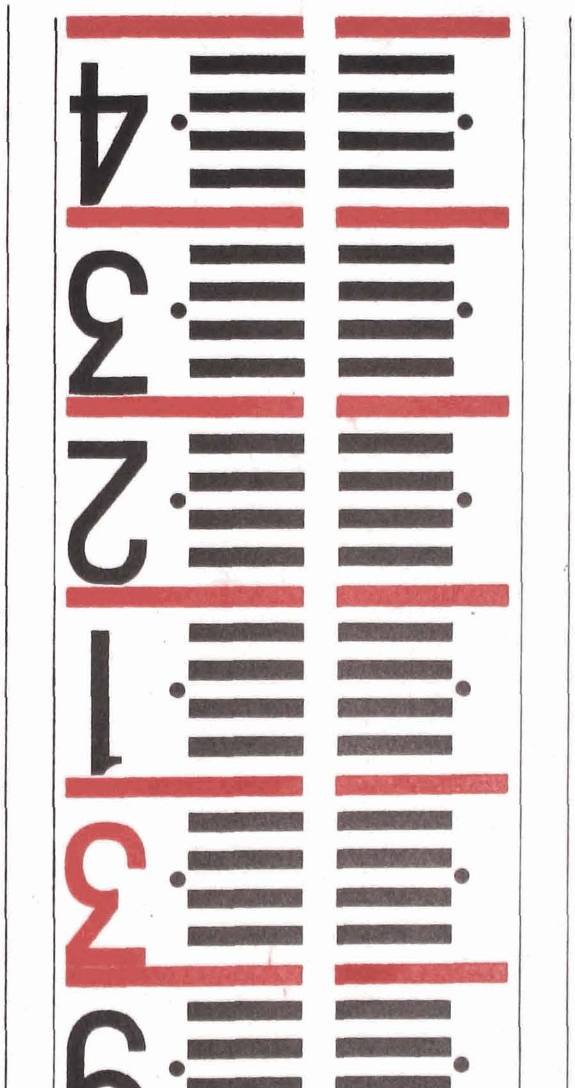
Foot Face



Full Size

Method of graduation finally adopted for
CAPTAIN COWIE'S STAFF

Foot Face

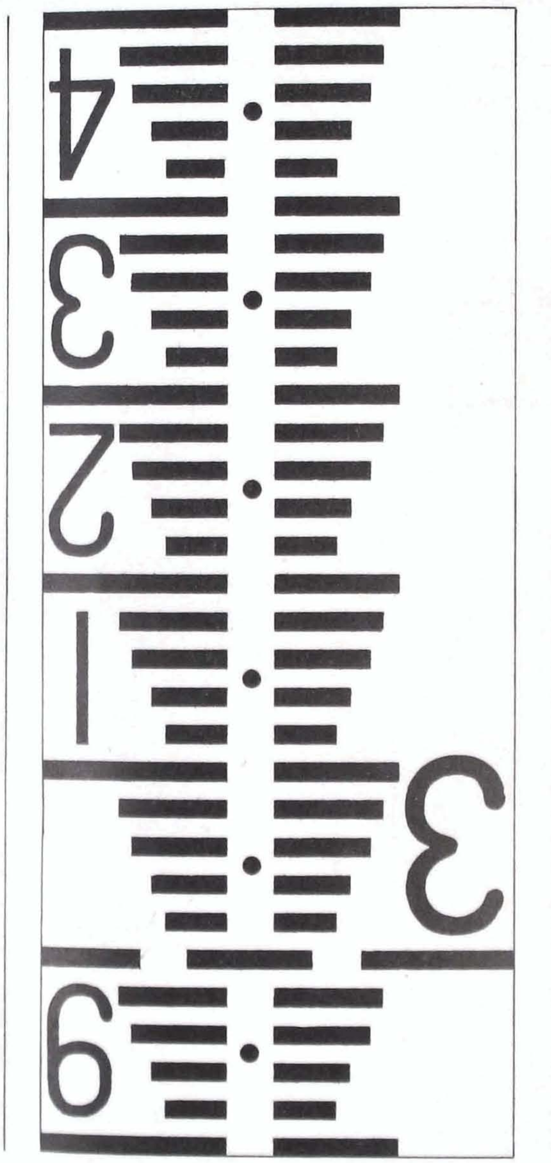


Full Size

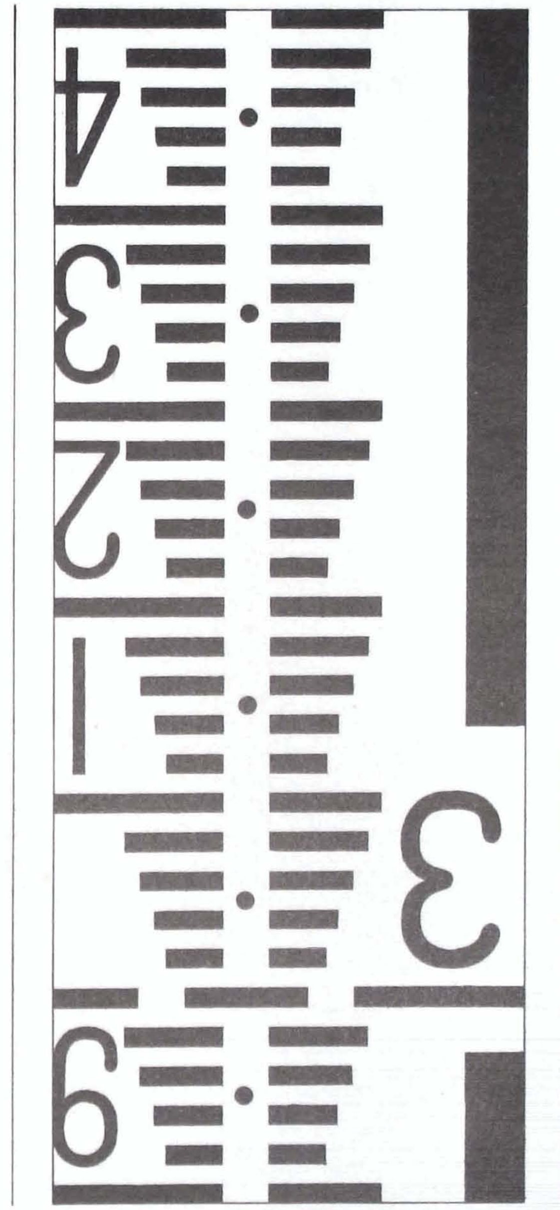
Method of graduation adopted for

THE COMMITTEE'S STAFF

Foot Face



12·5 inch Face

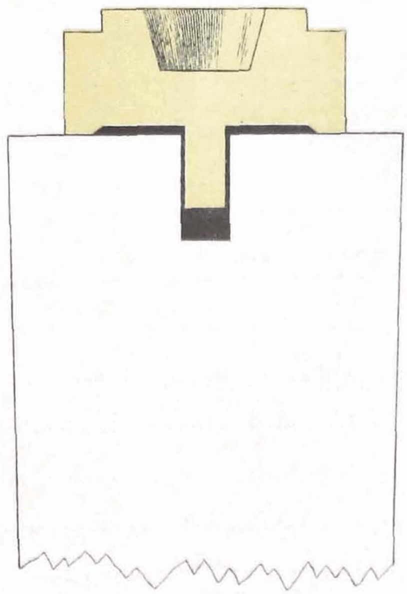


Full Size

Plate XIII

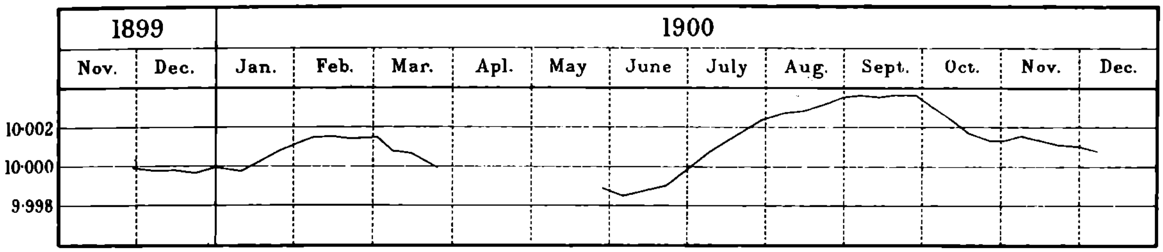
LEVELLING BRAD

designed by the Committee

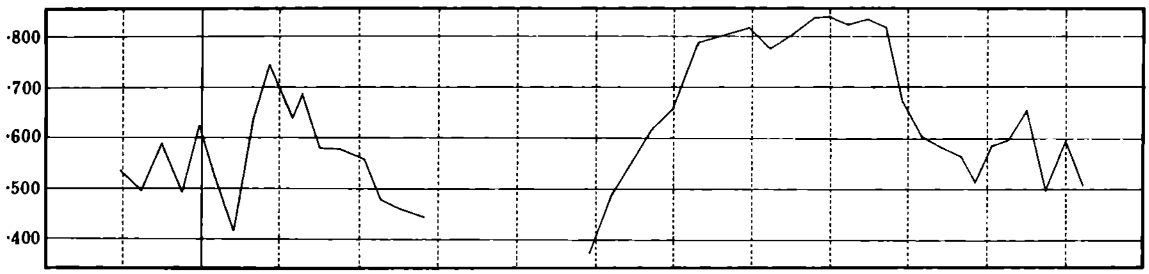


Full Size

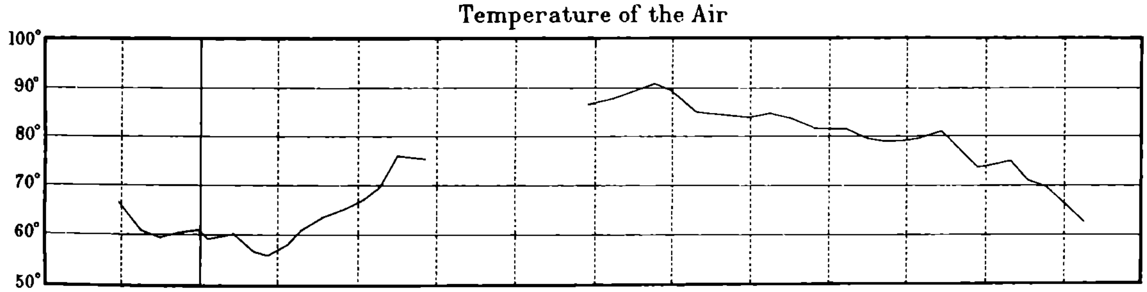
Variation in the length of the Levelling Staff



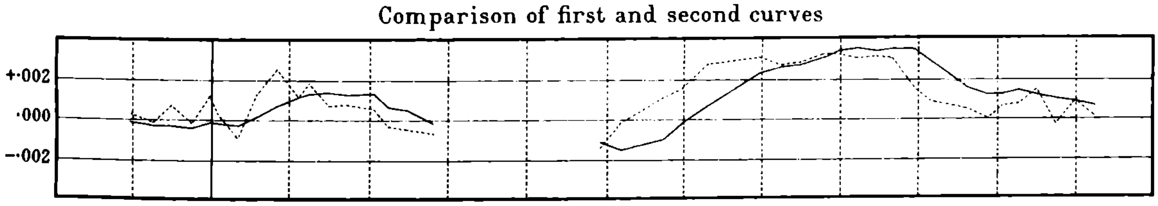
Relative Humidity



Temperature of the Air



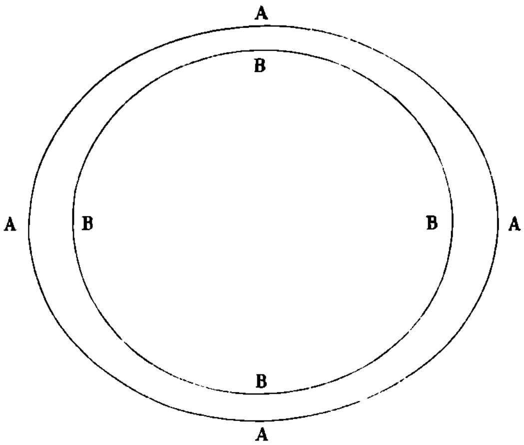
Comparison of first and second curves



To illustrate

the EFFECTS of VARIATIONS OF GRAVITY upon Levelling Results

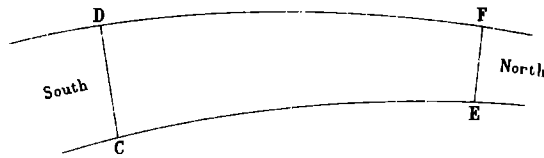
Fig. 1



AAAA *is the spheroidal form assumed by the envelope of water 15000 feet above sea level.*

BBBB *is the spheroidal form assumed by the sea.*

Fig. 2



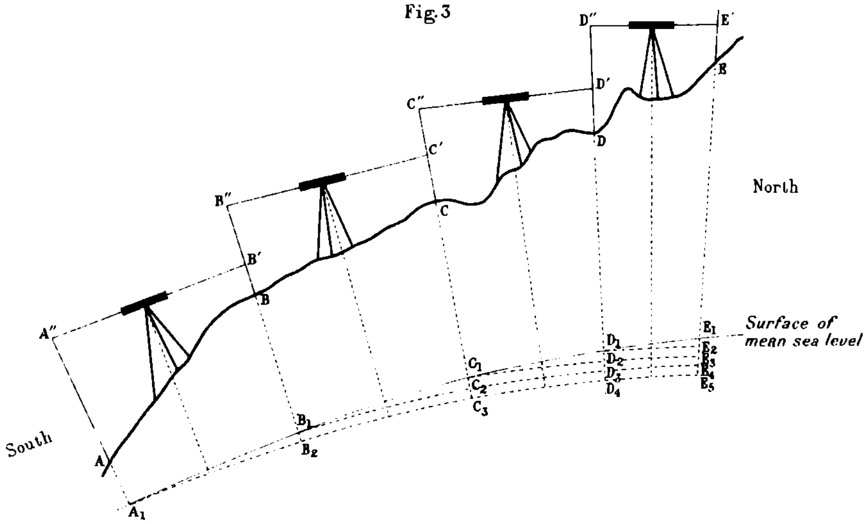
DF *is the surface of a high-level lake.*

CD *is the height of the southern end of the lake's surface.*

EF *is the height of the northern end of the lake's surface.*

Owing to convergence of level surfaces CD *is greater than* EF

Fig. 3



A, B, C, D, E *are the points on ground-level at which the levelling staves are erected.*

B′, C′, D′, E′ *are the points at which the lines of sight cut the forward (northern) staves.*

A″, B″, C″, D″ *are the points at which the lines of sight cut the back (southern) staves.*

A_1, B_1, C_1, D_1, E_1 *are the points at which the several vertical lines cut sea level.*

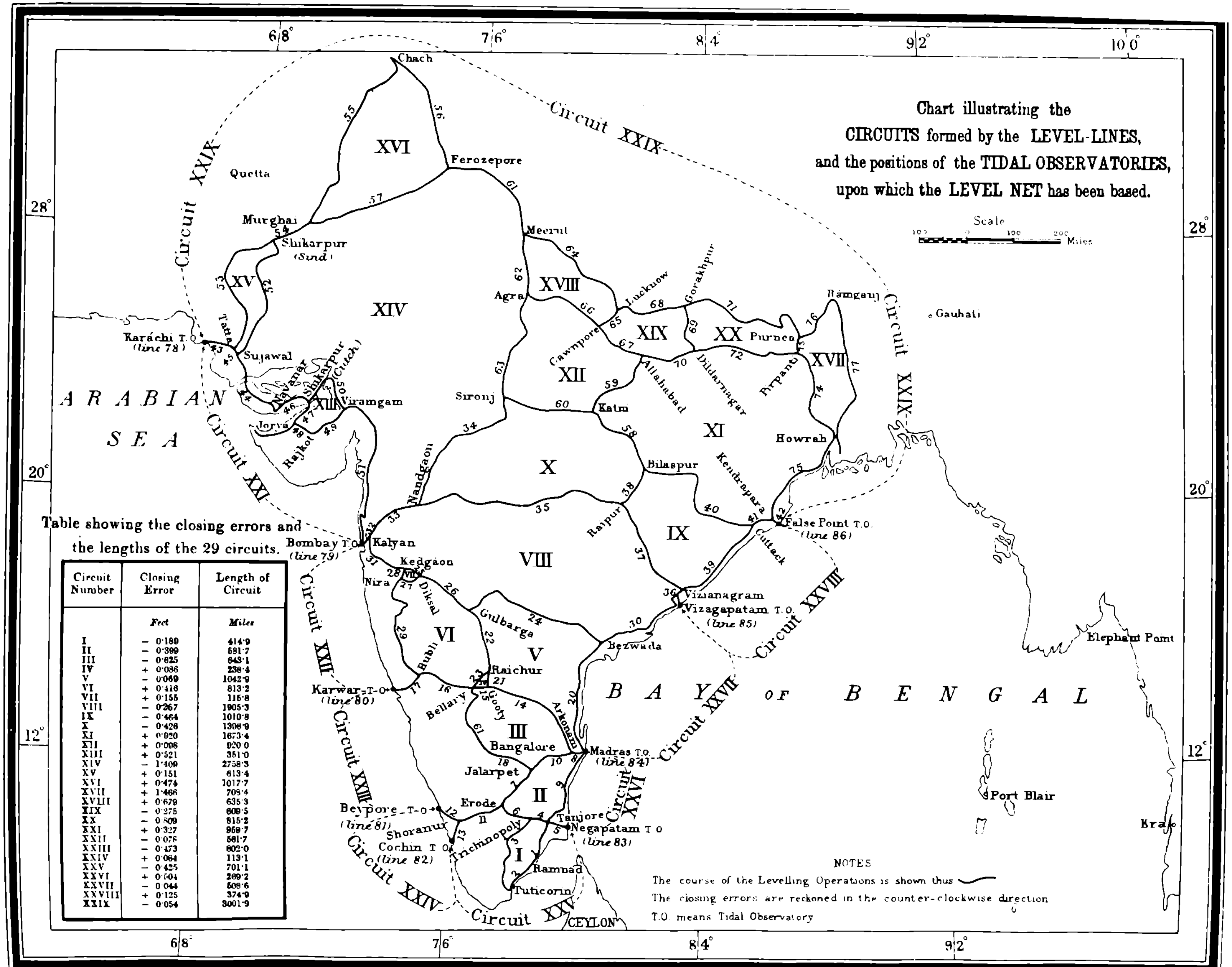


Table showing the closing errors and the lengths of the 29 circuits.

Circuit Number	Closing Error	Length of Circuit
	Feet	*Miles*
I	− 0·189	414·9
II	− 0·399	581·7
III	− 0·625	643·1
IV	+ 0·036	236·4
V	− 0·069	1042·9
VI	+ 0·416	813·2
VII	+ 0·155	116·8
VIII	− 0·267	1905·3
IX	− 0·464	1010·8
X	− 0·426	1306·9
XI	+ 0·020	1673·4
XII	+ 0·006	920·0
XIII	+ 0·521	351·0
XIV	− 1·409	2758·3
XV	+ 0·151	613·4
XVI	+ 0·474	1017·7
XVII	+ 1·466	708·4
XVIII	+ 0·679	635·3
XIX	− 0·275	609·5
XX	− 0·809	815·2
XXI	+ 0·327	969·7
XXII	− 0·076	561·7
XXIII	− 0·473	802·0
XXIV	+ 0·064	113·1
XXV	− 0·425	701·1
XXVI	+ 0·504	269·2
XXVII	− 0·044	509·6
XXVIII	+ 0·125	374·9
XXIX	− 0·054	3001·9

To illustrate Appendix No. 7

Fig. 1

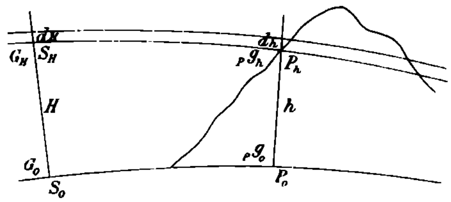
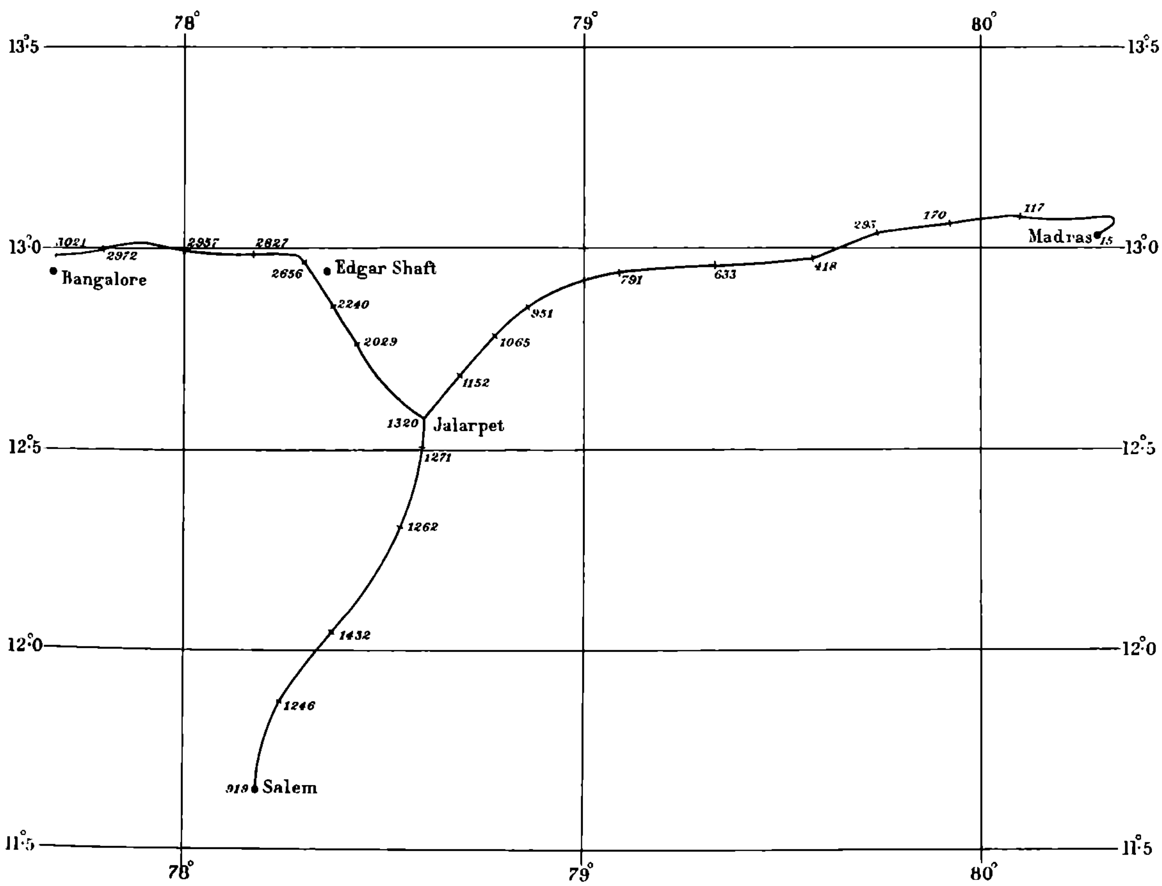


Fig. 2

Chart roughly showing the course of the levelling lines.

The figures indicate the heights of the several points on the lines, close to which they are written



To illustrate Appendix No. 4

Himalayan lines of level