Administrative

Report of the Construction

of the

Indus Vallley Railway

1878-79

Government

1879

Indus Valley State Railway.

ADMINISTRATION REPORT

ON THE

CONSTRUCTION OF THE RAILWAY

FROM ITS COMMENCEMENT

TO THE

CLOSE OF THE FINANCIAL YEAR

1878-79.

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1879.

Indus Valley State Railway.

Administration Report from the commencement to the end of the Financial year 1878-79.

THIS Report is for the most part a compilation from the Annual and other Reports submitted by the Engineer-in-Chief. A map is attached showing the country in the neighbourhood of the line and the principal geographical features which affect it.

Early History 1865 to 1870.

The line from Lahore to Mooltan had been constructed by the Punjab Railway Company, and that from Kotri to Karachi by the Scinde Company.

The "connecting link" of 500 miles between Mooltan and Kotri was first surveyed in the interests of the latter Company about the year 1865 by Mr. Brunton. The general line of his survey coincides with that finally adopted, except that he did not diverge to Shujabad between Mooltan and Bahawalpur, and that to avoid the Mirpur floods he kept to the eastward on the line of desert. He also surveyed an alternative line below Sukkur on the left bank of the Indus running directly to Hyderabad.

1870-71.

First undertaken as a State work in 1870-71.

2. The State first undertook this line of railway in 1870-71, and in the cold weather of that year the upper section, between Mooltan and Sukkur, was surveyed, being divided for the purpose into two Districts, the Mooltan District of 137 miles, and the Rohri District of 133 miles.

1871-72.

Operations during 1871-72.

3. The field work was completed, and during the hot weather of 1871-72 the parties were engaged in plotting and reducing their work and in preparing preliminary estimates, which were submitted to Government in the autumn. A party of Engineers was also engaged on the arduous task of watching and recording observations of the floods in the Upper Scinde District, a duty involving constant exposure and much hardship.

Orders to commence work given in November 1871.

4. In November 1871 sanction was given to commence the work generally of both Districts, excluding the bridge over the Sutlej river at Adamwahan. At the same time the two Districts were subdivided into six Executive Divisions,

and the name of the lower district was altered from "Rohri" to that of the "Upper Scinde" District.

Survey of the District below Sukkur undertaken January 1872.

5. In December 1871 an Engineer-in-Chief was appointed to the charge of the whole line from Mooltan to Kotri, and in January 1872 the lower section, Sukkur to Kotri, about 230 miles in length, was constituted a district, to be called the "Lower Scinde District" for survey operations which were immediately commenced and rapidly completed.

1872-73.

Completion of these Surveys.

6. In the hot weather of this year the Survey parties of the Lower Scinde District plotted their work, and submitted an estimate to Government, which was accepted, and work was ordered to be commenced.

Final equalization and distribution of Executive charges and Superintending Engineer's Districts.

7. To equalize the charges of the whole line, a final distribution was made in January 1873, as follows:—

Mooltan District—Mooltan to mile 172, excluding the Sutlej Bridge Division, which remained under direct charge of the Engineer-in-Chief, comprising—

Shujabad Division,	.. ..	50 miles.
(Sutlej Bridge Division,	.. ..	13 „)
Bahawalpur Division,	.. ..	59 „
Khanpur Division,	.. ..	50 „

Upper Scinde District—from 172 to 338 mile, excluding the Indus Bridge Division, which remained under direct charge of the Engineer-in-Chief, comprising—

Reti Division, ..	.. ..	49 miles.
Ghotki Division, ..	.. ..	49 „
(Indus Bridge Division,	.. ..	15 „)
Larkana Division,	.. ..	53 „

Lower Scinde District—from 338 to 498, comprising—

Mehur Division, ..	.. ..	53 miles.
Sehwan Division, ..	.. ..	55 „
Kotri Division, ..	.. ..	52 „

Engineering Staff appointed.

8. To each Executive Division an Executive Engineer and Staff of Assistant Engineers was appointed. The Sutlej Bridge Division was placed under charge of an Executive Engineer, with the powers of a Superintendent of Works. The Indus Bridge Division under an Executive Engineer, and for the administration of each District, a Superintending Engineer was appointed, the whole being under the direction of the Engineer-in-Chief, residing at Mooltan.

Progress made in the year 1872-73.

9. During this year the following progress was made in the works:—

In the Mooltan District 155 miles of embankment were completed, 32 cul-

verts were built, and 40 miles of ballast collected. The buildings of 8 out of 15 stations were erected, with 10 houses for Staff Quarters.

Progress in the Mooltan District.

Thirty-five lakhs of bricks were burnt in preparation for the Sutlej Bridge, and about as many more for works on the line.

10. Systematic observations were recorded of floods in the Sutlej river, a survey of the bed was made, trial wells were sunk to a depth of 100 feet, and other necessary measures, for completing the necessary data for designing a bridge, were taken.

Observations in the Sutlej river.

11. During this year serious damage was done by an incursion of the river into the newly established colony at Adamwahan. The stream, which had hitherto followed a fairly direct course past Adamwahan, suddenly became tortuous, it swung across from the Bahawalpur side and drove directly against the Adamwahan bank, which in spite of the efforts of the Engineers, who hastily constructed solid spurs and groynes of brushwood to withstand the attack, was eroded to a depth of some 400 yards, involving the destruction of the largest block of the quarters recently erected.

Destructive floods in the Sutlej river.

12. In the Upper Scinde District the embankments of 32 miles were completed, and 57 more in progress. No other work was done, nor were any materials prepared. Some delay had occurred in procuring Staff for the Larkana Division: the Executive Engineer joined quite at the end of the year, and the line had not even been properly set out.

Progress in the Upper Scinde District.

13. But little was done in the Indus Bridge Division, an Executive Engineer was appointed quite at the close of the year. Some observations of velocities were made, and two trial wells were sunk.

Observations in the Indus River.

14. Observations of the floods were resumed in the Reti and Ghotki Divisions, large gaps having been left in the embankments for their passage. The floods were not severe during this year.

Floods in the Reti and Ghotki Divisions.

15. In the Lower Scinde District a mere commencement was made, the Executive Staff having been organized late in the year.

Progress in the Lower Scinde District.

1873-74.

16. Up to this time all operations had been directed towards the construction of a line on the metre gauge, but intimation being received that possibly the gauge might be increased to 5′ 6″, arrangements were made at all of the works on the line which would permit of

Probability of change from metre to 5′ 6″ gauge.

this change. The culverts accordingly were left incomplete on one side, and all arrangements at stations which could be affected by the gauge were deferred.

17. During this year the Government appointed a Committee of experienced Engineers to consider the conditions of the Sutlej River, and the best method of crossing it. Serious injury to the bridge over this river on the Scinde, Punjab and Delhi Railway line near Phillour called for special care in determining the features of the bridge to be erected at Bahawalpur. The Committee submitted a report, and the Government decided on the following general features for the bridge:—

Committee appointed to report on method of bridging Sutlej.

18. The bridge to consist of 16 spans of 264 feet between centres, 250 feet in the clear. The piers and abutments to be founded each on three cylinders of brickwork 18 feet 9 inches diameter, arranged in line, sunk to a depth of 100 feet below the dry weather water level. Each foundation was to be protected by a mass of about 60,000 cubic feet of loose rubble stone thrown in around it, and the abutments were to be protected each with about $2\frac{1}{2}$ lakhs cubic feet of stone.

General features of Sutlej Bridge determined.

19. The following progress was made in the works during the year 1873–74:—

Progress made during 1873–74.

20. In the Mooltan District 15 miles of embankment were thrown up, making 170 miles completed; 43 miles of ballast material were prepared, making 83 miles to date, and 332 culverts and 152 lineal feet of flood openings were built during the year, comprehending about 5 lakhs of cubic feet of masonry, for about a half of which the bricks were manufactured. This made the bridging of the District nearly complete, excepting that as noted above, these works were all broken off on one side on account of the uncertainty about the gauge. Four more stations were built during this year, completing all required except that at Mooltan, which was left in abeyance, pending settlement of the question of a junction with the Scinde, Punjab and Delhi Railway line. The line works of this District were thus in a forward state, and almost ready for the reception of the permanent way.

Progress in the Mooltan District.

21. At the Sutlej Bridge 60 lakhs more bricks were manufactured, and other materials procured in preparation for a commencement of work. A workshop was built and supplied with machine tools. A commencement was made on the ironwork for well curbs, and other arrangements put forward with a view to an actual commencement being made immediately after the inundations of 1874–75.

Arrangements made at the Sutlej Bridge.

22. During this year an Executive Division was formed for the express purpose of controlling the river, and endeavouring to restrain its oscillations within fixed limits. The operations undertaken consisted of laying in floating obstacles secured at the top to empty casks, as buoys, and anchored below, and formed sometimes of coarse netting, sometimes

River Conservancy Division formed.

of single ropes, with brushwood attached and other such expedients, which, by checking the current, should cause a deposit of silt and turn the course of the stream. Some success attended these operations, and the fairweather stream was driven into a fairly direct channel, to which it was hoped the first freshes might take, and a good lead be thus given to the stream when it came down in flood. Nature favouring, these hopes were realized—the violent oscillation of the stream near the colony of Adamwahan, which had caused much damage during the previous two years, was interrupted, and the river assumed a fairly direct course. The floods, however, were not severe.

Work executed on main line of Sutlej Division.

23. The work executed in the 13 miles of line attached to this Division consisted of one mile of embankment, making 11 completed. The two miles of heavy embankment near the bridge were held in reserve as a reservoir for labour during the construction of the bridge, for which purpose the minor bridges and culverts near the river were also deferred. Twelve culverts were completed.

Progress on the Upper Scinde District.

24. In the Upper Scinde District 69 miles of embankment were thrown up, making 141 miles completed, 30 miles of ballast were collected, and the buildings of 6 stations, making 10 completed out of 15 required. A good quantity of bricks were manufactured and stone quarried at Rohri. A contract for manufacture of bricks was also entered into with a well known firm (Collins and Petman) who were to commence operations at Christmas 1873. The brickworks on this part of the line were deferred, pending a final decision on the amount of opening to be left for the Indus floods, and also to secure a sufficient supply of material in hand before gangs of skilled labourers should be collected from distant places and set to work.

Proposed tramway in the Ghotki Division.

25. A proposal was made for laying a tramway from the quarries at Rohri for 24 miles along the Ghotki Division, to carry out stone for the bridges: this was afterwards accepted.

Floods in the Ghotki Division.

26. The floods in the Reti and Ghotki Divisions were again systematically watched by means of the well defined gaps left in the embankments for their passage. They were not severe this year.

High price of iron.

27. A revision of the project for bridging this part of the line was made, as the high price of iron made it desirable to substitute arched for flat girder openings.

Observations in the Indus.

28. In the Indus at Sukkur systematic observations of the currents and bed of the river were continued, and were reduced to a form for submission to Government, before whom several proposals for bridging the river were placed.

Proposal for steam ferry.

29. A scheme was also submitted for establishing a steam ferry with approaches, to be used until the completion of the bridge.

30. At Sukkur a wharf was built and sheers set up for landing heavy weights, and a store yard with commodious godowns was erected.

Arrangements at Sukkur.

31. A petition was presented by the inhabitants of Shikarpur to have the main line carried past their town instead of on the alignment approved. All operations between Sukkur and Nawa Dera (20 miles) had to be placed in abeyance in consequence. After the close of the year the Government decided to adhere to the original alignment.

Proposed diversion of line to Shikarpur.

32. In the Lower Scinde District 150 miles of embankment were completed during the year, and a good commencement was made on the heavy rock cuttings at Sehwan, the completion of which, forming the key to the opening of this section of the line, could hardly be expected in less than three working seasons, or owing to the uncertain nature of the stuff to be met with in the deep cuttings, perhaps a longer time.

Progress in the Lower Scinde District.

33. The chief share of work in this District was done in the last 50 miles leading into Kotri, as it was thought this length might be opened out rapidly in extension of the Scinde line. On this length the bank was completed. Ballast was collected for 30 miles, the buildings of 4 stations were completed, and a large quantity of stone was brought to site for the bridges.

Special progress near Kotri.

34. As all material procured in England for the line would be landed at Karachi, and the Scinde, Punjab and Delhi Railway Company had possession by their Flotilla of the only high way, the Indus river, a contract was made with that Company for the carriage and delivery at certain places on the river of all such materials.

Arrangements with Scinde, Punjab and Delhi Railway Company for carrying English material.

35. Where these depôts were not situated on the river, it was necessary to connect them with the line, and permission was received to do this by tramways, over which locomotive engines should work. Accordingly a line was laid on the metre gauge from Hamdi to Shujabad, a distance of 8 miles, and the track was continued on the main line 5 miles towards Adamwahan with the intention, afterwards fulfilled, of completing the connection with that place; this being the line over which the very important business of supplying the Sutlej Bridge with rubble stone for protective purposes, and with other important supplies, would be carried. Three tank locomotive engines metre gauge and 10 wagons were received and erected at Hamdi for work on this line, and the manufacture of 150 other wagons was commenced at Adamwahan.

River depôts to be connected with the line by tramways.

Hamdi Branch.

36. A large timber depôt was also established at Hamdi, and steam sawing machinery set up for the purpose chiefly of preparing sleepers.

Hamdi Depôt.

37. 140 miles of rails and fittings (36 lb. and 40 lb.) were received at Karachi, and a number of wheels and axles, bearing springs and axle boxes for wagons, but no iron fittings for their frames and bodies. A large quantity of machinery and plant had also been received from England.

Stores received from England.

1874–75.

38. This year commenced with the communication by Government of its final decision that the Indus Valley State Railway should be constructed on the 5′ 6″ gauge, and in July 1874 the Director of State Railways paid a visit to Mooltan to discuss the prospects of the work with the Engineer-in-Chief. The following general conclusions were then recorded :—

Decision to construct the Indus Valley State Railway on the 5′ 6″ gauge.

39. Seeing that the heavy works on the Sutlej Bridge and in crossing the spills of the Indus in the Ghotki Division would certainly prevent the line being opened through to Sukkur for at least three years, there was no immediate need for pushing on the light works, extending over some 150 miles between the Sutlej River and Sukkur, which might readily be completed in a single season. Between Sukkur and Kotri on the other hand the only heavy work was the Laki cutting near Sehwan, and it appeared probable that with a full supply of funds this lower section might be completed within two years. There was no prospect of obtaining such a supply of money as would permit of work being pushed along the whole line, and the obviously reasonable conclusion was to stop work altogether on the part of the line indicated on the section above Sukkur, and to spend more freely on the works south of that place, with a view to an early opening of the line from Kotri up to Sukkur.

Scheme for prosecuting the works resulting from visit of Director of State Railways.

40. The works in the Bahawalpur and Khanpur Divisions and in part of the Reti Division were thereupon closed entirely, and the whole Executive Staff removed, excepting one officer, who was left in charge of the material and other property on the line, at the same time the office of Superintending Engineer of the Mooltan District was placed in abeyance, the duties of Superintending Engineer of the reduced District being undertaken by the Engineer-in-Chief himself. The arrangement, however, was not long continued, and a Superintending Engineer was again appointed early in 1875–76. The work thrown on the Engineer-in-Chief's office by the commencement of operations at the Sutlej Bridge was found to be more heavy than the office could conveniently undertake.

Closing of works on 150 miles south of Bahawalpur.

41. The new estimates for the 5′ 6″ gauge were at once put in hand, but there were many difficulties and delays owing principally to the employment of the Staff on works, and at last the Engineer-in-Chief was obliged to take the compilation into his own hands. The work was finally completed, and the estimate submitted to Government in November 1875. This estimate is generally distinguished as Colonel Peile's estimate, its general abstract was as follows :—

New estimates for 5′ 6″ gauge.

	Rs.
Preliminary Expenses, ...	6,18,000
Land, ...	1,90,974
Construction of Line,..	2,55,05,492
Ballast and Permanent Way, ...	1,75,04,612
Stations and Buildings, ...	38,41,980
Electric Telegraph, ...	4,55,400
Rolling Stock, ...	35,10,000
Maintenance, ...	1,55,000
Establishment, ...	60,00,000
Contingencies, ...	4,00,000
Grand Total Rs., ..	5,96,12,858

Superintendent of Works appointed to Indus Bridge.

42. In November 1874 an officer with the rank of Superintendent of Works was specially appointed to the charge of the Indus Bridge Division. It was understood that he should collect all data himself, and then proceed to draw up a project for a bridge over the Indus, in direct communication with the Consulting Engineer for State Railways.

Inundations of 1874-75. Indus spills, left bank.

43. The spills of the left bank of the Indus during this year were severe, and remained over the land till a late date, but they did no damage beyond retarding the works in the Upper Scinde District.

Indus spills, right bank.

44. The Kusmore spill over the right bank, the features of which are more particularly described later on under the report of the year 1876-77 was also severe. It happened, moreover, that in its passage towards the Manchur lake, the volume of the inundation was much augmented by a heavy fall of rain in the Cutchee hills, and that later on when the water had reached and filled the Manchur lake, another heavy fall of rain occurred in that locality. These combined floods and rain falls caused the Aral river and other outlets of the Manchur lake to overflow their banks—the waters united in one continuous flood and topped the railway embankment from Bhan to Sehwan. The station building at Sehwan was submerged to such a depth that a boat entering by one door passed out through another.

Railway submerged from Bhan to Sehwan.

Sehwan Station submerged.

Proposals made in reference to these floods.

45. In reporting upon this flood to Government, the Engineer-in-Chief represented that the simultaneous recurrence of these three contributaries to this excessive and unprecedented flood was very improbable, and that while he recommended the raising of the embankment, he did not think it would be desirable then to incur the heavy expense of providing so much extra waterway through the line as would suffice to pass a flood of this extent. Moreover, the project for this part of the line had been mainly based on the assurance that the Kusmore bund would be solidly reconstructed and adequately maintained, conditions which, if properly fulfilled, should certainly suffice to avert any serious danger.

In subsequent years, however, the apparently periodical access to the Kus-

Additions to waterway near Sehwan made in subsequent year.

more floods and the repeated failure of the bund forced on the conclusion that the Railway must be made self-dependent, and very large additions were made and projected to the flood openings near Sehwan. The station itself was moved to a high site beyond the reach of any inundation.

46. A great fall in the price of iron led to a return from arches to flat topped girder openings for the flood viaducts in the Upper Scinde District; at the same time the recent high floods dictated the necessity of a general raising of the formation level through the flooded country. The bridging had not been commenced, so these changes involved only alterations of design and estimates.

Fall in price of iron and revision of designs.

47. The progress of the works in 1874-75 was as follows:—

Progress of works 1874-75.

48. In the Mooltan District, as above stated, a length of about 150 miles of line south of Bahawalpur was temporarily placed in abeyance.

Progress in the Mooltan District.

49. In the Shujabad Division, between Mooltan and Adamwahan on the Sutlej River, 30 lakhs cubic feet of earthwork were executed in widening out the bank for the increased gauge, and 75,000 cubic feet of brickwork in culverts. Of the 176 culverts in the Division, 102 were completed for the 5′ 6″ gauge, and the remainder partially built for the metre gauge, and left incomplete on one side, as above described.

Shujabad Division.

50. The principal operation of the year on this part of the line, however, was the completion of the 63 miles of metre gauge tramway connecting the Hamdi Depôt with the Sutlej Bridge at Adamwahan, and the carriage over it of large quantities of stores for the bridge. Five tank metre gauge locomotives and 70 wagons, to which daily additions were being made, were at work on the line.

Tramway from Hamdi to Adamwahan.

51. At the Sutlej Bridge the early part of the year was devoted to clearing the way for a commencement of work, to the provision of material and plant, and also to the framing of the timber curbs for the wells with the manufacture of their ironwork.

Progress at the Sutlej Bridge.

52. It was decided to confine this first season's work to six foundations, three on either side of the river, comprising 18 wells; and to securing the abutment span on each side so as to fix the permanent limits within which the river's course must of necessity thenceforth be restrained.

Limitation of work for the season.

53. In the design for the bridge, the abutments consisted simply of an ordinary pier surrounded by a heavy mass of loose stone, which was to be extended as far as and connected with the stone protection of the first pier in the bed of the

Description of abutments designed.

river in such a manner as to entirely obstruct the intervening span below the level of low water. To aid this obstruction a row of square masonry blocks was to be sunk to as great a depth as possible extending from pier to pier along the centre of the span. It was thought that the two piers with their mass of stone protection, extending to a length of about 330 feet, would form an obstacle which could not readily be outflanked, and that the river would be forced to confine itself to the 14 spans of the bridge left free for its passage.

Method of distinguishing the piers by letters, and wells by numbers.

54. The 17 piers were distinguished by the letters of the alphabet commencing with A, the abutment on the Adamwahan or right bank, and terminating with R, the abutment at the Bahawalpur or left bank end. The wells were numbered consecutively from 1 to 51, commencing with the up-stream well of each foundation thus—

A.	B.	C.	P.	Q.	R.
1	4	7	43	46	49
2	5	8	44	47	50
3	6	9	45	48	51

Situation of A abutment.

Position of R abutment.

55. Abutment A was set just within the line of the comparatively solid high bank which formed that side of the river, and the top of which was just below the level of the highest recorded flood. Abutment R was so to say *en l'air;* the length of the bridge was 4,224 feet, the width of the river about two-and-a-half miles, and a long stretch of river bed, to be crossed by a high embankment, intervened between the bridge head and the high bank at Bahawalpur, which, on that side, formed the limit of the river's oscillations.

First curb pitched 2nd November, and progress made in well sinking.

56. The first curb was pitched on the 2nd November, and the last of the 18 on the 25th February. The depths reached by the several wells as recorded on the 31st March 1875 was as follows:—

Foundation and wells.		Depth reached.	Remarks.
A	1	24·31	Tenacious clay, silt at 30 feet.
	2	38·15	
	3	22·7	
B	4	34·4	Loose sandy silt. No obstruction.
	5	56·27	
	6	31·14	
C	7	55·79	Ditto ditto.
	8	23·85	Brushwood under number 9, and afterwards met with by number 8, when it reached 30 feet depth.
	9	34·95	
P	43	29·84	The whole of the wells on this side of the river entered a stratum of tenacious clayey silt at a depth of 26 feet. The stratum believed to be 14 feet thick.
	44	25·91	
	45	32·06	
Q	46	29·36	
	47	26·65	
	48	29·6	
R	49	23·32	
	50	32·58	
	51	22·81	

Abutment spans.

The sinking of the blocks in the abutment spans had also progressed, and the excavations for the deposition of the protective stone were fairly forward.

Temporary timber bridge.

57. The whole of the stock of building material had been prepared on the Adamwahan bank, where alone suitable ground for storage purposes could be found, and to that side also were brought all the plant and miscellaneous materials required for the work, notably the rubble stone for protective purposes. For the work commenced on the Bahawalpur side, every thing had to be transported across the river, and for this purpose it was necessary to construct and maintain, during the working season, a temporary timber bridge of 1,000 feet in length, over which the loaded trains might run. This bridge was removed during the inundations, and restored for each working season. It was a subsidiary arrangement, without which the work could not have been successfully carried to completion, but one which caused a vast amount of anxiety and trouble.

Inferior condition of plant received in transfer.

58. A large quantity of plant had been received in transfer from the Punjab Northern State Railway, set free by the completion of the large bridges on that line, but the steam machinery especially was so worn and defective as to cause much trouble and disappointment. The workshops executed a large amount of work. The iron fittings for 18 curbs, weighing for each curb 5·2 tons, were made up; 60 metre gauge ballast wagons were built, the ironwork for 20 having been manufactured in the shops. The straps and bolts for the temporary timber bridge formed a heavy job, and there was an increasing demand for miscellaneous articles and for repairs, all of which had to be satisfied on the spot.

Workshop operations.

Behaviour of the river during the season.

59. The river during this season behaved very well, the stream remained amenable to the gentle measures of control described above, and was maintained in a fairly straight course for 6 or 7 miles, passing nearly through the centre of the bridge limits. This favourable state of things, however, was not to last as will be noted later on.

Progress in the Upper Scinde District.

60. The progress made in the Upper Scinde District in masonry works was confined principally to the works in the Reti Division, where 50,000 cubic feet of concrete, and 96,000 cubic feet of brickwork were executed in 30 culverts, and six of the larger bridges for the passage of floods, aggregating 50 arched openings of 10 feet span, and 13 girder openings of 40 feet span, were commenced. Seventy-two lakhs of cubic feet of earthwork were executed in this Division in widening the bank for the 5′ 6″ gauge, 192 lakhs of cubic feet in the Ghotki, and 430 lakhs cubic feet in the Larkana Division.

Reti Division.

Ghotki Division.

61. In the Ghotki Division 100 lakhs of bricks were manufactured by the contractors, and 3 lakhs cubic feet of stone were prepared at the Rohri quarries, but the actual commencement of work was deferred pending only final instructions on

a report on the recent floods, and on the change of design and alteration of formation level referred to above.

Work retarded in the Larkana Division.

62. In the Larkana Division work was retarded first by the proposal to divert the line to Shikarpur referred to above, which was not disposed of until July, and afterwards by a remonstrance from the Officers of the Irrigation Department, who insisted that the alignment along the bank of the Canal must be changed, and that a wider space than had been previously allowed must be left between the Railway and the Canal. The new location of this portion, forming about one-third of the Larkana Division, was not completed until quite the close of the year. Fifty-five lakhs of bricks for bridge building were manufactured in this Division.

Progress in the Lower Scinde District.

63. In the Lower Scinde District the available funds were principally devoted to the Laki cutting, and to the works in the 50 miles north of Kotri forming the Kotri Division. The remainder of this District, comprising the Mehur and major part of the Sehwan Divisions, had to be starved.

Mehur Division.

64. In the Mehur Division the embankments for the 5′ 6″ gauge were nearly complete, and about 60 lakhs of bricks were manufactured. The station buildings were also completed as residences for the Staff.

Sehwan Division.

65. In the Sehwan Division the ordinary embankments were nearly completed, the station buildings were erected, the manufacture of bricks for bridge building was nearly completed, and ballast for 13 miles of line were collected.

Laki cuttings.

66. The rock cutting in the 8 miles of line skirting the Sehwan hills, known as the Laki cuttings, had been much retarded, first by the uncertainty about the gauge, and later on by a new location having to be fixed to suit the 5′ 6″ gauge. In about a half of the cutting the location was uniform for both gauges, and in this part, where the line is carried on a bench in the face of the cliff, and the work consisted entirely of side cutting, the work had been completed as far as metre gauge dimensions demanded. In the other half, the location depended on the admissible limit of curvature. On this portion a mere commencement was made during the year.

Kotri Division.

67. In the Kotri Division 115 lakhs cubic feet of earthwork were executed in embankments of the line, and 12 lakbs cubic feet in bunds thrown up to control water-courses—also 47 lakhs of cubic feet of cutting through rock and rocky soil. Ballast was collected for 29 miles of line, and 184,000 cubic feet of masonry were executed in the minor, and 115,300 cubic feet in the major, bridges, representing 117 culverts and small bridges out of 168 required, and 7 large bridges out of 24.

The state of this Division at the close of the year may be succinctly stated thus—The embankments and cuttings complete, ballast at site for 42 miles, culverts and small bridges nearly approaching completion, the larger bridges well in hand.

Deliveries of English material.

68. The delivery of creosoted sleepers and iron 60 lb. permanent way for 100 miles of line had just commenced at the close of the year.

1875-76.

Uncertainty about funds.

69. Some uncertainty existed in the early part of the year in regard to the extent to which funds could be supplied. The Indian grant was first fixed at 52 lakhs rupees, but in January 1876 it was increased to 67 lakhs. The programme of works for the season was not in consequence definitely arranged until September, and there was some retardation of the works.

Extraordinary floods and damages.

70. The year was marked by the occurrence of extraordinary floods in the Sutlej and Chenab rivers, whilst the inundations of the Indus above and below Sukkur were both later and less extensive than usual. Serious damage was done to the line below Bahawalpur by the first-named floods. About 45 miles of line between Channi Gote at the 100th mile and the Noorwah Canal were completely wrecked, and it became evident that this part of the line would have to be diverted and realigned along the comparatively high desert land to the eastward, where it would be beyond the reach of floods. Definite proposals to this effect were submitted to Government, but were not disposed of until November 1876, when the work was carried out.

Damages at Adamwahan.

71. Heavy damage to stores was suffered at Adamwahan: the colony was flooded, the dwelling houses, store houses and godowns were submerged, and the loss in perishable material was serious. To prevent the recurrence of such disaster, a solid embankment was thrown up around the colony.

Severe sickness followed the inundation.

72. A very severe type of fever became prevalent after the floods of this season, especially at the Sutlej Bridge. All the officers of the Engineer and Subordinate Staff at Adamwahan were subject to repeated attacks, until sometimes there was not one fit for duty. The mortality was very great among the workpeople, notwithstanding every effort made to mitigate and remedy the evil. Towards the end of December the severity of the sickness abated.

Progress made in works in 1875-76.

73. The quantity of work done in each Division during the year 1875-76 is exhibited in the gross in the Tabular Statement, and is more fully narrated below:—

Tabular Abstract of quantities of principal works done during 1875-76.

Division.	Embankments and cuttings, lakhs of cubic feet.	Foundation cylinders, lineal feet sunk.		Concrete and brick and stone masonry, lakhs of cubic feet.	Ballast material collected, lakhs of cubic feet.	Permanent way laid and ready for traffic.	Bricks for building, surki and other purposes.
		18 feet 9 inches diameter sunk 100 feet.	9 feet diameter sunk 30 to 40 feet.				
Shujabad, ...	43·25	...	...	0·86	...	46½	...
Sutlej Bridge, ...	12	2,200	340	5·78	...	...	60
Bahawalpur, ...	58	...	...	1·35	4·3	...	5
Khanpur, ...	...	...	...	...	8·	...	18
Reti, ...	101	...	4,400	9·58	...	...	135
Ghotki, ...	551·25	...	4,000	3·00	6·	...	190
Indus Bridge, ...	...	...	...	...	...	...	...
Larkana, ...	213	...	260	·72	...	..	70
Mehur, ...	98	...	...	0·06	3·	...	...
Sehwan, ...	343	...	...	2·76	...	...	40
Kotri, ...	50·5	...	...	6·81	9·	48	...
Total, ...	1470·0	2,200	9,000	30·92	30·3	94½	518

74. In the Shujabad Division, the culverts, bridges, platform walls, tank towers and other brick works were all completed. Forty miles of the metre gauge track were taken up, and the 5′ 6″ gauge track substituted, the remaining 21 miles of line connecting Mooltan and Hamdi Depôt with Adamwahan were also converted in April immediately after the close of the year. This change bringing Adamwahan into direct railway communication with Calcutta and Bombay without break of gauge was of infinite advantage to the works at the Sutlej Bridge.

Progress in the Shujabad Division.

Track changed from metre to 5′ 6″ gauge.

75. The value of the metre gauge line to the works, however, must not be underrated. During the year 50,000 tons of stone for the bridge, 4,600 tons of iron permanent way material, 6,000 tons of sleepers, 15,000 tons of miscellaneous material, and 20,000 tons of ballast were carried over it. The gross ton mileage of the year amounted to 3,500,000 ton miles, and the cost of haulage to 3·75 pies per ton mile for all expenses except wear and tear of line and rolling stock. Five tank metre gauge locomotive engines and 130 wagons were employed, which were transferred towards the end of the year to the Ghotki Division tramway. Three ballast tank and one mail tank 5′ 6″ gauge locomotive engines were purchased from the East Indian Railway, and some ballast wagons were hired from the Scinde, Punjab and Delhi Railway.

Valuable services performed by the metre gauge tramway.

Provision of 5′ 6″ gauge Rolling Stock.

Line not ballasted.

76. But little of the line in this Division was ballasted.

Progress at the Sutlej Bridge.

77. At the Sutlej Bridge, as above described, foundation wells had been commenced; the depths they had reached on the 31st March have been exhibited. Considerable further progress was made in the sinking, and at the approach of the inundation the following condition of things existed. The wells of abutment A were resting on a stratum of hard clayey silt at a depth of 30 feet, and they were so well protected by their position in the solid high bank and by the mass of stone in the shore span, that there was no room for anxiety on their account. The wells of B and C had reached depths varying from 60 to 70 feet and were fairly safe. Those of P, Q, and R, however, were from their situation subject to the full violence of the floods, and they had only entered a clayey stratum found at a depth of 30 feet without penetrating to such an extent as would render them secure. 60,000 cubic feet of loose stone were placed around each of the foundations C, P, Q, and R, and further protection was afforded to A, B, Q, and R, by the completion of the sunken blocks in the abutment spans, and by the provision of about a third of the large quantity of stone with which those spans and the abutment piers had to be filled and surrounded.

Condition of foundation wells on approach of inundation season.

Critical position of P foundation.

78. The full force of the floods, which were remarkably violent, was directed on P; the volume of the river passing between P and Q, and scouring out a channel 40 feet deep below flood level, so far as could be ascertained from soundings taken in the rapid stream. The wells of P had barely reached this depth, and considerable anxiety was felt for their safety. Fortunately material was at hand, and 60,000 cubic feet more stone was added around the wells of P, as the supply which had been first applied, subsided. The bridge works did not suffer the slightest injury, nor were the cylinders in the least disturbed. Altogether 7,85,000 cubic feet of stone were placed around the foundations during the season.

Limitation of succeeding season's work to seven more foundations.

79. When the floods subsided, the river channel maintained its position between P and Q, and a high sand bank formed on the Adamwahan side, on which it would have been easy during the succeeding season, to have pitched the whole of the wells of the 11 foundations remaining. A close inquiry having, however, been instituted into the state of the plant, most of which had seen long service on other works, and into the prospect of obtaining sufficient rails for weighting the wells, it was pronounced undesirable to undertake so much, and the work of the season was limited to seven new foundations D, E, F, G, H, I, and K. A very good start was made in October, and notwithstanding the terrible sickness which prevailed for some time, a large amount of work was done. The following Table, taken from the Annual Reports, exhibits exactly the progress in well sinking made during the year, and the condition of each foundation on the 31st March 1876:—

Tabular Statement.

Foundations.	Wells.	Depths attained. 1874-75	1875-76	Total.	Remarks on the wells.	Remarks on the foundations.
A	1	24·31	51·23	75·54	In abeyance till completion of H, I, and K.	The wells are all 18 feet 9 inches in diameter, and have 5 feet thickness of steining.
A	2	38·15	61·85	100·00	Hearted.	
A	3	22·70	77·30	100·00	Do.	
B	4	34·40	65·60	100·00	Do.	B. Superstructure commenced.
B	5	56·27	43·73	100·00	Do.	
B	6	31·14	68·86	100·00	Do.	
C	7	55·79	44·21	100·00	Do.	C. Connecting block of masonry about to be commenced.
C	8	23·85	76·15	100·00	Do.	
C	9	34·95	65·05	100·00	Do.	
D	10		75·44	75·44	The wells of D, E, F, and G, have met only with sand or light silt. The outer wells of each foundation are in advance of the centre wells.	There is good reason to expect that all the wells of these four foundations, D to G, will reach their full depth before the floods of this season.
D	11		52·10	52·10		
D	12		69·40	69·40		
E	13		78·09	78·09		
E	14		57·54	57·54		
E	15		80·05	80·05		
F	16		69·50	69·50		
F	17		63·41	63·41		
F	18		68·13	68·13		
G	19		78·39	78·39		
G	20		60·17	60·17		
G	21		78·38	78·38		
H	22		62·16	62·16	The wells of H, I, and K met with clay at a depth of 30 feet. The up-stream well of each foundation has penetrated the stratum.	The whole of the wells of these three foundations will reach a depth of 75 feet before the floods of this season.
H	23		30·69	30·69		
H	24		36·52	36·52		
I	25		61·96	61·96		
I	26		28·86	28·86		
I	27		40·81	40·81		
K	28		65·39	65·39		
K	29		38·46	38·46		
K	30		43·25	43·25		
		Foundations L, M, N, O. Wells 31 to 42 inclusive not commenced.				
P	43	29·84	38·89	68·73	The 9 wells of P, Q, and R commenced last season, met with a clay stratum at 30 feet, they have been driven through it with difficulty, and are now progressing well.	The 9 wells will all be sunk to their full depth before the floods of this season, the two of Q, which are down, have reached a bed of very hard blue clay.
P	44	25·91	41·50	67·41		
P	45	32·06	30·57	62·63		
Q	46	29·36	70·64	100·00		
Q	47	26·65	47·01	73·66		
Q	48	29·60	70·40	100·00		
R	49	23·32	43·48	66·80		
R	50	32·58	29·45	62·03		
R	51	22·81	42·91	65·72		
		573·69	2,202·53	2,776·22		

Abstract.

Lineal feet sunk to end of 1874-75, ...	573·69
Do. do. 1875-76, ...	2,202·53
Total feet to date, ...	2,776·22
	cubic feet.
Brickwork to end of 1874-75, ...	2,20,817·35
Do. do. 1875-76, ...	5,37,935·45
Total brickwork up to date, ...	7,58,752·80

80. A contract had been entered into with two firms in England for the provision of the ironwork in the girders for this bridge.

Contract for supply of the girder ironwork.

81. The training works, which were to all appearance successful in the previous season, failed before the violent floods of August 1875, and it was found that no reliance could be placed on the temporary expedients hitherto tried. A proposal was submitted by the Engineer-in-Chief to construct long groynes of loose stone in direct connection with the bridge abutments, as had been done at some of the bridges on the Scinde, Punjab and Delhi Ralway.

Failure of the training works.

82. In the Bahawalpur Division the works, as stated, had been in abeyance; they were resumed in November of this year, but only on the part of the line north of Channi Gote; a proposal for diverting the line below that place having been submitted. This portion of the line was made ready for the reception of the permanent way by the completion of the earthworks, bridges, station platforms and wells. A large quantity of ballast, prepared from time to time in previous years, was ready along this part of the line.

Progress in the Bahawalpur Division.

83. The construction of a branch line, 14 miles long, to connect Channi Gote with the Chenab River was undertaken for the transport of material carried by the Scinde, Punjab and Delhi Flotilla. It was thought possible that in the dry season this branch might also be utilized in connection with the goods traffic of the Scinde, Punjab and Delhi Railway and Flotilla, and a proposal to this effect was submitted and afterwards acted on. The Flotilla was to work up to Makan Bela, and the goods transferred at that ghat to the wagons were to be carried over the Indus Valley rails to Mooltan, the temporary wooden bridge serving for the passage of the Sutlej River.

Construction of Makan Bela Branch.

84. Work was not resumed in the Khanpur Division, as the distance to which the diversion on to the desert would be carried was not yet determined, but this postponement was felt to be of little importance, as the works required were very light, and could easily be finished in a single season.

Work still left in abeyance in the Khanpur Division.

85. In the Upper Scinde District the progress made in the year was as follows:—

Progress made in the Upper Scinde District.

86. In the Reti Division the earthworks were completed; 100 lakhs cubic feet having been thrown up during the year. Fifty-three of the culverts and minor bridges were completed, 16 in progress and approaching completion, and 10 remained untouched. Thirteen of these culverts had been completed, and 17 commenced in the previous year. Of the 23 large bridges in the Division, 17 of which were classed as major bridges, and 6 consisting each of five arches of 10 feet span, were among the minor bridges, 5 were finished, 8 in hand approaching completion, 8 had been commenced recently and were progressing favourably, and 2 had not been touched. Six of these bridges had been commenced before April 1875. The gross quantity of concrete and brick work in bridges executed during the year in this Division amounted to 9,58,000 cubic feet, and at the bridges, founded on wells, 4,400 lineal feet of well sinking were executed. The

Progress in the Reti Division.

Quantity of work executed.

following Table, taken from the Annual Report, exhibits the condition of the major bridges in this Division at the close of March 1876.

Tabular Statement.

Distinguishing number of bridges.	Mileage.	Description.	Present condition.
7	175·0	16 spans, 10 feet A	Excavation just commenced.
10	176·0	16 „ 10 „	Untouched.
13	177·0	10 „ 40 „	About quarter of the well masonry built. Both abutment wells sunk full depth; other two pairs half sunk.
19	182·0	12 „ 10 „ A	The inverts are being turned.
46	188·0	25 „ 10 „	Half the arches turned.
47	189·0	25 „ 10 „	Finished.
63	204·0	6 „ 40 „	Well masonry complete, sinking very nearly finished. North abutment and two piers built.
69	211·0	10 „ 40 „	Half the well masonry complete; four pairs of wells half sunk.
70	212·0	10 „ 10 „ A	Complete to springing.
71	212·0	1 span, 40 „	Foundation blocks just completed.
76	214·0	5 spans, 40 „	Curbs being pitched.
78	214·0	9 „ 40 „	Well masonry complete. Abutments and three piers built, one more pair of wells sunk, the other four pairs half sunk.
79	215·0	13 „ 40 „	Abutments and two piers built, another pair of wells sunk, all the other wells are nearly down to their full depth.
84	216·0	10 „ 10 „ A	Finished.
86	217·0	1 „ 40 „	One pair of wells sunk; the other wells three-quarters sunk.
91	219·0	2 „ 40 „	Half the well masonry built; sinking just begun.
93	219·0	3 „ 40 „	Well masonry complete. This bridge and number 91 have wells only 25 feet deep on account of the stiff clay soil met with.

87. In the Ghotki Division the earthworks were complete with the exception of 30 lakhs cubic feet of raising required in the Sangi Sub-Division, which were deferred on account of the tramway being laid on the bank; 551·25 lakhs of cubic feet were thrown up during the year. Thirteen of the minor bridges in the Division were completed, 9 in hand well advanced, and the materials for 6 at site. Of the 36 major bridges, many of which were large viaducts, 2 were complete, 6 in hand and approaching completion, 9 had been recently commenced and were progressing satisfactorily, and 19 had not yet been touched. In the general estimate of the line, 34 of these bridges only had been classed as major bridges, but an alteration of the dimensions of two minor bridges, numbers 2 and 70, brought them under the category of major bridges.

Progress in the Ghotki Division.

88. The total quantity of concrete and stone and brick masonry executed in this Division during the year, amounted to three lakhs cubic feet; and 4,000 lineal feet of wells for foundations were undersunk. The work in this Division did not fairly commence until January 1876; the Narra bridge, number 91, 8 spans of 20 feet arches, with two culverts near it, being all that had been undertaken in the previous season.

Quantity of work executed.

89. The following Tabular Statement, taken from the Annual Report, exhibits the state of the works on the major bridges of this Division at the close of the year :—

Tabular Statement.

Numbering. General Estimate.	Numbering. Progress Section.	Mileage. M.	Mileage. F.	Dimensions.	Present condition.
0	2	222	7	1 span, 40 feet, ..	First length of steining 15 feet completed for four wells, two spans of six metre originally proposed.
6	3	224	0	12 spans, 40 „ ..	The well sinking almost completed and superstructure commenced.
7	4	224	2	11 „ 40 „ ..	Second length of steining built on all wells and some are sunk 35 feet below ground.
8	5	224	6	3 „ 40 „ ..	Finished.
10	6	225	1	8 „ 40 „ ..	Sinking of all the wells in hand, 8 have 30 feet of steining built, and nearly all these have been sunk 20 feet, the other wells have 20 feet of steining built, and an average of 15 feet sunk.
11	7	225	4	5 „ 40 „ ..	All the first lengths of steining built and being sunk.
12	8	226	1	8 „ 40 „ ..	First length of steining being built.
13	9	226	4	8 „ 40 „ ..	Not commenced.
14	10	227	0	15 „ 40 „ ..	First length of steining built and about three-quarters sunk.
15	11	227	4	10 „ 40 „ ..	Not commenced.
16	12	228	2	8 „ 40 „ ..	Ditto.
17	13	228	6	10 „ 40 „ ..	Ditto.
18	14	229	4	10 „ 40 „ ..	Ditto.
19	15	230	0	10 „ 40 „ ..	First length of steining sunk, and part of second in some wells ; in the others the second steining being built.
20	16	230	3	2 „ 40 „ ..	Not commenced.
22	18	231	3	3 „ 40 „ ..	Ditto.
23	19	232	0	2 „ 40 „ ..	Ditto.
24	20	232	6	3 „ 40 „ ..	First length of steining being built.
25	21	233	6	5 „ 40 „ ..	Ditto ditto.
26	22	234	2	8 „ 40 „ ..	Ditto ditto.
27	23	234	6	2 „ 40 „ ..	Not commenced.
28	24	235	4	3 „ 40 „ ..	Ditto.
48	33	243	7	10 „ 40 „ ..	Ditto.
49	34	244	3	2 „ 40 „ ..	Ditto.
51	35	245	0	10 „ 40 „ ..	Ditto.
53	36	245	5	5 „ 40 „ ..	Ditto.
101	66	261	4	10 „ 10 „ A,	Foundations excavated and material at site.
102	67	261	7	10 „ 10 „ ..	Ditto ditto.
104	69	262	7	3 „ 40 „ ..	Curbs pitched, originally 10 spans, 10 feet arches.
105	70	263	3	2 „ 40 „ ..	Ditto ditto 5 ditto 10 ditto.
106	71	263	5	10 „ 10 „ A,	Curbs pitched.
107	72	264	0	5 „ 40 „ ..	Wells sunk to an average depth of 80 feet.
110	75	265	6	3 „ 40 „ ..	Ditto ditto 26 „
112	77	267	0	5 „ 40 „ ..	Ditto ditto 37 „
119	84	268	7	10 „ 10 „ A,	Blocks, drop walls and concrete half inch.
127	92	271	0	8 „ 20 „ A,	Finished.

Ballast material collected.

90. Six lakhs cubic feet of broken stone were collected at Rohri for ballasting the line; it was intended to use this material throughout the Ghotki Division.

Ghotki Division tramway.

91. A metre gauge tramway was being laid for the transport of the large quantity of material which had to be moved in the Ghotki Division. Twenty miles of main line had been laid on the bank, with deviations, each containing a tressel bridge at the bridge sites. About five miles more were laid in branches to the river at Sukkur and to the several quarries at Rohri. The remainder of the main line was being rapidly urged forward, towards the northern end of the Division. Five metre gauge tank locomotive engines and 100 ballast wagons were on

the line, transferred from the Shujabad Division, and two more engines with about 60 more wagons were shortly to be brought down.

Progress in the Indus Bridge Division.

92. No work was done in the Indus Bridge Division during the year. The Superintendent of Works was engaged in direct communication with the Consulting Engineer for State Railways in elaborating his designs for a bridge, and in August he submitted a preliminary report containing definite proposals, which the Engineer-in-Chief for the most part supported, and forwarded to the Government.

Progress in the Larkana Division.

93. Work was commenced in December 1875 on the 20 miles of the Larkana Division below Sukkur, which had previously been in abeyance. At the close of the year the earthworks were approaching completion, the embankments of the remaining 45 miles of the Division had been already previously completed. A commencement was also made in the bridging, as shown in the following Tabular Statement of the major bridges taken from the Annual Report.

Tabular Statement.

Distinguishing number of bridge.	Mileage.	Description.	Present condition.
31	289	25 spans, 40 feet,..	Curbs being pitched and brickwork commenced.
49	298	3 „ 40 „ ..	First length of all wells being sunk.
50	300	2 „ 40 „ ..	Well curbs pitched.
51	301	3 „ 40 „ ..	Ditto ditto.
52	302	5 „ 40 „ ..	All wells sunk, average 15 feet.
55	305	5 „ 40 „ ..	Well curbs pitched.
56	..	2 „ 40 „ ..	Not commenced.
134	..	1 „ 40 „ ..	Ditto.
164	..	3 „ 40 „ ..	Ditto.

The materials required for the minor bridges were all at site of work.

Progress in the Lower Scinde District.

94. The progress made in the Lower Scinde District was as follows:—

Progress in the Mehur Division.

95. In the Mehur Division the embankments were complete. The bridgeworks had just been commenced in January, they having been kept in abeyance owing to the uncertainty about funds noted above. There were but 4 major bridges of no great size in the Division, and the other masonry works consisted of culverts and small bridges for irrigation purposes, which might be completed very rapidly.

Progress in the Sehwan Division.

96. In the Sehwan Division the embankments north and south of the Laki cutting were complete.

Laki cutting.

In the Laki cutting 178 lakhs of cubic feet of hard gravel and rock had been excavated, but this was only in the top lift, the heavy work of blasting in the deep cuttings and removing the stuff by trucks run through narrow confined drift ways had still to be encountered. Masonry works had been in abeyance till November.

97. The excavation for foundations of the Sann River bridge, 23 girder spans of 40 feet, had been got out, and masonry commenced in them. There were only two other large bridges in the Division, *viz.*, that over the Aral of 4 spans of 12 metres, and that over the Kara Fitta of ten 6 metre spans; some long culverts had also been constructed under the heavy embankment in the Laki pass, in which 1,70,000 cubic feet of masonry, and 45,000 cubic feet of concrete had been executed.

Sann River bridge.

98. In the Kotri Division the embankments were complete, and so also were the bridges, with the exception of the group of five bridges at the Manjho Nai, aggregating 42 spans of 6 metres, and 10 spans of 12 metres. During the year 4,94,000 cubic feet of masonry, and 87,000 cubic feet of concrete had been executed. The station buildings, platforms, ashpits and signals were all ready. The ballast and permanent way had been laid on 48 miles; a temporary diversion of 2½ miles length being made around the Manjho Nai bridges. The track was carried into the Kotri terminus of the Scinde, Punjab and Delhi Railway over one of that Company's sidings, and connected with their line.

Progress in the Kotri Division.

99. A sufficient number of creosoted pine sleepers for the 226 miles south of Sukkur had been obtained in England, and were in course of delivery at Karachi. It had been decided to sleeper the line above Sukkur with deodar, and sufficient sleepers for 220 miles had been purchased and manufactured. 280 miles of iron 60 lb. permanent way had been received, or were in course of delivery at Karachi.

Provision of sleepers.

Provision of iron 60 lb. rails.

1876-77.

100. During this year it was found expedient to revise the general programme settled in July 1874, by which the section of the line below Sukkur was to be first pushed to completion.

Change in general programme of works.

The unforeseen difficulties and delays in the execution of the work at the Laki cuttings, the completion of which formed the key to the opening of the Lower Section, were principally operative in inducing this change.

Difficulties, delays, at the Laki cutting.

The great difficulty of communication between Mooltan and the Reti and Ghotki Divisions, which prevented the Engineer-in-Chief from affording to that part of the line much of his personal attention, made it very desirable to push the track already laid to Channi Gote (100 miles) as far further south as possible, and lastly there was a great advantage to be gained in the transport of material, specially that for the Sutlej bridge, if the line could be pushed as far as Sarhad in the Ghotki Division, and communication by tramway be established with Gobla, a ghat on the river about a day's steam above Sukkur, and but three or four miles distance from Sarhad Station, at which the Flotilla boats could conveniently discharge their cargoes.

Difficulty of communication between Mooltan and Reti and Ghotki.

101. Now that large quantities of permanent way material, bridge girder work and other stores were being poured into Karachi, the inadequacy of the Scinde, Punjab and Delhi Railway Flotilla to deal with the transport became thoroughly apparent, and although the Company took largely to conveying the stores on native boats, yet the absolute necessity of relieving the Flotilla by some means became daily more manifest. The simplest and most practicable method of relief was of course to be found in shortening the trip of the boats, by pushing forward the Railway track as far as possible to the southward from Mooltan, if possible even to Sukkur.

Inability of Scinde, Punjab and Delhi Railway Flotilla to deal with transport of material.

102. These considerations fully justified a change in the programme, and from this time every effort was directed towards the more speedy opening of the Upper Section, Mooltan to Sukkur.

Change in programme justified.

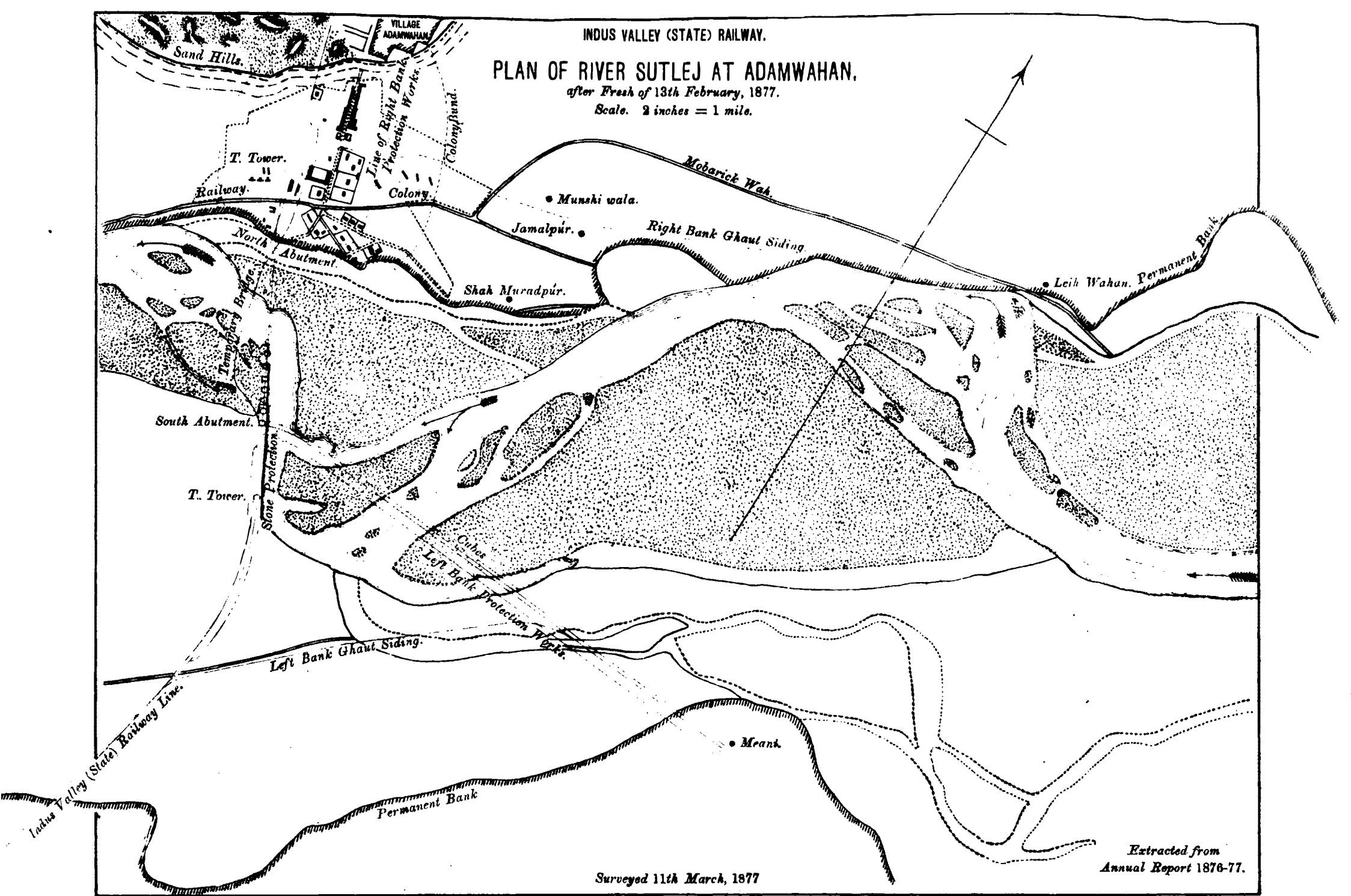
103. This year was again distinguished by excessive floods in the Sutlej, Chenab, and Indus Rivers. At Adamwahan the Sutlej rose to 380·72 above sea level, being 1·32 feet higher than that recorded in 1875, and 1·72 feet above the flood height recorded as the highest when the designs for the bridge were prepared. At Sukkur the Indus reached 15 feet 10 inches on the Bukkur gauge, being 5 inches higher than 1875, and 1 foot 5 inches higher than in 1874, when the height recorded was stated to be unusual.

Excessive floods in Sutlej, Chenab, and Indus Rivers.

104. The violent oscillations from which the river Sutlej at Adamwahan had been comparatively free for two seasons recommenced this year with increased violence; the stream which, during the previous flood season, had been flowing directly on the P, Q, opening in the bridge, on the subsidence of the floods commenced to encroach on the left bank above the bridge site, and in spite of every effort to drive it back the loop continued to force its way to the westward. This process continued with alarming violence and pertinacity, when the river rose in flood in August until the deep bay formed had reached a distance of 2,000 feet behind the bridge abutment R, where its further progress was finally arrested. The deep stream, however, continued thus to flow and scour alongside the embanked approach to the bridge, threatening to force its way through. Incalculable mischief would have resulted had the river made a way for itself behind this abutment of the bridge. Fortunately with a clear prevision that danger would threaten in this manner, the whole of the large reserve of stone collected during the previous season, in excess of what was required to be immediately deposited around the foundations, had been laid down in a continuous stack 2,000 feet in length, and containing 100 cubic feet to the lineal foot along the toe of the embanked approach to the bridge on the up-stream side. This loose stone fell in as the river undercut the bank on which it was lying, and by pitching the surface effectually arrested the underscour. From time to time the defence bad to be strengthened by throwing in all the spare stone available from the left land span and abutment, and even by bringing the right bank reserves across the river.

Violent oscillations of Sutlej River.

Danger to embanked left approach.



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Rafts of sleepers and boats were also moored along the bank, with the view of checking the surface velocity, but whilst the former were to some extent effective, the boats proved worse than useless.

Unusual fresh on 12th February.

105. The course of the river remained unchanged until 12th February, when a very unusual fresh of 3 feet 6 inches came down and resulted in a considerable improvement by opening for itself a new channel running more directly through the bridge.

Proposal to protect both abutments by long stone embankments adopted.

106. The catastrophe thus narrowly escaped, led to the final adoption of the proposal made some years previously that the left abutment should be connected with the high bank of the river by a solid artificial advanced embankment, to be formed principally of loose stone. At the same time it was resolved to provide a somewhat similar protection to the right abutment which was obnoxious to such attacks, but in a less degree than the left abutment.

Condition illustrated by annexed Map.

107. The condition of the river at this time will be more readily understood by inspection of the annexed Map, prepared from surveys taken immediately after the fresh of the 12th February.

No damage done to bridge works or colony.

108. No damage whatever was sustained by the bridge-work, and the embankment thrown up during the previous season sufficed to protect the Adamwahan colony from an incursion of this flood, although it rose more than a foot higher than that of the previous year.

Temporary timber bridge destroyed by fresh of 12th February.

109. The fresh of 12th February carried away the temporary bridge, but the interruption was not of long duration, communication being restored in 10 days.

Embankment constructed by Bahawalpur State.

110. During the cold weather 1875–76, the Bahawalpur State had thrown up a solid embankment from the Buktwah on the left bank of the Sutlej, to the Barnswah on the Chenab, a length of 25 miles, and proposed in the following season to extend it 16 miles further. This bund, designed for the protection of the cultivated lands from the destructive effects of the spills from these rivers, served also partially to prevent a recurrence of the flood, which in the previous year had been so disastrous to the line below Channi Gote. The floods, however, passing round the incomplete end of the bund reached Khanpur, where the station plot was again deeply submerged, and damage done to the buildings. It was in consequence decided to extend the diversion into the desert further to the southward beyond Khanpur than had been previously contemplated.

Inundation at Khanpur.

Slight inundation in Reti Division.

111. The floods of the Indus in the Reti Division and upper part of the Ghotki Division were lighter in character than usual, but an exceptionally heavy

spill occurred opposite Ghotki, which breached the bund thrown up around the town for its protection. Great damage was done in the town, and the station buildings, submerged to a considerable depth over their floors, were entirely destroyed. Other parts of the Ghotki Division, which had hitherto been effectually protected by local embankments, were reached by the floods in this season, proving that dependence must not be placed on such protection. Some increase to the flood openings was made to render the line more secure in the future.

Destructive inundation at Ghotki.

Additions to flood openings in Ghotki Division.

112. The line below Sukkur as far down as Sehwan is subject to floods from spills of the Indus. The first spill occurs at Kusmore, to prevent which, however, a long embankment is maintained by the Irrigation Department. Hitherto this bund had been invariably breached on the occurrence of high floods in the river. The inundation passing by Jacobabad and flowing down through the low land at the foot of the range of hills, reached the Manchur lake, which forms a sort of regulating reservoir, and finally the water passed back into the Indus through several depressions or natural canals, the principal of which is the Aral river. The next spill over the right bank, in order descending the river, is known as the Laki flood; this had been of unfrequent occurrence, as a system of embankments maintained near Abad on the bank of the Indus had usually proved sufficient to prevent the spill, the water flowing across would strike the Railway line near Ruk, where an opening provided for it would pass the water, and permit it to flow off again into the river, but for the intervention of an embankment, known as the Jalli bund, thrown up on the bank of the Indus to prevent incursions of the river in this neighbourhood. The Laki flood then imprisoned between the Railway and the Jalli bund being forced down to Allahdadani and Nawa Dera, passes the line through openings left for it, and joining the Kusmore flood, finds its way finally to the Manchur lake. The Jalli bund, not equal to the task assigned to it, had also frequently been breached, the spill water flowing off in the direction just described as that taken by the Laki flood.

Spills of the Indus affecting the line below Sukkur.

Kusmore flood.

Manchur Lake a regulating reservoir.

Laki flood.

Jalli floods.

113. These several spills combined during this year surcharged the Manchur lake, and in flowing back into the Indus greatly enlarged the gaps which had been left in the line for its passage. The opening designed for the Aral river was accordingly doubled in size, and considerable additions were made to the flood openings in the other depressions, the aggregate additions being 555 lineal feet. The Manchur discharge of this year was not aggravated as it had been in 1874 by a heavy local rain fall, yet the flood height was not far short of that reached in that year.

Manchur Lake surcharged.

Increase to discharge openings from Manchur Lake.

114. During this year Railway communication was established between Mooltan and Makan Bela ghat, and the Indus Valley Railway undertook the

Completion of track between Mooltan and Makan Bela.

transport of goods between those places for the Scinde, Punjab and Delhi Railway Company, the steam Flotilla plying only as far up as Makan Bela. This undertaking, which commenced early in the cold season, proved a very serious addition to the duties of the working staff of the line, but it was carried through successfully.

Scinde, Punjab and Delhi Railway goods traffic undertaken.

115. The Budget grant for the year was originally Rs. 66,20,000, but this was afterwards supplemented by further grants, and the expenditure of the year amounted to nearly 70½ lakhs rupees.

Funds and expenditure during the year.

116. A very large share of work was executed during the year 1876-77 all along the line. The following statement shows that in the masonry work of bridges 40·63 per cent. of the whole quantity provided for in the estimate was executed during the year, the largest advance being made in the Larkana, Mehur and Sehwan Divisions, where the works hitherto held in abeyance were of a light character, generally consisting of numerous culverts and irrigation ducts :—

Large progress made in the masonry works in 1876-77.

Statement of brickwork in Bridges.

Division.	Total estimated amount of work to be done.	Done on 31st March 1876.	Proportion to the whole.	Done on 31st March 1877.	Work of the year 1876-77.	Proportion of this year's work to the amount of estimate.	Work remaining to be done.	Percentage of work remaining to be done.
Northern Section.	lakhs.	lakhs.		lakhs.	lakhs.		lakhs.	
Shujabad, ...	2·52	2·31	91·66	2·36	0·05	1·99	0·16	6·35
Sutlej Bridge, ...	16·75	8·50	50·74	13·50	5·00	29·86	3·25	19·40
Bahawalpur, ...	3·74	2·79	74·60	3·34	0·55	14·71	0·40	10·69
Khanpur, ...	9·75	1·25	12·82	5·08	3·83	39·28	4·67	47·90
Reti, ...	16·33	10·40	63·68	16·00	5·60	34·29	0·33	2·03
Ghotki, ...	26·17	8·00	30·56	17·50	9·50	36·31	8·67	33·13
Southern Section.								
Larkana, ...	9·85	1·04	10·55	7·25	6·21	63·05	2·60	26·40
Mehur,..	6·60	0·52	7·88	4·18	3·66	55·45	2·42	36·67
Sehwan, ...	17·79	1·57	8·82	13·81	12·24	68·80	3·98	22·38
Kotri,..	12·45	9·44	75·82	12·35	2·91	23·37	0·10	0·81
Total, ..	121·95	45·82	37·57	95·37	49·55	40·63	26·58	21·80

117. The progress made generally in the works may be more particularly narrated as follows :—

Narrative of progress.

118. In the Mooltan District, Shujabad Division, the small balance of earthwork and masonry remaining incomplete at the close of the previous year was finished. The supply of ballast amounted to 10 lakhs of cubic feet only out of 31·68 lakhs cubic feet estimated. The line was partly boxed up with ballast run out from Mooltan. The stations were completed in machinery, and pointsmens' and gatekeepers' huts built. 185,000 sleepers were purchased and sawn out.

Progress in the Mooltan District, Shujabad Division.

119. In the 13 miles of main line attached to the Sutlej Bridge Division, of which the Sutlej bridge and its approaches occupied three miles, the earthwork was completed, and the bridges, excepting the Sutlej bridge, were finished. About one-third of the required ballast was collected, and the permanent way was laid.

Progress in the Sutlej Bridge Division.

120. At the Sutlej bridge, as shewn in the previous year's report, the undersinking of a large number of wells was in progress. These wells, with the exception of those in P foundation, which had been very intractable, were all driven to a secure depth before the advent of the inundation season, the dry weather channel adhering to the left bank had permitted direct access to all of the foundations, D to K, commenced in the early part of the season, and they were all securely pitched on the undisturbed sand bank, which extended continuously from A abutment up to the site for N pier.

At the Sutlej Bridge.

121. The continuance of this good fortune could hardly be expected; as described above, the river assumed a very tortuous course, by which the stream was forced obliquely through the bridge opening, its stream occupying all the sites of the foundations L to O. The wells of these foundations accordingly had to be pitched in succession on artificially formed islands of sand, the maintenance of which in such a swiftly running stream was a matter of great difficulty. This difficulty was much enhanced by the occurrence of the fresh on 12th February adverted to above. However the perseverance and resource of the Engineers were rewarded by success, the last curb of the bridge was got into place on the 1st February, and the sinking was rapidly prosecuted. Work was, however, a good deal impeded by the unsatisfactory condition of the plant, especially of the hoisting engines, many of which were incapable of carrying sufficient chain to work to a depth of 100 feet, and others were not of power sufficient to lift the heavy tools, which latterly it had been found necessary to employ in cutting through the hard clay silt—notably a new form of cutting tool invented and perfected by one of the Subordinate officers employed on the works.

Difficulties in pitching wells of four remaining foundations.

Insufficiency of the plant.

122. The condition of the undersinking on the 31st March 1877 is shown in the following Table, taken from the Annual Report, from which it will be seen that out of the 17 foundations 12 were completed, and the remaining 5 were in a forward state; some of the superstructure of piers also was built.

State of wells on 31st March 1877.

Statement of progress on the Sutlej Bridge Works on 31st March 1877.

Pier.	Beginning of Financial year 1876-77. Built 1 foot.	Sunk 1 foot.	Hearted No. of wells.	Pier superstructure built above R. L. 369·00.	End of Financial year 1876-77. Built 1 foot.	Sunk 1 foot.	Concreted and hearted.	Pier superstructure built 1 ft. above R. L. 369·00.	Progress of the year. Built.	Sunk.	Concreted and hearted.	Superstructure built.	Remarks.
			Wells.				Wells.	Feet.			Wells.		
A	300	275	2	*Nil.*	300	300	3	25	*Nil.*	25	1	25	The result of the year's work has been—*1st*, that the building of the wells has been advanced from ·66 to ·915 of the whole; *2nd*, the sinking from ·545 to ·867; *3rd*, the building of the superstructures of six of the piers.
B	300	300	3	2	300	300	3	24	...	*Nil.*	*Nil.*	22	
C	300	300	3	2	300	300	3	25	...	...	...	23	
D	271	197	...	...	300	300	3	24	29	103	3	24	
E	286	216	...	...	300	300	3	25	14	84	3	25	
F	272	201	...	...	300	300	3	24	28	99	3	24	
G	271	212	...	...	300	300	3	3	29	88	3	3	
H	226	129	...	...	300	300	3	1	74	171	3	1	
I	220	132	...	...	300	300	1	...	80	168	1	...	
K	222	147	...	...	300	300	2	...	78	153	2	...	
L	...	...	...	...	142	86	...	...	142	86	...	...	
M	...	...	...	...	205	124	...	...	205	124	...	...	
N	...	...	...	...	195	157	...	...	195	157	...	...	
O	...	...	...	...	230	169	...	...	230	169	...	...	
P	268	198	...	...	300	289	...	...	32	91	...	...	
Q	300	274	...	...	300	300	3	1	*Nil.*	26	3	1	
R	280	195	...	...	300	300	3	1	20	105	3	1	
Total,	3,516	2,776	8	4	4,672	4,425	33	153	1,156	1,649	25	149	

Weights placed on wells.

123. The weights superimposed on the wells during sinking varied much. As a rule the wells were built up and sunk in successive lengths of 34 feet, or one-third of their total length. Some of the wells which encountered nothing but sand in their descent, and which maintained a perfectly vertical position, ran down unassisted by any extraneous load; but as a rule it was found necessary to add 200 tons on the first length, 400 tons on the second, and 600 tons on the third length. In some instances as much as 1,000 tons extra load were added on refractory wells, and even this enormous load was found insufficient in the case of the P 44 well to force it through the compact mass of stone which had been thrown in from time to time for the protection of this foundation.

Quantity of stone used in protecting foundations.

124. The minimum quantity of stone used in this manner up to this date on any one foundation was 40,000 cubic feet, the maximum quantity 1,10,000 cubic feet. In the aggregate on the whole of the foundations 16,66,000 cubic feet had been used, besides the large quantity thrown in to secure the embankment behind the left abutment.

Heavy cost of the stone.

125. This stone was procured at the heavy cost of Rs. 30 per 100 cubic feet, being brought from a place called Chuneot on the Chenab, carried in boats about 200 miles to the Hamdi ghat, and thence transported by Railway over the

43 miles intervening between that ghat and the bridge. In substitution for this expensive material, the manufacture of 12 inch cubes of brick was commenced; this material could be produced at about a half of the cost of the stone, but its comparatively low specific gravity of course rendered it less effective, and experience alone could show whether in the long run the change would prove economical.

Preparation of brick cubes.

126. A great deal of work was executed during this year in the shops, the efficiency of which was much increased by the provision of a 25 H.P. Robey's semi-portable engine. In addition to new work, consisting of the manufacture of platelaying tools for the whole line, of bolts and ironwork for girder erection for incomplete wagons and carriages and for the temporary bridge, and of bolts and bond rings for the wells—the shops maintained the bridge plant in working condition, consisting of 26 steam hoists, nearly all old and much worn, 12 portable engines, 2 steam launches, 2 steam fire engines, 9 mortar mills, and 6 Gwynne's pumps. Six broad gauge locomotive engines were also kept in work, and 2 metre gauge locomotives thoroughly overhauled. At the same time a Carpenter's shop had been established with steam driven sawing and other machinery, in which the construction of vehicles was commenced.

Work in the shops.

127. The temporary timber bridge was of course reconstructed this year. It was first erected and opened in 30 working days, and subsequently, when destroyed by the fresh of the 12th February, was restored within 10 days. The value of this work may be estimated from the fact that at least 200,000 tons were hauled over it during the working season.

Temporary timber bridge.

128. In the Bahawalpur Division the work of this year consisted in the completion of the desert deviation line, and in the laying of the permanent way as far as the 107 mile on the main line, and completion of the branch line from Channi Gote to Makan Bela. A speed of one mile a day in platelaying was finally attained to in this Division. Twenty-seven lakhs of cubic feet, out of a total quantity of 37 lakhs of ballast required, had been collected. The new stations required on the deviation line were built, and nearly all the machinery required for all of the stations was supplied.

Progress in the Bahawalpur Division.

129. Orders not having been received from Government on the proposal to extend the desert deviation southward for some 10 miles beyond Khanpur, referred to above, nothing could be done to this part of the Division. In the other portions, the bridge-work, which had been in abeyance for two years, was resumed, and about a half of it executed. Sixteen lakhs of cubic feet, or about a half of the quantity of ballast required, had been collected previously; this work was now in abeyance for want of funds. The new station buildings required at Firoza and Khanpur, the latter a changing station, had not been commenced, the other stations had been completed in previous years. Arrangements had been made to deliver permanent way materials for 20 miles of line by water at Chachar, and thence down the large canals to the Railway line.

Progress in the Khanpur Division.

130. The progress in the Upper Scinde District was as follows:—In the Reti Division the embankments, to which considerable additions of height had been made in consequence of the floods of recent years, were almost complete. Sixteen out of the 17 major bridges, and 74 out of the 80 minor bridges required, were complete, the others in hand and well forward. A total depth of 6,372 lineal feet of undersinking had to be executed in the bridge foundations of this Division.

Progress in the Upper Scinde District.

In the Reti Division.

Nearly the whole of the 9½ lakhs of cubic feet of rubble stone required for the protection of bridge foundations and of embankments had been brought to site, 5 lakhs being this year's share of the work. Twenty lakhs of cubic feet of ballast, out of 31 lakhs required, had been collected. This Division was charged with platelaying from Gobla ghat, at which the material was delivered to Sarhad, 6 miles; from Sarhad to Mirpur, 8½ miles, both within the limits of the Ghotki Division; and of the 42¾ miles of the Reti Division, 12½ miles had been completed at the close of the year. The rolling stock received at Gobla for working over this detached portion consisted of 2 locomotive engines, 25 low-sided wagons, 20 heavy, and 20 light, trollies.

131. The earthworks of the Ghotki Division were very nearly completed. Of the 45 major bridges, aggregating 209 spans of 40 feet, 14 were finished as regards masonry, and 31 were in hand. Girders for 30 spans were about to be delivered at Gobla ghat, the remainder of the girders ordered in England had not arrived. Twenty-nine of the 51 minor bridges were complete, and 17 in hand. In the foundations of bridges in this Division, a total length of 18,637 lineal feet of undersinking of wells had to be executed; 14,200 were done during this year. This work was executed entirely by petty contract, at an average cost of Rs. 9 per foot down; the Government furnishing Bull's dredgers and native jhams. Of the 35 lakhs cubic feet of material required for protecting foundations and embankments, 8¼ lakhs of rough stone had been placed *in situ*, and 11 lakhs more had been quarried at Rohri. Sixteen-and-a-half lakhs cubic feet of burnt brick material were in course of manufacture at several points along the line. Only 7½ lakhs cubic feet, out of the 32 lakhs cubic feet of ballast required, had been collected, this work being deferred until the completion of the track should permit of material being run out from the Rohri hills. The metre gauge tramway was completed and maintained in this Division on a length of 48 miles, and during the year an addition was made to the rolling stock on it of one tank metre gauge locomotive engine and 58 low-sided wagons, transferred from the Mooltan District.

In the Ghotki Division.

132. In the Indus Bridge Division branches were laid down connecting the main line on both sides with ghats established at the river side. On the Rohri side a quay wall, 2,500 feet long, was also erected, up to which the steam ferry could ply during inundation.

In the Indus Bridge Division.

133. The preparation of the designs in detail for the bridge were also prosecuted by the officer specially appointed to this service. The designs, of which the principal feature was a great span of 780 feet over the Rohri channel, were near completion at the close of the year.

Designs for the Indus Bridge.

134. In the Larkana Division about one-third of the earthwork in embankments still remained to be completed, 8 major bridges, aggregating 36 spans of 40 feet had been estimated for, of which one was complete, two very nearly so, and the remainder well advanced; the girders for these bridges had not arrived from England. Of the 189 minor bridges, 136 were completed, and 27 in hand. Five lakhs of cubic feet only, out of 47 lakhs cubic feet of ballast required, had been supplied. This work was deferred until the completion of the track should permit of stone material being run out from Sukkur. Platelaying had not been commenced.

In the Larkana Division.

135. The following progress was made in the Lower Scinde District:—

Progress in the Lower Scinde District.

In the Mehur Division the earthworks were completed. Of the 175 culverts and minor bridges, 72 were completed, and 86 in various stages of progress; the masonry of the 4 major bridges was nearly completed. Seven and one-third lakhs of cubic feet, out of the 33½ lakhs cubic feet of ballast required, had been collected. It was proposed to ballast 20 miles of the southern end of the Division with stone, to be led out from Morluck; burnt brick being used on the northern 30 miles. For the transport of permanent way material from the river, the construction of a tramway, 3¾ miles in length, was sanctioned from Fattehpur Bunder to the Phulji Road Station. Some advance was made in Station arrangements.

In the Mehur Division.

136. In the Sehwan Division the earthworks were completed.

In the Sehwan Division.

In the Laki cuttings many difficulties were encountered, both in the nature of the work itself and from sickness breaking out among the work people. The date originally stated for the completion of this work was September 1876. At the close of the year, in March 1877, however, about 40 lakhs cubic feet of rock cutting still remained to be done. About four-fifths of the masonry in minor bridges was completed. Out of 2,970 lineal feet of waterway in 20 major bridges, 400 lineal feet were completed, and the rest in progress as regards the masonry; the girders for 59 spans out of 91 spans had been provided, the remainder had not arrived from England. Thirty-five and three-quarter lakhs of cubic feet, out of 51½ lakhs cubic feet of ballast required, had been collected. The platelaying was completed to five miles north of the Sann river in extension of the track in the Kotri Division, and a branch three-quarters of a mile long had been run from the Amri Station to the river for transport of material.

Laki cuttings.

137. The small quantity of earthwork and of masonry in minor bridges of the Kotri Division remaining at the close of the previous year were completed. The major bridges also were completed, but the 6 metre girders required for the Manjho Nai group had not arrived from England, and the 2½ miles of diversion around these bridges had to be maintained. The estimated supply of ballast was completed. The platelaying was extended to the end of the Division and to the Sann river. The first engine ran out from Kotri to Sann on

In the Kotri Division.

the 8th August 1876. The stations were completed and fitted with the necessary machinery.

Engine Depôt at Kotri.

138. An engine depôt was established at Kotri in connection with which an engine shed was commenced, and a block of quarters of two stories for the Locomotive Foreman was about half built. Two locomotive engines were purchased from the Scinde, Punjab and Delhi Railway Company, and a tank engine was hired from the Karachi Harbour works. Seventy-five ballast wagons built in the Scinde, Punjab and Delhi Railway shops were brought into use.

Western Extension Surveys. Ruk towards Dadur.

139. During this year parties were organized to survey for a line of Railway from Ruk towards Dadur. Before they got into the field, however, a prohibition to proceed beyond the frontier was received. The strength of the parties was thereupon reduced. Two lines were surveyed, the one from Ruk *viâ* Shikarpur and Jacobabad to the frontier, 50 miles, and the other taking a more northerly direction from Shikarpur towards Ghurrie Hussan, about 41 miles. The work was recorded, but no action taken on it.

1877-78.

Excessive rainfall at Shujabad and Laki.

140. During this year two excessive falls of rain occurred over limited areas which affected the works of the line. The first to be noted was on the 7th and 8th September in the neighbourhood of Shujabad, where 33 inches were registered in 24 hours. This heavy fall caused a sudden accumulation of flood water, which breached the line in 23 places, and destroyed most of the buildings at the Shujabad Station. 680 lineal feet of waterway were inserted in the line, and the Shujabad buildings restored with burnt brick; the walls of original buildings having been entirely of sundried brick. The other fall referred to occurred on the 3rd and 4th September at the Laki hills, where the rain fell at the rate of 2 inches per hour for several hours in succession. This was on the whole rather a fortunate occurrence, as it afforded a useful lesson in the nature of the side and cross drainage required in these cuttings. The accumulation of water was so rapid, that a train of earth wagons standing in one of the cuttings was swept out by the force of the water, and shot over the embankment beyond the cutting. A complete project for drainage, subsequently carried out, was prepared, by which all danger from the recurrence of such a heavy fall of rain would, it was believed, be averted.

Floods insignificant.

141. With these exceptions very little rain fell during the year, and the floods which came upon the line from river spills were insignificant.

Unusual freshes in the Sutlej during the dry season.

142. After the cessation of the rains and throughout the dry season a succession of quite unusual freshes occurred in the Sutlej River, which caused great trouble and anxiety on the works of the bridge.

143. It has been noted above that in November 1874 a complete estimate for the line (5′ 6″ gauge) described as Colonel Peile's estimate, had been submitted to the Director of State Railways. It happened, however, that the submission of the document to Government, deferred from time to time from various causes, had not been effected up to the time now under review. In the interim various unforeseen extensions of the works, such as the desert deviation below Bahawalpur and additions to flood openings, had been undertaken, and the estimate no longer represented truly the total probable expenditure on the line. As, however, the document in itself was complete, the Government consented to accept it, *quantum valeat*, a Supplementary Estimate being promised to include all the works not provided for in it.

Revision and submission to Government of Colonel Peile's estimate.

144. In the interval which had elapsed, various new rules had been issued for exhibiting the heads of expenditure, *e. g.*, Telegraphs, instead of forming a separate heading, were to be included under Construction of Line, Contingencies were to be included in Establishment, &c., &c. A re-distribution of these items, without any alteration of the amounts involved, was made in the estimate. A separate estimate in detail for rolling stock, amounting to Rs. 69,73,322, had been recently submitted and approved, the provision in the original estimate having been Rs. 35,10,000 only. The amount of this accepted estimate was adopted. Lastly, the amount likely to be demanded for the Indus bridge at Sukkur appeared so uncertain, that it was thought best altogether to exclude provision for this work, and the sum of Rs. 29,42,763 entered on this account in the original estimate was struck out.

Redistribution of amounts necessary.

Rolling Stock estimate.

Indus bridge omitted.

145. These re-distributions and alterations having been made, the estimate accepted by Government stood as follows:—

Estimate as now revised.

	Rs.
Preliminary Expenses, ...	9,77,468
Land, ...	1,90,974
Construction of Line, ...	2,31,28,129
Ballast and Permanent Way, ...	1,75,04,612
Stations and Buildings, ...	38,86,980
Plant, ...	14,31,400
Rolling Stock, ...	69,73,322
Establishment, ...	60,40,532
Grand Total, ..	6,01,33,417

against Rs. 5,96,12,858 in the estimate as originally presented. At the same time the Director reported that after as close enquiry as was at the time possible, he estimated that an additional sum of Rs. 80,00,000 would be required for the Supplementary Estimate, still excluding the Indus bridge.

146. The traffic undertaken in the previous year on account of the Scinde, Punjab and Delhi Railway Company between Mooltan and Makan Bela was not resumed in this year. The down river grain traffic having ceased, the Company had

Goods traffic Mooltan to Makan Bela not resumed.

not sufficient freight to keep their own steamers employed, and had no need to use the rails of the Indus Valley State Railway.

Principal works still in hand.

147. The interest of this year lay chiefly in the completion of the three large works, the Sutlej bridge, the viaducts over the Indus spills above Sukkur, and the Laki cuttings. A great deal of work of all sorts was, however, done on the line generally, in finishing up the lesser masonry works, fitting stations, platelaying, providing staff quarters, &c.

Progress made during 1877-78.

148. The following narrative describes in some detail the progress made in the works during the year 1877-78.

Progress in the Shujabad and Bahawalpur Divisions.

149. In the Shujabad and Bahawalpur Divisions, now united under one Executive Division, about 25 lakhs cubic feet of earthwork were executed in restoring the bank where damaged by the heavy rainfall. The small quantity of masonry required to complete the bridging was done: $7\frac{1}{2}$ lakhs of cubic feet of ballast were collected, making a total of $45\frac{1}{2}$ lakhs cubic feet out of $63\frac{3}{4}$ lakhs cubic feet required. The ballast was laid on the first 19 miles from the junction with the Scinde, Punjab and Delhi Railway line at Mozufferabad, 6 miles from Mooltan, on miles 42 to 52 and $63\frac{1}{2}$ to 101. The remaining lengths were only partially ballasted. The platelaying of the 14 miles to complete the Divisions was done, making 144 miles in main line, sidings and branches. The Ooch and Makan Bela branch was dismantled, and the permanent way material recovered from it sent on to the Upper Scinde District. With the exception of the Shujabad station, which had been destroyed and was in course of reconstruction, all the station buildings were complete, including their machinery. The roofs of the engine sheds, the framing for which had not yet arrived from England, were however incomplete.

Ooch and Makan Bela branch dismantled.

Sutlej Bridge Division, main line.

150. On the part of the main line in the Sutlej Bridge Division, all works including platelaying were complete.

Sutlej Bridge.

151. At the Sutlej bridge the well sinking was completed in August, and the superstructure of the 11 piers remaining incomplete at the close of 1876-77 was finished in February of this year.

Delays in obtaining ironwork from England.

152. It has been mentioned above that contracts had been entered into with two firms in England for the manufacture of the girder ironwork. The first delivery was to have been made in December 1876, and prompt shipment, it was thought, would bring to site at Adamwahan 3 or 4 spans at a date which would permit of their erection before the inundation season of 1877-78. The Contractors, however, did not keep to their time, and there was some difficulty about shipment, which delayed the deliveries in India till so late a date that this expectation was disappointed. The staging, which had been erected, had to be taken down again.

153. The inadequacy of the Scinde, Punjab and Delhi Railway Flotilla to transport the material now became more than ever apparent, and representations were made to Government, which resulted in the ironwork for 9 spans being sent to Bombay and Calcutta instead of to Karachi, so that they might reach their destination by railway. The results attained fully justified the extra expense incurred in this arrangement, without it the ironwork would not have been brought to site till long after the setting in of the inundation season of 1878-79, and the completion of the bridge and opening of the line to traffic would probably have been deferred for a year, and the line would not have served to assist, as it so materially did, in the transport of troops and stores to Sukkur for Kandahar for the expedition against Afghanistan.

Inadequacy of Scinde, Punjab and Delhi Railway Flotilla.

Nine spans ordered *vid* Bombay and Calcutta.

154. In Appendix C, attached to this Report, will be found a description of the method of dealing with the erection of the ironwork, and also some observations on the temporary bridge and protective works. The ironwork began to arrive only in November. By the end of March 13 spans had been completed, and the remaining 3 were finished in May. A very successful season's work, both in regard to the mere weight of material lifted and fixed, and to the peculiar difficulties which had to be overcome, chiefly in the erection of the last 3 spans, a description of which will be given under the year 1878-79. A map is attached, extracted from the Annual Report, showing the condition of the river on the 28th March 1878.

Progress in erecting ironwork.

Map of the Sutlej River.

155. In the Khanpur and Reti Divisions 21¼ lakhs cubic feet of earthwork were executed in the 10 miles, by which the desert deviation was extended southward from Khanpur, undertaken during this year. The masonry works in bridges were completed. Ten lakhs cubic feet of ballast were collected, raising the supply to 44 lakhs out of 64 required. The platelaying was completed. The new station building at Firoza was completed, and that at Khanpur well forward; at this station staff quarters were built, and the engine shed commenced. The station machinery was also completed.

Progress in the Khanpur and Reti Divisions.

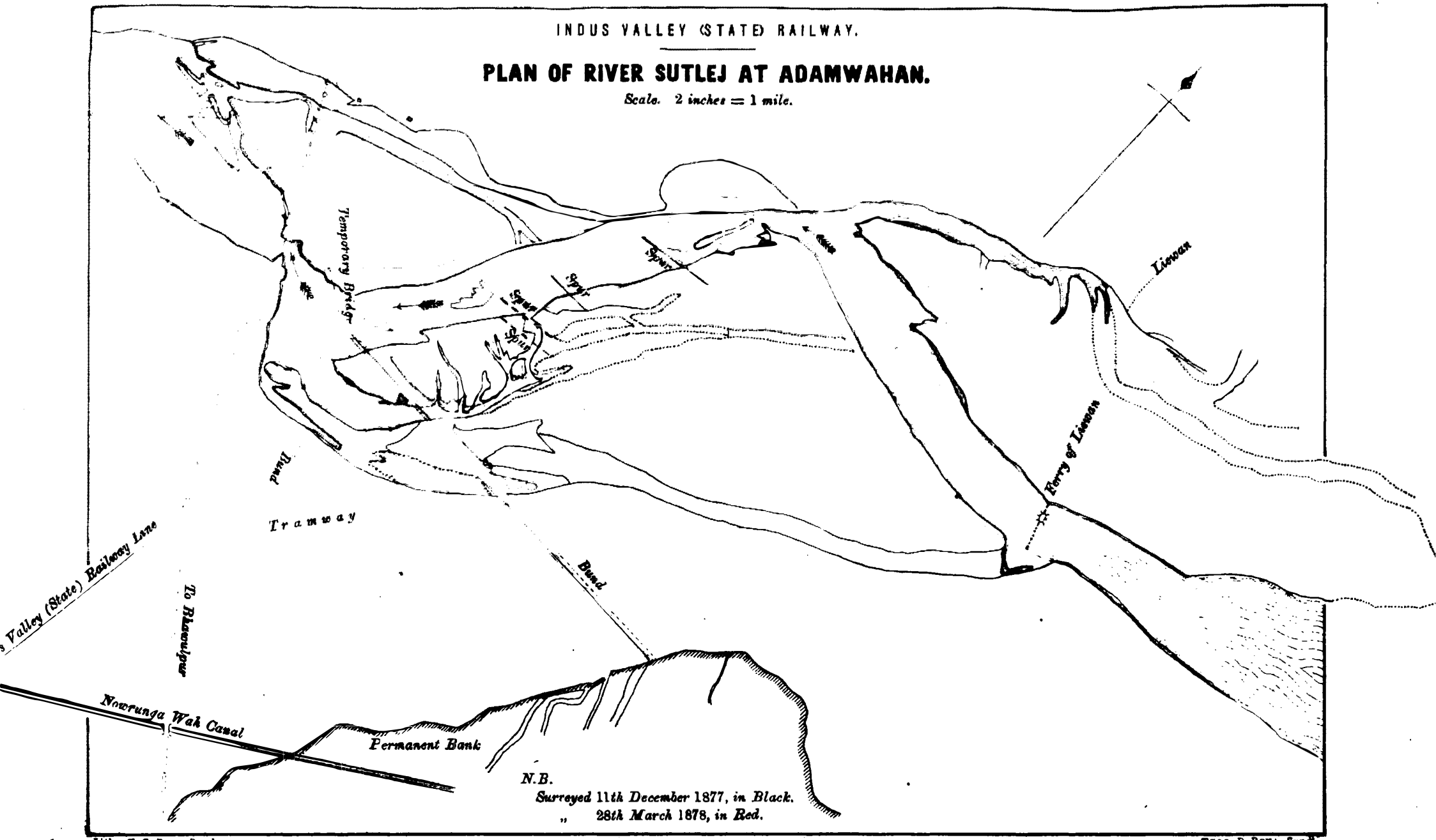
156. In the Ghotki Division 192 lakhs cubic feet of earthwork were executed, completing the bank. Eighteen lakhs cubic feet of concrete and brickwork were executed, bringing to completion all but 7 of the bridges, which were well forward and were completed in May. Nearly 13 lakhs of cubic feet of stone for protecting the bridges were put in place during the year. Of the 40 lakhs of cubic feet of ballast required, only 8·8 lakhs had been provided. As before mentioned, stone from Rohri was to be used throughout this Division, and could be carried out only when the carriage of bridge material should be completed. The metre gauge tramway was dismantled, and the 5 feet 6 inch track substituted. The station buildings and their fittings and machinery were all complete.

Progress in the Ghotki Division.

INDUS VALLEY (STATE) RAILWAY.

PLAN OF RIVER SUTLEJ AT ADAMWAHAN.

Scale. 2 inches = 1 mile.



N.B.

Surveyed 11*th December* 1877, *in Black.*

„ 28*th March* 1878, *in Red.*

Litho. T. C. Press, Roorkee.

No. 254.

THOS. D. BONA, *Supdt.*

157. The revision of the estimate for the Indus bridge was made, but nothing further done towards advancing the project for bridging the Indus. In the meantime it became necessary to organize a steam ferry, in connection with which a quay was constructed on the Sattian island, which could be approached by steamers at all seasons of the year, and which was connected with the main line run down to the quay wall constructed in the previous year along the Rohri bank. A small steamer and some flats were purchased from the Bahawalpur State, and negotiations commenced for the hire of one of the large steamers of the Scinde, Punjab and Delhi Railway Flotilla.

Progress in the Indus Bridge Division.

158. In the Larkana Division the embankments were completed and also the masonry works of bridges, excepting of that over the Ghar canal, which could not be laid dry to permit of a commencement of the foundations until a late date. This bridge was completed in June. Thirteen-and-a-half lakhs cubic feet of ballast were collected out of the 47 lakhs cubic feet required. Platelaying was completed with exception of a gap of 6 miles in length, closed in shortly after the end of the year. The stations were complete except at Sukkur, for which a final project was still required. Some blocks of staff quarters were built at Sukkur. The watering arrangements were complete only at alternate stations. A station was established at the river side at Sukkur.

Progress in the Larkana Division.

159. In the Mehur Division the earthwork and bridging were completed and the metals laid. Thirty-one and three-quarter lakhs cubic feet, out of 35¼ lakhs cubic feet of ballast, were collected, 19¾ being this year's work. The stations were all completed in essential requirements.

Progress in the Mehur Division.

160. The following extract from the Annual Report narrates what was done in the Sehwan Division:—

Progress in the Sehwan Division.

"The main feature in this Division is the Laki Pass, which is a heavy work. The line runs for "some miles through and around the hills overhanging "the Indus between Sehwan and Laki. This align- "ment has led to difficulties greater than appear to have been anticipated, and of which we have pro- "bably not yet seen the end. Everything possible has been done to expedite progress, but the hard- "ness of the rock in some places; its mixture with "sandy or shaly strata in others, which induces slips; "the intense heat from reverberation, which causes numerous deaths from sun-stroke and fever; as also "the unusual depth of the open cuttings, have, with other circumstances, tended to protract operations "long beyond the calculated date.

Difficulties in Laki Pass.

"The permanent way was laid on formation through a narrow gullet in all the cuttings of the Pass, "except two, so that material trains were enabled to pass through in October. At the two cuttings re- "ferred to, diversions were laid round the face of the cliff, and by these means permanent way and other "materials for the line up to Larkana were passed for- "ward to the platelaying head. This operation was "completed at the end of January, and there being then no further immediate prospect of through traffic, "the Pass was closed in order that the cuttings might be enlarged to the proper dimensions. But for the "time thus lost, it is possible that the gullet cuttings would be now finished, but no other course could "be followed under the circumstances, having due regard to the general progress of the line north of "the Pass. As it is, there is every probability of both gullet and diversion cuttings being finished by

Diversions round cuttings.

"the end of June. In order to ensure this end some modifications have recently been introduced, "which will result in a material saving.

"During September a heavy local rainfall occurred on the hills, which suddenly brought down vast "bodies of water on the line. Masses of boulders and gravel were swept along the rock and poured on "to the line, choking the insufficient culverts provid- "ed; in some cases burying them beyond reach.

Destructive fall of rain.

"The streams poured into the cuttings, which are on a gradient of 1 in 150; down this slope the "water flowed of course very rapidly, filling the cuttings from side to side to the depth of several feet, "and finally bursting over the heavy embankments at the lower ends, sweeping them away, and carrying "among other things a number of tip wagons over the cliff into the valley below. A project is in hand "for improving the drainage so as to prevent the recurrence of similar damage. If approved, it should "be carried out before trains are allowed to run, as work in the Pass can scarcely be attempted with "safety while traffic is going on. The project will consist of catch-water drains on the hill side, culverts "in the rock under formation, diversions of hill torrents, and paved water channels down the slopes of "all earthen embankments. When the cuttings have attained their full sanctioned width at formation, "so as to admit of proper side drains, it is hoped that with the proposed new works, the line through "the Pass will be tolerably safe.

"Exclusive of the Laki Pass, the Sehwan Division comprises works of some importance—as for in- "stance, the Sann bridge, 23 spans, and the Aral bridge, "8 spans of 40 feet, besides others of less dimensions.

Large bridges in the Division.

"Both stone masonry and brickwork have been used in bridges and other buildings.

"On either side of the Pass the country is level, but the works on the whole are considerable. * * * * * * * * * *

"The amount of earth and rockwork executed amounts to 1,442¾ lakhs cubic feet, of which "182¾ lakhs were done during the year. The work is "likely to be practically finished by the end of June, "exclusive of trimming and dressing to be done after the ballast is laid. * * * * * * * * * * *

Earthwork.

"The amount of masonry and brickwork in bridges on the Division, including concrete, is "20¾ lakhs of cubic feet, of which 7 lakhs were done "during the year. All the bridges, major and minor, "are finished. * * * * * * * * * * *

Masonry.

"The ballast is almost all of stone, and at 12 cubic feet per foot forward would amount to 36½ "lakhs cubic feet, which is all manufactured. The "Division is partially ballasted almost the whole way "through, and much of the boxing has been laid down south of, and in, the Pass. * * * * * * * * * * *

Ballast.

"The platelaying, with the exception of 5 miles laid previously, has all been executed during "the year, and the road throughout made passable for "trains. It has been maintained in fair order. Steel "rails have been used in the Laki Pass." * * * * * * * * * *

Platelaying.

The station buildings in this Division were completed with their machinery.

Station Buildings.

161. In the Kotri Division the group of Manjho Nai bridges, unfinished at the end of the previous year, was completed, the line was fully ballasted, the stations, with exception of the junction arrangements at Kotri, were all completed.

Progress in the Kotri Division.

162. To the one tender engine and 26 low-sided wagons provided in the previous year on this Division, an addition was made to the rolling stock of 3 tender engines, 100 covered goods and 100 platform wagons and 4 brake-vans.

Rolling Stock on Lower Section.

163. At the close of this year it will thus be seen, with the exception of the Sutlej bridge, of a gap of 6 miles in the Larkana Division, and of a part of the Laki cuttings, the line was ready to be opened for traffic, and this was effected early in the next year.

General condition of the line approaching completion.

164. The following extract from the Annual Report describes what was done in surveying routes to connect the Bombay and Rajputana Systems with the Scinde System at Hyderabad:—

Eastern Extension Surveys. Hyderabad towards Bombay and Rajputana.

"Orders were received early in November 1877, to organize four survey parties to explore alterna-
"tive routes for a line of railway to connect the Bombay and Rajputana Systems with the Scinde System
"at Hyderabad.

"Towards the end of November 1877, the officer appointed to charge of the surveys took the field,
"but it was a considerable time before the whole of his staff, consisting of 10 Officers and 6 Subordinates,
"could be assembled to join him, many of them being engaged upon construction works, which they
"could not quit suddenly. Late, as was the beginning, in being made, considering the burning and
"desert nature of the country to be explored, nevertheless all the results that could be expected were
"achieved before the parties left the field and went into recess at Karachi.

"The direct route *vid* Omerkote and Deesa appearing impracticable, owing to its direction being
"crossed obliquely throughout the desert, which stretches between those two places by lofty ridges of
"sand hills, attention was devoted to the only promising route north of the Runn of Kutch, that skirt-
"ing its northern edge, and then crossing it *vid* Nuggur Parker to Pahlanpur, and the Kachh Booj
"route *vid* Luckput and Bachow to Lilapur.

"The preliminary surveys and sections of both these routes, the former 294¾ miles, the latter 351¼
"in length, were completed, and all necessary information obtained to enable approximate estimates of
"the cost to be made out."

1878-79.

165. This year witnessed the completion of all of the important works of the line to such an extent as permitted of its being opened throughout for traffic. A good deal, however, still remained to be done to complete the line in all respects.

Whole line opened for traffic.

166. The Sutlej bridge was completed and tested on the 22nd and 23rd May, and was officially opened on the 8th June by the Honourable Member of Council for Public Works, by command of the Viceroy, and with the gracious permission of Her Imperial Majesty was named the "Empress' Bridge." The published account of this official ceremony will be found in Appendix A to this Report.

Sutlej Bridge officially opened and named the Empress' Bridge.

167. On the 1st July the line was opened for public traffic from Mooltan (Mozufferabad Junction) to Rohri, 272 miles. Insufficient rolling stock prevented the simultaneous opening of the Lower Section from Sukkur to Kotri, but this delay proved fortunate in the sequel, as during August a flood occurred severer in character than those experienced in 1874 and 1875, which damaged the line to such an extent in the neighbourhood of Sehwan, that despite the utmost efforts of the Staff, communication was restored only on the 27th October, when public trains at once began to run through from Kotri to Sukkur. On the 1st of the month

Opening of line, Mooltan to Rohri, 1st July.

Opening of line, Sukkur to Kotri, 27th October.

a partial opening had been made from Sukkur to Radhan, and on the 8th from Kotri to Laki.

Interruption to traffic by breaches from floods.

168. Traffic was also interrupted for 30 days on the Northern Section by a heavy flood during August, breaching the bank in several places below Khanpur at a part of the line never before attacked by heavy spills. Happily everything was restored to such an extent as made the line available in time for running the Troop and Commissariat trains for the Quetta Column early in November.

Report on floods of 1878.

169. The following extract from the Engineer-in-Chief's Report gives an account of the extraordinary floods which occurred during this year:—

"The floods in the Indus Valley in 1878 were the most remarkable on record, and were accom-
"panied by extraordinary rain storms which, although they caused some local damages and delays to
"traffic, did, on the whole perhaps, more good than harm by consolidating the embankments before the
"pressure of the floods came.

"The Mooltan Division escaped without damage. The discharge of the Sutlej was moderate
"throughout the season, and the training and protective works at the Empress Bridge were in no way
"damaged or threatened.

* * * * * * * * * *

"The spills from the Indus on the left bank extended continuously from mile 176 to 271, with the
"exception of a few hundred yards of dry ground here and there at sand hills, &c., causing extensive
"damage from 153 to 203 miles, and at Sangi at the 260th mile. Damage was afterwards done at
"Sehwan by the spills which had passed through the Kusmore bund on the right bank.

"A breach of 3,200 feet wide occurred in this bund on 14th July, and by 29th August the numer-
"ous breaches had increased to an aggregate of 10,170 lineal feet. * * * *

Khanpur Division.

"The inundations on the Khanpur Division came chiefly from the Indus left bank, and although
"the Chenab rose to an unprecedented height also,
"the Bahawalpur State bund stood well, and pro-
"tected the line above the 153rd mile from inundation.

"The flood reached the line at the end of July. * * * * *
"By the 10th August the line was so damaged by ripples washing the slopes north of Naushahra,
"that traffic was stopped; on 14th the bank was breached at 158 miles, and by the 22nd there were
"thirteen large breaches with rapid currents flowing through the bank in a length of 25 miles, from
"153 to 178 miles, besides much damage to the slopes and bridge approaches. * * *
* * * * * * * The floods reached their greatest
"height on the 24th August, remained so for three days, and then began to fall rapidly. Traffic had to
"be suspended from Khanpur to Reti, the mails being sent through by trollies and boats.

"The break in communication had by great exertions been reduced to two-and-a-half miles by 6th
"September, and trains ran through again on 13th September.

"The flood extended without break to Rohri. The slopes were much damaged, and heavy scour
"took place at many bridges, but the only place where there was serious difficulty in maintaining com-
"munications was at Sangi, where the rush through bridges Nos. 61 to 65, each being two spans of 40
"feet girders, was so great, that the embankment continued slipping into the great scour holes on the
"down-stream side, and could hardly be kept above flood level with stone brought up by train.

* * * * * * * * * *

Larkana Division.

"On the Larkana Division, from Sukkur to Madeji was exposed to considerable danger in the latter
"half of July from the Laki-Abad flood spill. The
"banks of the Sind canal, 18 miles above Sukkur,
"were extensively breached; the flood crossed the Shikarpur road, breaching it in several places, and by
"the middle of July had breached the Sukkur canal, and stood with a difference of level of 3 feet against
"the railway bank at mile 289. A breach took place here which was fortunately closed again instantly,

"before the rush through had gained the mastery; and no other very serious damage was done. There "was heavy scour at the Ruk bridge and others, but not enough to cause anxiety, and the thick jungle "of this part of the country prevented much damage being done to the slopes by waves on any consi- "derable lengths.

"The Jalli bund was not breached by the river in 1878, and it consequently kept any direct spill "from the Indus out of the area enclosed between it and the railway bank; the Laki flood discharged "through the Ruk bridge until this area became filled up, when the height of the water on each side "of the railway became nearly the same and higher than the Indus. The discharge then was through "the Ruk bridge from right to left, and through bridges at 300 to 307 miles from left to right. The "water was thus much confined between the Sind canal bank and the Jalli bund.

* * * * * * * * * *

"Numerous damages to the railway, caused by the floods in July, were being repaired, and the line "got into fair running order, when the Kusmore flood came down, rose to a maximum and unprecedent- "ed level of 119·00, or 2 feet higher than any pre- "viously recorded flood. The waterways immediately "north of Sehwan proved quite insufficient, and on 17th August four great breaches were made in the "bank between 408th and 410th miles.

Kotri Division.

"The depth of the inundation and the flow through the gaps would have prevented anything effectual "being done to get engines past these breaches before the end of September; but it was also deemed "unsafe to attempt to force any more water through the bridges by closing the gaps, for the piers of the "Kara-Fitta bridge had moved alarmingly in different directions and were thought to be in danger.

"Work was not begun therefore until 1st October, and trains were not able to pass over the diver- "sions until 23rd October. * * * * * * *

"The experience of this season goes to show that nothing can be done to close large breaches while "the floods are high, and the water running strongly through them, and any temporary bridging through "the flood, if possible at all, could not be got ready sooner than the probable subsidence of the flood. "In fact no reliance can be placed on unlimited materials, money, and skill and devotion on the part of "the Staff to restore communication over large breaches during the floods.

"Another lesson learned was that, during the floods the safety of the line in all places where the "slopes are not pitched or protected by very thick jungle is wholly dependent on the absence of high "wind. A moderate breeze continuing for two days would certainly destroy the embankment in any "open flooded place. In 1878 the line was particularly fortunate in experiencing calm weather on the "whole."

* * * * * * * * *

170. The critical condition of the Railway in seasons of inundation, and the anticipation that the spill over the left bank of the Indus would be seriously increased when certain works of reconstruction and restoration at the Kusmore bund should be completed, and the spills on that side be in consequence arrested, led the Government to call in the services of Major J. G. Forbes, R.E., who had acquired experience in the phenomena of large Indian rivers. This officer's report will be found *in extenso* in Appendix B. The recommendations were accepted by the Government, who agreed to the provision of a considerable increase to the ventage for inundations between Khanpur and Rohri and at Sehwan.

Major Forbes' recommendation to increase ventage for floods agreed to.

171. The line having been opened, a statement was called for of all the works remaining incomplete on the 31st October. An officer was officially appointed to the task of preparing this, but he was unable to complete his work until after the close of the year. The general result is shown in the following figures, which

Statement of works remaining incomplete after line was opened to traffic.

include all the extra flood openings proposed, but exclude the Indus bridge with its approaches, as the project for that work is still incomplete* :—

Head of Service.	Provision in Colonel Peile's estimate.	Expended up to 31st October 1878.	Estimated amount of incomplete work.	Gross cost of Railway.
	Rs.	Rs.	Rs.	Rs.
Preliminary Expenses, ...	9,77,468	6,28,288	1,000	6,29,288
Land, ...	1,90,974	1,57,923	67,200	2,25,123
Construction of Line, ...	2,31,28,129	1,90,18,412	92,81,156	2,82,99,568
Ballast and Permanent Way, ...	1,75,04,612	1,47,22,228	17,27,269	1,64,49,497
Stations and Buildings, ...	38,86,980	24,35,757	28,31,177	52,66,934
Plant, ...	14,31,400	13,43,458	1,62,403	15,05,861
Rolling Stock, ...	69,73,322	31,61,998	40,48,097	72,10,095
Establishment, ...	60,40,532	62,92,954	17,31,390	80,24,344
Total, ..	6,01,33,417	4,77,61,018	1,98,49,692	6,76,10,710

Re-arrangement of Executive Staff and Divisions.

172. A new organization of the Executive Divisions was introduced: they were re-distributed so as to suit the requirements of maintenance under Revenue. The office of Engineer-in-Chief was retained, but the Superintending Engineerships were abolished at the close of the year. The new Executive Divisions were :—

Mooltan Division, ...	Mile 0 to 113
Khanpur „	„ 113 to 221½
Sukkur „	„ 221½ to 303
Larkana „	„ 303 to 402
Kotri „	„ 402 to Kotri.

Appointment of Revenue Staff and general control vested in Consulting Engineer, Lahore.

173. Preparatory to the opening of the line, a Manager and Traffic Superintendent were appointed in May, and other Revenue Staff was arranged for, to which additions were rapidly made as the nature of the increasing business demanded. At the close of the year the control of the line passed from the Director of State Railways, Western System, to the Consulting Engineer to the Government of India for Guaranteed Railways, Lahore.

Proposal that the Scinde, Punjab and Delhi Railway Company should work the traffic of the Indus Valley State Railway.

174. At a Conference held at Lahore in November, a proposal was made by the Honourable Member of Council for Public Works to the Officers of the Scinde, Punjab and Delhi Railway Company, that they should take over the working of the traffic of the Indus Valley State Railway. The officers of the Company were obliged to refer to their

* This Estimate contains an item of Rs. 9,45,223, or 5 per cent. on the amount of "requirements to complete" to provide for further unforeseen works. This is necessary, and the amount has been added to the three items of "Construction of Line," "Stations and Buildings," and "Rolling Stock," in following proportion, viz.:—

Construction of Line, ...	Rs. 5,42,855
Stations and Buildings, ...	„ 1,65,595
Rolling Stock, ...	„ 2,36,773
Total Rupees, ...	9,45,223

Board of Directors before making a reply, but it was generally understood that an arrangement to this effect would be come to.

Narrative of progress in works during 1878-79.

175. The following narrative tells of the principal works executed during the year.

In the Mooltan Division.

176. In the Mooltan Division the extra flood openings, commenced in the previous year, were completed. All the stations were completed in all respects. Eleven and three-quarter lakhs of cubic feet of ballast were collected, bringing the total up to 56½ lakhs collected out of 82⅓ lakhs required.

Progress at the Sutlej Bridge.

177. The following extract from the Annual Progress Report narrates what was done at the Sutlej bridge, of which some additional details will be found in Appendix D.:—

"At the end of last financial year the works of the Division were complete with exception of the "bridge itself and its protective works. In the bridge at the beginning of the financial year all neces- "sary masonry was finished, 11 spans of the girders were complete, and 2 were under erection, 2 more "in course of arrival, and 1 had not left Kotri.

"In two of the uncommenced spans the river ran with a channel varying from 46 to 58 feet in "depth, and in the deeper of these a pile staging, erected under difficulties unexampled in this country, "had already been constructed from spars of about 70 feet in length driven into the river bed. The "base of the left bank protection bund was in hand up to within 1,500 feet of the left abutment, and "its end was connected by the third temporary bridge of that season with the right bank sand spit.

"To relieve the pressure of immediate freshes, and with an ultimate view to diverting the whole "river in the flood season, two canals, each 150 feet wide, had been cut through this spit as described "in last year's Progress Report, bnt were bunded up at the ends to prevent silting.

"By the 16th of April the 13 spans of girders then in hand were all completed, and the stage at "P, Q, was ready with its upper stage to receive the girders, when a sudden fresh in the river was tele- "graphed from Phillour, and work was suspended till its passage at midnight of Good Friday, April "19th. This fresh, or rather flood, culminated with a rise of 5⅓ feet, which would probably have reached "7 feet, but for the relief afforded by cutting the canal buuds.

"In spite of the completeness of our dispositions, there was necessarily a most serious sense of "anxiety, as the loss of the stage would have deferred the completion of the bridge for nearly a whole "year, and would have involved a very heavy loss of money and material.

"Fortunately all held good, and by the 22nd of May the whole bridge was completed and tested "by the Consulting Engineer for Guaranteed Railways, Lahore, in a manner equally satisfactory to the "designers and the erectors.

* * * * * * * * *

* * * * "The bridge was declared open for traffic on the 8th of "June, and by the end of July the left bank protection bund was completed. The completion of this "bridge in a year less than the estimated time, and in point of fact sooner by some weeks than the "through line to Kotri, is a source of great pride to the officers concerned, and the more so as the "bridge has been most useful for the conveyance of troops and stores for the Kandahar Force by rail.

"As a foot bridge it has been utilised by cavalry, by elephants, and by great numbers of camels "carrying Commissariat stores. It is a pity that means for opening it permanently for ordinary camels "and other pack animal traffic are not adopted, as these still have to use the ferry. For foot passenger "traffic I have proposed a way along the top of one of the girders, for which a design and estimate "of cost (which is small) have been submitted. I believe it would pay well and prove a great conveni- "ence to the public.

"When the floods of the year culminated in August, the canal cuts through the sand spit amply "fulfilled their ultimate purpose, and diverted the deep stream from its oblique crossing at piers O, P, "and Q, into one which ultimately lay in the centre of, and nearly at right angles to, the bridge.

"The spans where the 70 feet piles were used are now quite silted up. The bay of 1876, which so "nearly outflanked the bridge, now bears a luxuriant crop of brushwood, and so thoroughly was the river "diverted from the bund, that the protective materials of the year are still high and dry, and have obvi- "ously not been undercut at all except at the pier head. The accompanying Map shows the position "of the river at this date.

* * * * * * * * *

178. The following extract from the same Report describes the works of a permanent character undertaken for maintaining the river in its course in approaching the bridge:—

River Conservancy works.

"The main south bank spur was commenced in February 1877, from the village of Meani on the "high ground, and by the following July, the beginning of the flood season, was advanced to a point 86 "chains from its starting point; the bund being constructed to a height of 5 feet above high water, "*viz.*, 385·00 Reduced Level, and carrying a broad gauge tramway. This tramway was connected with "the main line at mile 55 by a branch tramway 84·48 chains long, raised so that rail level stood at "Reduced Level 384·00. No difficulties were encountered in the construction of the above, except at "the crossing of the first dhund or old river bed, which consumed 4,00,000 cubic feet of earth-filling. "The total work done before the floods of 1877 was as follows:—

Earthwork,	..	..	..	..	..	..	35,56,000 c. feet.
Fascine protection,	..	..	..	..	..	..	3,00,000 sq. „
Willow plantation,	..	..	..	..	..	..	3,40,000 sq. „
Cube protection,	..	..	..	..	..	..	3,57,236 c. „
Stone protection,	..	..	..	..	..	..	1,04,391 c. „

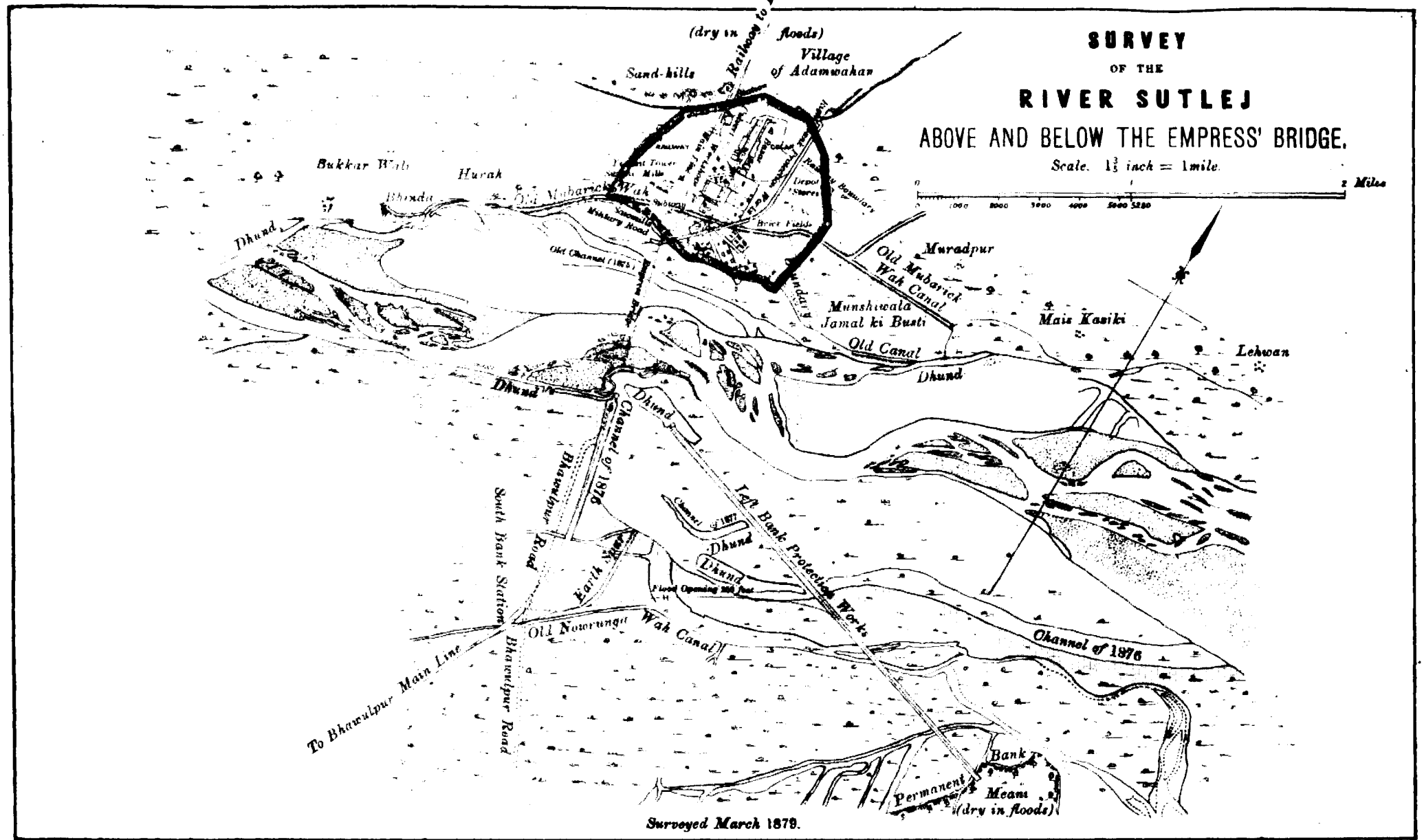
"During the flood of 1877 the temporary head of the bund, which had been protected by about "1,04,000 cubic feet of stone, was attacked by the river, and the stone at the immediate head, as well "as the protection on the face of the bund for 200 feet from it, settled down, and was rapidly replaced "by a fresh supply to the amount of about 20,000 cubic feet, till settlement ceased, when it was pos- "sible to sound stone at depth of 40 feet. After the flood had subsided, the cold weather stream ran "about 19 chains from the bund, under the head of which remained an arm of the river 400 feet wide, "and 27 feet deep in the middle. In October 1877 work was commenced, and pushed on vigorously; "but serious difficulties were encountered in closing the branch of the river just mentioned. Three or "four times unexpected freshes temporarily re-opened it, and carried away the new earthwork. Finally "a temporary pile bridge carrying the line of rails was constructed across it, and the gap rapidly filled "from the wagons of an earth train shunted on to the bridge. Though the unexpected rises in the "river had kept back the work as explained, they afforded an opportunity of pushing the bund still "further towards the bridge. Previous to the rises the prolongation of the bund had been projected "up to a point on the edge of the stream which was on the convex or cutting bank of a bend, this point "being temporarily secured against the cutting action by ample protection transported in boats. The "effect of the rise was to cause the river to cut straight across the chord of this bend, which latter it "at the same time silted up. Without loss of time the point where the centre line of the bund inter- "sected the new edge of the stream was made safe, and connected to the point formerly secured by a "strong line of cube protection transported in boats.

"Thus the present bund head was secured in 1878 at a distance of 117 chains from its starting "point, and about 18 chains from the bridge, and the entire new part of the bund raised to the Reduced "Level 374·50 by the end of the official year 1877-78. Thus at the beginning of the present official "year the work to be done was—

"(1). Raising the height of the new 31 chains of the bund from 374·50 to 385·00.

"(2). Depositing cube and stone protection along the same.

"(3). Protecting the rear slope of the same with fascine work and willow plantation.



Litho. T. C. Press, Roorkee.
No. 254.
THOS. D. BONA, Supdt.

"It was necessary that the new part of the bund should be, if possible, completed by the middle "of July. This involved the execution of work to the following extent:—

Earthwork, ...	28 lakhs c. feet.
Cube and stone protection, ...	10 „ „
Fascine protection, ...	2,40,000 s. feet.

"The earth had to be entirely brought to site by train, and was borrowed from the high ground in "front and rear of the bund close to Meani. The material for protection was brought from Hamdi, "Channi Gote, Mubarakpur, Lodhran, Gilawala and Adamwahan, and as many as four trains daily "were employed in its transport. Before the first flood arrived, July 2nd 1878, the stone and cube pro- "tection was nearly all at site, and the earthwork practically completed. Previous to the floods the new "bund head was frequently attacked with great force, and the stone was known to have settled down "30 feet below low water. The quantities of work executed up to July 31st 1878 were as follows:—

Earthwork, ...	78,39,216 c. feet.
Stone protection, ...	3,31,141 „
Cube protection, ...	13,68,091 „
Cube reserve, ...	1,14,484 „
Stone reserve, ...	98,000 „
Fascine and willow plantation, ...	4,00,000 sq. feet.
Extra stone protection in bnnd head, ...	85,100 c. feet.

"The river, which had risen to 375·30 on 2nd July, continued in flood till the middle of September, "the least gauge reading during the time being 373·40 on July 23rd, and the highest 379·60 on August "26th. At the commencement of the flood the bund head was slightly attacked, and slight settlement "of the material in front of the bund, about a chain behind the head, took place; but excepting this, "little or no action occurred, and the river steadily advanced its main stream towards the right bank, "leaving the bund head in comparatively slack water.

"From the very offset it was apparent that the canals constructed for relieving the discharge of the "main stream described in last year's Report were fulfilling their purpose admirably, and the spans OP, "PQ, which at first discharged nearly the whole river, were gradually relieved, and eventually began to "silt up rapidly.

"It was, however, by no means as relieving channels only, that these cuts did work. They appeared "to assist the action of the river wonderfully in its continued attack on the sand bank through which "they were cut, and the heads of both rapidly approached the bridge. The first canal had vanished by "the middle of July, and gave place to the river, the second was also absorbed by the river for about "half its length, and the remainder of it was choked by a deposit of silt 4 or 5 feet deep.

"As a proof that the river discharged itself through the bridge without any excessive scour or con- "traction of its channels, it may be mentioned that 30 feet was the deepest sounding found throughout "the length of the bridge, excepting just below spans OP, PQ, where 50 feet was sounded in dead water, "but this had been known to exist, being the result of the previous year's floods. At the end of this "year's flood season, the low water channel passed under the bridge between the spans IK, LM, and "since then it has shifted one span nearer to the north bank.

"Since the flood season the earthwork of the south bank bund has been finished, and 14·30 chains "of its length, previously protected by fascine and willows, has been secured by stone and cube protec- "tion from the reserve, so that assuming the present head of the spur the final one, it may now be said "that this work is complete.

* * * * * * * * * *

"In November last the right or north bank protective bund was taken in hand, and as no diffi- "culties whatever have interfered with its construction, it was almost, and would have been quite, com- "pleted by the end of the year, but that the rolling stock employed on the work has had to be tempo- "rarily taken away for urgent traffic purposes. As in the case of the south bank works, the main bund "has been provided with a tramway along its top, connected to the main line by branches, but so dis- "posed as to form the two legs of a triangle, of which the main bund is the third side. In the first 18 "chains from the high ground near the city of Adamwahan, the right bank bund is straight, in the next "16 chains it runs towards the bridge in a curve of 1,750 feet radius, and the remaining 16 chains are "in a straight line, making an angle of about 60 degrees with the centre line of the bridge. The pro- "tection has been thus disposed—

"(1). First 6 chains from the abutment 300 cubic feet of stone per foot run.

"(2). Next 10 chains about 200 cubic feet of cube.

"(3). Next 31 chains about 150 cubic feet of cube per foot run.

"(4). Last 4 chains about 200 cubic feet of cube per foot run, and as much stone as can be col-
"lected from all the old stone stacking grounds. The total quantities of work in the right
"bank protective works, which it is expected will be completed in the present financial
"year, are as follows:—

Rammed earthwork, ...	18,61,204	c. feet.
Stone protection, ...	2,14,000	„
Cube protection, ...	7,25,000	„
Permanent way, ...	1·80	mile.

"The total quantities of work in the protective works of both banks complete are as follows:—

Earthwork, ...	1,08,00,410	c. feet.
Stone protection, ...	7.85,142	„
Cube protection, ...	2,07,899	„
Fascine, ...	3,90,000	s. feet.
Willow protection, ...	4,80,800	„
Permanent way, ...	5·75	mile.

"The cost of left bank works including permanent way, which up till now has not been all debited "against the work, will be 7½ lakhs, and of the right bank works 2½ lakhs, or in all 10 lakhs. Out of "these total qnantities the following amounts have been executed in the official year 1878-79:—

Earthwork, ...	86,21,204	c. feet.
Stone protection, ...	4,41,850	„
Cube protection, ...	11,78,820	„
Fascine, ...	90,000	s. feet.
Willow, ...	90,000	„
Permanent way, ...	2·6	mile."

* * * * * * * * * *

Works in the Khanpur, Sukkur, Larkana and Kotri Divisions.

179. In the Khanpur, Sukkur, Larkana, and Kotri Divisions little remained to be done in important works at the close of the previous year. A good deal was done in completing buildings and station arrangements, and some advance was made in ballast collection. A commencement was also made in raising the embankments and flattening slopes determined on after the floods of July.

Laki Pass, not quite complete.

One cutting, No. 2, in the Laki hills was still incomplete at the close of the year, but was passed by a diversion. The drainage project for the Pass was completed during the year.

Designs for Indus Bridge.

180. Some advance was made in the project for the Indus bridge. The Consulting Engineer for State Railways visited England to confer with the Consulting Engineer there, and an Engineer was appointed to take further measurements and observations at Sukkur. The result it is believed may be a return to the site first suggested at Rohri, which offers the shortest span, 625 feet clear, in preference to that more recently advocated at the Hadji Motoo, to cross which a span of 786 feet was necessary.

Steam Ferry at Sukkur.

181. Pending a final decision about this bridge, the steam ferry above described is maintained at an expense of about Rs. 3,00,000, per annum.

182. The Survey parties who had been engaged in surveying from Hydera-

bad towards Bombay and Rajputana were occupied until June in recording their field work. While this operation was still incomplete, the parties were all transferred to the North-Western Provinces and Oudh, to assist in surveying for Famine works.

Eastern Extension Surveys.

183. Two alternative routes for a branch from the Scinde, Punjab and Delhi Railway at Karachi to the Mooch Salt works were surveyed, but the Government subsequently determined not to prosecute the scheme.

Mooch Salt Branch.

184. A party was sent out from Sukkur to examine the country towards Dadur, as it was thought possible that a Railway might be undertaken in that direction in connection with the expedition to Kandahar. The project was finally abandoned, and the party was recalled, and two out of the officers were retained to record the work done and to prepare an estimate.

Sukkur to Dadur Surveys.

185. As the works required to complete the Indus Valley State Railway will be executed by the Engineers of the Revenue Staff, all future notice of them will be found in the Administration Report of the Open Line.

186. The annexed statement exhibits the expenditure incurred year by year from the commencement to the 31st March 1879.

F. W. PEILE, Col., R.E.,
Director.

INDUS VALLEY STATE RAILWAY.

Statement showing the expenditure incurred on each Sub-head of Service from the commencement to 31st March 1879.

Sub-Heads of Account.	Expenditure to 31st March 1879.	Remarks.
I.—Preliminary Expenses—	Rs.	
1. Survey Expenses, ...	6,45,172	
2. Plant, ...	39,244	
3. Establishment, ...	3,38,775	
II.—Land, ...	2,32,190	
III.—Construction of Line—		
1. Earth-work, &c., ...	53,66,485	
2. Bridge-work—		
i.—Minor bridges, culverts and flood openings, ...	30,12,130	
ii.—Large bridges, ...	1,17,83,586	
3. Tunnels, ...	..	
4. Level Crossings, ...	1,09,778	
5. Fencing, ...	95,009	
6. Electric Telegraph, ...	29,648	
IV.—Ballast and Permanent Way—		
1. Ballasting, ...	20,07,725	
2. Permanent Way, ...	1,37,25,271	
V.—Stations and Buildings—		
1. Stations and Offices, ...	9,44,811	
2. Workshops, Store Buildings, &c., ..	1,16,134	
3. Staff Quarters, ...	10,61,253	
4. Station Machinery, ...	10,95,509	
VI.—Plant—		
1. Engineering, ...	13,42,272	
2. Locomotive, ...	1,953	
3. Carriage and Wagon, ...	22,703	
4. Station and Office Furniture, ..	1,59,351	
5. Traffic, ...	..	
VII.—Steam Ferries, ...	6,006	
VIII.—Rolling-Stock—		
1. Locomotive Stock, ...	21,58,230	
2. Carriage and Wagon Stock, ..	28,68,240	
IX.—Establishment—		
1. Direction, ...	13,63,902	
2. Engineering, ...	38,93,144	
3. Locomotive, ...	..	
4. Traffic, ...	7,501	
5. Stores, ...	5,71,101	
6. Audit and Accounts, ...	3,63,658	
7. Medical and Sanitation, ...	2,32,239	
Loss on Stores transferred to other Railways, ...	58,882	
Total Final Heads, ..	5,36,45,910	
Suspense, ...	38,84,589	
Total, ..	5,75,30,499	
Deduct—Receipts on Capital Account, ..	89,319	
Total, ..	5,74,41,180	
Deduct—Credits to Expenditure in England,	1,22,61,059	
Balance—Expenditure in India, ..	4,51,80,121	

Mooltan:
22nd July, 1879.

(Signed) I. Sherlock Hubbard,
Dy. Examiner of Accounts, I. V. S. R.

INDUS VALLEY STATE RAILWAY.

Statement showing the expenditure incurred year by year on each Main head of Service from the commencement to 31st March 1879.

Classification.	Expenditure during										Total Expenditure to 31st March 1879.	Remarks.
	1869-70.	1870-71.	1871-72.	1872-73.	1873-74.	1874-75.	1875-76.	1876-77.	1877-78.	1878-79.		
Preliminary Expenses, ...	2,941	5,06,389	51,260	16,722	17,169	10,955	6,905	3,79,602	22,860	3,385	10,18,191	
Land, ...	...	..	261	13,170	53,067	25,809	15,193	33,954	18,045	72,391	2,32,190	
Construction of Line, ...	...	638	78,357	5,63,786	12,75,248	17,91,388	51,23,052 6,578	46,92,025 6,578	59,74,077	9,02,065	2,03,96,636	
Ballast and Permanent Way, ...	...	...	13,052	30,720	5,24,878	12,15,270	24,22,412	40,19,444	64,98,087	10,09,135	1,57,32,998	
Stations and Buildings, ...	...	128	21,374	1,84,339	3,66,979	2,03,393	2,39,983	3,52,316	9,24,953	9,24,242	32,17,707	
Steam Ferries, ...	...	...	...	...	...	...	...	...	...	6,006	6,006	
Plant, ...	10,638	13,083	21,579	81,260	1,41,723	2,62,629	3,55,100	1,84,947	3,27,777	1,21,546	15,20,282	
Rolling Stock, ...	...	...	...	650	26,552	88,400	17,65,375	2,88,320	2,10,161	26,47,015	50,26,473	
Maintenance, ...	...	...	...	...	...	...	24,001	24,004	...	...	..	
Total, ...	13,582	5,20,238	1,81,883	8,90,647	24,05,616	35,97,841	99,58,902	99,20,626	1,39,75,960	56,85,785	4,71,50,483	
Establishment, ...	29,326	1,92,999	2,49,695	5,91,434	8,28,426	10,00,414	10,20,207	6,78,124	12,28,341	6,17,579	64,36,545	
Loss on stores transferred to other Railways,	...	...	...	...	...	959	54,981	2,939	...	...	58,882	
Total Final Head, ...	42,908	7,13,237	4,31,578	14,82,081	32,34,042	45,99,217	1,10,34,093	1,06,01,689	1,52,04,301	63,03,364	5,36,45,910	
Increase in Balance of Suspense Account, ...	12,524	6,082	27,246	6,27,854	33,15,152	27,96,532	9,59,003	9,66,081	23,72,397	14,08,841	38,84,589	
Total, ...	55,432	7,07,155	4,58,824	21,09,935	65,49,194	73,95,749	1,00,75,090	96,35,008	1,28,31,904	77,12,208	5,75,30,499	
Deduct—Receipts on Capital Account, ...	20	131	393	1,254	9,704	17,527	12,986	28,525	4,998	13,781	89,319	
Total, ...	55,412	7,07,024	4,58,431	21,08,681	65,39,490	73,78,222	1,00,62,104	96,06,483	1,28,26,906	76,98,427	5,74,41,180	
Deduct finally.												
"Debit to the Indian Books by credits to expenditure in England for value of English stores received and other items charged off in England" and English outlay in suspense,	...	...	...	1,04,419	20,11,124	14,59,567	14,71,553	21,89,889	29,29,826	17,94,681	1,22,61,059	
Balance—Expenditure in India, ...	55,412	7,07,024	4,58,431	20,04,262	45,28,366	59,18,655	85,90,551	74,16,594	98,97,080	59,03,746	4,51,80,121	

MOOLTAN,
22nd July 1879.

(Signed) I. SHERLOCK HUBBARD,
Dy. Examiner of Accounts, I. V. S R.

APPENDICES.

APPENDIX A.

Extract from the Pioneer of the 12th June 1878.

THE EMPRESS BRIDGE.

[FROM OUR OWN CORRESPONDENT.]

Adamwahan, 8th June.

THE bridge over the river Sutlej at Adamwahan was opened by Sir Andrew Clarke this morning in the presence of some 300 Europeans and many thousands of natives. The report of the Director of State Railways (Colonel Peile, R.E.) gives a full description of the bridge, so I will not say more of it than that it is handsome and good; that it looks as if made for all time, and exactly the kind of work that make the natives look up to and feel the superiority of the English, who are able to control and bridge their wildest rivers, and meet difficulties only to overcome them by their indomitable perseverance and engineering skill. The arrangements for the opening were excellent, and with the exception of one or two trifling delays, such as a hot axle at Mooltan on one of the carriages of the special, and the running over a stray camel by the same train at Adamwahan, everything went very smoothly. A special train of 22 carriages, containing the guests invited on the Lahore and Jhelum side, left Lahore at 8-15 P.M. on Friday. In it were Sir Andrew Clarke, his Private Secretary Captain Brackenbury, R.E., Mr. Molesworth, Consulting Engineer to Government, Colonel F. W. Peile, R.E., the Director of the Western System of State Railways, Lieutenant-Colonel Medley, R.E., Major Trail, R.E., Major Fenwick, the Bishop of Lahore, Rev. W. H. Tribe, Chaplain of Lahore, many officers of the S. P. and D. Railway Company, the Agent of which line was unfortunately unable, through sickness, to go down; Messrs. Bell, Morrison, Ross, Scott, Arundel, Conder and others. On arriving at Mooltan about 5-30 A.M., *chota hazri* was provided on the platform, and, after about an hour's stoppage, the train proceeded to the Sutlej bridge, having picked up at Mooltan eight more carriages and a number of ladies and gentlemen. On arriving at the station of Adamwahan close to the bridge, we found the buildings prettily decorated with the long grass (which seems almost the only form of vegetation in that howling wilderness) and palm branches. Banners were introduced overhead and in the groups of palm, and over the entrance to the bridge was an immense white banner, on which was in large crimson letters "The Sutlej Bridge." When the ceremony of naming was performed, this banner was reversed and showed "The Empress Bridge." When the train drew up at the platform, the Nawab of Bahawalpur, who had arrived before us, was introduced to Sir Andrew Clarke by Colonel Graham, the Commissioner of Mooltan, by command, representing the Lieutenant-Governor of the Punjab. The guests then walked on to the bridge, and when in their places, a procession was formed, consisting of Sir Andrew Clarke, the Nawab, Colonel Graham, the Bishop of Lahore, Rev. W. H. Tribe, Colonel Peile, Mr. Rayne, Engineer-in-Chief of the Indus Valley, Mr. Bell, who has completed the bridge, and others. On arriving at the bridge, Colonel Peile (the Director) presented Sir Andrew Clarke with a brief history of the bridge.

Then followed an impressive service read by the Lord Bishop of Lahore and the Rev. W. H. Tribe; after which Sir Andrew Clarke, in a few well-chosen words, congratulated those engaged on the bridge, on behalf of the Empress and Viceroy, on the completion of their work, informed the company of the Empress' permission that the bridge should be called after her and handed down to posterity as the Empress Bridge, and proclaimed the bridge open for traffic. Long and hearty cheers were then given for the Empress Queen, the band struck up the National Anthem, and the party went back to their carriages in the special train. To this train a gaily decorated engine was attached, and took us steadily across the bridge. The first train crossed amid the cheers of thousands of native workmen who were clustered over the structure. The train was then run down the bund to enable a good view of the bridge to be obtained, and then, for the first time, we recognised how vast and splendid a structure it was; and when one looked at the mighty river bed, and imagined that now placid stream, swollen and angry, rushing down its torrents with seemingly irresistible force, it appeared an impossibility that the bridge should ever have been completed, as it stands now, a specimen of what human ingenuity can devise, of

man's victory over nature, an enduring and a careful monument to be handed down to those who come after us, connected with the names of all who have worked, and some alas! who have lost their lives while engaged upon it.

The country round the Sutlej is arid and desolate to a degree, destitute of vegetation, and of a climate most inimical to health; so much so, indeed, that hardly a European engaged on the work but has felt it more or less severely, many having been forced to leave, and some of them having died on it. The train now recrossed the bridge, and drew up at Adamwahan station. Here we again descended, and passing down a prettily decorated passage, some hundred and fifty yards in length, entered the mechanics' shop, which had been stripped for the occasion, and ornamented with flags and devices, many of which I fancy had been used when the Prince of Wales was over here in India. The shop had been plentifully supplied with punkahs and a large steam thermantidote, and under their cooling influence were spread tables to accommodate about 250 guests. The *déjeúner* was presided over by Mr. Rayne, the Engineer-in-Chief of the Indus Valley State Railway, who had on his right Sir Andrew Clarke, on his left the Commissioner of Mooltan. At the high table which ran across the top of the room, were seated, in addition, Mr. Molesworth, the Nawab, Major Grey, Colonel Peile, Colonel Medley, Mr. Mundote, and others; and the other tables were well filled with well-known faces. After the *déjeúner*, the President proposed successively "The Empress;" "The Prince of Wales and the rest of the Royal Family;" and "The Viceroy," all of which toasts were drunk with much enthusiasm amidst hearty cheering.

Sir Andrew Clarke then rose to propose—"Success to the bridge and the Officers and men connected with it," which he did in the following words:—

I am glad to have received the instructions of the Viceroy to tell you that it would have been to him a source of much interest and pleasure, had the fact which we are to-day assembled here to commemorate occurred at a time when he could have arranged to be present. His Excellency has bid me assure those who have been engaged upon this work, that when he was here towards the end of 1876, he was deeply impressed with the magnitude of the undertaking, and thoroughly appreciated the difficulties which had been already overcome and still remained to be conquered. I am also commissioned by the Lieutenant-Governor of the Punjab, in whom you have an appreciative, indeed I may say almost a professional, critic—for he is by taste and study an engineer—to convey to you his regret that he is not able to be present to-day—a commission which I shall best fulfil by reading to you his letter to me. Writing a few days ago, Mr. Egerton says:—"I am very glad to hear from your letter that the Indus Valley Railway Bridge over the Sutlej is to be honoured by being named the Empress Bridge. I congratulate you and the officers of the department over which you preside on the successful completion of this magnificent work which is unsurpassed in India, and which is a most important link in the line of communication between Upper India and the seaboard. I regret that I cannot be present in person on the occasion of the opening, and I must therefore ask you to convey my congratulations to the officers who have been employed upon the work, on the success which has crowned their labours." Sixteen years have now elapsed since Brunton, the Engineer, pitched his camp and collected his forces on this wild and desolate spot, having a task before him not less vast, if tradition and history speak aright, than that which the mighty "Iscander" undertook when with his hosts he crossed the Ravi and the Chenab, and came, it is said to this very site, to pass his legions to the further conquest of an immense city and nation on the banks of far distant Ganges. Some of you, to whom I am now speaking, have by your previous labours succeeded in spanning with great works the Ravi and the Chenab, and in now bridging the river Sutlej have done that which baffled the great Alexander himself, when, disheartened by heavy falls of rain, more probably by fitful floods of this mighty stream, he had with his army to fall back upon the Indus, and compelled to abandon his golden schemes of ambition, sailed back on its broad bosom to the seaboard. Thus that river Sutlej, which to Alexander proved the *ne plus ultra* of his Eastern conquests, has been to you only one more opportunity of achieving another engineering victory, which will have to be followed up still by an enterprise which I dare to prophesy—owing its origin to the conceptive genius of that eminent Engineer, Mr. Molesworth, who has already done so much for India, and depending for its execution on the devoted labours of the men around me—will at no distant date be accomplished: the no less heroic task of spanning the mighty Indus itself. Great and interesting as have been the difficulties which have been overcome by the attention and care of Mr. Rayne, Mr. Galwey, Mr. Heenan, who fell on the field of his work, Mr. Graham, and others who have been employed here—if I do not note them all, let them not fancy their names or

labours are forgotten—these things are known to most of us here present to-day, and have been described to our visitors (I mean the difficulties in constructing the foundation of this bridge, and in raising the superstructure), perhaps even still more interesting and certainly no less perplexing was the task of training and curbing the river itself, so as to induce it to abandon its vagaries and wanderings and keep in the way it should go. It may perhaps be premature and hazardous to assert boldly that we have cured this most erratic-of-erratic Indian rivers, and have permanently placed it under discipline at this spot. Still it is not to be denied that what has been done promises right well, though it will need all the ceaseless vigilance and untiring care of its tutor, Colonel Peile, to guard against the river's rebelling and relapsing once more into the wildest, most untamed, and most frolicsome of mountain torrents. Without doubt one of the most remarkable features of the fabric itself has been the sinking and founding of the wells. To us engineers here in India, the system of founding the buttresses or piers over which the roadway is to pass is well known; and it is commonly said that we have learnt the practice in this country, having adapted and adopted it from the native engineers of India. I am myself under the impression that it has been stated under competent authority that this system of dropping hollow cylinders into the heart of treacherous soil owes its birth to an inventive genius of a date long anterior to any application of it in this country, and hence that it cannot be said to be of pure Indian origin. Be this as it may, however, it must be admitted that whatever was its source, it is in India that we have learnt the value of the principle; that our application of it has met with marked success so far, and that one of the novel and remarkable features of this fabric, I repeat, is the great depth to which in the bed of the Sutlej, the engineers have had to sink their piers. If I remember right, all are down some 100 feet below the natural, or what should be the natural, bed of this wandering river; and I cannot leave this part of my theme without mentioning with honour the name of one of ourselves a French Engineer, who has been associated with us in this particular work, and to whose skill and inventive genius it is due, that we have been able to accomplish the sinking of the wells with less difficulty, and with much economy of time and money. For though our roving, never-stay-at-home river, a very Bohemian in his nature, and a second Ariel in his eccentricities, loves soft lying, still his bed is in places hard, and was intractable to deal with until Mr. Gatmell invented a machine which I commend to the attention of those who have not seen it, which is as simple as it is original, and which has removed the hard and gnarled lumps that have been met with in the mattrass of the Sutlej.

Another feature in the practical erection of this bridge, and one which furnishes, I suspect, exceptional experience, is the rapidity with which the iron superstructure has been put in place. To have lifted on to the piers these girders, weighing tons upon tons, and clenched with thousands of rivets, would be in itself a feat of which any man, who had organised the arrangements, might justly be proud. But when you view the site on which he had to work, and call to mind that at the very moment of Mr. Bell's supreme agony, when the last of his waterspans was being lifted into place, our Ariel river suddenly took it into its eccentric head, or bosom, or what you will—to do what it had never done before in the memory of the oldest inhabitant,—if an old inhabitant ever survives in Adamwahan,—and at that very particular time of year came down in flood, and threatened the whole of the staging and appliances by which the girders were being adjusted; when you remember all this, you will, I am sure, agree with me in attributing the success with which the river was defeated, to the pluck, skill, and energy of Mr. Bell and his assistants, and to the men, both European and Native, who, confiding in their leader, worked with willing hearts and hands to beat the enemy. Intimate as most of you are with them, I will not weary you, gentlemen, with any further details of the technical or professional history of that work, the completion of which we are now commemorating. Colonel Peile, the Director of the Western System, and Mr. Rayne, the Engineer-in-Chief of the Line, will more ably comment on these. I hope though that not only will Mr. Bell, who has borne no small share in this great success, but that others also, will contribute to professional periodicals either in this or in the mother-country the outcome of their observations and experience, and that Colonel Peile will have leisure to record the results of his views, gathered from a fresh insight into the behaviour of the Sutlej under the treatment which it has undergone. Hitherto I have mainly alluded to the merely professional history of the structure; but there are other events connected with it which have a story of their own, and which invite our recognition and enlist our sympathy. Severed from society, on the borders of the desert, and on the banks of a turbulent river yellower than Father Tiber, has been created this colony, of which a few of those around me have been members from the very first. But not a few of those who once formed it are now absent, and the pestilential and malaria laden air has caused many a change in the lives of some, and

has made many a gap in the circle of the family hearth or of the friendly station mess. Unhappily these incidents are inseparable from the engineer's life and vocation in India; but because these instances are not uncommon, it is none the less my duty and my right not to pass them by unnoticed or scantily recognised. Without betraying a secret, for this is not known to me for certain, I may say that I have an impression that the alacrity with which Her Majesty the Queen and Empress gave her gracious assent to calling this bridge The Empress, was in itself a sympathetic acknowledgment of the devotion to duty, and of the sacrifice to honest work, which this bridge will ever illustrate. And here, gentlemen, in addressing you and asking you to accept from me the assurance of the pride and gratification I feel in being able to-day to speak face to face with you—an opportunity which the nature of my office and the character of my duties seldom afford to me—permit me to say to our co-workers elsewhere in India, whether in the fever-stricken plains of Northern Bengal or in the deadly gorges of the valley of the Nerbudda, that there rise to my lips the names of many men who share with us here the same claims to Royal sympathy and Imperial consideration as have now been given, on behalf of all who are labouring in the material development and improvement of India; and if I do not repeat these names here, it is not because I do not remember them, but because, by perchance, omitting one, I might give pain to the heart of some faithful toiler. From the immediate object of this festive gathering, I will now pass on to the larger subject of the Indus Valley Railway itself, of which this bridge is a most important link; and, after a few words on it, will release you from having so long to listen to my dry matter. I am not one of those who regard this great artery as a mere strategic line, and only of real use when the exigencies of war shall demand it. I have on a former occasion and more than once when the Government of India has been accused of sacrificing or squandering the resources of India on lines of railway projected on an insecure basis, and in subordination to ambitious strategic ideas, or in needless subjection to some possible military necessity, I have, I say, affirmed my conviction that these great works, from whatever source or for whatever cause they might proceed, would be more certain to secure a lasting peace, than could ever be assured by the agency or the provocation of war. Personally and practically in fact, I hardly know when and where I would consider a line of railway in this country to be a mere strategic agent. I believe the idea is a myth in itself, a mere creation of the recent schools of modern military pedantry. Give me for ordinary use and for the simple purposes of peace and of prosperous times the very best commercial route that can be aligned, and let the Genius of war apply it to its own wants when the occasion arises. I warrant such commercial lines will be found to contain every needful condition of war. It will be as interesting to you as it was satisfactory to me, when looking over some old records connected with the early history of this Indus Valley State Railway, to come across some remarks written long previous to his connection with this great Province, and thus not specially interested in it as a mere local work, but regarding it from a far larger field, to come across, I say, some remarks by Sir Henry Durand, then a Member of the Supreme Council.

In a note of his of 1869 on the projected Railways of India, Sir Henry writes:—

"Before touching on these points, however, I wish to remark, that in India the distinction between commercial and political lines, is a distinction to which I cannot give my own adherence. In our Indian Railways, it is, to my mind, impossible to separate the political from the commercial value of these great lines of communication. I certainly would not advocate the construction of any line from any purely political motives; and in strenously and repeatedly pressing for the early construction and completion of the Indus group of Railways, even when Sir John Lawrence and the rest of the Council were not disposed to accept my view, I was influenced quite as much by the commercial as by the political advantages of this measure. To bring the Punjab and the whole Indus Frontier into easy connection with the seaboard seemed to me of incalculable importance commercially, as well as politically of advantage. I do not think we have as yet any data on which to estimate the value of the trade which may accrue from facilitating the flow of British goods into Central Asia, and from remedying the defects of the position of the Punjab as to traffic ascending from the sea-coast. I therefore concur with the one despatch in the prominence given to the early completion of the Indus Frontier group of Railway lines, being confident that in the interests of peace and of commerce no other line is of equal importance. Of peace, because nothing is so calculated to insure that blessing, both internally and externally, as the conviction that the British Government is master of the position on the Frontier from north to south; of commerce, because no other line, whilst thus insuring the general confidence of the country in the peace and security of our frontier provinces, has a larger field than Central Asia for the consumption of many of our British and Indian products when once that region is actually tapped."

When Sir Henry Durand wrote, the realisation of this project was not near, nor had there been experience of other lines under similar conditions, which could be taken as guides. Every opinion and every word of Sir Henry Durand, written as the outcome of the large statesmanship of the man, and with the prophetic sight of the cultured student of the past, we can now endorse and confirm by practical experience and by the results of accomplished facts. The Rajputana Line, for instance, traversing through much of its length a country with but scant cultivation and a sparse population, has belied, by its results, both in goods and passenger traffic, the forecast made of its returns. The Punjab Northern again, though working under a mere makeshift, and far from satisfactory system, has surprised all by the traffic which it has suddenly developed. And I have every confidence that similar success awaits the Indus Valley Railway and its future extension as indicated by Sir Henry Durand, and that the day is not very far away when the astute Rulers of the countries beyond our frontier, throwing to the winds all suspicions of our intentions, and waking up to the real interests of themselves and of their people, will invite us to carry the winged fire chariot into the very hearts of their territories. I am hopeful that the early net receipts from this line will swell the sum total of our Revenue from Railways, which already obliterates the debt and leaves the balance to the credit of the tax-payer—a fact to which I would draw the attention of a few, no doubt well disposed, but certainly not well informed, publicists, among our native writers, who attribute to the operation of the Public Works Department and to its extravagance in its Railway schemes much of the burden which India has to bear. In saying this, I do not wish to ignore the truth that improved facilities of transport may press for a time hardly, and may possibly bear injuriously, on certain classes of the community, but I feel assured that this pressure will be but transitory, and that the cause itself will create the strength which will lighten the burden, if it will not remove it altogether. The success of our Indus Valley Line, will in this instance be in no small degree advanced and secured, if the illustrious Prince, whose ancestors have been the loyal and devoted lieges of the Imperial Crown, and who has already given practical pledges of his policy, guided by his intelligent and enlightened Counsellers, will realise the fact that this Railway, passing as it does through some 200 miles of his territory, may, if wisely used, confer on him and on his people the boon of a new and extensive prosperity. I am not ignorant of, nor do I shut my eyes to, the difficulties that in the first stages may be encountered by His Highness, because we in British territory shall have to meet much the same in encouraging settlement of population and the extension of cultivation in this tract, which, now a so-called desert, can become a fertile garden if once the flood waters of the Indus are brought under control, and wells are multiplied. But I am convinced that a liberal and permanent land tenure will accomplish much to aid man in his efforts to accept and avail himself of nature's gorgeous gifts. In the immediate present we cannot expect this line to be a brilliant commercial success. But if other lines, under not dissimilar conditions have agreeably disappointed their projectors, why should we not anticipate, in the not distant future, a like result for the Indus Valley Railway? Of one thing, however, we may rest assured, and no one will doubt it; and that is the benefits which this line will confer on the Punjab as well as on Scinde. I saw it publicly stated somewhere the other day, that the uncertainty which surrounds the political and administrative union of these two provinces will injuriously affect the prospects of the line. I believe no such thing. Whether we be all under the jurisdiction of Bombay or of the Punjab, or of both, it will matter little. "Cæsar's very much like Pompey, and Pompey very like Cæsar;" and if the line is to flourish at all, it will flourish independently of the smiles of one or the other, or even if the sunny smiles of the fair daughters of Bombay are absorbed by the robust and progressive Punjab. In what has been already accomplished within the short space of time, for which British rule is responsible in either the Punjab or Scinde, we have given no little promise that we need not doubt the early accomplishment of the wish that I ask you now to share with me, in pledging a long life to the Empress Bridge, and success to the Indus Valley Railway. And with this I ask you to couple the health of Mr. Rayne, Mr. Galwey, Mr. Bell, and the engineering staff engaged on the bridge.

Mr. Rayne, in returning thanks in a very able speech, said that the praises of Sir Andrew he disclaimed as far as he himself (Mr. Rayne) went, but for his staff he accepted them all, and from a man with such an engineering knowledge as that possessed by Sir Andrew Clarke, praise was indeed praise. (Cheers.) The work had occupied 3½ years, and the labour on it was continuous and severe. The theory that some philosophers held, that water was inherently malignant to man, seemed in this case to have been borne out, for the river pursued like an evil genius the little colony that had sprung up near it; and when the stream first felt those fetters which man has since firmly bound about it, it revenged itself by carrying off the larger house in the settlement, and cut away many acres of ground. Engineers in this

which might be called the stone chopping age of the bridge (laughter), defended the colony with all their science, and for two years the river was coated with large fascines and weed spurs, and ran straight. And in August 1875 it rose and flooded the colony, knocked down the stores, &c., and committed great havoc. At this time, diners out went to their host's huts or tents in flat-bottomed mortar boxes, and he (Mr. Rayne) was amused one evening to see in front of him a box with Captain Sparkes and Captain Wither also going out to dinner in it. Need he add that the box had such a list that she was almost unsafe (loud laughter and cheers). When the river went down, it left such a dreadful malaria that the works had practically to be stopped. This flood was of a most unusual height, but the river in the succeeding year rose 18 inches higher still; but a bund had been erected which sheltered the colony, but was insufficient to withstand the force of the flood, as the river made a break which was filled by men standing in it, and forming a living sand-bank. Then were the men of large proportions appreciated (laughter). Finding itself foiled here, the river went across and cut away three-fourths of a mile of ground; but here, thanks to the foresight of Colonel Peile when Engineer-in-Chief, a supply of reserve stone had been collected, which was most useful; and had it not been for these thoughtful precautions of his, a second bridge would certainly have had to have been built. (Loud cheers). After this the spur was made, consisting of huge masses of stone, in the providing which Mr. Baxter especially distinguished himself (cheers), and this saved the bridge and that side. It was one of the difficult works that Mr. Baxter is constantly asked to perform, and about which he generally says:—"I don't think it can be done, but I'll try it" (laughter), and then there is no more need for anxiety; for somehow or another it will be done, and done well. (Loud cheers). The river had now one more chance, namely, when the girders were put up, and it availed itself of its opportunity in this wise. Last year there was no flood at the usual flood season, but, when the cold weather set in, floods came on one after another; but they were conquered. The result has been success. The bridge was open (hear, hear), but continued care and vigilance were still necessary. Mr. Rayne went on to mention those who had so ably assisted him, more particularly Messrs. Galwey and Monk, for their excellent work in the well sinking (cheers), Mr. Graham who began the work (cheers), Messrs. Tait and Moyle, two young officers who reflected the greatest credit on the College engineers, and who in an incredibly short time became most useful and efficient officers. (Cheers). Among subordinates, he mentioned Mr. McInerny, of the carriage building department, who did piling in 40 feet of water with a stream running 6 miles an hour (cheers). Mr. Windmill, the foreman of the workshops, whose branch was properly locomotives, was ubiquitous and indefatigable (cheers). Mr. Bewell, who was often in the river bed at mid-day, and Mr. McPherson, who had charge of the rivetting, were deserving of special praise. (Cheers). Messrs. DeSilva and O'Shaugnessey were also most able assistants. Mr. Rayne concluded by praising very highly the conduct of the natives employed, and said that they did not know what fear meant. Wherever a European would lead they would follow, and follow well, though thoroughly aware of the danger they would encounter. Mr. Rayne again disclaimed his share of the praise (cries of no, no), and gave all the honour and praise to those under him.

The President then proposed the health of the Lord Bishop of Lahore, and his Lordship replied as follows:—

MR. PRESIDENT, YOUR HIGHNESS AND GENTLEMEN PRESENT WITH US TO-DAY.—I rejoice in the unanimous consent and hearty sympathy with which the proposal was accepted for commencing the proceedings of the day with dedication and commendation of the work to Almighty God. The telegram received to-day from our Empress (it seemed more like a telephone than a telegram, so vividly did the Queen's electric message thrill through our hearts, and set us in the presence of our Empress and her Court, and express the sympathies with all good and great works in her Empire of which her heart is full) was a pleasing and refreshing feature of the day's procedure: but what was more, our sacred service of to-day brought us near (I trust) to Him by whom Kings rule, "the King of Kings and Lord of Lords," who, I believe, is not indifferent to our gathering of to-day, but will give His blessing and favour, and prosper the work of our hands upon us.

It occurred to me on my journey by rail this morning to take up, as I do sometimes some old Roman Historian, and in this way some thought is often suggested pertinent to the matter in hand. The passage described the character of Antiochus Epiphanes, or as the historian says his people often called him "Epimanes," the mad man, because of the unaccountable fantastic follies and infatuations he was at times guilty of. On one occasion he built a magnificent temple of Jupiter Olympus, of which the rafters of the roof were of solid gold, and the walls throughout were plated with gold. I could not help

contrasting this work with that very useful work on which we met this morning, not only to connect with the name of our Empress, but also to dedicate to the Glory of God. Such a fabric might indeed be called in one sense a temple of science, but by a service of dedication may we not say that it becomes a temple to the living God? For does not our Holy faith set its seal and put a crown and concentrate in itself as in a focus all excellencies and virtues, all beauties and glories, all that is true, good, noble, honourable, lovely, but also what is useful advantageous, profitable; for are we not taught: "*Godliness is profitable for all things, having the promise of the life that now is and of that which is to come.*" Thus a place is found for the profitable as well as for that which is true and lovely and of good report. It cannot be indifferent therefore to the many advantages and benefits which may be looked for as likely to arise from the erection of this fabric.

It has a real privilege and pleasure to hear called out the long roll of those who in different capacities have contributed to the success of this work, devoting to it all the zeal and energy of their hearts, resources of mind, labour of hands. I believe they amply deserve all that has been said in their praise. I believe it to have been eminently a faithful and conscientious work, and faithfulness the wise man represents to be the rarest and scarcest of graces—"*a faithful man who can find.*" I have come more than once in hopes of holding a service, and found it was not possible through the extreme weariness and pressure of the work in hand: and it was only last Sunday week that I had the opportunity I desire of being associated the first time, as to-day I have been, with men whose character and work I so much respect, and whose names deserve to be handed down to other ages than this as the constructors of one of the noblest fabrics the world has witnessed, and of whose faithfulness I can bear record from my own ample experience.

Colonel Peile, R.E., the Director of State Railways, Western System, then rose and said:—

Mr. President, Mr. Commissioner of Mooltan, Your Highness the Nawab of Bahawalpur, Ladies and Gentlemen,—I am about to propose to you a toast which I am sure will meet with the approbation of every one here present; but especially to you gentlemen of the Public Works, whether serving under Government in the department, or on the Railways, do I look to support me heartily and lustily. I stand here amongst you the oldest representative of the Public Works Department during a career which has now extended nearly to a length of 30 years. I have witnessed many changes and the introduction of many novelties—all no doubt produced by an earnest desire for the welfare of the department, but of which we perhaps were not always able to perceive the benefit. Amongst all these changes none was hailed with so much satisfaction by myself, and none I believe was so favourably welcomed by the department at large, as that which gave us a responsible head to the department, a Member of Council and a Minister of Public Works for ourselves. Previously to this appointment it had been the lot of the department to have its affairs treated somewhat after the fashion of a shuttlecock in a game of badminton. At one time, perhaps, the Viceroy himself would have us in hand, then we might be picked up by a cavalry officer, and anon a civilian would hit us a drive, and during the process we could not but feel that we were in the hands of men who did not always understand our little ways, and who sometimes were supposed to look upon us with enmity mingled with contempt, and to regard the department a very costly, if not an altogether useless, incumbrance to the State. In the appointment of Sir Andrew Clarke to the post of Public Works Minister all these evil days have passed away. We have in him not only a gentleman of the highest professional attainments and a distinguished politician, but above all one who has been trained in the same school, has been moulded in the same mould, and has passed through the same mill as ourselves. Now we all know that we have a friend at Court. The man of humblest rank among us having a complaint to make or grievance to be redressed, has a full assurance that his case will be studied and disposed of in a calm, judicial spirit, tempered with great kindness. You, gentlemen, who have been engaged on this great bridge,—and it is my good fortune to be able to number myself with you,—we, I say, must feel that His Excellency the Viceroy has conferred on us a peculiar compliment in having selected Sir Andrew Clarke, the head of our department, to represent him on this occasion. Mr. President, ladies and gentlemen, I call on you now to join with me in drinking long life and prosperity to Sir Andrew Clarke.

Sir Andrew Clarke in reply said he trusted that no undertaking would be judged until it was completed; that he was rejoiced to meet those whose interests he had at heart; and that all should remember that in a Government little or nothing is known of individuals, but that the voice of the many speaks. He knew what things he would do if he could, but they were very difficult to do. He knew that there never was, and probably never would be, a feeling of perfect content, but he assured his hearers that

devotedness in the past would undoubtedly bear fruit in a happy and successful future. This was the first occasion on which he had had the opportunity of publicly meeting engineers. (Cheers.)

The President then proposed the health of the Nawab of Bahawalpur, and said that all who knew him and had partaken of his hospitality, and seen the kind and careful interest he and Colonel Minchin, and afterwards Major Grey, took in the progress of the work, must have formed a high opinion of him, and trusted that the bridge would prove advantageous to the Nawab and his nation, and that in the future the relations with the Nawab would always be as friendly as they were at the present time. (Cheers.)

Major Grey, who responded for the Nawab, said that His Highness requested him to say how deeply he felt the compliments of Sir Andrew Clarke and Mr. Rayne; that his house was always loyal; that he regarded Her Majesty as his Empress; and that he would always take a pleasure in assisting all schemes for the welfare of British subjects and his own people. (Loud cheers.)

The President then proposed the health (amid loud cheers) of Colonel Graham, the Commissioner of Mooltan, who had endeared himself to all, and whose approaching departure was so universally regretted. (Hear hear.)

Colonel Graham, in responding, stated that he felt convinced of the strategic importance of the Indus Valley line; that it formed a link between Upper India and its seaboard; was a highway from the sea to the North-Western Frontier, and was destined to play a great part in history. (Cheers.)

Sir Andrew Clarke, in proposing the S. P. and D. Railway Company, said he hoped the past would be forgotten, and that the Indus Valley line would shake hands with, and thank, the S. P. and D. Railway for its help; and that whether it should be left to the S. P. and D. Railway to make the missing link, or whether Government should find it necessary to perform the work itself, there would always be good feeling and co-operation between the two lines.

Mr. Ross returned thanks, and congratulated the Government on their success at the Sutlej, and wished them the same success at Sukkur. He looked to a large grain traffic on the line.

This closed the proceedings, and at about 4-30 the special train started back for Mooltan, where it was timed to arrive at 6-20. A large dinner was given at Captain Sparkes' house, at which about 60 sat down, including Sir Andrew Clarke and other officials who had been present during the day. The special left Mooltan about 11 o'clock and was timed to reach Lahore at 2 o'clock on Sunday morning.

All those concerned are to be congratulated on the arrangements made, and so well carried out. The heat was, as may be imagined, somewhat overpowering; the thermometer standing at 116° in the centre of the carriage, and when at the window at 134°. There were in addition to the *déjeûner* a dinner to the subordinates, two feasts for the natives, and 300 maunds of sweetmeats distributed among the native workmen, of whom there were some 5,000 or 6,000 employed.

Mr. Bell, the engineer in charge of the bridge, and to whom so much praise is due for his successful efforts at pushing on the work, is, I understand, taking a rest that he has so justly earned, and is proceeding home on leave.

The bridge is now open for traffic, and one more triumph of engineering skill, one more instance of the all-conquering power, of indomitable perseverance, when backed by genius; one more monument to hand to future ages as demonstrating the condition of science and mechanical aptitude of this nineteenth century; one more link in the chain of civilization and improvement, which we forge about all our territories, is finished; the result of months of thought and years of labour is completed, and given to the public—and the Empress Bridge is open. May it be a success; may its military uses never be brought into play, but rather let us hope that it will serve to connect together the different branches of our empire, to be a means of diffusing Christianity and civilization, of extending commerce, and facilitating the journey home to the old country, so dear to all Indians.

APPENDIX B.

Note on the Indus Floods, with reference to the Indus Valley State Railway. By Major J. G. Forbes, R.E., Superintending Engineer on special duty.

The absence of sufficient reliable data makes it a peculiarly difficult matter to offer any opinion on the best method of dealing with the floods of the Indus. The facts, however, mentioned in the Flood Reports of 1875 and 1876, together with those noted during the flood of 1878, show that on the left bank of the river, between the confluence of the Chenab and the narrow pass at Bhakkar, there are

four main or primary spills which cross the Railway near Naushahra, Mirpur, Ghotki and Sangi. On a map showing the original surveys made for the Railway, 15 or 18 years ago, these four spills are distinctly marked; thus denoting they are not casual, or secondary, spills like those mentioned in next paragraph; but that their positions may be looked upon as *comparatively* fixed, and not liable to any very sudden alteration.

2. Besides these four main spills, the Indus, like other rivers, floods over its banks, sometimes in one spot and sometimes in another, according to the set of the stream, and attacks the Railway at uncertain places between Kot Samaba and Rohri, along the whole of which distance (120 miles) the line is carried through the flooded tract.

3. Taking up the Index Map of the Indus Valley State Railway, we can see that from Mithankot to about 20 miles above Kusmore the country through which the Indus flows must have a steady fall from the hills to the Bahawalpur desert, as this is clearly evidenced by the trend of the hill streams, which flow perpendicularly towards the river on the right bank; and by the absence of inundation canals on that bank between Mithankot and Kusmore. That this slope is continued on the left bank is also shown by the course of the Bahawalpur canals, which, following the natural slope of the country, run roughly perpendicular to the stream of the river. When the Indus arrives at a short distance above Kusmore, it can be seen that the slope in the country at once changes. Instead of running down direct at right angles from one side only of the river, it spreads out diagonally on *both* sides like a fan, which is slightly squeezed on the right, but more opened out on the left. This then would lead us to expect that while the flood between Mithankot and Kusmore would come more directly on to the Railway, the number of primary spills would probably be less than from Kusmore downwards. This conclusion is borne out by the fact that in the upper portion there is only one main spill, *viz.*, at Naushahra; whereas in the lower portion of the river to Sukkur, which is about the same length as the upper, there are five, *viz.*, two on the right bank at Kusmore and Begari, and three on the left, at Mirpur, Ghotki and Sangi.

4. The construction of any long line of embankment will at once alter existing conditions. The practical effect of long embankments is to raise the high water mark, and to slightly increase the caving of banks;* thus inducing larger floods, not only at the primary and secondary points, but also the formation of spills at places not previously attacked.

5. An embankment has within the last few years been made for a length of 41 miles along the left bank of the Chenab, from the junction of the Sutlej to the confluence of the former river with the Indus. This embankment effectually protects the ground behind it; and also probably conduced last year to prevent the floods, as formerly, attacking the Railway above Kot Samaba. It is proposed to extend the embankment still further down the Indus; but if this is done, the increased volume, which is now expended in spill, will undoubtedly cause the river, which already has a great tendency to do so, from being above the natural level of the ground, to burst through its banks lower down in a greater number of spots, and with much more force than it now does. As it is utterly impracticable to construct continuous lines of embankments along the whole length of the Indus from Mithankot to the sea, it is evident that any extension of the Bahawalpur embankment will only save a small portion of country at the expense of a much larger area lower down; and that the more the embankment is extended, in a constantly increasing ratio will the country below be swamped, especially where the change of slope occurs near Kusmore. There can, therefore, I think, be no doubt that the Bahawalpur embankment should *not* be extended.

6. The accompanying table shows the height of flood levels, in 1878, along the Railway, from mile 150 to mile 220:—

Nearest Station.	*Mile.*	*R. L. of flood.*	*Fall per mile.*	
Kot Samaba	150	278·50		
Naushahra	160	278·00	·55	
	170	267·60	·54	Average fall ·61 per mile.
Sadikabad	180	260·90	·69	
	184	258·40	·62	

——— .... AHMADWAH CANAL.

* See page 17 of Report dated 18th January, 1875, of Commission of Engineers appointed to investigate and report on a plan for the reclamation of the basin of the Mississippi river, subject to inundation. This Commission was composed of Major-General Warren, U. S. E., President, Brigadier-General Abbot, U. S. E., Major Benyaurd, U. S. E., and Messrs. Stokels and Hébert, Members. The Report was submitted through Brigadier-General Humphreys, U. S. E., who stated that the views of the Commission met with his full concurrence.

Nearest Station.	*Mile.*	*R. L. of flood.*		*Fall per mile.*	
		255·30		·38	Probably affected by back-water from lower spill.
Walhar	.. 190	253·00		·60	
Reti	.. 200	247·00		·77	
	207	241·60	Level.		
Khairpur	.. 210	241·60			
Mirpur	.. 220	238·00		·86	

7. Between Kot Samaba and Khairpur the line was breached in numerous places, especially between miles 154 and 178; but the greatest strain was from mile 165 to mile 166. A reference to the Flood Reports of 1876 will show that it was at these places also where the heavy burst of the upper or Naushahra flood was experienced. It will be noticed also, in the above table, that where the Ahmadwah Canal crosses the Railway, there is a sudden drop of three feet in the flood level, the water on the north side of the canal bank being 258·40, and that on the south 255·30. For the six miles below the canal the surface slope of the flood is only ·38 per mile, being probably affected by the back-water of the secondary spill near Reti, against an average of ·61, for the 34 miles immediately above it; but in the next 10 miles it again resumes this normal slope. The sudden drop (which was also noticed in the flood of 1876, *vide* para. 10 of Executive Engineer, Reti Division's letter No. 1277, dated 8th September, 1876) and the alteration in, and eventual resumption of, the regular flood slope, shows that the canal kept the upper floods entirely distinct from those lower down. It would therefore apparently be advisable to take advantage of the circumstance, and still further strengthen the bank of the canal, if there is any fear of its being breached, so as *completely* to isolate the Naushahra from the lower floods; especially now that the thorough reconstruction of the Kusmore bund will throw more water on these spills. If free exit is given through the Railway to the upper floods, they will pass off by the old river-bed, which runs parallel to the line at a lower level, and be absorbed in the desert. I concur therefore in the recommendation that this portion of the line should be raised and the waterways increased; but the amount recommended, *viz.*, 85 lineal feet per mile, is, I think, inadequate.

8. I have not sufficient data to show the actual amount discharged through the Railway last year, or the possible quantity of flood that might have to be provided for; but on the East Indian Railway, where it crosses the Sone floods, which have a discharge of 165,000 cubic feet per second on the left bank of the river, 296 lineal feet (2871 superficial feet) of waterway per mile has been clearly proved to be insufficient. On the right bank, however, where the floods amount to 65,000 cubic feet per second, a waterway of 153 lineal feet (949 superficial feet) has been found effectually to discharge the spill. In the former case the average depth of water is 9·70 feet, and approaches with a velocity, due to a fall in the country, of two feet a mile; in the latter, the depth is 6·20 feet, and the slope about one foot per mile.

There is nearly as much uncertainty on the Sone as on the Indus, where the floods will first attack the Railway. The points of attack of the primary or main spills, which are almost invariably marked out by local depressions, are known; but floods do not always come down these main spills in force, the secondary spills, which generally in floods of any duration find their way into the depressions of the main spills, are often at first of as great violence as the main floods, and rush on the Railway at totally unexpected places. As long as the bank is not overtopped, and a sufficient aggregate amount of waterway is given in the flooded tract, the effect is that the water is ponded up for a greater length of time in local spots, and that greater work has to be performed by the flood openings lower down; all of which of course must be protected to withstand the extra scour that may be thus induced. In the Sone floods of 1876, on the East Indian Railway, there were three bridges on the left bank of the river, and two on the right, absolutely dry. In the former high floods of 1864 and 1867, these bridges had discharged very considerable amounts of water, but, on the other hand, waterways which had done no work in the former years were in 1876 running with a velocity of 14 feet and upwards.

9. The conditions of the right spills of the Sone approximate to the upper Indus floods; where, however, apparently the depth and slope are somewhat less, *i. e.*, the direct transverse slope from the river to the Railway is only about ·75 per mile. Allowing for differences, it would not be safe to accept less than 120 lineal feet average waterway per mile as a *minimum* on the Indus Valley Railway between Kot Samaba and Reti.

10. It is true that in addition to the 85 lineal feet per mile of waterway recommended, it is proposed that long paved causeways for the escape of heavy floods should be put in, thus evidently showing that more waterway is considered necessary. But this proposal is saddled with the proviso that it is

only to be done if the causeways "can be constructed at reasonable cost, and that sites can be found where they would act with efficiency." With all due deference, I submit that the construction of these causeways will be interpreted as an open admission of the failure of the line as originally projected. The Indus Valley Railway was taken along its present alignment with the full knowledge that the floods would have to be combated, and I presume that no alteration has been made in the original intention of its being a permanent and not a simple fair-weather line. Putting aside the obvious disadvantages, both public and private, which will be entailed by the detention of trains, and totally ignoring the comments which will be occasioned thereby, it appears to me that once we admit causeways, we admit weakness and invite disaster.

11. The question of expense was, I take for granted, fully considered by Government when it was determined to lead a railway through the flooded tract, which so palpably might easily have been avoided. After an expenditure of six millions, the difference is comparatively so trifling between putting in permanent and temporary openings, that I have no hesitation in recommending the former, especially as I believe they will be found cheaper in the end.

12. There remains the doubt about the site of these openings. In the conclusions of the Committee held at Sukkur on the 23rd November, 1878, the places where the flood attacks the Railway between Khairpur and Rohri have been accepted as fixed, judging by the fact that nothing more is apparently required than the filling in of holes below bridges. If the sites in this part of the line, which is more difficult to deal with than the upper, can thus be definitely accepted; in the upper portion surely there cannot be such an absolute uncertainty as to preclude permanent openings being built, especially after the experience gained in, at least, three great floods. The existence of "depressions," "great depressions," "low ground," &c., is continually spoken of in the reports of different officers as places where the floods came down; in some cases the banks were breached, and in others the water was turned off laterally until it found vent in bridges or culverts lower down; the velocity through which was enormous, 18 or nearly 19 feet per second having been measured in one case. One certainly of these great depressions (the Madd Dhora, in the Ghotki Division) was entirely embanked across, and the spill which came down it completely shut off at the request of the Civil Officers. In 1876 the bank was breached, and 200 lineal feet of waterway put in, but other marked depressions may exist which still are embanked or inadequately provided with ventage. These facts would point to the conclusion that permanent sites can be obtained at once by extending the present flood waterways, and opening new ones, if necessary, at the "Dhunds," "Dhoras," and other well known localities where floods constantly come down or accumulate.

13. On the grounds above stated, I am of opinion that in lieu of 85 lineal feet waterway per mile, plus temporary flood gaps, it will be better at once to put in permanent waterways, aggregating at least 120 lineal feet per mile, not scattered about in small and danger provoking vents, but concentrated as much as possible in effectually large flood passages.

14. With reference to the lower part of the line, the effect of a practically continuous bund from Kusmore to Sukkur must be to raise the flood level, induce fresh sets, and increase the spill on the left bank. This of course could be counteracted by a parallel embankment; but the danger attendant to Sukkur and the villages below, as well as to the Railway between Sukkur and Larkana, would put this project out of the question. As it is, the Kusmore bund may appreciably increase the afflux already existing in high floods at the narrow pass at Sukkur. This amount of increase is easily capable of calculation, but the data to determine it have not, as far as I am aware, been collected yet. In a similar case on the Ganges near Rampur Bauleah, which was most carefully worked out two years ago (by Mr. A. J. Hughes, Executive Engineer, Irrigation Branch, Bengal) on extensive and very accurate surveys and levels, it was found, I think (I have not my notes to refer to) that the effect of an embankment 80 or 90 miles in length along one side of the river to shut out a spill of upwards of 200,000 cubic feet per second would probably be to raise the height of the flood two feet at the lower end of the embankment. Taking this as an approximate guide, and allowing roughly for the difference in the slopes, and number of curvatures, also for the lesser spill and length of embankment, it certainly would not be safe to accept less than one foot as the increased height of a maximum flood wave below Ghotki, and an increase of some inches in the afflux at the pass. To mitigate the effect of this possible increase then, the spill must be passed off through the Railway as quickly as possible; and if this is done effectually, I see no reason why the afflux at Sukkur should not remain unaltered.

15. Referring back to the table shown in para. 6, it will be seen that from mile 190 to mile 200

the flood surface is still ·60 per mile, or the same as in the 34 miles above the Ahmadwah, but in the next seven miles it is suddenly increased to ·77; it then remains perfectly level for three miles to Khairpur, and in the next 10 miles to Mirpur the slope is only ·36 per mile. The section does not extend below this point.

The cause of the surface level being horizontal has been ascribed to the large amount of cultivation near Khairpur, but this can scarcely account for it; nor does it afford a key to the reason why the slope should be suddenly increased from Reti to near Khairpur, and again very materially reduced below. An easier explanation will possibly be found if we remember that just above Reti the junction takes place between the perpendicular and diagonal slopes from the river; near Khairpur the Railway begins to curve round, and for the three miles where the flood surface is level, is probably nearly parallel to the edge of the fan which spreads out from its apex above Kusmore; from Khairpur to Mirpur the line probably does not follow the circumference, but is slightly inclined upwards to it, hence the alteration in the flood levels.

16. This, combined with the fact that at Reti the distinctive flood tract is entered on boats (used to ply from Reti to Sukkur over the inundated ground), and that it is here that the large and well defined "Dhunds" commence to be more marked, would signify that any alteration in the regimen of the river near Kusmore (especially noting the bend due south of Kusmore from which a primary spill occurs) will be peculiarly left below Reti and near Mirpur.

17. At present the average amount of waterway allowed between Reti and Sukkur is 190 lineal feet per mile. In the section between Reti and Sarhad, from mile 200 to mile 230, I would strongly advocate a further extension so as to bring up the amount to *at least* 250 lineal feet per mile, as much as possible in large flood openings, notably in the vicinity of Mirpur. Between Sarhad and Rohri, or from mile 230 to mile 270, we know there are at present two main spills, besides many secondary ones, the numbers and effect of which will in time be increased by the action of the Kusmore bund. Taking this into account, as well as the present inefficiency of the ventage given, it is evident that the waterways in this section must also be materially increased. Probably they will have to be brought up to a *minimum* of 300 lineal feet per mile—an amount which is not sufficient to pass off the left Sone floods (para. 8) without a considerable heading up. Besides the large opening which will be required for the Ghotki spill (unless there is any fear of the river breaking across the line there), a very large increase will have to be made at Sangi; judging from the fact that the waterway already existing there was evidently greatly too small for the flood of last year, as below every one of the five large bridges near the station, enormous holes extending to 40 and 50 feet in depth were formed.

18. It will be seen that the total amount of waterway that probably is required, at present in the 120 miles of flooded country through which the Indus Valley Railway is taken on the left bank of the river, is 25,500 lineal feet, or very nearly 5 miles, *viz.*:—

				Feet.
From Kot Samaba to Reti,	50 miles, @	120 feet per mile,	.. .. ..	6,000
„ Reti to Sarhad,	80 „	„ 250 „ „	.. .. ..	7,500
„ Sarhad to Rohri,	40 „	„ 300 „ „	.. .. ..	12,000
Total, ..	120			25,500

or about 4 per cent. of ventage on the length of line between Kot Samaba and Rohri—an amount which cannot be considered excessive under existing conditions. Whether this amount will eventually be considered sufficient, time alone will show. The allowance proposed is admittedly empirical, but it is founded on the East Indian Railway experience of 20 years, during which period three maximum floods have occured in the Sone, attacking the line in a length of 26 miles. Whatever is done now on the Indus Valley Railway must to a certain extent be tentative. The total amount of waterway now provided between Kot Samaba and Sukkur is about 16,000 lineal feet, which was recommended by the Sukkur Conference to be increased to 17,700 lineal feet, supplemented by flood causeways between Kot Samaba and Khairpur.

19. Coming now to the question of the Kasimpur bund, I would certainly deprecate its extension to Pano Akil, unless there is any immediate fear of the Indus, as I see noted in one of the reports, deserting its course for the Narra. Taking into consideration the extra rise which may be expected in the floods, and the danger of permitting this rise to affect the river at Sukkur, it would be inexpedient to prolong the bund, and thus tend to aggravate, although, perhaps, only to a slight extent, the afflux already existing. The best method of meeting the difficulty would be, as already suggested, by opening out

sufficiently large waterways higher up in the Railway, in order to pass off the extra spill that may be induced by the Kusmore bund, in addition to the extraordinary floods which now come down the river. If the floorings of the flood openings in the Railway are kept up to a proper level and efficiently protected, I see no reason to apprehend their being turned into ducts for a permanent change of the river. These openings will only come into play when the river rises to a certain height, and will cease to act when the flood falls below the river banks; and as long as the floorings and their protection exist, there can be no fear of the channel scouring back to the main stream, especially if the slope from the river to the level of the flooring is made less than that of the longitudinal flood surface down the river.

20. On the right bank of the Indus, the chief point of danger appears to be in the 10 miles of line, from mile 400 to mile 410 between Bhan and Sehwan, where the Kusmore and Begari spills, added to by the Jalli spill below Sukkur, unite with the Cutchee Hill tract torrents, and after filling and overflowing the Manchur Lake burst across the Railway in enormous force. Outspills from the Kusmore and Begari floods, also combining with the Jalli spill, encroach on the Railway below Ruk.

The Kusmore bund will now keep out the two former floods, and an extension of the Jalli bund would apparantly keep out the latter; but on this point I cannot venture to offer an opinion, as I did not have an opportunity of meeting the Superintending Engineer for Irrigation in Scinde, in whose charge are the embankments; and in the absence of local knowledge and information, it is impossible to say whether it would be advisable to extend the bund. If it was done, however, there would remain only the floods due to the hill streams and the overflow of the Manchur Lake to be provided for. Anyhow between Bhan and Sehwan it would be expedient to allow the full amount of waterway indicated as necessary by the flood of last year, and to raise the line at and below Ruk.

LAHORE:
20th February, 1879.

APPENDIX C.

Extract from Annual Report 1877-78 *giving some account of the method of erecting the ironwork of the Empress' Bridge.*

"Six sets of timber staging have been put together for the erection of the girders, and have been so "far used, that, at the end of the year under review, only 2 spans awaited the erection of stagings. Each "stage consists of 20 four-post tressles, 10 feet square and 18 feet high. In moving the stages each "tressle complete is skidded along a line of rails from its old to its new site; 10 such tressles, with nine "spans of 17 feet intervening, form one side that is one-half of a stage. The beams of the spans, when "in place, are braced to the tressles, the outer lines of beams and posts coming vertically under the "wheels of the travelling crane. The inner lines of beams and posts are directly under the girders to be "erected, and the spacing adopted brings each inner post vertically under the camber blocks on which the "girders are built. A stage contains about 8,000 cubic feet of timber, and can be dismantled, removed, "and re-erected in seven working days. * * * * * *

"In all but the three water spans, the stages rest on a substructure of sand, filled to a depth in two "instances of over 24 feet. The very considerable embankment thus formed, contains close on 20 lakhs "of earthwork, and carries not only the stages, but a service tramway on either side of them.

"At the end of the floods of 1877, the river had one branch running parallel with the line of the "pier points above bridge, and crossing obliquely between piers C and G, while the other branch crossed "the piers directly at N, O, and P. To provide ground for the stages, the first named branch was entirely "closed, * * * * * * * * * *
"this work demanded much patient skill and careful watching when threatened, as it so often was, by "unexpected freshets in November, December and January.

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"Sorting of the girder ironwork is effected on sloping platforms having a descent from the line on "which broad gauge wagons arrive, down to the line along which low trollies take out the pieces; each "span of girder is unloaded on its own platform, and each class of piece of girder, on its own section of "platform or 'skid.' Each class of piece is thus made accessible to the trollies, and a single shunting "operation with these, brings any individual piece into the order in which it is required to ascend the "staging.

"On the sorting platform all packings and temporary rivets are cut out, and each main piece has all "its small loose accessories bolted on, in order to reduce the number of hoisting operations to a

"minimum. These operations have more than kept pace with the arrivals, and foreign wagons arriving "in the day, are invariably returned next morning.

"In erecting, the trollies are run up to the top of the stages by a temporary ramped siding, con- "nected with a line along the stage between the camber blocks and the travelling cranes.

"The four Wellington cranes are those purchased from the Punjab Northern State Railway, 36 feet "span and 35 feet high. The longitudinal, traversing, and hoisting motions of the cranes are all effected "by hand gear; and the latest results, with one crane, are, that a span is erected, and ready for rivetting "in from 8½ to 10½ working days. This includes hoisting 400 tons of permanent ironwork, 100 tons of "light rails for scaffolding, and some 150 tons of sleepers and other timbers in the rivetter's platforms.

"The rivetting is now fairly well done, but much trouble was experienced in training the men to "'knock down' *inch* rivets. Bombay, Bengal, the North-West, Scinde and the Punjab, all contribute "to the present working staff. The former two classes are too feeble for this heavy work.

"The Scindees proved inferior and intractable workmen, and some of the Punjabees display an un- "satisfactory knowledge of the art of caulking a slack rivet to make it appear tight. But they, and the "men from the North-West Provinces, are the best hands we have on the work. Bad 'holding up' is "the worst failing of all, and great credit is due to the officers * * * * "for patiently training their men, and for many ingenious adaptations of tools to suit particular "circumstances.

"The delivery of ironwork has not quite kept pace with the erection, and for the 3 spans not begun "on 1st April, parts of two sets of ironwork were incomplete on the ground, and one (from Karachi) "has not begun to arrive; indeed, has not yet left Kotri. In 10 months the Scinde, Punjab and "Delhi Flotilla has delivered 2 spans at Hamdi and 4 at Gobla, but, had all gone to Hamdi, even this "small result would have been still less. Of 9 spans sent by Bombay and Calcutta, all but portions of "two are on the ground, and the rest will be here in a few days.

* * * * * * * * * *

"The principal works supplementary to the bridge proper are the temporary pile bridge, and the "protective works.

"The temporary bridge of last year, after being breached and repaired in February, lasted till the "beginning of July, and was of immense use to these works, and to the line at large.

"In October of the present year, a new temporary bridge was begnn and completed in a few weeks, "but unfortunately was scoured out before there was time to protect its bed.

"The conditions of pile bridges in this river are—(*a*), That piles can only be driven 12 or 15 feet "in the sand at all; (*b*), That where the bed is not protected with stone or brick, it will scour the "whole depth of a pile in a few hours during a freshet; and (*c*), That if the bed be protected beforehand, "the piles cannot be driven in it at all.

"It follows that if a fresh comes during the construction of the pile bridge, or so soon after as "leaves the protection of the floor incomplete, the work is bound to fail. In this way the bridge of this "year failed three several times, and had ultimately to be abandoned in favour of a new site, which only "became feasible for a bridge owing to the protective bund having advanced more than half a mile into "the water since the first site was chosen.

"The present temporary bridge was opened on the 14th March 1878, by the passage of His Honour "the Lieut.-Governor of the Punjab's Special Train over it. As an instance of quick work, it may be "stated that one week before this train crossed, 16 spans of 20 feet had first been washed out by a fresh, "and were re-constructed in 5½ days, and the remaining 21 spans completed. * * *

"The protective works of the left bank have made excellent progress. The new part of the main "bund is now some 4 or 5 feet above water, and will be complete in 3 months. Although the strength "and solidity of this bund are such that it may fairly be expected to resist all attacks of the river, still, "the height of the great sand bank which overlies the up-stream face of the bridge is so considerable, "that it can only be overtopped by an excessive flood, and then only to a small extent. This means "great constriction of the deep stream up against the bund, and in 2 or 3 spans of the bridge, at the south "end, during floods. To avoid or alleviate this, two canals each of 150 feet in width, have been cut "through the sand bank and down to low-water level. These, even if neither of them succeeds in divert- "ing the channel, will certainly afford an escape for a considerable portion of the floods when they come.

"The workshops have received a great access of work during the financial year from the very consi-

"derable number of locomotive engines brought upon the line. It is useless to recapitulate in detail the "work of the year, but it would be wrong not to call attention to the unostentatious solid work done "in this branch. * * * * * * * *

"In temporary bridges, stages, erecting girders, and especially in rivetting, an almost fabulous quan- "tity of bolts, tools, and ironwork of all kinds, is always being urgently wanted, and by different "sub-divisions at the same time. To this must be added the requirements of locomotive and wagon "work and a mass of undertakings for other divisions. * * * * *

"Both these departments have well maintained their efficiency, and now control some 22 locomotives, "and over 400 vehicles, exclusive of trollies."

APPENDIX D.

Copy of letter No. 5118, *dated* 20*th April* 1878, *from the Engineer-in-Chief, Indus Valley State Railway, to the Director of State Railways, Western System.*

I have the honour to report the occurence of a very unusual, indeed as far as our records inform us, an unprecedented flood in the Sutlej, on the 17th and 18th instant.

2. The river began to rise during the night between the 16th and 17th, and reached its highest during the forenoon of the 18th. At 4 o'clock on that day, the water began slowly to recede from its maximum of 374·85, but next day (yesterday) at 2 P.M. it had only gone down to 373·20. The earliest date on which such a flood has before happened is 25th June 1871.

3. The cause of this flood is of course not snow water. Heavy rain in the valley of the Sutlej in the mountains accounts for it. Of this, however, we had no warning till the consequences became apparent at Phillour and Beas, when the telegraph informed us on the evening of the 13th, that about a 4 feet flood might be expected in due course.

4. Every preparation was at once made. Trains carrying protective material worked day and night from Mubarakpur and Hamdi. All the ironwork of the Sutlej girder span, which owing to the long delay in getting the last span up the river from Kotri, had to be taken across from the north to the south bank, was passed over the temporary bridge, one train alone remaining, which when about to cross had to be stopped, the bridge showing signs of yielding.

5. That a flood of nearly 6 feet, instead of the one of 4 feet expected, had to be encountered, is probably due to rain-fall below Phillour and Beas, but the addition was likely to have been fatal to our temporary works, which could not I had thought stand anything over a 4 feet 6 inches flood.

6. Thanks however to the original stability of these structures, and the completeness of the measures taken to strengthen and protect them, no damage whatever has been suffered beyond that already alluded to, by the temporary bridge, four or five of the pile piers of which having been underscoured have so much settled and gone out of line as to require renewal, a work of a few days only.

7. The piled stage for the erection of the span PQ, through which the bulk of the river passes, stood perfectly notwithstanding the enormous rush of water through it, the initial velocity of which, about 6 miles an hour, being increased by an afflux of about 2 feet caused by the obstruction offered by the piles and their bracings.

8. Constant soundings were taken as well as the terrible force of the water permitted, and protective material thrown in as scour manifested itself about any particular pile, an average depth of 40 feet of water throughout the bay being maintained, though with great difficulty. This left from 15 to 25 feet of the piles still in the ground and what with this, and the completeness of the bracing, the result was that while standing on the stage during the height of the flood, when the corbel pieces resting on the cap sills of the pile-heads, were immersed and the beams above them awash—hardly a tremor could be felt.

9. No settlement took place, but the force of the water pressing with such leverage against the piles, and the immersed portion of the superstructure caused the staging to deviate about 2½ inches from the true line down-stream, without however in any way affecting its strength.

10. This slight deviation it will be remembered is that resulting at the top of the staging which rests on the heads of the piles, and is consequently some 25 feet above the water and between 80 and 90 feet above the pile shoes.

11. When you were at Mooltan a few days ago, and the subject of risk to the girders remaining

to be erected over the two water spans was under discussion, I informed you what was the intended programme of operations in the event of a flood, and that programme was followed.

12. The bottom booms of the span PQ were in the act of being hauled into place, when the telegraph informed Mr. Bell of the coming flood, and the work was at once stopped, every effort being directed to making the position safe.

13. The span NO had fortunately just been rivetted up, and the wedges struck; consequently the flood could not have come at a more fortunate time, since none of the ironwork was for a moment in any danger.

14. The stage PQ was stiffened with chains and protected with cubes and stone as already described. The temporary bridge was chained together for its whole length and anchored securely, so that if swept away, it should not be carried down to the staging of the spans PQ and OP, every part being lashed to the longitudinal chains.

15. When the river rose beyond the calculated 4 feet, the bunds were cut, by which the stream had been forced to leave its course along the axis of the bridge, and it immediately began to follow its old bend, thus relieving the piled water spans, though not the temporary bridge. By the afternoon of the 17th the flood had increased so much that it became necessary to open the cut recently made across the sand spit. This drew off a stream of 150 feet in width by 5 feet in depth, relieving both the temporary bridge and the piled spans, and it was hoped would have sufficed, a very early abatement of the flood being expected. But next morning so far from there being any such abatement the river was still continuing to rise, and the second cut alongside the Adamwahan shore was also opened, with the effect of drawing off another volume of water similar to that in the first cut.

16. The effect of these measures was apparent in an evident reduction in the force of the current through the piled spans, and no further change took place till the water began to recede on the evening of the 18th.

17. I need not say it was an anxious time for all of us, not indeed because any of the permanent works or girder material were for a moment in danger, but because failure of the temporary works would have meant probable failure to complete the bridge this season; as it is, I believe, that if the river remain quiet for a month, there will be a delay of no more than 10 or 12 days in the finishing of the bridge.

18. Vast quantities of stores and plant were removed from the river bed during the space between the warning and the coming of the flood, and I believe nothing has been lost, unless it be a few Belgian 20 kilo. rails used about the staging, and the value of which is very small.

19. Mr. Bell and all his staff worked day and night with the energy and devotion which have been so often called for from them during the progress of the great work upon which they have been engaged, and which is now so near a successful completion.

Copy of letter No. 7148, *dated* 14*th June* 1878, *from the Engineer-in-Chief, Indus Valley State Railway, to the Director of State Railways, Western System.*

In reply to your No. 2434W., dated 9th May 1878, forwarding copy of Government of India, Public Works Department letter No. 1632R., dated 2nd idem, calling for an explanation of the circumstance that the erection of the girders over the water spans of the Sutlej Bridge was delayed so long as to involve a certain amount of risk from the rising of the river, I have the honour to submit copy of a letter No. 1439, dated 15th May 1878, and its accompanying memorandum from the Superintendent of Works, Mr. Bell, which latter will I think be found to afford all the information required, and establish conclusively that the procedure followed in the erection of the girders was the only one practicable under the circumstances.

2. Briefly the explanation is as follows:—

When the first span of girders arrived on 5th November last, and it became necessary to put erection in hand at once, the water spans through which the deep river ran, could not be undertaken, firstly, because the piers were not then built; secondly, because the river was too high, and the current too violent through those spans to allow of even preliminary works being begun, as piling, which might otherwise have gone on concurrently with the building of the piers.

3. The floods and freshes repeated throughout the cold weather delayed the completion of one of these piers P, till the end of February, its foundations upon the well-heads having been three times destroyed.

4. Nothing could be done during this period in the water spans owing to the violence of the river, but every effort was made to push forward girder erection over the spans next to them on the Adamwahan side, with a view to at least a partial diversion of the river under them, and thus to relieve the pressure of the stream on bays OP and PQ.

5. This could not be done in time to be of any use, the river having destroyed the reclamation works in span NO twice, and threatened to break through by the back channel on the Adamwahan side, by following an old bed which runs parallel with the axis of the bridge and just above it.

6. As such a contingency would have been disastrous in the extreme, if not fatal to the completion of the bridge this season, it became necessary at all costs to prevent the river getting in that direction, and this was effected by means of bunds difficult of construction and difficult afterwards to remove.

7. Their effect was, while preserving the ground on which all the girders from O to B were to be put up, necessarily to confine the river to the two water spans in which its deep bed was already placed.

8. The circumstances above described so far delayed the erection of the span NO, that it was not completed till 17th April, long before which time all idea of being able to divert the river at all had been abandoned, and indeed the span PQ had been piled, its stage erected, and but for the known approach of the flood, the occurrence of which was reported in my No. 5118, dated 20th April 1878, would have had some girder ironwork upon it.

9. Thus the piling of the water spans as soon as it became inevitable that recourse must be had to that process, an eventuality always contemplated, was undertaken without the loss of a day, and the best efforts of the Staff were directed to the completion of what was in itself a most arduous and difficult task, the pitching and driving in water from 30 to 55 feet deep running at great velocity, of four rows of piles from 50 to 70 feet long. That these efforts were completely successful I need not now say.

10. The risk incurred, as very striking events have proved, was amply provided against by the precautions taken, and if we had the same work to do again and under the same circumstances, I can only say that I should do it again in the same way.

11. As a matter of fact there was no time during the six months that sufficed for the completion of the heavy work of erecting the Sutlej girders from beginning to end, that the spans over the deep river could, as the season turned out, have been put up without risk, nay, had it been possible by reason of their piers being built in time, to have begun upon those spans in November, it is far from improbable that they would then have been exposed to greater danger than they were subsequently in April and May; for we could not then have known what great precautions the abnormal behaviour of the river would require; and trusting to the immunity from floods looked for during the cold weather, it is likely—certain, indeed, that all the manifold precautions taken in April would not then have been thought necessary.

Copy of letter No. 1439, *dated 15th May* 1878, *from the Superintendent of Works, Empress's Bridge Division, to the Engineer-in-Chief, Indus Valley State Railway.*

In announcing for the information of the Director, that the last of these girders was erected on the 9th instant, I have the honour to forward a Memo. on the subject of the erection which may possibly serve to refresh your memory, and to put the whole matter definitely on record.

2. Mr. James Tait, Assistant Engineer, now 1st grade temporary, was in charge of the steps taken for erecting girders last season while employed in your office. He was succeeded in this charge by Mr. G. Moyle, Assistant Engineer, 2nd grade, who erected the 1st span of the first sub-division, the 6 spans of the second sub-division, and Bahawalpur abutment span, Mr. Tait on his return completed the remaining 5 spans of the first sub-division, the Adamwahan abutment span, and finally with Mr. Moyle's men and his own, the two water spans. Mr. B. Baxter, now temporary 1st grade Assistant Engineer, erected both temporary bridges, carried out the sand filling from A to O, made and maintained

the various dams and bunds, and the breakwater. Mr. W. C. Hennessey has supervised the protection from scour of the staging piles.

3. The Subordinates worthy of mention are—

Mr. L. Desmazures, Sub-Storekeeper, 1st grade, Divisional Storekeeper.
„ M. MacInerney, Sub-Engineer, 2nd grade, and Mr. T. MacInerney, Temporary Overseer, 1st grade. } All staging whatever.
Mr. G. Winmill, Sub-Engineer, 2nd grade. Workshops.
„ T. Macpherson, Sub-Engineer, 3rd grade, all rivetting.
Azis-ud-din, Overseer, 1st grade, lines, levels and protection.
Babu Kristonauth Banerjee, Overseer, 2nd grade, earthwork and bunds.
Nur Mahomed, Sub-Overseer, temporary bridge-work.
Mr. T. Sharrocks, Foreman, on erection only.

4. The works establishment men of most note are—

Mr. J. W. DeSilva, } erectors.
„ C. A. Rex, }
„ C. Smith, }
„ D. O. Shaughnessey, } rivetters.
„ Girdlestone, }
Safar Ali, } rigger mates.
Narain Singh, }

MEMORANDUM

On the order in which the spans of the Sutlej Bridge were erected and the reasons for the arrangements adopted.

1. When spans began to arrive in November it was known that not more than 8 of the 16 spans could possibly reach here, *vid* Karachi in time for this season. As a matter of fact after landing the material at Sukkur, and using all the resources of the line to supplement the defects of the Flotilla, the 7th span *vid* Karachi only reached here on May 4th, and quite a month after 9 spans had come the other way.

2. Government had telegraphed orders to divert those still unshipped from Karachi to Calcutta, but it was matter of uncertainty whether all would arrive in time, and it was quite possible that even if shipped in time and to Calcutta instead of Karachi, one or more spans might not have been lost at sea.

3. The information received later on that as many as 3 spans, or parts of 3 spans were loaded in one ship, showed that the risk of disasters at sea were actually greater than it would have been in our power to repair.

4. The earlier spans from Karachi, and all spans from Calcutta and Bombay, would necessarily arrive on the Adamwahan side of the river, and as will be seen below, this side was the only one from which operations were possible at the beginning of the season.

5. To meet the clear possibility of all the spans not arriving, it was determined from the beginning that the two abutment spans should be left untouched, until all ironwork was known to be certainly in the country, and probably available here in good time. This decision was based on the fact that the spans indicated have a solid substratum of stone and block wells, on which girders could safely be erected even in the floods. Moreover communication could be made good across these openings in case of total loss of their girders, by adapting the erecting staging to the support of a temporary line of rails.

6. To this end a stack of sleepers, filled in solid with earth as a protection from fire, was actually erected in span AB. Along this communication with the land was maintained, and materials were carried over this and the erected spans to those beyond when the stages themselves had been carried forward in rotation. The abutment span at QR was not, however, filled up in this way, as sleepers were not available, owing to causes beyond the control of this division, and it was clearly out of the question to divert one of the stages to this purpose, so long as it (the stage) could be advantageously used for erecting girders in the bed of the river on the Adamwahan side, so long, that is, as the possible deficiency of girders did not admit of QR span being itself erected.

7. The position of the river and the bridge at the commencement of the season was as follows:—

Commencing from the Bahawalpur abutment, span QR was, as already stated, blocked with stone and wells. The deep river flowed through spans PQ, OP, and NO, the depth in OP and PQ being some

55 feet, with violent swirls and eddies, rendering sonnding difficult and piling impossible. In NO the water shelved from a foot or two at N to 25 feet at O, and the tendency was for the river to silt up at PQ, and gradually to cut its way from O to N from N to M, and so on towards Adamwahan.

8. From N to M, L, and K, various shallow channels crossed the line of bridge, but these were stopped up, aud, by a strenuous effort, were filled with sand to a level proper for the stages to stand on by the middle of December. In this half of the bridge piers Q and R were built; L, M, N, O, and P, unbuilt in October, were ultimately finished, P being the last in February.

9. Parallel with the bridge on the up-stream side, a shallow branch of the river ran from O pier to C, and crossed the bridge between B and C, where the water, though slow, was 17 feet deep. In DE and EF there were 4 or 5 feet of still water, and from F to K there was a sand bank varying from a foot or two above water to 4 or 5 feet.

10. On the Adamwahan side of the Dhund at CD, spans AB and BC were alone available for immediate erection, but, as above stated, AB was left out, rather than use up a span that might under possible contingencies be required elsewhere.

11. On the above data, and on the necessity for working the cranes onwards continuously from one stage to the next, the programme for the season was at once formulated, and the work divided into three portions as follows:—

(*a*). The sleeper stack was inserted in AB. Span BC was erected as a trial span on which to train the men, and the work of filling up spans CD, DE and EF, with sand for a basis to the staging was vigorously pushed. This, with spans FG and GH, constituted the first sub-division of erection, and spans FG and GH were left to the last, as (being on a 4 feet sand bank) their ground was probably secure till February, whereas the sand filling at CD, DE and EF, was just as likely to be destroyed by an early flood as any other part of the work in the river bed.

12. (*b*). The bund closing the arm of the river which crossed at CD, was so arranged as to form the base for a tramway from Adamwahan to pier G, which stood as before stated in a sand bank. From G to H this tramway ascended by a steep ramp to the top of H; and from H to I and K, the first stages of the second sub-division were erected on the dry island, and their spans also were erected while the building of the piers beyond, and the formation of more staging was in progress. The object of the second sub-division was to begin as near the deep river as was then feasible, and to push forward as quickly as possible with the spans up to the brink of the deep stream, if possible to O, but certainly to N.

13. (*c*). Meanwhile the river sub-division used every possible endeavour to hold the acquired ground from N towards Adamwahan, and if possible to reclaim span NO also, with a view to the early completion of the second sub-division, and the diversion of the river from spans OP and PQ, under the second sub-division girders, during the first anticipated serious rise in February.

14. This part of the programme was so far steadily adhered to, that from the time when the first trial span in the first sub-division was erected, before any work was practicable in the river bed, all the spans that arrived, in order from the second to the sixth, were devoted to sub-division No. 2. At this point, however, the reclamation of span NO had twice been lost through unexpected floods, and the risk of losing the costly filling from C to F had become so imminent that the 7th, 8th and 9th spans, in order of arrival were given to the first sub-division, and it was not till the 10th span came to hand that NO could be gone on with.

15. During this interval one of the cranes of the second sub-division was taken down and re-erected at the south abutment, in readiness to begin the water spans from that end, as well as from N pier. The fact that the removal and re-erection of a crane occupied at least three weeks, should be mentioned here as showing how absolutely necessary it was to carry on the work progressively in one line, so that the cranes might pass from one stage to the next uninterruptedly.

16. The third part of the programme referred to the two abutment spans, (which were necessarily left to the last, as per para. 5,) and the two water spans, in which the river was ultimately confined for a time at OP and PQ. This sub-division, up to the point when it was ready for the erection of the girders, formed the peculiar charge of the Executive Engineer personally.

17. The first project for this part of the work was to erect a temporary bridge, as near the line of staging as might conveniently be, and then, with the matured experience gained on the temporary

bridge, to erect the staging proper in the still deeper water which is necessarily occasioned by the violent scour to which the piers give rise.

It was as a rider to this programme, which has never in fact been for a moment lost sight of, that the second sub-division was to be pushed forward, both as a means of getting the cranes and materials to O and P piers at all, and with a view to a diversion of the river towards M and N, leaving the deep water at OPQ comparatively slack, if not partially silted.

18. The first attempts to pitch isolated piles in the 40 or 50 feet of water at the proposed line of temporary bridge were so unpromising, that a plan was devised for using strong tressles of four piles, heavily braced together, as piers for a temporary bridge, which was to be strengthened by additional single piles, for which the tressles would serve as guides and as "steadiment." This method was tried early in November, but was abandoned as unfit for the staging when one leg of the experimental tressle was found to stick up upon the stone sunk in the protective works, while the other legs were free to sink in the soil of the river bed.

19. The river, it is almost needless to say, tears up its bed with the utmost violence in the floods, while, during the working season, although interrupted at irregular intervals by casual freshes, the tendency is for the stream to shoal, and consolidate its bed, while operating mainly on its banks in its efforts to establish a regimen. The regimen it seeks is, in fact, a gradient so long in proportion to the fall, and a section so shallow in point of depth, as between them to reduce the velocity of the stream below the point at which eddies, and their concommitant scour, can be produced. It is a fact that in the Sutlej a flood gradient of 1 in 7,500 is thus reduced to 1 in 10 or even 11 thousand, and that the mean flood depth, which is certainly over 30 feet, and not infrequently 45 or 50, diminishes, as the season advances, to a point which makes the river impracticable for vessels drawing 4 or 5 feet of water, although, as may well be supposed, the contraction which occurs in the spans of a bridge keeps the depth in these very considerable at all times.

20. In virtue of these conditions the river bed became so far steady by the middle of December, that a temporary bridge had been erected, though not without serious difficulty, a few chains above the main bridge. Owing, however, to a totally unlooked for flood occurring before the temporary bridge floor could be protected from scour, the work was utterly destroyed, and the river bed was so violently disturbed, that operations on this line, and *à fortiori* in the spans, were necessarily postponed throughout January.

21. By February the admirable progress in the river sub-division with the left bank breakwater, made a site feasible for a temporary bridge, which was at first out of the question, owing to its great length. The extension of the breakwater had moreover another effect, for by pushing the river out of an oblique position into one where the stream ran squarely and comparatively smoothly through spans OP and PQ, it at once made piled staging practicable, and, at the same time, deprived the river of the cant through which it formerly extended to divert itself under NO.

22. When it is remembered that the temporary bridge, in but 15 feet of water, was damaged more than once, and only finally completed for the Lieutenant-Governor's train on the 14th of March, it will not be surprising that the first water stage, in 55 feet of water, was not an assured success, till the Director's visit at the end of the financial year.

23. The many unlooked for floods were certainly the main cause of delay to the temporary bridges, and hence to the stagings, of which they were the necessary preliminary experiments. Besides waiting for girders, NO had ultimately to be not only thrice reclaimed, but also piled, owing to the restlessness of the river, and it thus fell out that the alternative of diverting the river under NO span could not have been begun, in point of time, until as a matter of fact the stage in PQ was ready, while the advantages of reserving this work for the period of the river's bed being most steady, and our own experience most matured, is fairly proved by the fact that it took from middle of November to middle of March, before a temporary bridge was fairly established, after which one stage was finished in four weeks, and the last one in a clear fortnight.

24. It is gratifying to report that the first sub-division was ready at the same time as the second, and hence when the last and very serious flood of Good Friday came, the breaches in the sand filling at OD, FG, LM, and NO, found all the girders over them ready, and their stages in the act of being dismantled. It would have been even worse to have let a half erected girder down, than to have failed, as, in such a season, we easily might have failed, in staging spans of 56 feet and 48 feet depth.

No. 3210 W.

From

THE DIRECTOR OF STATE RAILWAYS,

WESTERN SYSTEM.

To

THE ENGINEER-IN-CHIEF,

INDUS VALLEY STATE RAILWAY.

Dated Murree, 19th June 1878.

The following is forwarded to the Engineer-in-Chief for information, with reference to the correspondence ending with this office No. 2617W., dated 20th May last.

(Signed) F. W. PEILE, COL., R.E.,

Director, Western System.

Copy of a letter No. 1141, *dated the 1st June* 1878, *from the Consulting Engineer to the Government of India for Guaranteed Railways, Lahore, to the Director of State Railways, Western System.*

Has the honour to forward for information, copy of Note by Consulting Engineer, dated 29th May last, on his Official Inspection of the Sutlej Bridge at Adamwahan, on the Indus Valley State Railway.

Note by Consulting Engineer for Guaranteed Railways, Lahore, on Official Inspection of the Sutlej Bridge at Adamwahan, on the Indus Valley State Railway.

Mr. Bell's Memo. herewith forwarded prevents the necessity of my giving any description of the bridge.

2. I began the inspection on the afternoon of Wednesday the 22nd May.

3. As there are 16 spans, all of which it was desirable to test, I arranged to observe the deflection under the test load of the 8 spans on the Bahawalpur side myself; Colonel Bonus,* R.E., who was with me, kindly consenting to do the same for the 8 spans on the Mooltan side.

4. For the former 8 spans, a train of three engines and tenders with five trucks loaded with stone in front and the same behind, was employed, a diagram of this train showing the weights at different points is appended, drawn out by Mr. Moyle, Assistant Engineer. The total weight on the span was 254 tons on a length of 260 feet, or very nearly one ton per foot run.

5. This train was brought over each span in succession, and the deflection of each girder noted—*first*, when the train came to a stop; *second*, after an interval of 10 minutes; *third*, after the train had rolled off again.

6. For observing the deflection two parallel vertical deal rods were employed, one fixed to the lower flange, the other supported on the ground or fixed in the water. By ruling fine pencil lines across the parallel rods, the deflections to the $\frac{1}{16}$th of an inch could be noted with great accuracy, and were judged to the $\frac{1}{32}$nd of an inch.

7. For the other 8 spans, as stone trucks were not available, a train of five engines (three tank engines and two with tenders) was employed, though this did not quite cover the whole span, it was really a severer test than the other.

8. The results under both trains were, however, singularly uniform, as will appear on reference to the Table, the deflection in no instance exceeding $\frac{15}{16}$, and being generally under that, while the set in one instance only amounted to as much as $\frac{1}{8}$th of an inch.

* Engineer-in-Chief, Punjab Northern State Railway.

9. On the following morning, the train of five engines was passed slowly over the bridge from end to end, and the deflection noted by pencil diagrams. The results are recorded, they do not differ sensibly from those under the former test.

10. On this morning I visited the protective bund, and, passing slowly over the bridge on a trolly, examined the details of the work as far as possible.

11. In the evening the train of five engines was driven over at speed, and the oscillation noted of three of these girders, including the one last finished, on which the roadway plates were not completely rivetted, and which was therefore likely to show the most unfavourable results, I took the observations on this myself with the vertical wire of a spirit level, which was directed on a card divided to $\frac{1}{10}$th of an inch fixed laterally to the lower flange. The result of several observations showed a mean oscillation of $\frac{4}{10}$th of an inch only, the girders observed by Colonel Bonus showing $\frac{3}{10}$th. The deflections under the fast train as shown by diagram were 1·4 and 1·3 on the same girders.

12. The result of the above tests being so completely satisfactory, I did not think it necessary to pursue them further.

13. I compute the strain on the centre of the upper and lower flange of any girder, produced by its own dead weight of 460 tons, and a uniform live load of 250 tons, as amounting to $2\frac{1}{2}$ tons per square inch in compression, and 3 tons in tension respectively.

14. I am of opinion that the speed of trains over the bridge need only be limited by the ordinary speed over the line, so soon as the roadway is quite finished. At present the rails follow the camber given to the girders, but they will, I understand, be lifted and packed to a level.

15. The covering plates of the roadway were intended I believe to be laid with asphalte, this has not yet been done, and it is, I understand, under consideration to cover them with concrete. This, if laid to a sufficient thickness over the crown of the cover plates, will bring a considerable extra weight on the roadway, which it would be as well to avoid if possible.

16. It certainly seems a pity that the top of the girders cannot be utilized for a carriage roadway, but the cost of the necessary approaches, *at present*, appears to put it out of question.

17. The ends of the earthen approaches where they join on to the abutments are at the present very ragged, and should be finished off as soon as possible. I am not certain whether there will not be some trouble with the masses of loose stone here proposed.

18. It may be as well to have fixed marks on each pier, which can be observed through a level from either shore during and after heavy floods. In spite of the great depth to which the well foundations have been sunk, it is still possible that subsidence may occur.

19. I think the protective spur bund is likely to answer well, judging from the experience obtained by the Scinde, Punjab and Delhi Railway on the Sutlej, Beas and Jumna, where similar groynes have certainly done good service, and I think it will not be found necessary to continue the spur right on to the abutment. But I certainly think the stone protection should be extended backwards over the crossing of Nowrungawah, and I believe the Director concurs in that view. I should also object to the continuous channel along the toe of the present bund. If the river *did* take a set in that direction during a period of high flood, the safety of the bund would certainly be endangered by any scour along its upper side.

20. At present there is no sign of any action of the river, which would threaten the *right* abutment or approach, but as I believe Adamwahan itself (which stands on this bank) was inundated only a few years ago, it is quite possible that protective works may be required on this side also, and common prudence will dictate the maintaining of large reserves of stone on both banks for some years to come.

21. Although not strictly within the sphere of my Report, as I happened to see this bridge little more than a year ago, when the foundations were still unfinished, I cannot help bearing my testimony to the extraordinary energy and skill, which must have been shown by the officers concerned in completing this great work under circumstances of considerable difficulty in so short a time.

Testing Sutlej Bridge Girders, May 22nd and 23rd, 1878.

Showing deflection at centre of girders, lower flange.

Spans.	Test A. Up-stream.	Test A. Down-stream.	Test B. Up-stream.	Test B. Down-stream.	Test C. Up-stream.	Test C. Down-stream.	Test D. Up-stream.	Test D. Down-stream.	Test E. Up-stream.	Test E. Down-stream.	Test F. Up-stream.	Test F. Down-stream.	G. Lateral oscillation.	Remarks.
Mooltan end.	Amount of camber given to the several girders will be reported afterwards, it is about 4" on an average.										Others not taken.	Ditto.	Ditto.	
A. B.			1 3/16	1 5/16	1 3/16	1 5/16	1/32	...	1 1/8	1 5/16	1·4	1·4	·8	Col. Medley, R.E.
B. C.			1 1/4	1 1/4	1 1/4	1 1/4	1/16	1/32	1 1/4	1 5/16				
C. D.			1 9/32	1 5/32	1 9/32	1 5/32	1/16	1/32	1 5/16	1 5/16				
D. E.			1 3/16	1 3/16	1 3/16	1 3/16	1/32	1/32	1 1/4	1 1/4				
E. F.			1 1/4	1 1/4	1 1/4	1 1/4	1/16	...	1 5/16	1 1/4				
F. G.			1 1/4	1 1/4	1 1/4	1 1/4	1/16	...	1 5/16	1 1/4				
G. H.			1 1/4	1 1/4	1 1/4	1 1/4	1/16	...	1 1/4	1 5/16				
H. J.			1 3/16	1 3/16	1 1/4	1 3/16	1/16	...	1 1/4	1 1/4				
J. K.			1 1/8	1 3/32	1 1/8	1 3/32	1/32	1/32	1 1/8	1 1/8				Col. Bonus, R.E.
K. L.			1 1/8	1 1/8	1 1/8	1 1/8	1/16	1/16	1 1/4	1 1/4				
L. M.			1 3/32	1 3/32	1 1/8	1 3/32	1/16	1/16	1 1/4	1 1/4				
M. N.			1 1/8	1 5/32	1 3/16	1 5/32	1/16	...	1 1/8	1 1/8				
N. O.			1 3/32	1 1/8	1 3/32	1 1/8	...	...	1 1/4	1 1/4				
O. P.			1 3/16	1 7/32	1 3/16	1 7/32	1/16	1/8	1 5/16	1 1/4				
P. Q.			1 3/16	1 3/16	1 3/16	1 7/32	1/32	1/32	1 1/8	1 1/8	1·3	1·3	·2	
Q. R.			1 1/8	1 1/8	1 5/32	1 5/32	1/32	1/32	1 1/4	1 5/16	1·3	1·3	·2	
Bahawalpur end.														

Test A. Before load comes on, *i. e.*, camber.
„ B. Deflection on load coming on.
„ C. Deflection after 10 minutes.
„ D. Deflection on load coming off, *i. e.*, set.
„ E. Deflection on load passing over at 5 miles per hour.
„ F. Ditto ditto 20 ditto.
„ G. Lateral oscillation U. S. only, taken mean of 4 observations.

Lahore,
May 29th 1878.

(Signed) J. G. MEDLEY, Col., R.E.,
Consulting Engineer.