From a Sketch by W. Kay, Engineer

GANGES CANAL, LOOKING UPSTREAM.

REPORT

ON THE

GANGES CANAL WORKS:

FROM THEIR COMMENCEMENT

UNTIL THE OPENING OF THE CANAL IN 1854.

BY

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PREFACE.

THE following Report was drawn up on my leaving India, in 1854. It was written expressly for the information of the Government of India, for the aid of my successor in carrying on the works, and for the use of the Irrigation Department, generally, in the North-Western Provinces.

Beyond answering these purposes it has no pretensions whatever. For the English public it can have no interest, and but little even for the English Engineer. To the officers and men of the Irrigation Department, and particularly to those of the Ganges Canal Works, for whose information I have entered into such minute details, these details will, I hope, prove useful.

Many years of doubt and difficulty have been cheered by the prospect of my ultimately being permitted to place this Report in the hands of two of the warmest friends and supporters of the project, James Andrew, Marquess of Dalhousie, Governor-General of India, and the Honourable James Thomason, Lieutenant-Governor of the North-Western Provinces.

In the case of Lord Dalhousie, my hopes have been realized; but Providence has ruled it otherwise with my excellent friend Mr. Thomason, who died six months before the Canal was opened.

PROBY T. CAUTLEY.

London, September 1, 1860.

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ERRATA.

Vol. I. p. 207, line 7, *for* "Mozuffnuggur," *read* "Mozuffurnuggur."
Vol. I. p. 303, diagram, *for* "Cola Ghat," *read* "Gola Ghat."
Vol. I. p. 304, line 11, *for* "struggling," *read* "straggling."

GLOSSARY.

Akh, Asclepias Gigantea.
Bajra, Panicum spicatum.
Bangor, high land.
Bazar, market for general purposes.
Beega, a measure of land, in the canal district, North-West Provinces, 55 yards square, or five-eighths of an acre.
Beldar, an earth-digger.
Beri, *Byr*, Zizyphus jujuba.
Bhabur, Eriophorum comosum.
Bulla, a large pole made of a single tree.
Bulli, a small pole made of a single tree.
Bund, embankment.
Chittak, a weight equal to two ounces or 1-16th of a seer.
Choki, a guard-house, a building for protective purposes.
Chupper, thatched roof.
Chuprassi, servants, wearer of a belt with a chuprasor plate on it.
Classi, servant, tent pitcher.
Daghbel, a mark laid out on the ground as a guide for excavating or building.
Daul, scoop for raising water, term applied to irrigation by means of machinery.
Doob, Cynodon dactylon.
Ghat, steps or slope to reach the canal water.
Gram, Cicer arietinum.
Gunj, market for corn.
Gusht, patrol.
Jamun, Eugenia jambolana.
Jhama, vitrified brick from brick-kilns.
Jheel, pond, hollow, marsh.
Jowar, Holcus sorghum.
Jute, Corchorus olitorius.
Khadir, low land.
Khalesuh, land held immediately from Government.
Khekur, Acacia arabica.
Khet, a field.
Kist, instalment.
Kool, artificial water-course, to the east of the Ganges termed "gool."
Koora, manure, refuse used in burning bricks in the native brick kiln or puzawa.
Kujoor, Phœnix sylvestris.
Kunkur, alluvial deposit of a clayey limestone modular or in tabular masses.

Kupas, cotton (uncleaned).
Kurreel, Capparis Aphylla.
Khureef, rain and warm weather crop, from May 1st to October 31st.
Kurri, a small sawed-up rafter.
Kutcha, unburnt, reverse to pukka.
Kyr, Acacia catechu.
Lakhraj, rent-free.
Lobya, Dolichos sinensis.
Makkee, Indian corn.
Mali, gardener.
Mangoe, Mangifera Indica.
Maund, a weight equal to 80 pounds in the canal department.
Mistri, head mason, or head artificer of any sort.
Mong, Phaseolus Mungo.
Moonje, Saccharum manja: the culm is *sirki*.
Moonshi, writer, secretary, superior to mutsuddi.
Mutsuddi, writer, keeper of accounts.
Neem, Melia Azederachta.
Neemchuk, a wooden frame, on which masonry is placed for undersinking.
Nuddi, natural watercourse (wet).
Nulla, natural watercourse, wet or dry.
Oopla, cow-dung made into cakes for burning.
Oorud, Phaseolus radiatus.
Oosur, barren.
Pukka, burnt. Metaphorically applied to anything solid and substantial.
Puzawa, brick-kiln.
Rajbuha, a main line of artificial watercourse directed from the main canal or reservoir.
Rooi, cotton (cleaned).
Rora, broken brick.
Rubbee, cold weather crop, from November 1st to April 30th.
Saees, groom.
Sal, Shorea robusta.
Seer, a weight equal to two pounds.
Simul, Bombax Malabaricum.
Sissoo, Dalbergia Sissoo.
Soorkhi, *Soorkhee*, pounded burnt brick.
Suddur Bazar, Government market.
Tar, Borassus flabelliformis.
Teak, Tectona grandis.
Til, Sesamum orientale.
Toddy, (properly, Tarri,) unfermented juice of the Tar-tree.
Toon, Cedrela Toona.
Tor, term applied to surface irrigation.
Tughar, trough in which water is mixed (in the ground).
Tulao, tank.
Tukkavi, cash advances to cultivators.

PART I.

HISTORICAL SKETCH OF THE ORIGIN AND PROGRESS OF THE GANGES CANAL.

THE GANGES CANAL.

CHAPTER I.

PRELIMINARY PERIOD,

Under the directorship of Lieut.-Col. P. T. CAUTLEY.

From 1839 *to* 1845.

THE direction of the drainage on the southern slopes of the Himalayas throughout the provinces of Upper India lying to the north-west, the character of the rivers which constitute this drainage, and the topographical features of the country through which it passes, point out by unmistakeable signs a region designed by nature as a great field for artificial irrigation. These rivers after their debouche from the mountains enter upon a champaign country with a rapidly decreasing slope, and from the parallel direction which they assume in their passage to the Indus on one side, and to the Ganges on the other, divide the country into sections of a larger or smaller width, all of which, both in soil and declivity of surface, possess in themselves every requisite for irrigation. The steep slopes that exist at the immediate debouche from the mountains enable the engineer, by a proper adaptation of levels in his artificial channels, to obtain a command of water, which places the whole country under his control; the benefits, in fact, that he is able to confer upon it by means of irrigation are limited by the volumes of water which are at his disposal; and his greatest, it may be said his only, difficulties are in the neighbourhood of these steep slopes, and in their connection with mountain torrents. From the above description it will be evident that a canal whose head supply is derived from the higher levels of these rivers, and whose course is carried parallel to them, must inevitably act as a medium for irrigation; this plain fact is appreciated by every villager who resides in the vicinity of these rivers, and who, although he may not have the means, in the possession of land, of turning it to account in irrigation, yet adopts the principle in designing cuts to turn his corn-mills, or in establishing dams for the application of his fishing apparatus. On a larger scale this same fact has been taken advantage of by our Puthan and Moghul predecessors, not only on the Jumna, but on the rivers in Rohilkund and in the Punjab; on the Jumna especially the canals on the east and on the west of that river, which within the last thirty years have been restored by the British Government, are vestiges of its early appreciation. The Husli Canal from the Ravi in the Punjab is of the same character; while Rohilkund, and the countries bordering on the Indus, throughout their length and breadth offer a variety of specimens of canals of more humble pretensions, but proving in every case that the method of obtaining irrigation was perfectly understood. With so many examples before us, no great exertion of intellect was required to arrive at the conclusion that the system might be generalized; with a map before us, it was fair to infer that, if canals had been so easily supplied from the Jumna, similar canals might, under similar circumstances, be taken from the Jhelum, from the Chenab, from the Ravi, from the Sutlej, from the Ganges, from the Ramgunga, or from any other of the rivers that, after leaving the mountains, pass over a country possessing in its contour every qualification for enabling the engineer to make the best possible use of the water that could be distributed over it.

It was under these well-known characteristics of surface, and with the example of the Jumna Canals before us, that the idea of taking a line from the Ganges originated. There were natural difficulties existing on both sides of this river at and immediately below the point where it leaves the mountains, that had notoriously injured its reputation as a source of supply for a canal; but so little was known of the detail of these difficulties, or of the extent to which the surface of the country was affected by them, that, in consequence of the similarity of connection between the Boodhi Gunga and Boodhi Jumna, and the main rivers of which they were respectively ancient branches, a hope was entertained that the former would furnish a site for the head works of the Ganges Canal equally appropriate and effective with that supplied by the latter for the head works of the Eastern Jumna Canal. It was from a point near the village of Badshahpoor marked A in diagram I. that the first line of levels was taken; the extraordinary elevation of the country at D, from whence the high land of the Doab commences, was not then known by those interested in irrigation. At the point where the line of levels from A crossed the boundary of the high land, the rise of country was equal to 83·225 feet; the possibility, therefore, of using the Boodhi Gunga as a head for a canal was totally out of the question; but the same course of reasoning which had led to the adoption of the Boodhi Gunga in the first instance, led further to that of a point situated on the main river at higher levels; as it was clear that by proceeding higher, and leaving cost out of consideration, the certainty of discovering a line upon which a canal might be traced was indubitable.

Before entering upon the narrative of the rise and progress of the works of the Ganges Canal, a few words on former projects for the irrigation of the districts which are to be placed under its influence may be appropriate; these, so far as I am aware, are only two in number: the first, or Muhummud Aboo Khan's Canal, which appertains to a period prior to the accession of the British—the second, a project of Captain Debude's, of the Bengal Engineers, submitted to Government in 1827.

The canal of Muhummud Aboo Khan, the remains of which still exist in the neighbourhood, and to the north-north-west of Meerut, consisted of a cut made from the West Kalli Nuddi, near the village of Rampoor, to the head of a small tributary of the East Kalli Nuddi, called the Khodara Nulla, which rises near the village of Deorala. The length of this cut did not exceed 12½ miles, and its dimensions, judging from the existing hollow, could not have exceeded 15 feet in width. The water, after reaching Deorala, must have passed down the Khodara Nulla to the town of Meerut, in the neighbourhood of which there are many groves and gardens, and it is supposed that it was for the purpose of supplying water to these that the canal was originally projected. There is no tradition, however, of its existence as a running stream, although there is no reason to doubt that, for a season at least, it was so. The canal was evidently one of those which, from the circumstances affecting its supply, and from the total absence of all masonry works, could not have been classed under the head of permanent works for irrigation. The West Kalli Nuddi, at the village of Rampoor, although a perennial stream, is one of those lines of drainage which, during the periodical rains, is subject to very great floods.

The river meanders through a valley of considerable extent, and during the dry months is 30 feet below the level of the country, or below that land over which Muhummud Aboo Khan's Canal was carried. The canal was merely excavated to a few feet in depth, and water was supplied from a lake, formed by throwing an embankment across the bed of the West Kalli Nuddi. The flooding of the valley by this retention, or damming up of its waters, must have done extraordinary damage to the properties within its limits; the amount of money and labour expended on an embankment, of proportions sufficient to gain the engineer's object, must have been very great; and the necessity for an annual reconstruction of a work, which was inevitably destroyed during the rain-floods, and the certainty that water could only have reached the mouth of the canal during the dry months of the year, are facts which reasonably led us to conclude that no great benefit was ever derived by the cultivators on the high lands in its vicinity. The line of the present Ganges Canal channel crosses the remains of Aboo's Canal (as it is now called), at an angle of 50°, near the village of Jowalagurh, and, by a singular perversion of purpose, that portion of it which approaches the canal from the West Kalli Nuddi is now converted into an escape, for throwing the waste water from the canal into the valley of the river. The plan above described as carried into effect by Aboo Khan, is an illustration of canal-designing, which is by no means uncommon in this part of India. It possibly originated partly in the inability of the owners of the site upon which the bund was erected to take possession of land at a higher level of the river's course, and partly from the apparent magnificence of a design which, in converting dry land into a lake, realized in the eyes of the multitude the acts of the jinns, or genii, of Eastern fable. Over the Kirsunni or Kristna

River, which runs westward, and parallel to the West Kalli Nuddi, and close by the towns of Jullalabad and Thannabhown, a similar work appears to have been executed during the short period of Gholam Kadir's government. The bund thrown over the river at this point was of moderate extent in comparison with that at Rampoor, but its purposes were the same. Bunds of this sort were by no means uncommon in the earliest history of these districts, and at the present day every river in the tract of country between the Jumna and Ganges is interrupted in the upper parts of its course by embankments, more or less extensive, for the purpose of collecting a supply of water for irrigation. In the Delhi and adjoining districts, as well as in the districts farther west, irrigation from reservoirs of the above description is extensively used.

Captain Debude's project, to which I have referred as the second instance recorded of an attempt to supply the means of irrigation to the lands on the right of the Ganges, was in fact a mere enlargement of the scheme originated by Muhummud Aboo Khan, in so far that the plan of damming up the West Kalli Nuddi, and raising the water until it was able to afford a supply to a channel excavated on high levels, was resorted to. Captain Debude, in fact, adopted the site of Muhummud Aboo Khan's embankment on the West Kalli Nuddi as the position of the head of his canal, and, although the works for irrigation which were projected by him were calculated to be of more extended benefit, they were, as all our canal undertakings had been up to that period, a simple attempt to restore, and in restoring to improve upon, the acts of our predecessors.

I have before explained that Muhummud Aboo Khan's Canal was a mere cut, for the apparent purposes of giving water to the town of Meerut and the gardens in its neighbourhood. Captain Debude's idea was to extend the benefits of the introduction of water on the high levels, by carrying a canal to the south, through the Meerut, Bolundshuhur, and the northern portion of the Aligurh districts. The possibility of obtaining a supply for this purpose from the Ganges River, under the difficulties that were supposed to exist, did not enter into his calculations, and the whole bent of his mind was directed to devising the best and most economical method of turning to profitable account the whole available supply furnished by the perennial streams connected with the West Kalli Nuddi and its tributaries.

The Hindun River, which in character is similar in every respect to the West Kalli Nuddi, runs parallel to and joins the latter river on its right bank, at a point about 10 miles below the village of Rampoor, or the site of Muhummud Aboo Khan's embankment. The supply of water in the Hindun River is continuous during the year, and, as is the case with the West Kalli Nuddi, increases during the rainy months to a very considerable volume. It was Captain Debude's intention to throw embankments, with masonry sluices, over both these rivers; to create by such means two gigantic reservoirs, connected by an excavated cut; and by these works to raise the level of the water to a sufficient height to enable him to pass it off at a canal head, which was situated at Rampoor.

It would be out of place here to enter into a detail of a project which, although it was never carried out, may be considered as the germ of future operations for the economical application of waters now allowed to run to waste; it will be sufficient to state that Captain Debude's scheme involved the construction of two very extensive masonry dams, with their embankments, over the rivers above described, the sill of that on the Hindun being 15 feet, and that on the West Kalli Nuddi 25 feet, above the beds of their respective rivers; it involved, moreover, a sacrifice of a considerable tract of very valuable land, which would have been inundated on the formation of the reservoirs. There was reason, however, to doubt whether, during the rainy months, or for that period when irrigation is especially required for sugar-cane and rice, the regularity of supply could have been insured, and whether, even during the dry months, the reservoirs, being subject to diminution of volume from the effects of evaporation and absorption, could keep up a supply sufficient for the purposes of irrigation, and, in all probability, uncertainty on these points led to the sacrifice of the project. The plans and papers were submitted in great detail to Lord William Bentinck, who was then Governor-General, with an estimate amounting to about three lakhs of rupees.

The difficulty as well as danger of interfering with the courses of rivers liable, as the Hindun and West Kalli Nuddi are, to floods of the most violent description during the rainy months, were by no means unappreciated by Captain Debude; but the times during which he carried on his labours were not those when the advantages of irrigation were understood and recognized as they were a few years afterwards. Captain Debude's means were limited, not only by instructions under which he acted, but by the certainty that estimates to a large amount would not be viewed by the Government with the slightest satisfaction; whatever, therefore, may have been Captain Debude's views as to the feasibility of obtaining a supply of water from the Ganges on the principles that had already been adopted on the Jumna River, no reference is made to them in any of the papers that have come under my cognizance, and his ultimate removal to a superior appointment in Calcutta, which took him entirely from the scene of his early engineering inquiries in the North-West Provinces, gave a new direction to his thoughts, and introduced him to new fields wherein his talents were as profitably exerted as they had been elsewhere.

As time advanced, and the results of the Jumna Canals had proved to the Government that the money which had been laid out on these works had been most profitably expended; that, independently of paying off their own expenses annually, they were, both directly and indirectly, increasing the land revenue, improving the resources of the country, and greatly benefiting the community; views of irrigation on a more extended scale were freely advanced. Rohilkund, which had from time immemorial been the field of very extensive irrigation, disarranged it is true by the anarchy that had prevailed previously to its settlement as a regulation province, but still containing within itself all the vestiges of its ancient canals, water-courses, and dams, was one of the first localities that came under the notice of Government: a series of papers illustrative of this irrigation was submitted to Colonel Colvin, the Superintendent of Canals at that time, and subsequent inquiries led to the deputation of that officer to report upon certain projects for the immediate restoration of some of the old lines. Colonel Colvin's report, and the favourable opinion he expressed of the extraordinary capabilities of the district, led to the appointment of an engineer officer to superintend the execution of a line of canal near the town of Nugeena; the completion of this work, and afterwards the appointment of Captain Jones, of the Engineers, to carry out the intentions of Government in extending the means of irrigation throughout the province, led to the establishment of a permanent system under an officer entitled "Superintendent of Canals and Embankments in Rohilkund." Captain Jones, who still continues to hold this appointment, is the author of a variety of reports on the subject of irrigation in the province.

In 1836, Colonel Colvin left India, having devoted a long period of his life to the canals in these provinces, and having left a spirit of emulation amongst his successors, the result of which has been favourable in no small degree to the advancement of those objects to which so much of his time had been devoted.

In 1837, the Deyra Doon, or valley between the Jumna and Ganges, lying north of the Saharunpoor district, from which it is separated by a low line of mountains called the Sewaliks, became the field of inquiry for purposes of irrigation; the valley itself was intersected by running rivers, and the Himalayas, which bounded its northern front, supplied from numerous perennial streams of greater or less volume, ample means for providing irrigation to the high lands forming the northern part of the valley. The examination of a field thus prolific in its means for irrigation, has led to the execution of numerous works: the Beejapoor, Rajpoor, and Kutta Puttur Canals have been already executed; two other lines, which come under the designation of the Kalunga and Sunsadharra Canals, have been delayed in execution merely from want of executive superintendence; and numerous unexamined streams, now lost in the ravines and forests which skirt the base of the Himalayas, are in all probability as capable of being turned to useful account, as those which have been already worked upon.

About the same period that the Doon irrigation was brought to the notice of the Government, Major Baker, the superintendent of the Delhi canals, was occupying his time in many useful inquiries as to the means for supplying irrigation to the country lying between the Jumna and the Sutlej rivers; the results of these inquiries, as embodied in a series of reports and papers, were published by the Government of the North-Western Provinces. The Tihara Canal, for supplying during the periodical rise of the river two natural channels in the ceded Sikh States and Bhutti territory, referred to in these printed reports, was examined more minutely and reported on in 1847. There appear to have been difficulties unforeseen in the original plan, which put a stop to the undertaking. This canal would have left the Sutlej on its left bank between Loodiana and Ferozepoor, near the village of Tihara. The Cugger, which leaves the hills at the eastern extremity of the Pinjore valley, was the only line of perennial river that, prior to the period of Major Baker's inquiries, had been taken up as a supply for irrigation. Its being brought under the consideration of Government at all was, I believe, due to certain disputed rights of water claimed by an independent Sikh chief (the Puttialla Raja) through whose territories a portion of its course runs. Engineer officers had been deputed to establish works for regulating and equalizing the available supply. The means of irrigation offered by the Cugger were, however, comparatively small, and were confined entirely to the establishment of earthen dams at fixed intervals for the formation of reservoirs from whence the irrigators drew their water; the value of the Cugger as an irrigating stream was, in fact, confined to a narrow tract on each edge of the river. Major Baker was accordingly led on to the consideration of some more comprehensive scheme, embracing not only certainty of the supply, but extension of the area to be irrigated, so as to include the distant lands to the south and west of Ferozepoor, together with those on the right bank, or to the north of the Delhi canals, the levels of which were too high to admit of their being watered from that line.

The Sutlej River, on its approach to the plains at Roopur, takes a considerable turn to the west, regaining its eastern direction by a sharp and abrupt bend; the course of the river at this point forming a long loop, the neck of which is not more than seven miles in width. It was to a point above this loop, as giving evident advantages of slope, that Major Baker's attention was first directed, as promising an appropriate site for the head of a canal. To this idea, however, the mountain ridge, which leads to the deviation of the river from its direct course, offered an insurmountable barrier; the highest accessible point, therefore, was selected by Major Baker for the commencement of a line which was to pass centrically through the country bounded by the Sutlej and the Jumna. The results of the survey showed the feasibility of a project which would provide irrigation to an immense extent of country, the more western parts of which are at present totally unirrigatable even from wells, and at the same time would supply water for domestic uses in regions now reduced to deserts from the total want of it.

Major Baker, having satisfied himself of the fact that the Sutlej might be made use of for irrigation, and having carefully examined the country lying between Loodiana and Kurnal, submitted his views to the Government. At this time a great portion of the land over which the projected canal would have taken its course was in the hands of independent Sikh chiefs and others who recognized no further control by the British Government than that offered by treaty for their protection; no regular plans and estimates were therefore submitted to the Government, and the whole question, interesting as it was at the time, was allowed to drop. Laying aside the reasons for adopting this course, which I have no doubt were in every way sufficient, but, at the same time, looking to the extraordinary benefits that the country would have derived from the introduction of water, and the consequent establishment of villages and agriculture on a large area which is now a wilderness; knowing, moreover, the singularly fertile nature of the soil at those points where the blessings of water are felt even in their most limited extent; looking to the predatory life of the scattered population now existing, and contemplating the certain change to that of agriculture, with all its concomitant advantages; the causes that led to the abandonment of Major Baker's project may, I think, be regretted; and we may hope that, with the satisfactory data he has provided, and with the daily increasing interest that is arising in the extension of irrigation, the subject of the Sutlej Canal may ere long be resumed with full vigour.

I have now completed a rapid outline of the different projects for canals in the North-West Provinces, the surveys of which had been conducted at the same time with those of a line of canal for the irrigation of the country between the Jumna and the Ganges, or of that line which is especially the subject of the present paper.

I have before mentioned that the only attempt which had been made in our time for the irrigation of the land lying on the right of the Ganges River, was when Captain Debude proposed to make use of the waters of the Hindun and West Kalli Nuddies, and by establishing dams over their courses to obtain the means of irrigating the Meerut, Bolundshuhur, and Aligurh districts; the site of the proposed works being on an ancient canal bearing the name of Muhummud Aboo Khan, a native chief, by whom it was supposed to have been dug early in the eighteenth century.

Captain Debude's inquiries established the fact that the united volumes of the above-mentioned two rivers would not during the dry months provide a supply that would last longer than 180 days, and that during the rainy months the works on the rivers themselves would be subjected to the most extreme flood action. To these sources, therefore, it was hopeless to look for the means of meeting the demands of any comprehensive scheme for irrigation: the Ganges River alone could consequently be depended on. Colonel John Colvin, C.B., at that time Superintendent General of Canals, was satisfied that an examination of the river above and below Hurdwar would prove its efficiency for the purposes required. Colonel Colvin's views and my own coincided on the advisability of making early inquiries, and subjecting that part of the Khadir or low land lying between Hurdwar and the head of the East Kalli Nuddi, to careful survey. The impracticable lining out of this part of the country, especially the depressed tract of land above alluded to, and the abrupt transition from high to low levels in the neighbourhood of Jourassi, Noornugger, and Sookurtal, were certainly features by no means favourable to success; but it was determined to settle the question at the earliest opportunity possible.

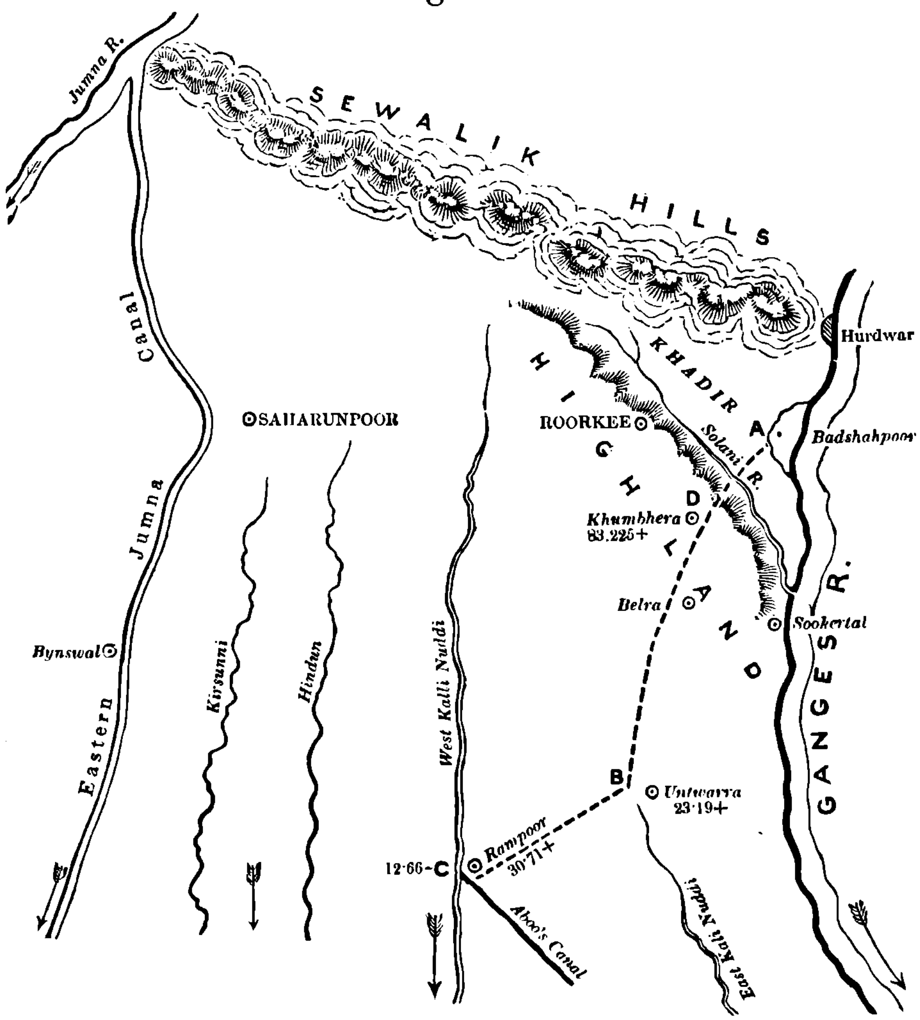
Colonel Colvin left India at the end of 1836, giving over charge of his duties as Superintendent General of Canals to me; and it was in November of that year that the first series of levels was taken. The Bangunga, an old branch of the Ganges River, is connected with the parent stream, in the same way that the Boodhi Jumna is with the Jumna River. The head of the Boodhi Jumna is the head of the Eastern Jumna Canal; it was supposed, therefore, that the Bangunga might do equally good service at the head of a canal from the Ganges. The village of Badshahpoor, which is close to the Bangunga, was selected as a favourable point from whence to commence a series of levels; and the most desirable question to decide, was the difference of level between the water at that point, and the high land near the village of Rampoor, the site of Captain Debude's canal head, after he had raised the water by means of dams to a height of 30 feet from the bed of the West Kalli Nuddi. The results, as will be seen from Diagram 1, were very unsatisfactory, and showed that the point which had been taken up on the Bangunga was totally unfitted for the site of a head of supply. To try, therefore, a point higher up on the line of the Ganges, was the evident method of overcoming the difficulty which next offered itself; and it appeared that by taking a circuitous route the impracticable line of country might be avoided. Colonel Colvin, with whom I was in correspondence on the subject, was sanguine that success would ultimately attend an inquiry having for its object the examination of the country lying between the Sewaliks and the high land of the Doab; it seemed to me, however, that under such difficulties it was more than probable that the cost of a canal would be too great to warrant the undertaking of the work; and it was not until some time afterwards, when I had made myself acquainted with the features of the tract above referred to, and had examined the data which I had obtained in my Badshahpoor levels, comparing them with those of the Eastern Jumna Canal, and the known barometrical heights which connected the whole, that I was able to form a proper estimate of the practicability of such a work: at the time, however, my occupations were of a nature that prevented me from continuing the inquiry, and the question remained temporarily at rest. At this period the appointment of superintendent of canals, in which I had been acting since Colonel Colvin's departure for England, was abolished, and I returned to my duties as Superintendent of the Eastern Jumna Canal and its dependencies.

The calamitous events of the year 1837–38, and the extent of human misery then caused by the utter failure of the crops in the central provinces, especially in the lower districts of the Doab, leading to famine in its most aggravated shape, and to misery such as is unknown in civilized Europe, are not even at the present day forgotten by those who at that time were resident in Upper India. The exertions of the European community in alleviating the sufferings of a starving population were carried on with true Anglo-Saxon energy; and the sacrifice of a million sterling in revenue, either in remission or in distributing food, was a guarantee of the interest that the government felt in this frightful calamity.

As the famine was chiefly felt in the lower and centrical districts of the Doab, and as the evils had after all been only partially relieved by such an amount of philanthropic exertion, and such an enormous sacrifice of revenue, the question, as to what might have been the results if a canal for irrigation had been completed previously to this year of famine, naturally suggested itself for consideration; had such a work been executed, the Government would in all probability have been saved this sacrifice of money, and in a moral point of view have been spared the distress of witnessing so much misery. The project of making a canal from the Ganges so as to provide irrigation to the Doab was, therefore, no longer to be considered a mere subject for speculation, but a question to be decided at the earliest possible period. My views regarding it were explained to Lord Auckland, who was at that time Governor-General, with a recommendation that Government should authorize the disbursement of a few thousand rupees for an examination of the Khadir, to prove the practicability, or not, of overcoming the difficulties which were supposed to exist in that region. His lordship having approved of this measure, and having directed me to carry on the inquiry, I proceeded to Hurdwar, and commenced operations early in the month of December, 1839.

My design for carrying out these operations will be best explained by a diagram, and by a detail of the data on which my views were founded.

Diagram 1.



The line of levels which had been taken by me in 1836 is shown by the dotted line; it commenced from the surface of the water in the Bangunga near the village of Badshahpoor, which is situated 23 miles south of Hurdwar. From the point A the levels ran for a distance of 4 miles (impinging on the head of the East Kalli Nuddi at B or at the village of Untwarra marked in the above diagram) to the point C on the West Kalli Nuddi; it was at the point C immediately under the village of Rampoor, that the head of Muhummud Aboo Khan's Canal was situated, and where the dam proposed by Captain Debude was to have been built.

The following results were obtained from the above line of levels:—The point A—83·225 feet below D; A—23·19 feet below B; A—12·66 feet above C; A—30·71 below the land on which the village of Rampoor stands. In other words, on a line of 40 miles, or from the surface of the river near the village of Badshahpoor, to the surface of the West Kalli Nuddi at Rampoor, the fall is only 12¾ feet; and to the surface of the high land on which Rampoor stands there is an actual rise of 30 feet.

From the point A to D, a distance of 10½ miles, the land is almost entirely on one level for the distance of 9 miles; at this point it rises suddenly until it gains an elevation of 83·225 feet near the village of Kumbhera at D; its slope onwards towards Rampoor may be estimated at 2¾ feet per mile.

The debouche of the Ganges into the plains lies at least 25 miles lower on a latitudinal line than that of the Jumna. The Eastern Jumna Canal, which leaves the Jumna at the point of debouche from the hills, has opposite the town of Saharunpoor (which is nearly on the same parallel as Hurdwar) lost 300 feet of level. The Eastern Jumna Canal at the village of Bynswal, which is similarly situated to Belra, is 125 feet below Saharunpoor. Taking, therefore, the known barometrical heights of Hurdwar and Saharunpoor, and reducing the canal levels accordingly, the following results were arrived at:—

	Above the Sea.		Above the Sea.
Saharunpoor . . .	1,013 ft.	Hurdwar	1,024 ft.
Bynswal, on the Eastern Jumna Canal .	888 ft.	Belra	888 ft.
		Total fall from Hurdwar to Belra . . .	136 ft.

I assumed, therefore, that the village of Belra was not very far different in barometrical height to that of Bynswal, and that as by taking a circuitous route from Hurdwar to Belra, which could hardly, under any circumstances, exceed 50 miles in length, the object of my survey was evidently attainable even were the land at Belra much more elevated than I had assumed it to be. The line of operations for the survey, therefore, was sufficiently clear: it resolved itself into a simple examination of the ground between Hurdwar and the westerly portion of the Khadir, both above and below Roorkee; and, to use the words of my original Report to the Government, "the only objections (supposing that my assumed height of Belra is correct) to the project depend upon the state of the country's surface in that direction; if a connected ridge can be discovered, only broken by the escape of the Solani, this river would, I imagine, offer no unconquerable impediment to a canal."

By feeling my way along the country westward of Hurdwar, and embracing the westerly portion of the Khadir by circles of levels in numerous sweeps both above and below the true line upon which the canal would take its course, this true line exhibited itself in two directions—the first extending very much to the west, by which the line of canal bed would continue in soil; the second, a more direct line crossing the valley of the Solani River by an aqueduct. The one had a very extended circuit, stretching far to the west into the high land which forms the heads of the Solani River, and thereby coming in contact with a great quantity of mountain drainage; the other was more direct. In avoiding the forests and drainage which the first line had to contend against, it necessitated, however, the crossing of the valley on high levels, and the construction of an aqueduct, the cost of which was great.

After completing the survey of the Khadir tract, and satisfying myself of its being suited to the required purposes, I continued a series of levels both longitudinal and transverse to a point near Mynpoori. I had, during my survey at Hurdwar, measured the discharge of the Ganges River, the supply of which in the months of December and January was equal to 8,000 cubic feet per second, and therefore capable of providing for any demands that we might make upon it. I had, in my progress down the country, observed that material of all sorts could be procured without much difficulty, and it appeared to me that in submitting a project to Government it was desirable to produce one on a minimum scale, in which the cost of the works through the Khadir would be met by a sufficiently remunerating return on the irrigation which lay below that tract; the estimate, in fact, which I proposed to submit was intended to show the smallest amount at which a canal could be made with advantage; and having explained the facilities that existed, both in material and in a supply of water, together with the means of carrying that supply over the difficulties of the Ganges Khadir, I left it to the Government to determine whether, by the construction of a larger and more spacious channel, the extent to which the water of the Ganges could be applied to irrigation in the Doab might not be taken the fullest advantage of.

My report and estimate on the Ganges Khadir is dated 30th June, 1840; the amount of the latter was Company's rupees 10,00,113

The supplemental report on the prolongation of the canal down the Doab is dated 15th August, 1840, and the amount of the estimate which accompanied it was . 15,91,045

Total Company's rupees . 25,91,158

The foregoing included 255 miles of main canal, 73 miles of branch, and the necessary machinery for converting the main into a navigable line.

The return, which was calculated on the average of that from the irrigation canals on the Jumna, was estimated at about 10 per cent. on the outlay.

With reference to the abstraction from the Ganges of large bodies of water, which would be the first effect of the execution of the proposed canal, it became an object at this period of the inquiry to establish gauges at different points on the river, and to obtain as many measurements of discharge as opportunities offered. Water gauges for measuring the rise and fall of the surface of the river were established at Hurdwar, Gurmookhteesur, Futtehgurh, Cawnpoor, and Allahabad. The registers of these gauges, with the exception of the two first, which were entrusted to native agency, were kept by the engineers or civil officers of the stations. The Hurdwar, Gurmookhteesur, and Allahabad gauges were discontinued in consequence of disarrangement by floods and doubts as to the dependence to be placed on the records; but those at Futtehgurh and Cawnpoor, which are to be found in the atlas, may be depended upon, and for the last ten years will give a very accurate representation of the rise and fall of the river's surface.

From a series of measurements for discharge taken by myself, at a point on the Ganges just above Hurdwar, I calculated that the discharge, which might be considered a minimum at that point, was equal to 8,000 cubic feet per second—an amount that did not differ in any great degree from that which was formerly given by Captain Herbert from measurements taken by him about ten years before, when he was employed on the Himalayan survey.

At the Gurmookhteesur Ghat, a point situated below the shingle, a set of observations was made simultaneously with those at Hurdwar; the time selected was early in March, when the river is supposed to be at its lowest, and just before the melting of the snow of the mountains leads to a rise in the surface. I hoped to obtain the minimum discharge of the river by making these measurements in March, and the uniformity of the results of different trials gave me great confidence. The results were as follow :—

		Discharge per Second.
Hurdwar .	1st March, 1842 . . .	7,166·1891
Gurmookhteesur,	1st ditto . . .	8,685·2194
	2nd ditto . . .	8,883·195
	25th February, 1842 . .	8,681·894

Gurmookhteesur is situated 95 miles south of Hurdwar, and the excess of volume at the former point is to be accounted for by the river having in its course received all the drainage of the Khadir, including that from the Puttri, the Solani with its tributaries, and the different smaller lines both on the right and left banks of the river. The results of the measurement at Hurdwar, it will be observed, showed that in the driest season of the year we might depend upon 7,000 cubic feet per second, and the establishment of gauges at different points on the course of the river would, hereafter, when a body of water had been abstracted for canal purposes, show the effects of that abstraction on the surface level of the river.

The Government of India having been satisfied of the advantage that the high land of the Doab would derive from the introduction of irrigation, and being convinced by the plans and surveys of the practicability of overcoming any engineering difficulties that might occur in the Khadir, recommended to the Court of Directors that the works should be designed on a scale capable of taking the fullest advantage of the supply available at Hurdwar. The Court, in their despatch dated the 1st September, 1841, recognize the importance that is attached to works for irrigation, and to their financial benefits, and observe that, "apart from the consideration of financial results, which we are far from contemplating with indifference, there are few measures connected with our revenue administration in India more calculated to contribute to the general improvement of the country, the amelioration of the condition of the people, and to raise the character of the Government, than those of the nature now under our consideration. We concur in opinion with the Government of Agra that a higher ground for advocating these works is found in the security which they afford against famine and its attendant horrors." "Two years," Mr. Robertson remarks, "have scarcely passed since the very country through which the proposed canal will be excavated was laid waste by a famine, which cost the lives of thousands, and presented a scene of suffering still fresh in the recollection of all classes; to such another visitation the canal will afford a palliation, if not a remedy. Influenced by these considerations, which are strengthened by the observations contained in the minute of the Governor-General, dated 3rd April, 1841, and relying on the discretion of your Government with reference to the period of commencing, and in carrying this project into execution with due caution and with a strict regard to economy, consistent with the importance of the work, we have resolved to give our sanction to the proposed undertaking, on such a scale as may be consistent with safety to the works, and the accomplishment of the important objects contemplated in their construction."

On the receipt of the despatch from which the above is an extract, a Committee, consisting of Major Abbott, of the Engineers, as President, with Captain Baker, of the Engineers, and myself, as members, was directed to proceed to the ground and report on the efficiency of the proposed works, the probable success of the undertaking, the scale on which it should in the first instance be carried on, and the precise measures to be recommended for adoption. The letter conveying this order was dated, "Military Board Office, 24th November, 1841," and, on the 7th of February following, the Committee's report was submitted to the Government. I may remark here that the attention of the Committee had also been called to the following points:—1st, the probable effects of the abstraction of the maximum supply of water on the navigation of the Ganges; 2ndly, the probable cost of extending the canal to Allahabad; 3rdly, the probable return from the work. On the first of these points I shall have more to say hereafter, but in the meantime the Committee, when recommending the abstraction of 6,750 cubic feet per second, or very nearly the whole of the supply in the river at Hurdwar during the driest months, came to the following conclusions, founded on the analogous example of the river Jumna:—"During two months, January and February, of each year," the Committee remarks, "the whole apparent supply is diverted from its channel to feed the two canals east and west, yet the under-current which percolates the gravelly bed, together with the drainage of the intermediate country, furnishes a navigable stream of water at the station of Agra, a distance of 260 miles by the river's course; and the Committee infer from this example that, in abstracting 6,750 cubic feet from the Ganges supply at Kunkul, which, during the dry season, is estimated at 8,000 cubic feet per second, the navigation of this river will not be injured below Cawnpoor. Between that point and Gurmookhteesur Ghat, the navigation for the larger classes of river craft will probably be impaired, if not altogether stopped; therefore it appears to the Committee to be absolutely necessary that the main line of canal from Kunkul to Cawnpoor should be rendered completely efficient for navigation."

The Committee considered that it was in every way desirable to provide irrigation for the whole of the lands lying between the Hindun and the Ganges rivers, and that this should be combined with navigation; to effect these objects it would be necessary to use 6,750 cubic feet per second of supply. This supply, the Committee observe, "will be found ample to carry one main line of navigable canal from Kunkul to Cawnpoor, and to supply irrigation to the whole district bounded by the Ganges on the one side, and by the Hindun and Jumna on the other."

The straight line by aqueduct (the aqueduct being faced by revêtments in the form of ghats) was preferred and recommended by the Committee after a careful investigation of the ground, especially of that on the circuitous route, over which a levelling instrument was passed. The preference to the aqueduct line was given on account of the many difficulties which attended the other in crossing numerous lines of drainage by dams constructed across the sandy beds of rivers on steep slopes; estimates, however, were submitted for both lines, and the following detail left the adoption of either one or the other to the judgment of the Government:

On Aqueduct Line.

	Co.'s Rs.
Cost of Works in the Khadir up to the Town of Roorkee	18,70,835
Cost of Works from Roorkee to Cawnpoor	27,01,220
Ditto Futtehgurh Branch	6,22,540
Ditto Tuppul ditto	1,84,520
Ditto Shekoabad ditto	6,77,140
Ditto Allahabad ditto	2,91,580
Five per cent. Contingencies	3,17,391
Total	66,65,226
Cost increased by Building Ghat Revêtments	5,61,180
Grand Total Cost of Aqueduct Line	72,26,406

Circuitous Line without Aqueduct.

	Rs.	A.	P.
Cost of Works in the Khadir	11,88,335	14	0
Ditto, from Roorkee downwards, including branches as before	44,76,920	0	0
Five per cent. Contingencies	2,83,262	12	8
Grand Total Cost without Aqueduct	59,48,518	10	8

From the investigations of the Committee on the subject of returns, it was calculated that irrigation would be provided for 2,303 square miles, the return upon which, at the average rate of 10 annas per beega, would be equal to $\frac{\overset{\text{sq. miles.}}{2{,}303} \times \overset{\text{beegas.}}{1{,}024} \times \overset{\text{annas.}}{10}}{16} = 14{,}86{,}420$ rupees, independently of the collections for mill-rent, transit duties, and the miscellaneous sales of canal produce.

In closing their report, the Committee recommended that no time should be lost in commencing the manufacture of bricks at those points which are common to both the straight and circuitous line, and that Captain Cautley should be permitted to commence at once the main trunk from Roorkee onwards to Cawnpoor, completing all the masonry heads of branches, and excavating such portions of the branches themselves as the executive officers may find it in their power to undertake.

It was also recommended that a staff of three executive officers, six assistant executives, and twelve overseers should be placed at Captain Cautley's disposal.

During the whole of the preliminary period above adverted to, Mr. T. C. Robertson, who was holding the reins of the Government of the North-Western Provinces, and who, from his appreciation of the value of the Jumna Canals, looked with extraordinary interest and favour on the Ganges Canal project, exerted every energy to break ground, and to advance the progress of the works. The time, however, was that of our disasters in Afghanistan, and in these, combined with a change of the heads of the Supreme Government, may perhaps be found sufficient explanation of that want of sympathy with the project which, by leading to my being refused the aid of assistant engineers, left me to carry on the work as well as I could without it.

On the 25th of February, 1842, orders were issued by the Agra Government for the commencement of the work on the terms of the Committee's recommendation, and on the 16th of April following ground was broken in the neighbourhood of Kunkul by a commencement of the excavation of the channel. At the same period, also, brickmaking was commenced at different points on the line under the supervision of Mr. Wright, an uncovenanted officer who was under my orders on the Eastern Jumna Canals. At this period, also, Lieutenant Turnbull, of the Engineers, was detached by me from the Eastern Jumna Canal works to commence operations on the high land from Roorkee downwards; so that with the means at our disposal we had in the month of July, 1842, lined out nearly one hundred miles, collected a large quantity of materials, and had excavation in full progress at three different points.

As far back as May of the same year, some doubts had been expressed by the Supreme Government as to the propriety of proceeding with the works, and various reasons were alleged for entertaining this view. My application, in fact, for staff had been met by a desire to suspend for the present, on financial and other considerations, the arrangements and appointments which I had recommended. The collection of material and excavation, however, was allowed to proceed until the month of July, when the Supreme Government, in a letter dated 21st June, 1842, to the address of Mr. Hamilton, the Secretary to Government, North-West Provinces, in directing all the works to be stopped, called for statements of expenditure up to the time of closing the works, with a report upon their present state. My report, which accompanied these statements, was dated 7th August, 1842. It referred to a letter addressed to the Military Board by Colonel Stuart, Military Secretary to the Government with the Governor-General, dated Allahabad, 29th June, 1842 (eight days after the letter from the Supreme Government to Mr. Hamilton just alluded to above had been written), by which it appears that the intentions of the Governor-General had been modified, and that it was now his wish that the works should be prosecuted on the principle established in Mr. Hamilton's letter, No. 980, of the 17th June, 1842. Accordingly, I stated in my report that in consequence of having received the Military Board's orders conveying those of the Government, dated 29th June, "I had directed the daily parties to be again entertained; at the same time it would relieve me from much anxiety if Government would at once place a limit on my annual expenditure, which will enable me to work satisfactorily under the conviction that I am acting strictly agreeably to the wishes of Government." I observed that a lakh or two of rupees per annum would enable me to carry on work very steadily with the small establishment at my command: "Both brickmakers could be entertained, and about fifty or one hundred earth contractors might be kept in employment; if only half a lakh, or even a smaller sum, was allowed, I can regulate my expenditure accordingly."

The statements that accompanied my report above alluded to showed that up to the 14th July, 1842, the actual expenditure and liabilities had amounted to Company's rupees 1,38,198-8-3.

The Supreme Government, in their Military Secretary's letter No. 38, dated 17th September, 1842, in reply to the above report, observe: "In compliance with Captain Cautley's wishes, and for the purpose of obviating any misconception of the wishes of Government, the Governor-General is pleased, until further orders, to restrict the annual expenditure on the Ganges Canal, salaries and establishments included, to two lakhs of rupees."

The above précis of correspondence which took place, will throw some light on the interruptions which were experienced in the early days of our progress; a variety of difficulties had been urged by parties, and these difficulties had been answered; an error in my original report, due to the omission of a decimal point, by which the proportion of surface of the Doab which would derive benefit from the canal was much exaggerated, was brought forward, and it is possible that this error had some influence on the indecision which the above correspondence exhibits. The error was undoubtedly an unfortunate one, but it vitiated none of the calculations on which the merits of the project were based, and this was immediately and most fully explained, especially by the Military Board in their letter No. 2,294, dated 17th August, 1842, to the Lieutenant-Governor of the North-Western Provinces. The probable effects of earthquakes were brought forward as obstacles to the construction of the Solani aqueduct. The destruction to the navigation of the Ganges was urged as a sufficient cause for not proceeding with the works. The effects in a sanitary point of view upon the districts which compose the high lands of the Doab by introducing miasma were urged with a perseverance scarcely justified by the information at command. The works, however, had proceeded too far to be violently stopped, and under the restrictions pointed out above they proceeded steadily, with the cordial support of the Agra Government, but with little countenance from other quarters.

My duties and responsibilities had meanwhile been progressively extending: the executive duties of the canals in the Deyra Doon had been added to those of my specific appointment as superintendent of the Eastern Jumna Canals; in addition, I had at this period the whole of the responsibilities of the Ganges Canal works and its expenditure.

The Supreme Government, in the month of July, 1843, placed me in independent control of the canals in the Doab, relieving me from executive duties; and on the 21st February, 1843, I had the satisfaction of obtaining the services of Lieutenant Strachey, of the Corps of Engineers, for the executive duties of the Ganges Canal. No additional expenditure to the two lakhs already granted, however, was authorized, and the Gwalior campaign, which took place at the end of 1843, still further reduced the chances of obtaining aid from the Government, and still further destroyed the hopes that I had at one time entertained of being permitted to push the works on with proper vigour.

At the period of my giving over charge of the executive duties to Lieutenant Strachey the amount of expenditure was thus:

	Co.'s Rs.	A.	P.
Excavation	73,970	9	4
Materials and Sundries	36,988	0	0
Total expended up to 1st March, 1843 .	1,10,958	9	4

Early in the cold weather of 1843-44 the levels of the Doab, which in my survey of 1839-40 had been completed only to Mynpoori, were pushed forward to Cawnpoor and Allahabad, and the whole of the cold season of 1843-44 was passed in perfecting the levels and reconnaissance of the country. The completion of this survey enabled me to draw up a full report and estimates of the canal works; these were submitted to Government, and are dated 12th February, 1845.

Before entering into a detail of this report, I must observe that previously to my undertaking the survey above alluded to, the Supreme Government had decided that a total modification of the original design should take place, and—to use the words of the minute to which my attention was directed—"it should be in the first instance a canal of navigation, and all the water not required for that purpose may be distributed for the purposes of irrigation."

The main trunk, in short, was to be directed upon Allahabad, that being the point to which steamers now ascend the river; the original project, therefore, whereby the navigable line was carried merely to Cawnpoor, having been merged into one of considerably greater length, and (as connected with irrigation) into one leading to much greater difficulties, I submitted three projects which will be explained hereafter, noting at the time that I had endeavoured, so far as was in my power, not to lose sight of the purposes for which this canal was originally projected, and to provide means for irrigation as extended as the security for navigation to Allahabad would admit of.

With these views, I placed before the Government three projects, with estimates of the cost of each appended to them.

The first project was one wherein the main line had a declivity of bed varying from 24 to 12 inches per mile, with falls and locks attached, to overcome the superfluous slope of the northern district, and with works of ascent and descent into the Jumna River at Allahabad. Efficient means for irrigation on the main line were provided in this project as far as the boundary of the Cawnpoor and Futtehpoor districts, in advance of which they were somewhat interfered with by the depth of the excavated channel. In addition to the main line, the following branches for irrigation were proposed:—

Futtehgurh branch, 160 miles in length; Bolundshuhur branch, 70 miles in length; Etawah branch, 172 miles in length; Cawnpoor branch, 43½ miles in length.

This line is an artificial river, constructed on the same principles as the canals now existing in the North-Western Provinces. The total amount of the estimate on project No. 1, was Company's rupees 1,02,36,643. 14. 11.

The second project differed from the first in continuing the main line from the boundary of the Cawnpoor and Futtehpoor districts to Allahabad, by a system of reservoirs with locks to the Jumna, and extending the Cawnpoor line of irrigation to the neighbourhood of the town of Cawnpoor,—the tail water being discharged into a ravine or tributary connected with the Pandoo River near that place; or, if such disposal was more convenient, by using it as the means of supply for an irrigation channel, bearing upon a point where the Pandoo unites with the Ganges River. The total amount of estimate on this project was Company's rupees 97,03,558. 2. 9.

The third project differed from the first in continuing the navigable line from the boundary of the Cawnpoor and Futtehpoor districts to the Jumna near the town of Jar, turning from thence to the south, and connecting the canal with the Jumna at a point opposite the junction of the Kane River. In this project, the canal which for the last 80 miles had run contiguous and parallel to the

Rinde River would in fact have maintained its relative position to that river until it falls into the Jumna. The Cawnpoor line was designed to be navigable and locked into the Ganges with a branch for irrigation towards the junction of that river and the Pandoo. The total amount of the estimate for this No. 3. project was Company's rupees 93,39,746. 12. 6.

It was evident that to carry out any of these modified plans, works of a much more extensive nature than those originally contemplated would be found necessary. The determination to make the main line navigable to Allahabad instead of to Cawnpoor led not only to an excess of length in the excavated channel, but the flatness of the country through the districts of Futtehpoor and Allahabad rendered it necessary to restrict the declivity of bed for the last 173 miles to 12 inches per mile, and to increase proportionably the area of the excavated channel, so as to effect a discharge of the calculated volume of water. With such a length of navigable channel, it was found convenient to straighten the course of the canal between Roorkee and Mynpoori, thereby bringing the calculated fall between those points on a much shorter distance. The necessity of additional arrangements for disposing of this surplus slope was obvious; another masonry fall, therefore, was projected at Boodpoor in the Saharunpoor district, for clearing out the tail of which further excavation was required. Many works in the shape of aqueducts and means of crossing rivers, which were not anticipated by the committee, were included in the present estimates, and in proposing means for still further securing the stability of the works on the Solani valley, the cost of these works was materially increased. In all these projects it may be remarked that the efficient drainage of the country through which the canal passed had been one of the leading points of inquiry; it had in a great measure influenced the direction in which the canal had been carried, and had on all occasions been considered as one of the first points for investigation.

The above estimates were framed on the supposition that the Solani River in the Ganges Khadir would be passed by an aqueduct. My report, however, in including the reduced estimates for the circuitous route, placed it in the power of Government to make its own selection. In submitting these estimates, I remarked that the profile on the circuitous line was in every way adapted to the purpose of the canal, and that its original cost would be much less than of the direct route. I drew attention, however, to the fact that the numerous ravines, rivers, and cross-drainage lines, whereby the course of the canal would be intersected throughout its whole length, were not only very serious objections to the former route on the first construction of the works, but that they increased so much the contingencies of subsequent repairs and maintenance, as to make it questionable whether a course subject to so many sources of accident would not ultimately prove much more expensive than the direct line. The country traversed was further a wild and uninhabited tract, and it was evident that want of supplies for our working parties would be a constant inconvenience. It would have been impossible to avoid inundation at the head of each dam; communication would have been liable to frequent interruptions, inspection always difficult, and unhealthiness in the neighbourhood inevitable. Finally, as all our works must have been established at points high up on the courses of the intersecting rivers, all the evils notoriously due to the excess of slope would have been greatly augmented. On these various considerations therefore the committee was unanimous in preferring the direct line by Bajooheri and Muhewur with aqueduct to the circuitous line whereby this work could be avoided.

The estimates for the three projects above described, based on the adoption of the circuitous route in the Khadir, were as follows:—

	Co.'s Rs.	A.	P.
No. 1 Project . . .	92,26,695	12	4.
„ 2 „ . . .	86,93,610	0	2.
„ 3 „ . . .	83,29,798	9	11.

By taking this line, and avoiding that of the aqueduct, a saving would be effected of Company's rupees 10,09,948. 2. 7, or upwards of ten lakhs.

Previously, however, to the submission of the estimates above described, considerable changes had taken place in the administration of the country; Mr. George Clerk had succeeded Mr. Robertson in the government of the North-Western Provinces, and in the fullest appreciation of all projects for the improvement of the country, had given not only his countenance to the project for the Ganges Canal, but all the aid that he was able to bestow upon it during his administration, had resigned his seat to Mr. Thomason, formerly secretary to Mr. Robertson. Mr. Thomason, in the early days of our progress, had given his deepest attention to the subject of the canal, to the influence that it was likely to exert upon the welfare of the country, and by urging on by every means in his power energetic movements to facilitate its completion. In the middle of 1844, Lord Ellenborough was replaced by Sir Henry Hardinge, who as Governor-General reached Calcutta and assumed the reins of Government in the month of July, 1844.

At this period my health, which after twenty-six years of Indian service had been gradually failing, determined me to proceed to Europe, and early in February, 1845, I left the North-Western Provinces, having made over charge of the Ganges Canal works to Major W. E. Baker, of the Bengal Engineers.

CHAPTER II.

INTERMEDIATE PERIOD,

Under the directorship of Major W. E. BAKER.

From 1845 *to* 1848.

THE state of the works at the period to which I have alluded in the last chapter corresponded with the amount of annual expenditure that had been accorded to us by the Supreme Government; bricks had been burnt and collected at numerous points on the line from Hurdwar to below Meerut and Sirdhunna; masonry work had been commenced on a small scale on the dam and regulator at Myapoor, the commencement of the excavated channel above Kunkul; workshops had been built at Roorkee; Choki posts had been established at Myapoor, Roorkee and Munglour; and a considerable portion of the channel between Myapoor and the town of Jowallapoor had been roughly excavated; excavation had also been commenced upon, on the high land of the Doab near Munglour, and lining out had been completed for about 100 miles, south of that place.

When I delivered over charge to Major Baker, the amount of annual expenditure to which we were limited was two lakhs of rupees. For the management of this expenditure, there were two executive officers, Lieutenants Strachey and Turnbull, of the Engineers, and two uncovenanted Assistants, Mr. Wright and Mr. Read, to assist them.

War, and its consequences on the improvement of the country and the progress of works of public utility, appeared to be perpetually the rock upon which the advancement of these works was to be wrecked. It may be said that the Ganges Canal, originating as it did during the commencement of the Afghan war, was nursed at a period of intense trouble to the State; its weary progress was unwillingly prosecuted during the whole of a warlike administration, in which the return of the armies from Afghanistan, and fierce battles with the Mahratta chiefs, were the most remarkable events. The early part of the succeeding administration, distinguished as it was by Sikh invasion, and the consequent demands on the public treasuries, was marked by still further interruption to the progress of the canal; Major Baker and his two engineer assistants in joining the army which was concentrated on the northern frontier, had, in fact, by their departure, virtually put a stop to all further progress, excepting that of continuing contracts which had already been entered into; and it was not until the close of the war, and on the return of those officers to their respective duties, that the subject of the Ganges Canal works was allowed again to occupy the attention of the Government.

In the interviews that I had with Lord Hardinge previously to my departure from Calcutta in 1845, I had gathered from his lordship the especial points which had influenced parties in their objections to the project; these resolved themselves into the injury that would be caused to the Ganges as a navigable river by the abstraction of water for the canal supply, and to the probable effects upon the high land of the Doab by the introduction of malaria from irrigation. As these were the two leading points, and as the first had for the present at least been disposed of, the malaria question was naturally one for specific sanatory inquiry. For this purpose a Committee was assembled in November 1845, and on the submission of its report in 1847* the whole question of the Ganges Canal was brought under the notice of Government. In March, 1847, the Governor-General visited Roorkee and the site of the proposed works in the Ganges Khadir; and it was on this visit that the vigorous prosecution of the undertaking was determined on. During this period my sojourn in England brought me in contact with those whose views on the navigation and malaria questions led them to doubt the policy of continuing the canal works. As these questions had considerable influence in party feeling towards the project, I will here interrupt the thread of my narrative by explaining the views of them that had been adopted by myself and others, who were advocates for the establishment of the Ganges Canal. I will take up the questions as they were argued, beginning with that on navigation, or "on the probable effects to the Ganges as a line of navigation to Allahabad, arising from the abstraction of 6,750 cubic feet per second from its volume at Hurdwar." The arguments which were used by me may be thus explained:—

The discharge of the Ganges at Hurdwar during the driest season of the year, or that previous to the melting of the snow in the mountains, is calculated at about 8,000 cubic feet per second; if, therefore, at this period we

* The Committee, which commenced its operations on the 30th of November, 1845, and had proceeded through the irrigation districts of the canals west of the Jumna as far as Hissar, was broken up at that stage of their labours for the purpose of its members joining the army of the Sutlej. On the 1st of November, 1846, the Committee resumed its labours, and completed its investigations. Its report, which was dated 3rd March, 1847, was presented to the Governor-General on his visit to Roorkee.

Of this committee, Major Baker, of the Bengal Engineers, was president, and Dr. Dempster, of the Bengal Medical Staff, with Lieutenant H. Yule, of the Bengal Engineers, were members.

remove for the purposes of the canal, 6,750 cubic feet per second, it appears that we leave only 1,250 for the supply of the river.

There is a peculiar feature attendant on the tract of country lying at the foot of the Sewalik hills as connected with springs that is well known in the Rohilkund territory, and is also observable through the Doab and westward of the Jumna. In the immediate vicinity of the passes and at the foot of the hills, spring water rises to the surface, sometimes exhibiting itself in mere pools, at other times in small streams and rills, which flow for a short distance, and then disappear in the sand and shingle of the river. Parallel to and south of this line is a belt varying from five to ten miles in breadth, in which water can only be reached at extreme, and in some cases, at unmanageable depths.

In advance of this dry belt the springs rise to or near the surface, forming in Rohilkund the unhealthy tract called the Turai; in the Doab, a decrease to the depth of wells marks the approach to the belt in question; although on a line traceable from Badshahpoor near Dhunowri to the southern angle of that part of the Ganges Khadir with which the canal works are connected, the existence of detached, and in some cases extensive, jheels and marshes assimilates the surface to that of the Rohilkund Turai. The cause of this peculiarity is, that in the whole of the tract skirting the mountains there is a deep-seated impervious stratum rising near the foot of the hills, and cropping out on the northern limit of the Turai belt, that the water passing down the rivers percolates through the shingle, and passing under this impervious stratum rises again to the surface at a considerable distance, leaving the intermediate space dry. The following section is explanatory of the views that I hold as to the springs above alluded to :—

of consideration: it appears, therefore, that in defiance of the abstraction of the whole apparent supply of the river from the shingle tracts at the canal heads, the Jumna opposite the city of Agra still maintains its character as a river, navigable to a certain extent, and carries a volume of water the origin of which can only be explained by springs and percolation.

Between Hurdwar and Allahabad, or Cawnpoor, on the Ganges, there are the following tributaries :—

Solani and Bhat Nuddies and Turai,

Tracts of the Ganges Khadir :—

East Kalli Nuddi,
Yar Wooffadar,
Ram Gunga,
Eesun.

All giving a perennial supply to the main stream: the system of percolation which is so manifestly conspicuous on the Jumna may equally be anticipated in a river placed in its neighbourhood, and flowing over a country similar in geological character. The extent of percolation (if percolation is admitted at all) will, it is presumed, bear the same ratio to the original volume on the Ganges, as it holds in the parallel case of the Jumna. Should this be acceded to, we have the following results (laying aside the supplies of tributaries, and assuming that the Ganges canal absorbs the whole volume of the Ganges, as the Jumna canals do that of the Jumna).

As 400 : 1,861* : : 8,000 : 3,722 cubic feet per second; that is to say, that independently of the supply received by the Ganges in its course from the five rivers above noted, the volume of water which would pass Cawnpoor under the conditions above supposed would be 3,722

* 1,861 = 2,061 — 200 cubic feet: 200 cubic feet per second being the calculated supply received from the Hindun River between the Sewaliks and Agra.

cubic feet per second! in short, that the Ganges River at Cawnpoor would, when the canal was in full vigour, still possess a volume of water nearly as great as that of the Jumna before the canals on that river were constructed.

The conclusions at which I arrived from the above investigations tended to show that little or no interruption would arise to the navigation of the Ganges as high up as Futtehgurh, even supposing that the whole body of the river as it leaves the hills was taken for the supply of the Ganges Canal. North and above Futtehgurh the demands for navigation are trifling, and the few boats which pass up to Gurmookhteesur and Sookertal (the latter being the most northerly point to which boats reach) would readily be accommodated in the canal itself, and with infinitely greater convenience as regards the land carriage of goods to the large towns and cantonments in the Doab. Moreover, that were the canal to be made a navigable line from the Jumna upwards, it would be preferable to the main Ganges, and thus compensate fully for the evils it might cause to the stream itself, by the additional facilities for transit which it would thus supply. As to the question of the Ganges being affected *below* Allahabad, or *below* the junction of the Jumna, the question was one of great importance, but it was one upon which we had no sufficient data to guide us; the map of India with the configuration of the drainage of the Gangetic Valley, and the proportion borne by the line under discussion to that of the numerous tributaries extending from the Himalayas to the Bay of Bengal, appeared to supply evidence in favour of those who anticipated no injury to navigation.

The whole question was an intricate one; nobody ever doubted that the abstraction even of the smallest possible quantity of water affected to a certain degree the navigation of the Ganges, but the effects were merely in degree, and the general results of the inquiry appeared to resolve themselves into this: "Were the evils to navigation of a nature so injurious as to counterbalance the benefits arising from the canal?"

To those who considered that the navigation of the Ganges would not be interfered with by the Ganges Canal works, the analogous position of the canals on the Jumna, and the effects they produced on that river, were peculiarly conclusive and satisfactory; a question, in fact, which might have been otherwise perplexing was, if not reduced to a very simple one, rendered comparatively easy.

The Jumna being a smaller stream than the Ganges, was more dependent on the canal heads for its supply; the canals on the Jumna abstracted at certain seasons of the year, and at periods when the navigation of the river was least able to afford it, the whole available volume; a great part of this volume, passed off to the westward towards Hansi and Hissar, and, whether by means of percolation or evaporation, was entirely lost to the parent river: along the greater portion of its course the Hindun, which affords a supply of little or no consideration, is the only tributary; on its banks are situated the large towns of Delhi, Muttra, Agra, Etawah, and Kalpi, to which the Jumna affords the only means of water-carriage for all the rich and extensive districts that lie on its banks; if, therefore, under these circumstances, the Jumna canals having done their utmost to destroy the navigation, the navigation that exists continues to be of the greatest importance and value, why should the Ganges River, the supply of which is less influenced by the canal works, be supposed to produce other results? The Ganges canal, in the first place, does not take away the whole of the supply from the Ganges, there are numerous tributaries or feeders scattered along the whole course of the river; the percolation from the canal is confined to its own region, and whether it escapes into the Jumna or the Ganges, is equally available for the purposes of navigation. The absence of all large towns on the left bank (or that unconnected with the canal) of the Ganges as far south as Allahabad, with the known fact that the tributaries on that side are imperfectly navigable, reduces to some extent the value of the Ganges as a navigable line to that particular region. The navigation of the Jumna, on the contrary, appears to be of importance to many large towns which lie on the right, or bank unconnected with the canals, to all of which the river provides water-carriage. The inferences are, that the abstraction of water from the Ganges at Hurdwar will be of less importance to that river, than the abstraction of water for the Jumna canals is to the Jumna; and I must add that whilst the latter is providing the means of water-carriage to some of the most rich, and, in a commercial point of view, most valuable provinces of the North-West which lie on its banks, and whilst the canals which are taken from it are the source of great wealth and prosperity to the tracts that come under their influence, it seems to me that the philosophy of denying advantages of a similar nature to the Ganges, which it is proposed to place under the same regimen, is somewhat questionable.

From the month of April to the month of December following, when the rivers are either affected by the melting of the snow in the Himalayas, or by the periodical rains, the abstraction of water for canal purposes has less influence than it has in the remaining months. During those of the rains, when the greatest part of the traffic of the country is transported by water-carriage, no sensible effect is produced by the canals at all, and it is only during the months of January, February, and March, when the supply taken for the canals bears the greatest proportion to the volume of the river, that the reduction of surface level is appreciable. During this period, or rather during the seven months, which are entirely free from the rains or their effects, the navigation of both the Jumna and Ganges is confined to their own lines; the tributaries at this period having no pretensions to being navigable. The extreme points to which boats reach on the Jumna are Agra and Muttra during this period: on the Ganges, Gurmookhteesur and Sookertal. The size of the cotton boats which reach Agra gives the tonnage of boats on the two rivers in favour of the Jumna, and these cotton boats to which I refer reach Agrà at periods when the whole of the supply of the river is derived from percolation. In the foregoing paragraph I have attempted to show that the Jumna suffers from the abstraction of water for the canals to a much greater degree than the Ganges will suffer, and that, therefore, there is every probability of the latter being more favourably placed with regard to navigation than the former.

Whatever may be said as to the effect of the Jumna canals on the parent river, the fact is a notorious one, and one of which every resident in these provinces might convince himself, that the Jumna during the whole year continues to be the line of water-carriage of a large and flourishing trade, the best exemplification of which is in the fleets of boàts, many of them cotton boats of large tonnage, which pass up to the city of Agra.

It is, however, solely in the distribution of the volume that the water which (under the worst circumstances of canal interruption) passes down the course of the Jumna and Ganges rivers in their approach to Allahabad, can be said to be insufficient for navigation! This evil arising from distribution would, in consequence of the excess of breadth of the bed of the Ganges, show itself in all probability under more exaggerated circumstances in that river than it has done in the Jumna, and shallows rendering navigation difficult, or even in some cases impracticable, might be the result of an over-reduction of the volume of the river; but artificial means which lead to the evil, are at hand to remedy it, and the process of deepening channels in wide sandy beds is one so well understood in India, and can be effected with such moderate means, and at so small a cost, that the injury to the navigation arising from this circumstance is one properly of no serious moment. As long as there is a body of water in the bed of a river sufficient, if properly distributed, to ensure navigation, it is the fault of the Government, or of those concerned, if there is no navigation. To raise objections to the abstraction of water for canal purposes, when these purposes are acknowledged to be conducive to the prosperity of the country, to the increased wealth of the inhabitants, and consequently to the improvement of the revenue to an enormous degree; and when such abstraction leaves an ample supply in the river for all purposes of navigation, if such supply is properly regulated; is simply the enunciation of a doubt as to the pecuniary value of the canal when contrasted with the cost of rendering the river navigable. It is granted, however, that the canals for irrigation in these provinces do return to the Government treasury the most liberal profits; if a portion of these profits, therefore, be expended in works for the proper regulation of the large supply unquestionably at command in both the Jumna and Ganges, even after the utmost demands of the canals have been adequately supplied, the advantages resulting from the improvement of the river, thus effected, may fairly be expected to be almost, if not entirely, sufficient to compensate the commercial community for any injury that the abstraction of the canal waters may temporarily entail upon it.

From the hills to Delhi on the Jumna, and from the hills to Sookertal on the Ganges, the navigation is restricted entirely to rafts of timber, and to the passage of boats, which, being built in the valley of Deyra, are with some difficulty and great danger floated, empty, down the rapids; from Delhi to Allahabad, the Jumna, with all its injuries as inflicted by the canal works, is the only medium of water carriage. The Jumna Canals themselves afford to the timber trade in the valley of Deyra, an immense outlet for wood of all descriptions to Hurriana and countries to the westward, as well as to the inland districts which are situated above Delhi: at that point, however, the advantages of canal navigation cease; nor are the canals themselves as navigable lines connected at their southern extremities with the Jumna, so that all craft which leaves the hills for places below Delhi must take directly to the course of that river, and, as I have before said, encounter such difficulties as the abstraction of water subjects them to, in their downward progress.

In such a state of things the advantages of the Ganges Canal would be of immediate importance; it would provide navigable lines from the mountains to Cawnpoor on the Ganges, and to a point opposite Kalpi on the Jumna: these lines, instead of being dangerous and interrupted, as the beds of the Ganges and Jumna naturally are, would be comparatively safe and convenient. During the dry months to which I have before alluded, the line of traffic on the canal would be open and unimpeded; and during the rains, when the water carriage of the country is in the greatest requisition, and when the main rivers themselves, relieved from all the effects of canal abstraction, were giving to the country the benefits of unimpaired navigation, the Ganges Canal would in its centrical course between the two rivers provide additional facilities for the conveyance of merchandise, and give fresh means for the distribution of the produce of the country.

So far for the question of the injury to navigation: let us now turn to the counterbalancing benefits derivable from the canal. I have in the former paragraphs shown that, as a navigable line, both in itself, and as far as its effects on the parent river are concerned, the Ganges Canal has great and favourable claims for consideration. The leading and most important fact, however, must not be overlooked, that the original idea of a canal from the Ganges was for the purposes of irrigation; and that, although at one period of its progress mistaken views led to its being diverted from its primary object, it has been from the first, both in the mind of the projector and in the contemplation of every one who has carefully turned his attention to the subject, distinctly a line for irrigation; its uses, as a navigable channel, being incidental and entirely of a subordinate character. To return, however, to the counterbalancing benefits which might be expected from opening the Ganges Canal, I cannot do better than introduce, nearly verbatim, the expressions made use of at the time by one who is well able to appreciate the true merits of the question. "To deny," says the writer, "the value of irrigation to agriculture in India, is like denying the value of manure to an English farmer! The difference between irrigated and unirrigated lands is the first rudiment of his profession which a revenue officer has to acquire. It is an axiom in most parts of Hindostan, that whatever affords new irrigation or cheapens that which exists, gives food and wealth to the people, and adds to the resources of the State. Hence, the efforts to multiply wells, to form tanks, and to make canals all over the country. In Rohilkund, on the Jumna, on all the rivers between the Jumna and the

Sutlej, the prosperity of the country depends on canals. In southern Madras, the waters of the Coleroon and the Cavery are used for the same purpose, and works are either contemplated or are in progress for turning the waters of the Kistna and the Godaveri to the same account. In times of drought, canals support the cultivators, because they bring the water from a source beyond the reach of the periodical rains, and because they give employment and support to a people who would otherwise be helpless. Famines may arise not only from a want of food, but from inability to obtain it. During the famine of 1837–38, there was good reason to suppose that grain sufficient for one or two years' consumption was then in store; in the private granaries in Hindostan there was grain in abundance, and when the Government found the people employment, they were able to support themselves on a pittance below the ordinary rate of wages.

"The cry was not for food, but for money to buy food. The whole population, who lived by tillage, were unable to till, and were therefore starving. If they could have watered their fields from canals, they would have continued to till, and instead of starving would have grown rich. This was notoriously the case on the Jumna Canals at the period of the famine above alluded to; the canal villages grew wealthy, on account of the miseries of their countrymen. In Ireland, railways and an open coast did little to alleviate the famine that raged in that country; whilst the people were starving, food was exported from the want of purchasers. It was necessary by employing the poor on public works to give them the means of purchasing food. What public works effected in a wasteful and extravagant manner, the canal is calculated to do in the most beneficial way possible.

"Famines do sweep over India occasionally in a most terrible form, and it is not perhaps much which the utmost human skill or foresight can do to alleviate them. No canal can be a substitute for the rain from heaven; but wherever its influence extends, it may incalculably lessen the evil. It may give life to thousands; it may save other thousands from utter destitution; and it may save the Government from that financial injury, which cannot but weaken its power, and impair its energy. But in all seasons irrigation from the canal will more or less give comfort to the cultivator, wealth to the proprietor, and revenue to the State. Are all these certain advantages to be forfeited, because for a part of the year boats will reach the villages on the banks of the Ganges with some greater difficulty than at present?"

We now come to the question of malaria as connected with existing canals, and to its effects on the population of these provinces; together with the increased evils from this source which the opening of the Ganges Canal has been supposed likely to engender.

In discussing the effects which may be produced upon climate by the introduction of canals for irrigation, I have in one of my reports made use of the following expressions:—"In referring to the low tracts of the Doab, and especially to those situated in the Futtehpoor district, my attention has been drawn, during the last two years especially, to an opinion which has been prevalent, that wherever lines of canal exist in these provinces, the genius of malaria and sickness holds undisputed authority. Without producing proofs that are numerous, that the epidemics which have shown themselves in towns and villages near the canals, have been equally felt at others far removed from the influence of either canals or of irrigation, it is natural to infer that the introduction of moisture and excess of vegetation on the surface of countries which had been comparatively dry before, must necessarily lead to a change of climate; that change must necessarily demand an alteration in the habits of the people subjected to its influence, and there can be nothing extraordinary when we look to the way of living adopted by the native community, their lightness of clothing, their indifference to exposure to the night air, their sleeping on the ground, and frequently carrying on their field labours during the night-time, as well as during the day, in arriving at the conclusion, that, by the change from a dry to a moist climate, some modification of this system is necessary." The paragraph which I have quoted is, in my opinion, the key to a great deal of canal sickness that takes place. The hygrometrical differences, as shown by the dry and wet bulb thermometers in regions uninfluenced by irrigation, are extraordinarily great; and the Englishman, fresh from Europe, or he who has spent the greater part of his life in the Bengal Provinces, is surprised, on reaching the latitudes above Allahabad, to find the green to which his eye has been accustomed no longer existing; to see before him plains as brown as the soil of which they are composed, and, with the exception of tracts irrigated, tracts totally denuded of verdure. The contrast is a very remarkable one, and the fact does not appear to have been at all understood by those who, without having visited the North-Western Provinces, have been called upon to give an opinion on the subject. Very serious sickness had occurred at Kurnal and Hansi; two large towns, with military cantonments attached, which were situated on the canals west of the Jumna; and to these two cases references were made on all occasions as examples of the evil effects of canals in general. Without data of a more extensive nature than we had at the time, it would have been difficult to say how far the sickness that existed at the above two places, as well as at other portions of the North-Western Provinces, was dependent on the canals;

at any rate, before these most necessary and useful works were condemned, it was desirable to have it proved whether the sickness complained of was confined to their vicinity—whether this sickness arose from malaria due to the canal, or to an epidemic common to the country; it was also advisable to discover, should it be proved that the sickness does originate in the canals, whether such sickness arises from lands irrigated, or from marshes caused by imperfections in the canal, or from jheels being filled, and allowed to remain as stagnant water. Water carelessly used, and allowed to run to waste, appeared to be another element in the inquiry which ought not to be overlooked; whether it is chiefly in the neighbourhood of rice, or in cultivation in general, that sickness is prevalent; and whether by carefully embanking the canals, and removing the evils above mentioned, the health of a country might not be restored.

The removal of the cantonments from Kurnal, which was situated on the banks of the Delhi Canal, was no doubt a political measure based on the necessity of establishing a post more advanced towards the Sikh frontier; this removal, however, which was popularly attributed to the effects of the canal, with very severe sickness at Hansi, a town situated on the Hansi branch of it, had been the chief causes for the canals in the North-Western Provinces having obtained a character for unhealthiness. The town and cantonment of Kurnal were situated on the edge of the high land which skirts the Khadir or valley of the Jumna River; the Delhi Canal, which at this part of its course winds through the Khadir, or the ancient line given to it by its Puthan projectors, skirts the foot of the high land on which the town of Kurnal is built, and to some distance north and south consists of extensive reed marshes, which in the decomposition of vegetable matter, and in the harbour which they provide for animals and nuisances of all descriptions, most indubitably acted very prejudicially on the health of the neighbouring country. At Hansi, the canal, from its want of slope and with its consequently sluggish stream, was a nursery for weeds of all kinds; the district of Hurriana, moreover, of which Hansi is the capital, was previously to the opening of the canal in a great measure pasture land; the introduction of water had entirely changed the appearance of the country throughout the whole region in which irrigation extended, and a richly cultivated had succeeded to a pastoral country. In both these cases, the reasons for the occurrence of sickness appeared to be sufficiently obvious. They depended upon the abuse rather than on the use of canals.

The canal in its northern parts and in the neighbourhood of Kurnal, notoriously required to be remodelled, but money judiciously spent on silt clearances and on embankments would in all probability have remedied the evil, even with all the faults of alignement admitted to exist by eradicating the marshes, and restricting the water to its own channel; funds, however, were not available for purposes of this sort at the period to which I allude. The sickness of Hansi arose in all probability from the effects of change of climate to which I have before adverted, added to the want of expenditure in maintaining the canal channel clear and free from silt and weeds.

The Eastern Jumna Canal (which is embanked, and is not liable to such marshes as are above referred to) has by no means escaped from the sickness complained of elsewhere; this sickness having been prevalent at Rampoor, Shamli, Saharunpoor, and in other large towns in the southern districts, whereas the tracts situated to the north, which, from their proximity to the Sewaliks, and from their jungly character, have the name of being the most unhealthy, have been comparatively free from sickness.*

Previously to 1843, inquiries had been instituted by the Government of the North-Western Provinces, as to the progress, causes, and localities of the universally reported sickness arising from the canals; it was the fashion at that period to make the canals the sources of all sickness, and to hold out the removal of the Kurnal cantonment as the great proof thereof; the reports which were called for at this period from the medical officers of the different districts, rather tended to mystify than to clear up the question: towns stated to be suffering under the effects of canal irrigation were shown to be at a distance, and altogether detached from the canals, and sickness appeared to exist quite independently of irrigation. A report from the Meerut district, in calling for medical aid for the population on the canal banks, exemplified in a remarkable degree the feeling which led people to conclude at that time that sickness and fever must necessarily depend on canal irrigation. The only canal that was connected in any way with the Meerut district was the Eastern Jumna Canal, which irrigated a comparatively small portion of it lying to the extreme west, and bounded by the Kirsunni River and the Jumna. At the period to

* The Muskurra and Nogong torrents, over which masonry dams have been constructed for the passage of the Eastern Jumna Canal, unite near the town of Sultanpoor, about ten miles below the dams. By an action (which is attempted to be described in Part II., Chap. II.) on the beds of the torrents, caused by the application of masonry bars across sandy beds on steep slopes, a retrogression of levels has taken place up to the dams; the beds of the torrents up to these points having become deepened to an immense extent, whilst the sand and soil thus excavated or cleared out by the action of the stream, have been deposited over the surface of the low country in the neighbourhood of Sultanpoor, to the very serious injury of a number of villages. The evil was quietly and gradually going on from the period (1830) when the canal was opened. The first complaint made of the damage done was fifteen years afterwards. Sultanpoor is altogether unconnected with canal irrigation.

which I allude, there was considerable sickness in the canal neighbourhood, but the same sickness prevailed throughout the whole of the Meerut district.

At the town of Begumabad and its neighbourhood, situated 23 miles east of the canal, and separated from it by the Hindun River, there was sickness fully equal to any that existed in the vicinity of the canal; Moradnuggur and other large towns, with which I at that time was acquainted, and which had no connection whatever with canal irrigation, were suffering precisely in the same way; there was an epidemic in fact throughout the country, with which I imagine the canals were in no way connected, and yet the canal neighbourhood only was selected as a matter of especial reference for medical aid. The conclusion arrived at was, that the authorities had taken for granted what had by no means been proved, and further, that the reputation for unhealthiness which the canals in the North-Western Provinces had obtained (being unsupported by the facts which this inquiry had developed) rested on no sound basis whatever. One question, however, forcibly attracted the attention of those who, seeing the benefit conferred by canal irrigation, wherever it was employed, were therefore anxious to check any mistaken views which threatened to delay its extension: "Allowing that canal irrigation leads to sickness in its neighbourhood," they argued, "is this sickness, confined to a comparatively small portion of the population (a population that eagerly appreciates the advantage of canal irrigation, and as with one voice anxiously calls for it), to be considered of sufficient moment to prevent the execution of a work which has for its object the salvation of the many? Is a sickness of this sort to be put in competition with the famine of Guntoor in 1833, so graphically described by Captain Best of the Madras Engineers, in which the loss of life was fearful, and that of revenue so enormous, that Captain Best clearly shows it would have been worth while merely in a financial point of view for Government to have expended 221 lakhs of rupees (2,210,000*l.* sterling) to have prevented it? Is the famine of 1837–38, which led to the sacrifice of a million sterling of revenue, and which raged in the North-Western Provinces, through the heart of which the Ganges Canal will run, and on account of which the project was specifically approved of, already forgotten?"

Those who were connected with the project felt sufficient confidence in such considerations to satisfy them that the progress of a work so intimately connected with the happiness and security of our North-Western Provinces would ultimately meet with the liberal attention and fostering care of the Supreme Government.

Whatever might have been the value of the arguments and opinions above given, they resolved themselves after all into mere speculations, and as such were not likely to carry much weight. The researches, however, of the Committee to which I have before referred, which was expressly assembled "for the purpose of reporting on the causes of the unhealthiness which has existed at Kurnal and other portions of the country along the line of the Delhi Canal;" "and further, whether an injurious effect on the health of the people of the Doab is, or is not likely to be produced by the contemplated Ganges Canal," placed the matter on a sound basis.

The results of the Committee's labours were arrived at after the most patient examination of the population in villages the lands of which were irrigated by the canals; the members were of high professional and scientific acquirements, and they were called upon to reply to certain categorical questions the answers to which must have been in one way or the other conclusive. As the report of this Committee is one of great importance, not only to the Ganges Canal Works, but to the future extension of artificial irrigation in the North-Western Provinces, I have in Appendix B given it *in extenso*, and shall content myself here by noting the principal conclusions at which the Committee arrived.

1st. That an extensive epidemic had of late years pervaded a large portion of the North-West Provinces, and especially during and after the rainy season of 1843. That to this epidemic, the sickness which occurred in the canal districts was partly attributable; and in these districts the disease was generally, though not universally, more prevalent and severe than in other situations.

2nd. Fever in a greater degree than usual visited nearly every place in the North-West Provinces; and in certain situations, neither irrigated from the canal, nor within reach of its influence, fevers prevailed to an extent and with an intensity as great as in the worst canal villages.

3rd. Evils not necessary to canal irrigation; but to irrigation impeded by bad drainage, natural drainage of the country checked or interfered with, stiff and retentive soils, and natural disadvantages of site enhanced by excess of moisture.

4th. Considers that if irrigation was stopped within a circle of five miles round military stations, their salubrity would not be affected, and that the effects of canal irrigation are remarkably local.

5th. Recommends certain conservative arrangements as beneficial near villages, but questions whether advice with regard to mode of life, exposure, &c. would be adopted and voluntarily practised by the agricultural population.

6th. That the Eastern Jumna Canal furnishes some of the best and worst results of canal irrigation:—SICK-

NESS where the drainage has been obstructed, and where the soil is clayey, as in the centre division; HEALTH where the drainage is perfect, and the soil is light, as in the northern and southern divisions.

The result of the Committee's inquiry led, therefore, to the conclusion that salubrity depended in a great measure on the nature of the soil and the efficiency of the surface drainage; it depended, in fact, on the irrigation from a canal being properly regulated, and on the canal itself being properly laid out, so as not to interrupt the drainage of the country. With reference to the Ganges Canal Works, "We consider ourselves warranted," say the Committee, "in anticipating a far less amount of contingent evil than has been experienced on those of the Jumna, which were originally constructed without reference to many important points, which have been kept in view in projecting the present work, and more especially in drawing inferences from results on the Delhi Canal great allowances should be made for the natural disadvantages of the country through which it flows when compared with the Doab generally."

With regard to its effects on the surrounding country, the Ganges Canal had, independently of the experience gained from the Jumna Canals, natural advantages of a very high order for securing the most perfect drainage. Its course was on the water-shed of the land lying between the Ganges and the Jumna Rivers; the beds of rivers or the hollows of ravines were on its whole course ready to receive any cut that might be made for the relief of land lying in its vicinity. The whole of the works had been designed with reference to the most perfect system that could be devised for effecting irrigation with as little interruption as possible to the natural drainage of the country, and by a judicious arrangement of inlet and escape to maintain an equilibrium of water during the monsoons, and during those periods in the cold weather when the country was liable to inundation by partial, though heavy, falls of rain. The Jumna Canals, on the contrary, were in some respects most inconveniently lined out with reference to the drainage of the country—the Hansi and a large portion of the Delhi Canal especially: they had in their original construction been planned without any reference to those points upon which the Committee place such especial weight. The system of irrigation, although by no means deprived of the benefits of rajbuhas, was, to say the least of it, very imperfect, and was occasionally of the worst possible description. It did not therefore follow that the evils of the irrigation from the Jumna Canals were to be perpetuated on a new line, where every attempt had been made to avoid them.

The recommendations of the Committee with regard to measures connected with the execution and management of the Ganges Canal Works were judicious; they were summed up in the following terms, and were strongly urged upon the attention of the Government:—

1st. That the Ganges Canal be kept as much as possible within soil, *i. e.*, that its ordinary surface level should be below that of the country.

2nd. That earth wanted to complete embankments be never obtained from excavations made outside of the canal, except in such localities as will readily admit of drainage.

3rd. That the canal and its branches be taken as much as possible along the water-shed of the country, so as not to interfere with the drainage; and in all cases where such interference may be unavoidable, that the executive officer be instructed to provide otherwise for the drainage.

4th. That masonry drains be constructed under rajbuhas or bridge ramps, whenever these cross the drainage of the country.

5th. That no private watercourses be allowed, but that irrigation be practised exclusively from rajbuhas or main watercourses.

6th. That irrigation be prohibited within five miles of a military station, and within one or two miles of large native towns.

7th. That in clearing embankments, the grass, weeds, &c., be not suffered to rot on the ground, but that they be burned as soon as possible after they are cut.

8th. That irrigation be altogether prohibited in localities which appear naturally to possess a malarious character.

In concluding these rules, the Committee observe that they are aware that their adoption will involve an expense not contemplated in the original estimates for the work.

The two main questions, therefore, upon which the further prosecution of the Ganges Canal Works depended had been seriously discussed and deliberately investigated. With the proper application of remedies as recommended by the Committee, the apprehensions regarding the effects of malaria on the health of the people were not deemed by the Government of sufficient consideration to warrant the relinquishment of the project; nor, although the difficulty of obtaining satisfactory evidence on the question of navigation was fully admitted, were the apprehensions entertained on that subject considered to be sufficient to justify any departure from the original scheme.

The Supreme Government, therefore, in a despatch dated 1st May, 1847, issued directions to the Agra Government to prosecute the work with the utmost diligence, on the principle that "the more vigorously the work can now be prosecuted, the cheaper it will be to the State."

From this period, therefore, the Government were fairly embarked in the undertaking. Major Baker was called upon to report on the best measures for carrying out the wishes of Government, and his attention was drawn to the following points regarding the construction of the work which Government had finally determined on:—

1st. The primary object of the canal is to be irrigation; navigation is to be a secondary object, but is to be accomplished so far as may not be inconsistent with irrigation.

2nd. The work is to be constructed in the most complete and substantial manner practicable. This includes the construction of all the works between Roorkee and the Ganges, in the manner recommended in Major Cautley's last printed report of 1845, with any subsequent improvements and precautions suggested by Major Baker. The precise course of the canal and its several branches below Roorkee is yet open for determination.

3rd. The precautions recommended by the Committee in their Report of the 3rd March, 1847 (of which I have before given a copy), are to be adopted as far as may be practicable. The first four of these suggestions must be borne in mind in the construction of the canal. The last four will come into operation after the canal has been opened and irrigation commenced.

4th. The available water-power is to be employed as extensively as may be practicable for moving machinery at suitable places for the erection of such machinery; where there may be no immediate demand for it, provision should be made for its future erection.

5th. In taking land for the canal, arrangements are to be made for the formation of reservoirs and plantations on the plan which has been adopted on the Jumna Canals.

As the above rules are those upon which the work has been conducted, I have considered an introduction of them *verbatim* as an interesting feature of my narrative. There was some discussion at this time on the subject of the more southern districts, and of those which would derive the greatest benefit from the canal. As these were questions, however, which depended on close surveys of country, they will be more fully entered upon hereafter. It was evident, however, that the surveys for my original project having been made for the purpose of discovering the watershed or backbone of the Doab, and therefore conducted through one line of country merely, were insufficient for laying down branch lines, or of determining through what districts such lines might be most advantageously carried.

Major Baker's report was addressed to the Military Board, and dated the 13th April, 1847. The document is an exceedingly interesting one, and as it bears upon the whole of the question, and defines the rules upon which the executive officers and others have been since guided in the progress of the work, an abstract of its contents will in this place be explanatory of the views that were then entertained on the subject.

Major Baker's plan of operations was founded on the following considerations :—

1st. That a very small portion of the canal can be brought into use before the Solani Aqueduct is completed.

2nd. That earthwork in channels and embankments being liable to much injury from the weather, and consequently requiring extensive repairs, it is desirable that these should not be completed before the masonry works.

3rd. That the whole project, including both main and branch lines, should be completed at once, both with a view of bringing the whole into operation as soon as possible, and to admit of a full supply of water being used, which could not be the case unless the branches were ready to receive their respective shares.

The rapid completion of the Solani Aqueduct was a necessary desideratum under the above considerations; and it was proposed to concentrate all means upon this work, by which the object would in all probability be gained in six years. The calculations on which this was based were as follow :—

The cubic contents of the aqueduct being 8,749,524 cubic feet, the following quantity of material would be required for its completion: Bricks, $12'' \times 6'' \times 2\frac{1}{2}''$ for building, 69,996,192; ditto, ditto, for soorkee, 13,474,258; lime, in cubic feet, 962,447; or, in round numbers, 1,000,000 cubic feet of lime and 850 lakhs of bricks.

The workpeople required in preparing and using the material would be as follows: In brickmaking, inclusive of wood-cutting, 3,143,333 labourers; in building masonry and laying floor, 781,946 ditto; in pounding soorkee, 641,632 ditto; in undersinking the blocks, 311,040 ditto; in the earthwork of the aqueduct (exclusive of draught cattle), 1,972,750 ditto. Brickmaking, to be completed in five years, allowing 190 days in each year (deducting Sundays and rainy season), would require per diem 149 brick-moulders and 3,309 labourers. The remaining work, to be completed in six years, allowing 250 working days per annum, would require 204 bricklayers and 2,471 labourers per diem. The workshop would require 50 smiths, and 80 to 100 carpenters per day; and an establishment of about 1,000 bullocks, exclusive of contract carriage, would be required for the earth-waggons and other purposes.

To those who are unacquainted with the part of India in which the above works are situated, and with the system which the nature of the people and of the country itself renders necessary in the Department of Public

Works, it may be advisable to point out here that there are no contractors to depend upon for the supply of material. The engineer, as the architect, has to make his own bricks, and to burn his own lime; he has to purchase his supplies of timber, and, in many cases, to proceed to the forests himself to superintend its collection. He has, in fact, neither contractors for making his material, nor contractors for putting that material together; he is literally driven to his own resources, and, although the contract system in a limited sense is by no means misunderstood in these provinces, it is confined to the manufacture of material in small quantities, and to the excavation of earth—the latter being a trade which has long thrived both in the Punjab and in the more southern States. The earth-contractor must have originated in the great demand for tank or reservoir digging, which exists both amongst the Mussulman and Hindoo population, or for watercourses on the canals for irrigation. There are tribes of a wandering class whose chief, if not entire occupation, is digging tanks and watercourses, and to these people we are indebted for the greater part of all our canal excavations. The respectable and wealthy class of contractors which in Europe relieves the engineer and the architect from the detail of building, is unknown in the North-Western Provinces of India; the difficulties, therefore, that were encountered by the Director of the Ganges Canal Works at the early period of their establishment may be fully estimated.

In continuing his Report, Major Baker, when referring to the executive establishment that would be necessary, drew especial attention to the unusual quantity of material that was required for the construction of the Solani Aqueduct, the position in which it was placed with reference to supplies, and the impracticability of meeting our wants excepting by the exertions of our own establishments. The appointment of an officer expressly for the purpose of superintending the manufacture of material for the Solani Aqueduct was recommended. This officer's duties were to be restricted to the northern division, to which a second executive officer was to be appointed for the supervision of the works. Five other executives were recommended for the works south of Roorkee, their divisional duties being confined within certain limits detailed in Major Baker's Report.

It was proposed that the whole of these officers should, as early as possible after the close of the rains of 1847, or in the month of November of that year, employ themselves in obtaining an accurate survey of their respective districts, and such a series of connected cross levels as would enable them, in consultation with the Director of the Works, to fix on the best possible line for the canal: they would burn bricks wherever fuel might be available along the probable course of the canal, and in quantities proportionate to the probable requirements. On the approval of the line by the Director, it would be carefully marked out, and masonry bench marks established; and, to use the words of Major Baker's Report, "The principal masonry works would then be commenced, and a careful calculation having been made of the quantity of excavation in the channel, and the time required for its execution, the ground would be taken up, and the excavation be commenced with such reference to the progress of the Solani Aqueduct as would admit of the simultaneous completion of all the works."

The extent of the divisions which were thus told off to the different officers was arranged on the supposition that the third project which I have, in my Report of 1845, recommended for adoption, would prove to be the most desirable; but before this could be determined on, accurate surveys of the country were required: it was therefore proposed that the Director should personally visit the different districts, and, in communication with the civil authorities, determine the best and most favourable lines upon which irrigation could be extended. This determination would necessarily be based on the results of the different surveys and levels upon which the executives were to be engaged during the cold season of 1847–48, regulated by the instructions conveyed in the report of the Medical Committee. In the meantime, the progress of the works in the northern division, or in that portion between the hills and Roorkee, especially that of the main works at the canal head and on the Solani River, would go on unimpeded, their positions having been accurately determined in the earliest stage of the project.

The establishment which Major Baker recommended was in accordance with that of my Report; it gave to each executive the following aid, independently of that of two assistants, in his executive duties :—

ENGLISH OFFICE.

	Co.'s Rs.	A.	P.			
1 English Accountant	100	0	0			
1 Ditto Writer	45	0	0			
1 Ditto Assistant . . .	25	0	0			
				170	0	0

NATIVE OFFICE.

1 Moonshee	30	0	0			
1 Assistant ditto	15	0	0			
1 Native Surveyor . . .	25	0	0			
1 Native Doctor	15	0	0			
2 Sowars, @ 15 rupees each .	30	0	0			
1 Duffadar	6	0	0			
4 Burkindauzes, @ 4 rupees each .	16	0	0			
1 Chuprassie	6	0	0			
2 Ditto, @ 5 rupees each . . .	10	0	0			
4 Classies, @ 4 rupees each . .	16	0	0			
				169	0	0
Carried forward . . .				339	0	0

				Co.'s Rs.	A.	P.
Brought forward				339	0	0
Treasury.						
	Co.'s Rs.	A.	P.			
1 Treasurer	20	0	0			
1 Assistant ditto	10	0	0			
1 Jemadar	8	0	0			
1 Duffadar	6	0	0			
16 Burkindauzes, @ 4 rupees each	64	0	0			
				108	0	0
Works.						
1 Mistry Smith	25	0	0			
1 Ditto Carpenter	25	0	0			
1 Ditto Bricklayer	15	0	0			
1 Ditto ditto	12	0	0			
1 Jemadar of Chuprassies . .	8	0	0			
10 Chuprassies, at 5 rupees each .	50	0	0			
				135	0	0
Total per Month				582	0	0

With permission to employ on detached works under-overseers—one mootsuddi, @ 10 rupees per month; one chuprassie, @ 5 rupees per month: and a guard proportionate to the stores and treasure in his charge was also recommended.

In reviewing the system of accounts as practised in the Department of Public Works, Major Baker drew the attention of the Government to certain points which appeared to him inapplicable to the expenditure on the large works of the Ganges Canal. Under the system now in force, the engineer in charge of the works keeps detailed accounts of expenditure, and on the completion of a work submits a bill for audit, in which the actual rates of work are compared with those of the estimate. If the estimate be not exceeded, or the excess be satisfactorily explained, the bill is passed, and the executive engineer is relieved of its amount.

Major Baker argued that if this system was observed in the Ganges Canal, the expenditure on the Solani Aqueduct, the Myapoor Regulator, the dams, and principal works of the northern division, would not come under revision for many years, when the work would have passed through the hands of several executive officers, and when, the money being spent, the check would be retrospective and inoperative; and that the amount of money at the personal risk of executive officers would accumulate before the completion of the works to an extent that would be felt as a grievous burden, whilst the arrangement of complicated and long-standing accounts would engross the time and energy which would be more profitably expended on the actual arrangements for work.

Major Baker therefore proposed for adoption a system which he considered more applicable to the Ganges Canal Works, and as this system was approved of, and, as far as possible, was carried out afterwards, I shall give it here in Major Baker's own language:—

I. The works shall be executed agreeably to Major Cautley's designs, no deviation from which will be made by the executive officer without the sanction of the Director of the Works, who will report the same to the Military Board.

II. When money is required for the execution of work, applications will be made by the executive engineer, through the Director, to the Accountant, North-Western Provinces, who will issue an assignment for the amount.

III. The executive engineers will send monthly to the Director detailed accounts of their expenditure, viz.: 1. List of establishment. 2. Account of workpeople employed and materials expended in each work, and measurements of work done. 3. Quantity of contract work and its cost. 4. Amount of advances for contract work. 5. Amount of advances for materials. 6. Quantities of materials received. 7. Quantities of materials expended.

IV. The executive engineer's monthly accounts will be abstracted in the Director's office, and, after examination, will be forwarded for audit to the Military Board, accompanied by a special report having reference to the following tests :—1. The regular establishment charged will be compared with that authorized by Government. 2. The subordinate establishment for the supervision of work will be tested by the extent of work in progress. 3. The work expenditure will be tested by the extent of work done. 4. The number of workpeople, by the known amount of one man's labour; their rates of pay, by the ordinary rates of the district. 5. The quantity of material used, by what is known to be necessary for each description of work.

V. On completion of any work the Director will draw out and submit to the Military Board, a comparison of its actual cost with that estimated.

VI. General accounts of expenditure on the canal works of all descriptions will be kept in the Director's office, and balance-sheets will be submitted to Government quarterly or half-yearly, as may be required.

VII. To carry on the plan as above detailed, an accountant with the requisite number of assistants would be required in addition to the present establishment of the Director's office.

Major Baker, in soliciting the favourable consideration of the Military Board to the above system of accounts, observes that although it would involve a greatly increased amount of labour to the Director of the Works, it would place in his hands a control over the expenditure, and an insight into its details which under the existing system would be difficult of attainment, if not impossible, and that the labour and responsibility saved to the executive officers would be proportionately much greater than that entailed by the new system on the Director.

Major Baker concludes his Report, by pointing out, that to place the establishment of executives and assistants on the footing which he has proposed, seven executives and fourteen assistants would be required. Of this number there were at the time four executives and four assistants available, leaving a deficit of three of the former and ten of the latter; in the latter capacity Major Baker recommended the employment of three or four sub-assistant civil engineers, or young students from the Roorkee College, should so many be available. It was urged that nominations to these appointments should, as the period at which he was writing was unfavourable to field work, be deferred until the month of September, so as to admit of the work being set in active progress after the cessation of the rainy season.

This Report was accompanied by a statement of the expenditure which had been incurred on the Ganges Canal Works up to the 30th April, 1846, of which the following is an abstract:—

	Co.'s Rs.	A.	P.			
NORTHERN DIVISION.						
Excavation	3,54,525	5	6			
Masonry	19,783	2	9			
Materials and Sundries, including Establishment .	2,19,032	6	7			
				5,93,340	14	10
SECOND DIVISION.						
Excavation	93,903	9	4			
Masonry	1,267	4	0			
Materials and Sundries, including Establishment .	80,296	10	6			
				1,75,467	7	10
Director's Office, Establishment, &c. . . .				33,894	6	5
Grand Total Expenditure up to 30th April, 1846				8,02,702	13	1

The suggestions and recommendations which had been made in the above Report were entirely approved of by the Government in its letter of the 25th August, 1847. A quarterly system of accounts conforming in every other respect to that proposed by Major Baker, was however considered to be better than the monthly one, and rules to the following effect were laid down for future guidance:—

"In the northern division, the Executive Engineer of Works will submit quarterly to the Director a bill for three months' work, prepared in the usual departmental form, *i.e.* exhibiting quantities, rates, and amounts, and accompanied by detailed measurements of work done.

"The materials used to be charged for on the rates furnished by the Executive Officer of Materials.

"When the rates of work differ from the estimated rates, full explanation to be given at the foot of the bills in the usual manner.

"The bills, after careful examination by the Director, will be submitted with his remarks to the Military Board.

"The executive officer whose duty it will be to collect and prepare materials and to take charge of bullocks, carts, &c., will submit quarterly to the Director for transmission to the Military Board, a detailed statement of expenditure and results on each item of his charge, including carts and bullocks, accompanied by such explanations as may appear to be necessary.

"To the above statement will be appended a balance-sheet, showing on one side the actual expenditure on each item, and on the other the amounts received from the Executive Engineer of Works and the stock in hand.

"He will also submit a list deduced from the above-mentioned accounts, of prices of materials, bullock hire, &c., which he proposes to charge during the ensuing quarter to the Executive Engineer, to whom it will be communicated by the Director, if approved.

"The Executive Officer of Materials will get advances from the Executive Engineer of Works, and will write off, per contra, the value of materials supplied.

"In the smaller divisions, it may be expedient from motives of economy to unite in one officer the functions of the two allowed for the first division.

"The Executive Engineer of a smaller division will, therefore, keep and submit quarterly to the Director distinct accounts of works and materials as laid down for the two officers of the first division.

"On completion of any work extending through more than one quarter, the Director will draw out and submit to the Military Board a comparison of its actual cost with that estimated, at the same time reporting on the quality of work, &c. Every work commenced and completed during the quarter will, by the Director, be separately reported on, as to its quality, &c.

"General accounts of expenditure on the canal works of all descriptions will be kept in the Director's office, and balance-sheets will be submitted to Government quarterly or half-yearly as may be required."

In providing Major Baker with the above rules, he was told that if he "considered it necessary to increase the strength of his own office establishment, in order to conduct this new system of accounts with punctuality and efficiency, he was authorized to entertain an accountant on a salary not exceeding 300 rupees, and two assistants on a salary not exceeding 100 rupees each per month."

The forms of accounts and papers which were submitted on the above system will be found in the volume of Tables, Appendix C.

On the 1st of October, 1847, a series of instructions were circulated to executive officers on their proceeding to commence field work, to examine the country as before explained, and to determine the best line upon which the canal and its branches should be carried (a copy of these instructions will be found in the volume of Tables, Appendix D); in the meantime the different works in the northern and in the early part of the second division in the Mozuffurnuggur district were proceeding with all the vigour that additional means had instilled into the establishment; and at the period when I rejoined, early in January, 1848, I found everything prepared, both in money and establishment, for carrying on the works with the utmost energy.

VIEW OF THE GANGES CANAL HEAD AT THE POINT WHERE THE WATER LEAVES THE MAIN GANGES ABOVE HURDWAR.

CHAPTER III.

FINAL PERIOD,

Under the Directorship of Lieut.-Colonel P. T. CAUTLEY.

From 1848 *to* 1854.

MAJOR BAKER delivered over charge of the works to me on the 11th January, 1848, with the necessary memoranda as to progress and expenditure; and it may be interesting here to place upon record the state of the works at this period, as well as the amount of money that had been expended upon them.

I have, in the volume of Tables and Appendices (Appendix E), given in full the report on the state of the Ganges Canal Works at or about the period when Major Baker delivered over charge to me; the introduction of this paper in its fullest details is necessary to show the progress that had been made up to this period, together with Major Baker's views on points connected with the general project. I may observe, however, that independently of the block foundations, and of the side revetments of the Solani Aqueduct which had been commenced, very considerable advance had been made in the works at the Myapoor Dam.

The Regulating Bridge at that point, together with the bridges for cross communication at Kunkhul, Jowalapoor, Munglour, and Toghulpoor, were in an advanced state, the arches and superstructure of the Myapoor Regulator were very nearly completed, the foundations of the Belra Falls had been commenced upon, numerous choki buildings had been finished, and excavation was either in progress or had been completed from the 1st to the 40th mile of the course of the canal.

On the 31st of December, 1847, the state of the expenditure was as follows:—

NORTHERN DIVISION.

	Co.'s Rs.	A.	P.			
Excavation	4,76,190	0	0			
Masonry	2,57,878	0	0			
Materials and Sundries, including Establishment . .	4,33,228	0	0			
				11,67,296	0	0

MUNGLOUR, OR SECOND DIVISION.

Excavation	3,02,900	12	4			
Masonry	25,823	5	3			
Materials and Sundries, including Establishment . .	1,27,914	1	4			
				4,56,638	2	11

3RD, 4TH AND 6TH DIVISIONS.

Preliminary Surveys, Establishments, &c. .	5,539	10	11
Director's Office, Establishment, &c. . .	72,565	10	7
Grand Total Expenditure on the 31st Dec. 1847	17,02,039	8	5

The staff which was attached to the works, and the duties upon which I found them engaged on my accession to office in 1848, were thus:—

In the northern division, which extended from the head at Hurdwar to a point 4½ miles below Roorkee, Lieutenant H. Yule (who, in the month of April following, was succeeded by Lieutenant A. G. Goodwyn), the executive engineer in charge of the works, had under his orders—Lieutenant Price, of the 1st Bengal Fusileers; Mr. W. Kay, uncovenanted; Mr. T. Login, uncovenanted; and Mr. J. Parker, uncovenanted. The works in progress were general throughout the division; Sergeant Finn, a canal officer of great experience, being in charge of the material department, of which he had shortly before assumed the direction.

In the 2nd division, which extended to the 110th mile, running through portions of the Saharunpoor, Mozuffurnuggur, and Meerut districts, Lieutenant Edward Fraser, of the Engineers, who was the officer in executive charge, had under him as assistants, Lieutenant Dempster, of the Bengal Artillery, and Mr. F. Read, uncovenanted. Excavation had been in progress in this division from the earlier periods of the operations, and before I left India: at the time of my rejoining the works, considerable advancement had been made, and parties were excavating as far south as the 50th mile; the collection of bricks and other material was in active progress throughout the whole of the division; and in the more northern parts some of the masonry works had been commenced; the Munglour and Toghulpoor bridges having been completed up to the spring of the arches.

In the 3rd division, Mr. Volk, who had been appointed executive officer for the superintendence of the works, with Lieutenant Merrick, of the 3rd Native Infantry, and Lieutenant Newmarch, of the Bengal Engineers, as his assistants, were engaged in surveys and levels of the country, and were collecting the necessary data for laying down the main line of the canal. This division extended through portions of the Bolundshuhur and Alligurh districts, as far south as the town of Koel.

The 4th division had been placed under charge of Lieutenant Hodgson, of the Bengal Engineers. This officer, with Lieutenant Dumbleton, of the 10th Cavalry, as his assistant, was employed on the surveys and levels of the country lying through the Alligurh and Mynpoori districts.

The 5th division, which consisted of the line of country on which it was proposed to carry the Etawah branch, was unoccupied.

The 6th division was held by Lieutenant Charles Hutchinson, of the Engineers, with Lieutenant Hume, of the 48th Regiment of Native Infantry. These officers were engaged on the surveys of the country in the Furruckabad and Cawnpoor districts, in extension of the line occupied by Lieutenant Hodgson.

In addition to the above officers, who were strictly attached to divisions, Mr. Dodsworth, as surveyor, was engaged in carrying on a series of longitudinal and cross sections on the line of country between the Rinde and the Jumna River, for the purpose of determining the best line of direction for the Etawah branch, or that which had been fixed upon as the fifth division.

It will be understood, therefore, that at the period to which I am referring, excavation and masonry works were in progress from the canal head to the 50th mile of its course; beyond that point, the surveys and levels of the country upon which the direction of the canal had to be determined were still in embryo.

The works at this time had been proceeding on the plan laid down in the third project, which I had submitted to Government previously to my departure for England in 1845. All the projects suggested by me for the consideration of Government had their works and directions in common for the first hundred miles; but beyond that distance opinions were very much divided as to the line which would be best adapted for meeting the wants of the agricultural community; and my attention was directed to the following views, which were entertained by the Agra Government on the subject of its extension:—

"The course of the canal below Roorkee, or rather from the point in the Muzuffurnuggur district whence the Futtigurh branch will be thrown off, requires mature consideration. The primary object of the canal is to be irrigation, and it is very doubtful whether the course which follows the watershed line down to Allahabad is that which most needs a supply of water for agricultural purposes. The Kalli Nuddi, the Eesun, the Pandoo, the Rinde, the Seyngoor, and the Kurroon, each have their rise in the plain of the Doab, south of Roorkee; and, after running for some time in a direction nearly parallel with either the Ganges or the Jumna, empty themselves into one or the other. They thus divide the Doab into several longitudinal sections, the present state and actual capabilities of which are very different.

"This is peculiarly the case in the district of Cawnpoor, which stretches across the Doab from the Ganges to the Jumna; and through the centre of which, intermediate between the two rivers, the Rinde pursues its course. In the purgunnas (division of a district) between the Rinde and the Ganges, water is near the surface; wells are consequently numerous, and the country is rich and well cultivated. Between the Rinde and the Jumna, water is far from the surface, and wells are constructed with difficulty; the country is exceedingly ill cultivated and poor. There can be little doubt that a canal for irrigation is more wanted in the latter than in the former; and yet the plan, as originally laid out, contemplated throwing the largest supply of water into the former.

"These circumstances regarding the Cawnpoor district are mentioned as illustrative of the considerations which may influence the course of the canal, but are not to be considered as at all affecting the final determination which may be reached after the country has been examined, and reported on by competent officers."

The surveys and levels upon which the projects which I had up to this period submitted to Government had been based, consisted merely of the examination of the tract of country which might be considered the line of watershed between the great rivers. The whole of the work, with the exception of two or three cross levels, which were taken in the Futtipoor district, had been done by myself, unaided by staff of any description; the only lines, therefore, that had undergone the test of positive survey were those from Hurdwar to Allahabad, with a branch line to the Ganges at Cawnpoor; the country towards the Jumna had not been examined; the sketch that I had given of it was necessarily a general one, and an evident necessity, therefore, existed of subjecting the country that would come under the influence of the canal, whether on its main line or on its branches, to a more detailed and comprehensive examination than I had been able to bestow upon it, previously to the determination of the precise direction to be finally given to the lines.

There were also other questions which immediately occupied my attention. To carry into effect the sanitary measures recommended in the report of the Medical Committee, although the plan of excavation which had been proposed for the main line and its branches was in no great degree affected thereby, yet required consideration on the best methods for supplying the irrigation channels, and for placing their heads in a position the best adapted to the works; it was further necessary to determine more deliberately the position and number of escapes, as well as the means for regulating the water in its connection with the branches; and these various measures clearly depended a good deal on the results of the detailed surveys.

The channel excavation, which, as I have before stated, had been steadily in progress from the first commencement of our operations, had advanced far down the high land south of Roorkee. The results of this excavation, so far as it had been carried, had exhibited throughout a soil of an exceedingly unsatisfactory character: the clay supersoil, which had been observed in a greater or less degree to be a characteristic feature of the country, turned out to be a mere superficial stratum, varying in depth from 3 to 10 feet, and overlying a deposit of (in many cases) purely river sand, extending apparently to an unlimited depth. The excavation which had up to this period been made, had in fact removed the whole of the good, leaving the sandy substratum for the bed of the canal. As further inquiry and examination by excavations carried on in the more southern districts exhibited results equally unfavourable, my attention was directed to the inapplicability, not only of the slopes of the canal bed as originally projected, but to the design of the works generally, which with reference to their foundations, and to the means provided for their protection, were clearly inadequate to the contingencies arising from these unexpected difficulties.

The points above noticed were brought under review at the earliest period possible; and the surveys and levels of the country in the southern districts having been completed, and the direction of the main line and its branches having been determined on, the whole of the works of the main line were in progress during the cold season of 1849–50.

In 1850, at the desire of the Agra Government, I submitted a report, with a revised estimate founded on data, derived from 2½ years' experience, of the cost of labour and materials of the different districts, and showing the actual amount of expenditure which, in providing for the contingencies above referred to, would be required to complete the works.

The lining out of the canal channel had at this period been devised so as best to economize the water, and to deliver it over those southern districts, where, from the difficulty in sinking wells and from the depth at which spring water was found, its uses would be the most appreciated, and its benefits would be the most palpable.

The main trunk was carried in the direction proposed in the original estimates as far south as the 180th mile, throwing off from the left a branch to Futtigurh, and to the right a branch to the Bolundshuhur or Tuppul districts; the former leaving the main line at the 50th and the latter at the 110th mile: between the 110th and 180th mile, and intermediately between the latter two points, another branch, not included in the original estimates, had been projected for the irrigation of the country lying to the left of the Kurroon River and to the right of the town of Koel; this branch, which left the main line on its right bank, was intended to irrigate a tract of country equal in extent to that of the Bolundshuhur branch.

At the 180th mile, or at a point a few miles below the town of Koel, the main line is divided into two canals, or branches of nearly equal dimensions; the one on the left bearing directly upon the Ganges River at Cawnpoor, and the other upon the Jumna at a point near the boundary of the Futtipoor and Cawnpoor districts; the latter keeping to the right instead of to the left of the Rinde River, as was originally contemplated, and passing through the districts lying on the Jumna side of the Doab. This arrangement was consonant to the views expressed by the Government, and better adapted to the economical application of the water for the purposes of irrigation.

In submitting my estimate of 1850, it was prefaced by the following observations:—"There are three points which have greatly influenced the designs of the works now estimated for, viz.:—

"1st. The results of the proceedings of a Medical Committee, which determined that the high water of the canal should be kept as much as possible below the surface of the country.

"2nd. The results of excavations in the upper divisions, showing that the supersoil only was clay, with an uninterrupted substratum of sand.

"3rd. The change of design in the distribution of the supply below the 110th mile, which, in connection with the results above referred to, have, in fact, led, with few exceptions, to the total re-projection, not only of the masonry works, but of the capacity of the canal channel."

In referring, therefore, to the papers already printed, I observed, "that the present may rather be considered a fourth, in succession to the three projects formerly submitted, than a revised estimate on what has gone before."

As the alterations arising from the above considerations necessarily added largely to the amount of estimate, it will be satisfactory in this place, without entering into the particular detail of each work, which will be fully described hereafter, to give a general outline of the changes which were proposed, and of the effects that such changes had on the different divisions.

The 1st division, as I have before explained, includes the whole of the works in the Khadir or low land of the Ganges, and extends to a point on the high land of the Doab, about 4½ miles distant from the town of Roorkee. With the exception of a more direct bearing upon the Rutmoo torrent from that of the Ranipoor, the direction of the canal alignement in this division was in close approximation to that of the original design. The works on the early part of its course, as well as those on the Solani torrent, were, with the addition of improvements arising from local circumstances, also similar; intermediately, however, between the town of Jowallapoor and the Peeran Kulleeur ridge, great modifications had been made, not only in the slopes and capacity of the excavated channel, but also in the design of the masonry works. It had been found necessary to carry the deep digging to points much farther back than was originally intended, to enable the floods of the Ranipoor and Puttri torrents to pass over and run independently of the canal channel—an arrangement which the enormous quantity of silt brought down by these rivers appeared to render indispensable. The greater part of this excess of digging had to be performed under great difficulties, arising from the height of spring water, with the necessity of providing against the inroads of floods during the progress of excavation; the soil was of such a light description that foundations for the masonry works of a character not before contemplated, either in massiveness or depth, became a necessary part of the estimate. The more direct bearing on the Rutmoo torrent, and a general consideration of the action of water upon a bend of greater or less radius, together with more deliberate observations upon the torrent itself, led to a complete remodelling of the works opposed to this river. Masonry revetments were projected upon the curve of approach, and the foundations of the whole were designed of a much more massive description than those originally estimated for. The works on the Solani valley were (with the exception of terminal cattle ghats and a bridge at the north to correspond with that of the south end) unaltered in elevation; the foundations and floorings of the masonry aqueduct had been strengthened, and in consequence of kunkur not having been found in sufficient abundance, the use of brick had been more generally practised.

With the exception of the first two miles of its course, the slopes of the canal bed had been revised and modified, superfluous slope had been disposed of at the masonry falls, and an additional fall of 8 feet had been designed at the extreme end of the division near the village of Assufnuggur. Below Assufnuggur the slopes of the canal bed had been reduced from 18 to 15 inches per mile, the superfluous slope having been disposed of in additional masonry descents or falls of 8 feet in perpendicular height each, as far south as the 105th mile, and beyond that point to the 180th mile, by two falls of 5 feet each. The sandy nature of the soil, especially on the line extending from Roorkee to the 110th mile, rendered it advisable to extend the waterway of the falls, which were built within these limits, so as to admit of the run of water over them being as little obstructed as possible. For the same reason, foundations and floorings of a much more massive description and greater depths than those originally estimated for, were considered to be indispensable. The waterway of bridges was slightly increased, their foundations strengthened, and the usual means were adopted for overcoming the dangers and difficulties attendant upon laying foundations in a sandy soil.

The number of bridges which had in former estimates been fixed on a scale allowing one bridge to every three miles, was more determinately arranged on the actual wants of the country; the width of roadway of bridges was increased to meet the high military district, and grand trunk roads and means of access to the canal-water were provided at all parts where the convenience of the community rendered such a course necessary.

At the points of departure of the various branches, works were provided for, by which the supply might be regulated according to the demand for irrigation, or by which a branch itself, or the main canal south of that branch, might be laid dry, when repairs or other contingencies might render such an arrangement necessary.

In the upper portion and in the sandy tracts of the canal, heads for irrigation were confined to the higher levels of the different falls or descents of masonry; and in the lower districts these heads were attached to the different bridges, forming a component part of their design.

It will be understood from the above detail that the line of the canal had been entirely remodelled, not only in depth of section, to meet the 1st and 2nd articles of the rules that had been laid down for my guidance, but to meet the change in the distribution of the water which the alterations in the direction of the branches in the southern divisions had rendered necessary.

In summing up this Report, I observed that the expenditure which was included in the estimate embraced not only that of the works themselves, but of all repairs and establishments appertaining to the Ganges Canal from 1842 to the 30th June, 1853; at which period, unless unforeseen accidents intervened, it was supposed that the works contained in this estimate would be completed. I pointed out that in the southerly divisions the masonry works had been planned on one general scale, the perfect working out of which would depend very much upon localities; that, in many cases, the estimated cost would be in excess of the actual expenditure; that I had endeavoured to include in this estimate the irregular works attached to the torrents in the Ganges Khadir, as well as at Hurdwar and in the bed of the river Ganges, and that it had been my object to exhibit in one connected sheet the whole of the liabilities.

Without laying any particular stress on circumstances which the times rendered quite unavoidable, I alluded to the many interruptions that had taken place to the progress of the works since ground was first broken, on the 16th April, 1842, and to the order of Government issued in 1846, giving to the establishment and labourers, both

Hindoo and Mussulman, the Sunday, in addition to the numerous holidays of their own particular faith.

The total amount of the estimate of 1850 was as follows :—

	Co's Rs.	A.	P.
Total of Estimate for Works on the Main Line and its Branches	1,41,60,311	7	5
Total expended on and estimated for Establishments to 30th June, 1853 .	11,55,936	14	11
Ditto, for Ordinary Repairs, ditto .	2,69,733	3	0¼
Ditto, for Sundry Expenses, ditto .	19,824	14	2
Grand Total	1,56,05,806	7	6¼

At the period that this estimate was submitted, or up to the 30th June, 1850, the following expenditure had been incurred :—

	Co.'s Rs.	A.	P.
1st Division, including Materials . .	29,77,731	10	5
2nd Ditto	15,97,234	15	11¼
3rd Ditto	4,39,434	2	4
4th Ditto	1,56,587	13	6
5th Ditto	10,382	15	8
6th Ditto	69,989	7	11
Director's Office	1,22,750	13	0
Grand Total expended to the 30th June, 1850	53,74,111	14	9¼

It would be a hopeless and somewhat unprofitable task to advert to the various interruptions to progress that had taken place since the 11th of January, 1848, the date on which I reassumed charge of the works, and the date figured in the above estimate. The second Sikh war deprived us for many months of the services of some of our most valuable officers; sickness and other causes had led to the departure of others; but the Government steadily persevered in providing funds for every demand that we could make upon the public treasuries; nor for a moment did the expenses of the Sikh war, nor the great demand for money that such a concentration of forces must have called for, interfere with the expenditure on this great work of public utility.

The above estimate was framed under the idea that the works included in it would be completed in three years. There were, however, contingencies beyond those of the mere interruption from change of executive officers from sickness, or from the many other causes which influence the progress of works in general; the completion of the works in the estimate was, in fact, the completion of the works in the northern division, and the completion of these works depended entirely upon our success in brick-making. I have, in the early part of this narrative, pointed out the demand that is made upon the engineer's time and patience by the absence of the wealthy and respectable contractors, who, in Europe, go hand in hand with the engineer; this absence throws the whole of the material manufacturing and collecting into the hands of the builder, who, in addition to his other numerous and responsible duties, has to manage the detail, and keep the accounts of every brick and lime kiln that supplies his work. The executive engineer in the northern division was relieved from this detail by the appointment of an officer, whose duty was confined to the collection of material: in the southern divisions, no arrangement of this sort had been entered into, and the executives had to supply themselves to the best of their ability.

Mr. Finn, the executive officer in charge of the material department of the northern division, had, by the greatest perseverance, and an energy not to be interrupted by disappointments, succeeded in establishing brick manufactories on a large scale at four different points in the northern division, in which the kilns, made according to a plan which had been brought from Sind by Captain Weller, of the Bengal Engineers, but altered to meet the particular circumstances under which they were used, and the varieties of wood fuel which the forests in the neighbourhood produced, succeeded to an extent that had hardly been anticipated. Interruptions arising from strikes amongst the brick-moulders, upon whom Mr. Finn had been for a long time dependent, had been completely put a stop to by the introduction of brickmaking machinery, the model of which had been imported from England; the difficulties, in fact, which had marked the early part of our experiments in brickmaking, had entirely ceased; and a cold weather favourable to progress, or one moderately free from rain, was all that was required to secure the manufacture of bricks in sufficient quantities to enable us to complete the works in the Khadir within the period calculated upon in my estimate.

The working season of 1850–51, or that from the commencement of October, 1850, began under very unfavourable auspices. Lieutenant Fraser, the executive engineer of the 2nd, and (as regards the difficulty of the works) the next in consequence to the northern division, was unexpectedly attacked by illness, which rendered his departure for Europe on medical certificate a matter of urgent necessity; the removal of one of the assistants of this division also, at the same time threw the whole of the responsibilities on the shoulders of the remaining assistant, Mr. Read, who, totally unaided, had to carry on works which were in active progress on a line of upwards of 80 miles in length.

The cold weather rains of 1850–51 were unusually severe, and from their continuing uninterruptedly for a long period, were more injurious to the brick manufactories than had they been more violent and fallen at detached times. The effects of these rains were seriously felt throughout the whole line of the works; the quantity of bricks and brick kilns that was destroyed in the southern divisions was very great; but the evil was felt more severely in the northern division, where, in all probability from its proximity to the mountains and forests, the rains were more severe than elsewhere. For three weeks, or for twenty-one successive days, during the most active period of the season, and unfortunately at the early part of the cold weather, all attempts at burning, or even making bricks failed; the brick fields were totally cleared out, the large parties of masons which had been collected in the hopes of an unfailing supply of material had to be broken up, and a great number of men had to be discharged.

The discharging of men of this class was a matter of very serious importance: the detached situation of Roorkee, and its position with regard to neighbouring towns, placed us in dependence on Oude, Rajpootana, and the country north of the Sutlej; to break up the parties of masons, therefore, was tantamount to delaying the completion of the works; the nature of our position, however, rendered such a step necessary; and, although I have no doubt that, had fine weather succeeded, the effects of these rains would have been in some degree neutralized by Mr. Finn's activity, the season continued to be a most unfavourable one; and I have no hesitation in placing the delay that has occurred in the completion of the aqueduct and the works in general to this most unpropitious cold weather of 1850–51.

The destruction of bricks, which were, in fact, the first necessity for progress; the quantity of work yet remaining to be done in the second division (in the executive duties of which Mr. Read had succeeded Lieutenant Fraser); the impossibility of maintaining staff adequate to the efficient furtherance of progress, determined me at this period to confine all my endeavours to completing the main line, and the two branches into which it separates below Alligurh.

There were many reasons, laying aside the causes above described, why this step was a very desirable one: the nature of the works in the northern division, especially those connected with the great aqueduct over the valley of the Solani River, appeared to point out the advisability of admitting in the first instance a moderate supply of water into the canal, and to increase this supply gradually in a ratio proportionate to its effects upon the channel and slopes. Whatever may be the knowledge at present possessed by our canal engineers, this knowledge is confined to dealing with comparatively small bodies of water (the maximum being 2,250 cubic feet per second), and with channels of moderate dimensions; it would therefore be unwise to commence on the Ganges Canal with supplies larger than we have been accustomed to; and whatever may have been the sanguine views either expressed or written on the subject of "at once throwing over the surface of the Doab the means of irrigation," a deliberate reflection on the nature of the works, on the knowledge we at present possess, and on the dangers that we should incur by any precipitate measures with regard to supply, satisfied me, that to do justice to this great undertaking, we ought in the first year that water is admitted to confine the supply to a minimum, *i.e.* to that which now runs in the Eastern Jumna Canal, that by the admission of so small a body of water we should be able to observe its effects upon the aqueduct and the sandy tracts that lie in the Mozuffurnuggur district, and be able, by observation, to suggest and to apply remedies for counteracting any of the evils that may practically exhibit themselves.

The above supply would annually be increased under the advantages of a most useful experience, and by the time that the supply had arrived at an amount equal to 4,470 cubic feet per second (or to double the amount in the canals west of the Jumna), which corresponds to the quantity required for the main line of canal and its two tail branches; and by the time that the consolidation of the earthwork both at the aqueduct and elsewhere had been perfected and the stability of the channel ensured, the opening out of the branches towards Futtigurh and the Bolundshuhur and Koel districts, the works of which would have been steadily going on during the above period, which we may call the probationary service of the main line, would be effected with the greatest security, and with the most satisfactory results.

I believe that the above is the soundest view that can be entertained of the question, and that the objects desired by Government will, by following it, be the most certainly gained: but at any rate there were at the period when the question of discontinuing the branches was settled, practical reasons of a sufficiently obvious character why the works could not be done. There was a clear necessity for limiting the progress by the establishment we had at command, which was barely sufficient to enable us to complete the works of the main line, a consummation indispensable to the admission of water; and it would have been impossible, without defeating this main object, to have extended our views in other directions, or to have divided our establishment by undertaking additional works detached altogether from the main line of our operations.

The country over which the Futtigurh branch, which leaves the main canal at the 50th mile, passes, had been accurately examined by Mr. Dodsworth, the surveyor; its surface had been covered by a reticulation of levels, which left the determination of the line a matter of no difficulty; this line had been tested by a series of levels and proved by Mr. Read; bench marks had been established at every mile, and brickmaking and brick collecting had been steadily in progress in those districts over which he was able to exert his control.

The country over which the Koel and Bolundshuhur branches extend, lies in the third division; the estimated length of each of these lines is only 70 miles; their direction and uses will be closely connected with the lining out and extent of the rajbuhas, or main lines of watercourses, which will extend over that part of the Koel and Bolundshuhur districts towards the town of Hatrass, and their direction will depend very much upon that of the rajbuhas with respect to the tail discharges, and the connecting links which are, in my idea of the rajbuha system, one of the most indispensable elements.

The projects for these different lines, as far as capacity of channel and bridge waterways are concerned, having been accurately determined, the excavation and masonry works can be carried on as soon as a supervising establishment is available for the purpose. I have, in fact, shown that some progress has already been made on the Futtigurh branch, not only in laying down the line, but in collecting materials; on the Bolundshuhur branch, six miles of the channel have been completed, and some small progress also has been made in material collecting.

The disappointment arising from interruptions to progress, which so unfortunately took place during the cold season of 1850–51, was in some degree alleviated by the results of the succeeding years. The seasons of 1851–52 and 1852–53 were marked by an uninterrupted and steady advance in the northern division, on a scale that could not have been exceeded; and, although very considerable additions had been made to the designs by which the amount of work to be executed was increased, the improved organization of our establishments, and the increased means at our disposal in the shape of "plant," placed us in a position which, at the close of the season of 1852–53, enabled us to arrive at satisfactory conclusions as to the period when the works would be sufficiently advanced to allow of the admission of water. In my estimate of 1850, the above period had been fixed at a date early in 1853–54, or by the termination of the month of June, 1853; the causes why this had not taken place have been sufficiently described, but it is satisfactory that under the necessity of making these explanations, and under the interruptions which led to such necessity, we find that the work of one season only in addition to those formerly contemplated, has enabled us to bring these gigantic works to a conclusion at the end of the year. I use the term *conclusion*, as, although a good deal still remains in finishing off the masonry and earthworks, and to the fixing of the dams, the line of channel throughout the northern division has been brought to that state in which the supply of water can be passed to the southern districts and from whence may be dated a new era in the History of the Ganges Canal.

The works, however, on the Etawah branch, which were commenced at a later period than those elsewhere, and which have been much retarded by want of European establishment, will at the period above mentioned be incomplete; they will be ready to receive water on the first 60 miles; and the Gihror escape, which is situated at the extremity of that distance, will admit of a stream being passed down the channel. On the Cawnpoor branch, with the exception of the locks into the Ganges, and the terminal works in and near the town of Cawnpoor, the whole line will be ready to receive water, which may be passed off in the meantime at the different escapes which are situated at intervals down its course. The works here have been retarded by the departure of the whole of the staff of the sixth division, in which the Cawnpoor works were situated, the consequent breaking up of the division, and the often told tale of "want of materials."

Amongst all the disappointments that have arisen either from the removal of officers to higher appointments, or to the departure of others on medical certificate, by which the advancement of work has been more or less impeded, the staff of the northern division has remained intact, without changes, excepting by additional members, and with as little interruption from sickness as could reasonably have been expected. It would be useless to expatiate on the advantages that the works have derived from an occurrence which, considering that the time alluded to extends through six years, is a very unusual one: it has, however, given to each work the inestimable benefit of having been carried on through all its progress by the same individual; and it has given me the benefit of an uninterrupted connection with a staff of officers, who, from the highest to the lowest, have devoted their undivided attention to the interests of the great works upon which they have been engaged. The names of the officers who composed the Ganges Canal Staff on my joining the works in 1848, were given in a former paragraph; I will close this chapter by giving the names of those who were present at the works when the canal was opened.

1ST DIVISION.—Captain A. G. Goodwyn, Engineers,
Lieutenant G. Price,
Mr. J. Parker,
,, T. Login,
,, W. Kay,
,, C. Anderson,
,, W. D. Hogan,
,, J. C. Kay,
,, J. Finn.

2ND DIVISION.—Mr. F. Read,
Lieutenant Mainwaring.

3RD DIVISION.—Mr. P. Volk,
Lieutenant Merrick.

4TH DIVISION, Cawnpoor Branch.—
Lieutenant J. C. Hodgson, Engineers,
" Lamb,
" Willoughby (specifically for the Cawnpoor Works.)

5TH DIVISION, Etawah Branch.—
Lieutenant F. Whiting, Engineers,
" Brownlow,
" Angelo,
" Span.

The 6th division, which, during the season of 1852, had been deprived of its officers (the executive engineer and one assistant having gone away on medical certificate, and the remaining assistant having been removed to a higher appointment in the road department), had been incorporated with the fourth division, the works of the whole of the Cawnpoor branch having been placed under the management of Lieutenant Hodgson.

Mr. Dodsworth—who, besides some very useful surveys in mapping the details of the very intricate drainage of the country through which the Cawnpoor branch took its course, had completed the whole of the surveys and levels of the country lying between the Ganges and the East Kalli Nuddi, as well as that between the Jumna and Rinde, the sections of the Doab which were to be irrigated by the Futtigurh and Etawah branches—was at this period engaged on a series of levels for working out a contour of the Ganges Khadir, or that portion of it which lies to the north and north-east of Roorkee, between that place and the Sewalik Mountains; an undertaking requiring extraordinary care, patience, and perseverance, and one of the highest importance, as conveying by the most careful delineation of minute, topographical details, the fullest information on the drainage which crosses the canal works in the region under examination.

NOTE.—Major Baker's plans having determined him to leave the works in December, I quitted England at the end of August, 1847, for the purpose of reassuming the duties that I had left three years before, and of relieving Major Baker from a charge, which had by the most judicious management on his part, and by the best tact in organization, become one of comparative ease and simplicity. My object in leaving England at such an early period, was to visit the canals in Lombardy and Piedmont, and make myself acquainted with the method of embanking, and the works connected with the regulation of the course of rivers, for which the Italians have been long celebrated. To do this my time was limited to the space of about six weeks, but during that period, I inspected the heads and other works on all the canals in the neighbourhood of Milan, examining in detail the course of the Ticino River from Sesto Calende to the mouth and along the line of the Naviglio Grande to the town of Buffalora. I visited also the locks and other interesting works for navigation on the Pavia Canal. In Lombardy, I saw for the first time the (*fontanili*) method of collecting water for irrigation by tapping springs, and by these means, providing irrigation for considerable tracts of country. The Milanese module for regulating the discharge from the canals and the meadow (*marcite*) irrigation, with all the attention which that system necessitates in levelling and equalizing the surface, were objects of peculiar interest: I inspected also some very interesting and successful works, although on a small scale, for the riddance of silt from a canal in the neighbourhood of Bergamo; and in the vicinity of Mantua and Cremona became acquainted with the bunds, and works of that description for which the river Po is celebrated.

In Piedmont, the canals from the Dora Baltea, and their heads in the neighbourhood of Ivrea, were inspected in great detail; as although the canals themselves carried, comparatively to those in the North-West Provinces of India, small volumes of water, they were connected with mountain rivers subjected to violent floods, and therefore liable to evils similar to those with which we have to contend. The works over the Po connected with the Genoa Railroad, situated near Moncaleri, as well as the bridges, either building or built over the numerous tributaries which cross the high road between the Ticino River and Turin, were all of them subjects of great interest. At the time that I visited Turin, a masonry bridge over the Stura River, was in progress of construction, the river at the point where the bridge was being built, took a considerable curve, at which a wooden bridge kept up the line of communication; the engineer had fixed the site of his masonry bridge on the chord of which this curve was the arc; the bridge, in fact, was being built on dry land, and under circumstances precisely similar to those which we are constantly in the habit of adopting in these provinces: the proposed design for making a straight cut to deliver the stream upon the bridge, and the system of bunds and spurs on the up-stream side of the works, for the purpose of regulating the river in its new course, were observed by me with much attention. The character of the Stura River at the point in question was exactly that of the mountain torrents (or Raos, as they call them in the North-Western Provinces) at the foot of the Sewalik Hills—a wide, straggling, shingly bed, depressed below the surface of the country to a very moderate degree, fringed and scattered over with long grass, and from its appearance running on a considerable declivity. A set of plans descriptive of the whole of the operations was purchased by me from the office of the Board of Works at Turin for our Ganges Canal Library; and as I consider these plans to be admirably descriptive of the system of bunds and spurs adopted by the Italian engineers for regulating and directing the course of rivers, I would recommend them to the Department of Instruction for the Civil Engineers' College at Roorkee. With the exception of some canal works in the neighbourhood, and to the north of the town of Novara, and to the works for hydraulic instruction near Turin, I saw nothing further in Piedmont; but I regretted exceedingly that the limited time that I had at my disposal prevented me from making a further stay amongst works from which I had already gained a great deal of valuable information, and from the engineers of which the information which I required was imparted with the utmost *esprit* and liberality. Should my friend M. Carlo Noe, the Inspector of Canals on the Dora Baltea, ever cast his eye on these pages, I trust that he will accept the expressions which I now make as a small return for the time and trouble which he, as a perfect stranger, and without my having any introduction to him, so kindly devoted to my services.

Captain Baird Smith, who, two years after my visit, was deputed by the Honourable the Court of Directors of the East India Company to Lombardy and Piedmont, for the purpose of reporting on the works for irrigation in those provinces, has, in his two admirable and instructive volumes, entered so fully into the subject, especially into that in which the fiscal and legislative management are concerned, that the few remarks which, before dropping the subject, appear to me to be in this place necessary, must be confined to the impressions that my mind received on visiting works, the reputation of which had been for so long a time familiar to me. With regard to the canals in Lombardy, I confess that I was disappointed: this disappointment, however, did not arise from the works themselves, from which I not only derived great instruction, but a number of useful hints from which I have largely benefited in designing the Ganges Canal Works; but from the peculiarity of their position, and, if not their entire freedom from the effects of mountain torrents, their connection with them under such peculiar circumstances, that the effect of their contact, which is a source of such difficulty and danger on the canals in the North-West Provinces of India, is almost entirely neutralized.

The Ticino and Adda, from whence the great Milanese canals to which I have before referred derive their supply, have their sources in the large lakes which lie at the foot of the Alps to the north of Milan;—the Lago Maggiore in the case of the Ticino; in the case of the Adda, the

Lago di Como. The torrents which, during the rainy months, come down from the mountains with equal force both in Italy and India, are in the former case received into the bosom of the great lakes, where they exhaust themselves over very extended surfaces before the effects of the influx of water can be felt by the canals; in the latter, they cross the lines of canals with violence unmitigated by any intervening circumstance. "It is scarcely possible," as Captain Baird Smith observes when adverting to these large lakes and the influence that they exert on the canals in Lombardy, "to overestimate the value of this natural arrangement; it is one of which Lombardy has constant cause to be grateful to a skill above that of man; and, looking to the natural features of the country, it is perhaps not too much to say that without it the rivers flowing directly from the mountains would as often have blighted the land by their destructive floods, as blessed it by the discharge of their fertilizing waters."

Being then almost entirely relieved from the effects of mountain torrents in crossing their alignement, with an admitted superiority of soil which is highly beneficial to the beds of the canals, and affords the greatest stability for foundations, and with the finest material in the world perhaps, viz., the granite from the Bavino Quarries, from which to build his works, the Lombardese engineer is placed in the opposite extreme to his brother engineer of India, who, without the slightest exaggeration, has to deal with the mountain torrent in all its deformity, with illimitable depths of sand, and with difficulties in procuring material such as would hardly be credited without personal experience of them.

There were very striking features in the working of these canals, however, that could not escape my notice; and perhaps the most remarkable one was the use of the simplest means and the simplest expedients in all cases where regulating supply was necessary: the simplicity of the means for raising their sluice-gates, for relieving and filling their lock chambers, for fixing the gates of their locks, and for breaking the force of currents by piles, were matters of very great interest to me, and the interest was enhanced by observing that this simplicity of means had its desired end in producing real efficiency.

It may be observed, however, that the variation in surface of these canals during the year is not more than 12 or 18 English inches; that this freedom from floods and overcharges of water (arising from the circumstances above described in their connection with the lakes) gives them a security which no canal in the North-West Provinces of India can hope to enjoy. The most noteworthy consequence of this limitation of surface variation is, that no works for regulating the supply at the canal heads are considered necessary—a fact itself strikingly illustrative of the immunity from floods enjoyed by these canals.

The canal works of Lombardy, therefore, were to me wanting in the main point to which my views were directed: the river works, however, were full of interest; and I found with regret that the intention that I had started with of visiting the Po in the neighbourhood of Ferrara and the Adriatic, was frustrated by the necessity of my having to reach Trieste in time to join the steamer that was to carry me to Egypt and ultimately to India.

The canals which I visited in Piedmont were taken off from the Dora Baltea, a mountain river which, during the cold weather, is subject to floods of a very violent description. The canals themselves are, compared to those in the North-West Provinces, small; they are not used for navigation, and are regulated at their heads by a series of small sluices worked by handspikes—the sluices themselves being arranged in a covered bridge which crosses the canal head, and which entirely precludes all possibility of danger from sudden rises in the surface of the river, and prevents the passage of boats.

The water is taken from the river and directed to the mouth of the canal here, as in Lombardy, by a masonry weir unbroken in its whole length, excepting at one point, through which the surplus water escapes with great violence; between this weir and the regulator are sluices detached from the weir for the purpose of passing off surplus water into the bed of the river, and by these means regulating the canal supply. In Lombardy precisely the same plan is adopted, and in the case of the Muzza Canal the weir extends completely over the bed of the river; and the regulating sluices, which are situated between the head and the bridge of communication for the railroad, are of the same description and on the same principle as those used in Piedmont. Within the last few years, before I visited the works in 1847, it had been found convenient on the Muzza Canal to multiply the number of these escapes. This system of detached sluices in the position which I have above described is much approved of by the Italian engineers, as —independently of giving a ready escape for surplus water—they provide a scour, and thereby the means of getting rid of the silt and deposits which invariably establish themselves in the mouth of the canal.

On the Lombardy canals, and under the advantages with which their water reaches the canal heads, the elevation of the sills of the weirs does not appear to be of serious consequence in raising the beds of the rivers on the up-stream side. In Piedmont, on the contrary, where the weirs are built over rivers directly running from the mountains, the effects of deposits above the weir, as might have been expected, are of a very serious nature. At the time that I visited Ivrea and the head of the Ivrea Canal, this evil appeared to me to have reached a maximum, and large parties of labourers were employed in the water in removing the sand and gravel, and clearing an open channel in the direction of the canal head. It has been found expedient in the canal works in the North-West Provinces of India to avoid as much as possible any elevation of sill to the masonry dams which cross the rivers at the heads of canals; these dams are, in fact, a line of sluices with gates or shutters, which are capable of being entirely laid open down to the bed of the river during the period of floods. In rapidly rising rivers, like those in India, the method which has been adopted by our engineers is, I believe, the most appropriate. In some cases, perhaps, it might be modified with advantage, where the head supply for the canal must necessarily be raised to a considerable height above the dam flooring, as in the case of the Myapoor works at the head of the Ganges Canal; but in such cases, the advantages of modification would be found in increased facility of management during floods, due to the diminished area of sluice surface rather than in any particular benefit in the maintenance of supply.

As far as my travels extended in Piedmont, I looked in vain for examples of canals crossed by mountain torrents after their departure from the source of supply; with the exception of a case north of Novara, where the Agogna River is passed by a masonry channel carried under it, or by a "salto di gatto" (a cat's leap), as the Italian engineers call it, I saw nothing approaching to the great evil which renders our canal engineering in India a matter of such serious difficulty. The Mora Canal, which crossed the above-mentioned river, was a mere watercourse, and would have come under the denomination of a first-class rajbuha in these provinces, whilst the bed of the Agogna, under which it passed, did not exceed 150 feet in width. The river, at the point where the Mora crosses it, has a well-defined, deep section, with a shingly bed, nearly dry at the period of my visit in October, and is crossed by a bridge of three arches at a distance of about 100 feet above the line of canal.

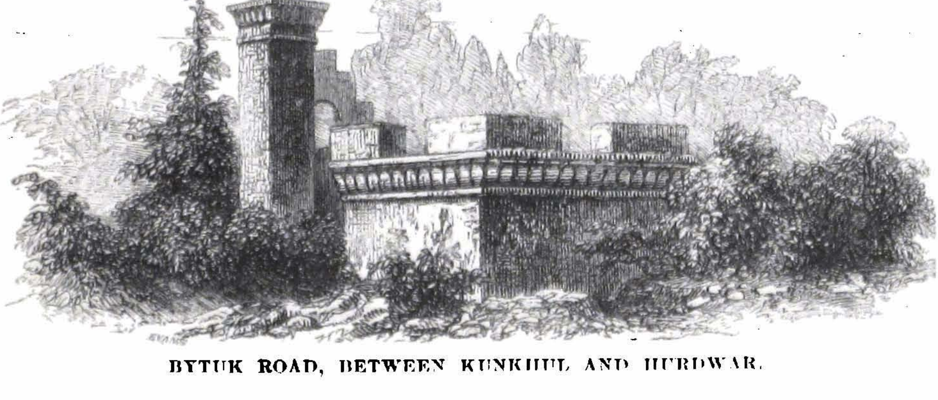
I cannot leave the subject of these Italian canals and their works without an expression of surprise, mixed with a good deal of satisfaction, at the numerous instances in which we, who were entirely separated from all communication with the Italian engineers, had, by the mere process of simple reason, arrived so frequently at precisely the same results, and in so many cases had adopted the same expedients. This is remarkably shown in the protection given to the aprons and tails of their weirs. When standing on the weir at Ivrea, I could have imagined that I had before me the works of our native establishments in India. In all their temporary bunds, spurs, and flank protections to cuttings, the devices for making them useful and efficient are very much the same in both countries; and the feeling that exists amongst the Italian engineers of introducing the utmost simplicity into their works, so that the establishment, which consists generally of village people, may perfectly comprehend the ways and means to which machinery may be applied, accords peculiarly with the experience which we have gained in our dealings with the same class of people who have the charge and supervision of detached works on our canals. The system of retaining dams, or bars constructed across the bed of a river for the purpose of holding up the bed to a fixed level, which appears to be practised universally, both in Lombardy and Piedmont, is another example of expedients being devised by simple inductive reasoning, without the parties having any connection or communication with each other. The retaining dams on the Muskurra and Nogong Rivers, two of the mountain torrents which cross the line of the Eastern Jumna Canal, have their representatives on the Po at Turin, on the Serio river at the village of Albino, near Bergamo, and on a river from whence a supply for mills (and on which the Hydraulic Establishment is situated), is taken near Turin; in the latter case, the retaining dam is placed at some distance below a weir, made of timber and shingle, which is thrown across the bed of the river for the purpose of turning water into the canal, and the retrogression of levels upon which led to the necessity of its being protected; the work that has been built for its protection is similar in every respect to the retaining dam used in these provinces. In the other places to which I have alluded, the retaining dams are built on the down-stream side of bridges, and with the intention, I presume, of protecting those works from the effect of retrogression.

I have before remarked, on the Piedmont canals, that the immediate connection of their beds with mountain rivers renders them in some degree liable to the dangers from inundation and accident to which the canals in these provinces are subjected. The circumstance of their being very much smaller, however, of their not being available for navigation, of their heads being protected and crossed by a bar of masonry pierced with small and easily-worked sluices for the admission of water, and of their not being crossed by lines of mountain torrents, placed them, so far as difficulty of management is concerned, on a scale inferior to the canals for irrigation in the North-West Provinces of India.

In my progress through Egypt, I visited the works of the head of the Delta of the Nile, which were at that time under construction on the designs of a French engineer with the Egyptian cognomen of Mousul Bey. These works (Barrage), independently of toll, are intended to maintain the river at the point where the Rosetta and Damietta branches separate, on levels appropriate to the supply of three canals which are to be taken from it. I regretted that my time was too short to admit of an examination of the numerous works for irrigation that are connected with the Nile, with many of which I came in contact in the neighbourhood of the Barrage and Cairo.

The works for, and the system of, irrigation practised in the land of the Ptolemies ought to be the subject of deliberate history.

On the 14th December, 1847, I reached Bombay, and on the 11th of January following, as stated at the beginning of this chapter, I resumed charge of the Ganges Canal Works from Major Baker, having in the few previous months travelled over some of the finest fields of artificial irrigation in Europe, and having derived as much benefit as I could from the inspection of numerous works devoted to the peculiar object on which my time was hereafter to be occupied.



BYTUK ROAD, BETWEEN KUNKHUL AND HURDWAR.

PART II.

TOPOGRAPHY OF THE COUNTRY AND DESCRIPTION OF THE WORKS.

Chapter I.

PREFATORY REMARKS.

The canals for irrigation which had hitherto been constructed in these provinces, with the exception of the water-courses in the Deyra Doon and Rohilkund, were supplied exclusively from the river Jumna, and consisted of two lines—one on the right bank for the irrigation of the Kurnal, Paniput, Delhi, and the districts to the westward; the other on the left bank, for the irrigation of the districts of Saharunpoor, Mozuffurnuggur and Meerut, lying on the right bank of the Hindun between the hills and Delhi.

The country at the foot of the Sewalik Range is crossed by numerous mountain torrents, which the above canals intersected, under circumstances of remarkable difficulty. It will be interesting, therefore, to give a sketch of the peculiarities of surface and of the profile of the country in the neighbourhood of these torrents, preparatory to entering upon a description of the Ganges and its drainage, the subject to which this chapter is more especially directed.

In tracing on the map, the direction of the Jumna from the point where it leaves the hills to Delhi, and observing the position of the Eastern and Western Jumna Canals, with their heads of supply opposite to each other, their alignements parallel, and their escape or tail water joining the parent stream at points also opposite, an indifferent observer would naturally conclude, that under circumstances so strikingly coincident, such difficulties as were due to surface contour would be common to both, and that the works required for the maintenance of one canal would, *cæteris paribus*, be similar to those of the other.

In the centrical and southern regions, the levels of both canals correspond generally with each other. On the eastern bank, however, the limit of the river valley, or Khadir, is thrown back as far as the village of Surrowli, on the Eastern Jumna Canal, a distance of about 12 miles from the existing bed of the stream, and the step thereby caused is passed by a succession of falls and lockage. On the western bank, the high land bounding the Khadir is maintained up to the immediate vicinity of the city of Delhi, to which the Western Jumna Canal is enabled to provide an abundant supply of water for domestic use. The rapid descent into the river valley itself takes place virtually at the tail of the canal, and the fall thus obtained is economized for flour-mills worked by the surplus water, for which an escape into the river is provided, through paved and well-protected channels.

It is in the northern region that we observe the greatest difference. On the west of the Jumna, the canal, on its leaving the parent stream, passes over wide and open beds of shingle, upon which the force of the current is able to exhaust itself; these beds extend as far south as the Dadoopoor dam, to a distance of 16 miles, and during the whole of their course are the receptacles of the country drainage, which passes off during floods either over the country, or through breaches, which are repaired annually after the rainy months. The Dadoopoor dam, which regulates the supply into the canal channel, is also the escape for the flood-water of the Putralla and Sombe, the latter being a torrent of very large dimensions. From the dam, the canal proceeds along the low land, until it reaches a point 60 miles from Dadoopoor, at which it has gained the levels of the high country, continuing to follow these to Delhi on its left, and to Hansi on its right branch.

Although, therefore, masonry works are provided on this canal for the passage of the Putralla and Sombe torrents, the two following facts—viz., first, that 60 miles of its course are in the Khadir, or low lands of the Jumna, through which the channel wanders with all the tortuosity of a natural river; and, secondly, that the whole line, after its escape from the shingle beds, is out of the influence of the rapid slopes, which are natural to the proximity of the mountains—render the occurrence of floods, even of an extraordinary volume, a matter of comparatively little moment. Leaving out of the question the Putralla and Sombe, floods do in fact pass directly over the course of this canal on the tracts both above and below Dadoopoor, without doing any material injury either to the works, or to the country.

The Eastern Jumna Canal, after passing down the shingly bed of the Boodhee Jumna for the short distance of four miles, enters on deep cutting, and takes a south-easterly direction, commencing at the village of Nyashuhur; from this point, it plunges at once into all the difficulties peculiar to a line crossing mountain drainage at right angles to its course; the Raipoor, Jatonwala, Nogong, and Muskurra, four mountain torrents of greater or less dimensions, are passed within a distance of 10 miles from the Nyashuhur deep cutting. The Muskurra and the Nogong are torrents of considerable magnitude, and are provided with masonry dams for the passage of floods during rains. After passing the Muskurra, the Eastern Jumna Canal channel continues on the high land of the country.

With a similar declivity, therefore, on both the Eastern and Western Jumna Canals between their terminal points, its distribution in detail leads to most remarkable differences in the requirements for works. The great northern step which on the western canal is passed by a succession of wide beds of shingle, with considerable tortuosity of channel, through low or Khadir country, is on the eastern line maintained for many miles on the high land in the face of numerous mountain torrents, and finally overcome by a succession of masonry falls. These characteristic differences accordingly determine the nature of the means to be employed in passing this step of country. On the west, the broad and winding beds of shingle absorb the fall naturally and easily, and thus obviate the necessity for artificial descents. On the east, where no such low shingly tracts are to be met with, but where the canal enters at once on the high land of the country, the common object must be attained by purely artificial and expensive falls.

The works on the Delhi or Western Jumna Canal were designed partly by Captain Blane of the Bengal Engineers, and partly by Colonel Colvin, C.B., of the same corps. Those of the Eastern Jumna Canal were designed by Colonel Robert Smith of the Bengal Engineers; on these latter works my early career as an officer of the Canal Department was passed. I joined Colonel Smith in 1825, shortly after the works were commenced, and superintended the opening of the canal in 1830.

The mountain torrents connected with the Eastern Jumna Canal have naturally been the impediments to regularity of supply, as well as to the repose of the superintendent; but time and experience have given the establishment a perfect command over them, while the constant attention that has been given to their vagaries, and the application of remedies when such were required, have reduced to a matter of simplicity what in the early days of the canal was considered by no means of a simple nature.

One very remarkable feature in the topography of the country over which the Eastern Jumna Canal passed, will give at once a key to the general remedies that were at hand for enabling us to contend against the difficulties due to the torrents; and as these were remedies which were not always to be found when projecting canal alignements, I must allude to them here in anticipation of what has to come hereafter.

From the description before given, of the direction taken by the Eastern Jumna Canal on its leaving the parent stream, and entering upon the high land at Nyashuhur, it will be observed that the very circumstance of the line of canal running at right angles to the drainage of the mountains, and consequently in a direction parallel to those mountains, showed that the country sloped from west to east, and therefore that, although the mountain drainage in its natural state crossed the canal line, we held the power in our hands of changing the course of this drainage at points lying above the canal channel, and by passing the water off to the eastward, to relieve the works from a great deal of the inconvenience to which they were naturally subjected.

A leading feature in the original project was the neutralization of the effects of the Muskurra upon the works at Kulsea, by taking advantage of this natural arrangement of slopes, and by turning its waters to the eastward, to connect them at three different points with rivers which were tributary to the Hindun. The effect of these arrangements has been to reduce the Muskurra at its point of contact with the masonry dam at Kulsea, to a comparatively inconsiderable volume. The Jatonwala drainage has on the same principle been turned into the Nogong River; at times the violence of a Nogong flood has been relieved by allowing a portion of its volume to pass down the canal channel towards the Muskurra. The influence of the arrangement of surface slope above described, has therefore been undoubtedly of the highest importance and value to the works on the Eastern Jumna Canal.

It is with these peculiarities of drainage, as affecting the works in the northern district of the Eastern Jumna Canal, which is in itself, in fact, the western water-shed line of the northern Doab, and with the details of this tract of country fresh in recollection, that I would turn the reader's attention to the eastern water-shed, or the drainage which flows towards the Ganges River. The line of separation is well defined: the western drainage, including the West Kalli Nuddi, and its tributaries, flows into the Jumna; the eastern, including the East Kalli Nuddi and its tributaries, flows into the Ganges: the point of separation in the Sewaliks being the Shahjuhanpoor and Koonjnawur Passes, to reach which from the plains, a section of country free from cross drainage is traversed; this section being, in fact, the backbone of the northern Doab.

It will be observed, by referring to the map, that from the point of water-shed, or from that ravine in the hills, which supplies the most westerly tributary of the Solani River, there is a bank which extends in a south-easterly direction, increasing in departure from the hills as it proceeds onwards; upon the edge of this bank are situated the towns of Bhugwanpoor, Roorkee, Jourassi, Landoura, Noornuggur, and, on and near its approach to the main stream of the river Ganges, the towns of Bhookurheri and Sookurtal. These towns overlook, as it were, an extensive valley, the maximum depression of which must be very considerable. Opposite the town of Noornuggur, and at the village of Badshahpoor, from which my line of levels of 1836 commenced, this depression was found to be 84 feet. The tract of country referred to, bounded by the Sewaliks and the high bank above described, receives the whole of the hill drainage from the western extremity of the water-shed; this drainage is, in fact, restricted to the above limits by a well-defined barrier. To the west of the high bank, the drainage of the country passes off by shallow tributaries to the West Kalli Nuddi, and ultimately to the Jumna River. A series of sand-hills (provincially termed Bhoor) is here a remarkable feature; these show themselves in undulating elevations and depressions, running parallel to the drainage of the West Kalli Nuddi; sometimes, however, they are found in ramifications, thrown off from the main line, pierced at points, to admit of the passage of the side drainage, occasionally in extended and unbroken ridges. The slope of the country is from the edge of the high bank *towards the westward;* and, strange as it may appear, the water-shed line of the Jumna and Ganges passes directly along the top of the ridge on which the towns are situated.

The low tract of country which I have before described, is that portion of the Ganges Khadir with which the works on the canal are connected. It is of a triangular form, bounded on the north-east by the Sewalik hills, on the south-west and south by a steppe or bank, and on the south and east by the Ganges River. The Sewaliks on the north-east and the bank which lies on the south-west and south meet at an acute angle near the Shahjuhanpoor and Koonjnawur passes; the bank, as I have before described, decreasing in abruptness up to this point of junction, in the vicinity of which it is lost entirely. The Khadir receives the whole of the drainage up to this angle, which is the true point of departure of the water-shed separating the drainage of the Jumna and Ganges rivers. The depression of the triangle thus defined is by no means uniform; as to the westward there is an isolated portion of it considerably elevated, on which are situated the towns of Kheri, Imli, and numerous villages; the surface of this elevated portion is much intersected and cut up by channels; and it is separated, or nearly so, in its centre by a large ravine receiving a portion of the drainage collected in the forests. In addition to this main insular tract of high land, there are other smaller mounds in detached or outlying positions, upon which villages have been built. The town or village of Dowlutpoor is thus situated; and to the north of Dowlutpoor, these mounds or knolls appear to be ramifications from the higher levels lying at the foot of the hills above which they are much elevated. The drainage is well marked, and may be divided into three distinct basins, the most westerly one embracing all the hills and country lying to the north of Kheri and Shah Munsoor, including the drainage from mountain torrents, over a distance of 8 miles from the western angle; this, which is by far the most extensive, has its waters collected into the Solani River, which flows at the base of the high bank, and reaches the Ganges in the neighbourhood of Bhookurheri.

The second or centrical basin is drained by the Rutmoo River, the heads of which are in the neighbourhood of Shah Munsoor. This river receives the waters falling on 11 miles of mountain, and is a tributary of the Solani, which it joins under the town of Jourassi.

The third is the Puttri basin, which receives all the water from the country between the towns of Gurh and Jowallapoor, with a hill drainage of six miles. The drainage of the Puttri basin, however, is in the earlier parts of its course divided into two distinct mountain torrents, the one to the westward being *par excellence* the

Puttri; that to the eastward, and in the neighbourhood of Jowallapoor, being called the Ranipoor River.

These two branches, as they may be designated, run in separate, though ill-defined basins, being, to all intents and purposes, distinct torrents, and as such have been separately treated.

To the eastward of the Puttri drainage, or rather to the eastward of that drainage connected with the Ranipoor river and the town of Hurdwar, where the Sewalik hills impinge upon the Ganges River, there is a good deal of scattered drainage, which, during heavy rains, comes down with considerable rapidity from the low spurs and ridges which lie at the foot of the Sewaliks; the water derived from this source passes directly into the Ganges through numerous small channels, which lie to the south of Hurdwar and Kunkhul.

The Solani and Rutmoo rivers exhibit in their course, under the bank at Bhugwanpoor and Roorkee, unmistakeable marks of their mountain origin; they are Raos,* in the most extended sense, with wide sandy beds; and, although during exceedingly dry seasons showing no external stream, bearing under a dry sandy surface perennial spring water.

The Puttri and Ranipoor rivers differ very materially from those above described. The map which shows in detail the courses of all the Khadir drainage will give a better idea of the nature of this drainage in the direction of its different channels than I can give in description.

* Rao (torrino, torrent), a provincial name given to the shallow, sandy, or shingle beds directly connected with the hills, the drainage of which is carried off by these channels. During the greater portion of the year, they are either perfectly dry, or with a small stream running in them. After heavy rain, they are liable to severe freshes and floods, and at this time are impassable for man or beast. The great declivity upon which they run, enables them to pour out a volume of water with immense and dangerous velocity. These floods, however, do not last above a few hours, and subside as rapidly as they commenced.

In the proximity of the hills, they exhibit the character of well-defined mountain torrents, with shingly and sandy beds, which they lose, however, at lower levels, where well-marked sections of beds present themselves only at detached points, scattered here and there over the surface of the country. In a more southerly direction, these detached bits of drainage become united into one perfect channel, which, skirting the Puttri forest, wanders ultimately over the low lands, and joins the labyrinth of rivers which intersect the Khadir at its south-eastern extremity.

In further illustration of the features of the country, of which so much necessarily must be said in explanation of our proceedings, I may observe that, although spring water may be, and is, even at the hottest periods of the year, found near the surface in the immediate vicinity of the hills, it is one of the characteristic phenomena of the line of country adverted to, that on a belt extending to an irregular width south of and parallel to the hills, water is only found at considerable depths; whereas, at points lying beyond this belt, spring water either appears at the surface, or can be obtained by very moderate excavations. In exemplification of the above, although somewhat anticipating the events which I am about to describe, it was found that in all our excavations lying within a moderate distance from the foot of the hills, neither spring water nor any appearance of spring water exhibited itself. As we got farther from the hills, and arrived at the Puttri works, on our approach to the Rutmoo valley also, spring water became an evil of very serious importance; the Badshahpoor Nulla, with which we came in contact between the Puttri and Rutmoo valleys, was, in fact, a perennial stream; the ridge between the Rutmoo and the Solani River was by no means free from an inconvenience, which we did not get rid of until we reached the excavations on the high land at Roorkee.

The evils which arose from the interference of springs were really such as we had anticipated; and, although these evils became very much enhanced by the necessity for altering my original design, which had, comparatively speaking, avoided the inconvenience of deep digging in the tract connected with springs, the difficulties that we met with did not after all exceed our expectations.

With the exception of that immediately in the neighbourhood of Kunkhul and Hurdwar, the whole of the country lying at the foot of the Sewaliks, and at the heads of the rivers above described, was, at the period of my original surveys, forest and uncultivated; and although the triangular tract, which I have described under the name of the Khadir, was neither wanting in villages nor population, the greater portion of it was jungle and marsh; of the latter, there were some very extensive tracts connected with the Puttri, and situated centrically and to the eastward of Santuh Shah; and others, with the Solani and Bhat rivers, which, under the name of the Jogiwalla Jheel, covered a large area of country near Bhookurheri, at the time which I talk of were supposed to be inaccessible, as it certainly was avoided by those who visited the Khadir on tiger-shooting expeditions.

If a tolerably accurate idea has been given by the above detail of the peculiar features and character of the Ganges Khadir, and of the mountain torrents which flow through it, I shall be able, I hope, to render an account of my operations for laying down a line of canal in a way sufficiently distinct to be, especially with the aid of a map, perfectly intelligible.

In commencing the examination of the Khadir, in 1836, by taking a section on its southern limit at Badshahpoor and Kumbhera (the latter being a fixed point or bench mark, situated on the top of the high bank which I have described as being the south-western boundary of the low land), I determined on obtaining a similar section on an extreme northern limit, and for this purpose a line of levels was carried from a point on the Ganges between Hurdwar and Kunkhul, touching the towns of Kheri and Nanka, continuing down the high land by Bhugwanpoor, Roorkee, and Munglour, until it arrived at the Kumbhera bench mark; this gave me an uninterrupted circle of 34 miles. Intermediate levels across that portion of the Khadir lying between Kheri and the villages eastward of Roorkee, brought the whole profile and its capabilities for canal purposes distinctly under review. The result, in fact, showed that there were two lines open for adoption, viz., one on an extreme circle by which the bed of the canal would be maintained on a level corresponding with the surface of the country; the other on a more direct line, which, crossing the valley of the Solani River by an aqueduct, would deliver the water on the high land of the Doab immediately at the town of Roorkee.

For the circuitous line we had the example of the Jumna Canals before us, where the stream, when crossing the beds of mountain torrents, was retained by dams, with sluices for regulating and passing off floods; and we had in its favour the comparative security of keeping to the earth's surface, instead of carrying the canal water at levels far elevated above it. In opposition to these advantages, which are to a certain degree admitted, we had the evils of a more extended course, through a wild and broken forest country, with drainage very much divided, very much scattered, and with the certainty of that species of inundation which necessarily attends the dam system. It was impossible to calculate on the extent of the inundation that would be incurred by this circuitous route, but it would occur on the up-stream side of every dam, and of these there could not be less than six, the whole of which would be situated at points where the great declivity of bed of the different mountain torrents over the course of which they would have to be built, would necessarily, it was supposed, lead to all the evils of retrogression of levels on their tails, of which we had had dangerous experience in the works on the Eastern Jumna Canal. The objectionable influence in a sanitary point of view that the introduction of so much inundation would exert upon the neighbouring country, was by no means the least effective in leading me, and ultimately those who were called to give their opinion on the subject, to reject this circuitous line.

The direct route, which was confined to the more civilized part of the Khadir, passed the Rutmoo River immediately to the west of Peeran Kulleeur, and bearing directly upon Roorkee, reached the Solani valley at a point between the villages of Bajooheri and Mahewur. From this point to Roorkee, which was on the high land of the Doab, the breadth of the valley was 2¾ miles, and its maximum depression below the estimated bed of the canal was 24 feet. The objections to this course were, first of all, the novelty and probable danger of a design which contemplated the transport of a large body of water at high levels above the surface of the country; and, secondly, the expense, which would undoubtedly be great. To counterbalance these objections, however, we had the advantages of avoiding inundation; of maintaining a line through a more healthy and accessible country; of keeping the canal in its passage over the Solani free from the sand and silt, which are inherent evils where a canal comes in contact with a mountain torrent; and of being able to maintain an unimpeded line of communication across the Solani valley in connection with the more northerly works.

Even on this direct route, which appeared to be in every way so superior to the other, the Rutmoo River had to be passed by the dam system, as it obtains on the Jumna Canals. It was concluded, however, that there would be no difficulty in so designing the works as that the evil of inundation on the up-stream side might be got rid of by retaining the canal water in its own channel, and carrying the drainage which during the dry months comes down the river or is caused by leakage from the canal channel, through drains under the canal, so that the water might pass down the course of the river. The profile of the country was favourable to the adoption of the aqueduct system over the Rutmoo as well as over the Solani, and the advantages attending such a plan in carrying the canal water free from the silt and rubbish of the Rutmoo torrent were much in its favour; but very extended lines of earthen embankment are not only very expensive in the first instance, but require much subsequent looking after, entailing upon the Government a large establishment for their supervision. The masonry portion of the aqueduct, which would necessarily be over the rao itself, would, from the difficulties of foundation, be equal in expense to that over the Solani, and there was no object in upholding the levels of the canal bed over the valley of the Rutmoo, as the natural slope of the country in advance was sufficient for all the purposes of the project, and to have continued the high levels thus would have necessarily led to the construction of a series of falls on the Peeran Kulleeur ridge intermediate between the two aqueducts. A dam, therefore, on the principle of those used for the Sombe and Muskurra rivers, on the Jumna Canals was finally adopted for the Rutmoo.

The project that I submitted at this period was accompanied by a report, in which, when discussing the merits and demerits of the two courses open for selection, I gave my reasons for preferring the line bearing upon Roorkee, and crossing the Solani valley by an aqueduct.

As the project and estimate which were at that time submitted were on a very small scale, and were drawn up simply with a view of establishing the fact that a remunerative work might be constructed, there appeared to be no object in drawing any further attention to them ; they were, however, the basis upon which the Committee which was ordered to report on the project founded their plans, and the line adopted by me in the original project was in every respect the same as that which the Committee selected. To meet the desires of Government, and in accordance with the views I had expressed in the report above alluded to, the Committee, in looking to the irrigation of a more extended tract of country, deemed it advisable to increase the head supply from 1,000 to 6,750 cubic feet per second, in consequence of which it became necessary to increase the capacity of the canal excavations, and to extend the dimensions of the works. The result of this decision, and the approval of Government to the recommendations of the Committee, led to my report and estimate of 1845, to which especial allusions have been made in a former chapter.

Without, therefore, entering into any description of the works of the former estimate, it will be sufficient, as the line of country for which they were projected was precisely the same, to review in detail the works that have been actually constructed, and in as succinct a manner as possible to make the reader acquainted with the peculiarities of the surface of the country upon which they have been executed.

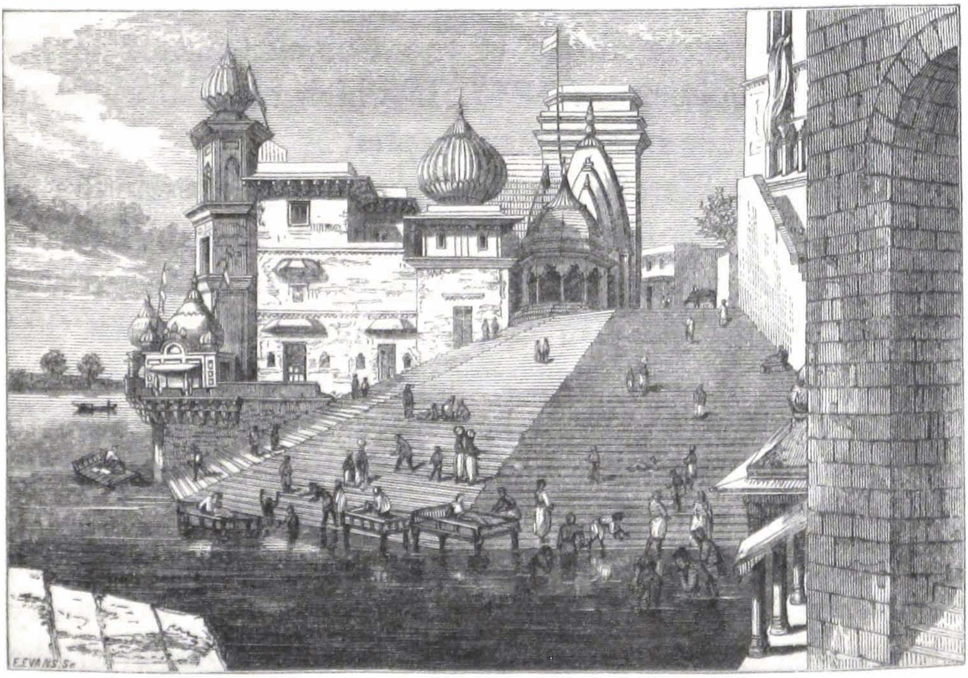
With this view I shall, in preference to wearying the attention by tedious and unbroken descriptions of country and works extending throughout the whole length of the canal, diversify the subject by separating the detail into three sections, each of which contains in itself peculiarities of a sufficiently marked order to render such a division not only convenient but natural, and conducive to distinct explanation.

The three great divisions which naturally arise under the above view of the question are :—

I. The Ganges Khadir, extending from the Ganges river to the high land of the Doab at Roorkee; the length of canal course being in this section 19 miles.

II. The country from Roorkee to Nanoon, marked by great declivity of fall in the surface and by its connection with the Bhoor or sand tracts; the length of the canal on this section being 161 miles.

III. The country from Nanoon to the Ganges and Jumna rivers, marked by a deficiency of fall in the surface of the country, and by its connection with the Rinde, Seyngoor, Pandoo, and other rivers, which drain the flat lands of the centrical districts; the length of the canals on this section being 345 miles.



GHAT OF THE PILGRIMS, HURDWAR.

Chapter II.

DETAIL OF ALIGNEMEMT AND WORKS.

I.—*The Ganges Khadir, extending from the Ganges River to the high land of the Doab at Roorkee.*

The main stream of the Ganges, the discharge of which is estimated in the driest months of the year at 8,000 cubic feet per second, after passing through the valley of Deyra, opens upon the plains of India by a well-defined gorge, or, as it may be termed, a natural breach, in the Sewalik mountains. Immediately on the right, and close at the foot of these mountains, are situated the town and temples of Hurdwar; on the left is the Chandui Puhar, a hill of a remarkably picturesque outline, on the top of which is a temple, and place of pilgrimage connected with Hurdwar itself. The river may be said to occupy the whole of this gorge, the width of which at its narrowest point is about one mile. Like all the great Himalayan rivers, however, where they are in immediate connection with the mountains, where their beds consist of shingle, and their declivity is great, this wide expanse is intercepted by numerous channels, separated by well-wooded islands, many of which are placed beyond the reach of high-flood water, and are partially cleared by the labour of the husbandman. A branch which was formed by an island or islands of this sort, passed directly under the town of Hurdwar, and, proceeding onwards in a tolerably even and unbroken section, rejoined the parent river at a point below Kunkhul, a large town situated about $1\frac{1}{2}$ mile below Hurdwar.

The main river, which runs under precipitous banks scarped by its own action on the left, throws out on its right, and within a distance of $2\frac{1}{4}$ miles above Hurdwar, a minor stream of considerable importance, which, under all the fluctuations that characterize these constantly varying beds, appears to carry, and to have carried for years, a very uniform supply of about one-third of the whole volume. From this branch the inhabitants of Hurdwar and Kunkhul had been in the habit of bringing a water-course for the purpose of supplying the towns, the priests being interested in maintaining water at their ghats or bathing places; the community in general depending upon this supply for water both for drinking and for culinary purposes, for turning corn-mills, and to a moderate extent for the irrigation of the gardens.

The head works of the Ganges Canal, therefore, were, *in limine*, determined by the priests and the people; so far as supply was concerned, it was only a matter of degree. The source from whence their small channel was fed, was ample for the purposes of a canal, and the only questions left for my consideration were those of capabilities, which depended entirely on the results of a very simple series of longitudinal and cross sections, the former extending from the departure of the branch (to which I have before alluded as the source of supply) from Hurdwar to a point south of Kunkhul, and the latter giving an accurate profile of the gorge through which the river flowed. The high-water marks of floods, the effects that these floods had upon the islands, and the capacity of the different channels, especially of that one which passed under the towns of Hurdwar and Kunkhul, had also to be ascertained. A series of levels on the above plan, in connection with a survey, showing the full details of channels and islands, disentangled the whole question from any difficulties, and at the same time unmistakeably determined the point from whence the head of the canal was to leave the branch.

There was a well-trodden footpath down a ravine leading to the water's edge in the branch running from Hurdwar to Kunkhul. At the head of this ravine and overhanging the river, was a large peepul tree, and at its foot a lingam. The spot itself went by the name of the Gunes Ghat, but there was neither building, nor temple, nor flight of steps, to show that the locality in question was remarkable for its sanctity. The Gunes Ghat was situated on the down-stream side of two mountain torrents of no great dimensions, but of sufficient consideration to render their inlet into the canal channel a matter of inconvenience. The section of the branch at the spot in question was well defined, the sides were steep, and the island on which its left side rested was one that was raised above the limits of inundation, and consequently well adapted to my purposes. The spot selected was situated on the lands of the Myapoor estate.

The Gunes Ghat, therefore, was determined upon as the point at which the head works should be erected, and from whence the canal excavation should commence.

For the details of the examination of the bed of the Ganges, and the branch which had now become a leading feature in the project, the Atlas which accompanies this volume must be consulted. My levels, however, were carried from a point north of Kunkhul to the junction of the branch with the main river, which, as I have before noted, takes place at about 2¼ miles above Hurdwar.

The total declivity of surface on this line was 34′ 10·4″ in a distance of 19,864 feet; the branch itself was well adapted to the purposes for which it was required; its average width was 300 feet, and its section at those points where it was free from breaches was deep and well defined. Immediately above Hurdwar, however, the branch is connected on its right with a good deal of drainage running from the hills and flats situated in the Deyra valley; but inconvenient as this might be, it presented no obstacles to the passage of the canal supply. At a point on the south, and immediately below the town, a second tributary, which is designated the Lulta Rao, enters the branch on the right. This Lulta Rao is a mountain torrent of no great magnitude, but it runs on an extraordinary steep slope, and comes into connection with the branch at a point almost immediately after it has left the mountains. It will in all probability be the cause of annoyance in the quantity of silt with which its waters during floods are loaded; its position is, however, above the masonry works at the canal head, and I anticipate that the evils which might arise from the silt brought down by this torrent will be very much modified by the stream which will hereafter pass down the branch, and at all events, that whatever the amount of silt may be, its concurrence at intervals and during the rainy months, will lead to little or no interruption to the bed of the channel. I look upon the silt that will be here deposited much in the same light as I do that which, after each flood in the Muskurra, is deposited on the up-stream side of the regulator of the Eastern Jumna Canal at Kulsea, and between that point and the dam. This deposit is so infinitesimally small as compared with the area of the canal bed below the regulator, that its admission is a matter of no importance, and of no consideration whatever. At the time when I visited the branch in 1839, the volume of water passing down its course from the main stream, was equal to 2,500 cubic feet per second. There were strong rapids at its mouth, offering in themselves facilities for the admission of a further supply.

Immediately north of Hurdwar, a great portion of this water escaped through a wide and extended channel, that passed off to the main stream; and opposite the Great Ghat, at the town itself, a further escape was effected by a similar channel. There was a third smaller channel, situated farther down the branch, which was only effective as a line of escape during heavy floods. It was proposed to construct temporary bunds or embankments across the heads of these different escape channels, and by advancing a spur into the river at the head of the supply branch, to obtain from the main stream whatever quantity was necessary. These were my views in 1839–40, when designing the original works, and they have been carried out very closely, or as closely as the changes that have taken place in the bed of the river would admit of. These changes, in fact, are exceedingly small, and in the year 1853 they are confined to a diminution of water in the branch, and an enlargement of the escape channel opposite the main ghat at Hurdwar: in other respects, the state of the river, and its numerous channels and islands, is much the same as when I first visited them in 1839.

During the year 1852, certain preparatory measures were adopted for excavating the canal channel down the branch. These measures consisted in throwing shingle bunds or embankments over the courses of numerous channels, that brought down during floods unnecessary supplies of water, and they did their duty very efficiently by insuring the steady progress of the excavations without any material interruption. The channel, which is excavated entirely through beds of shingle, was 14,750 feet long, with a slope of bed equal to 24 feet; the initial depth of digging was 3′ 10″, and the slope is uniform from the head to the point established as zero, or to the flooring of the regulating bridge at the Gunes Ghat.

It was an object when laying out this line of excavation—which passes directly in front of the Pyri or main ghat, and the other ghats and buildings of the town of Hurdwar—to keep the main channel and the deep excavations as far as possible to the opposite side of the branch, an arrangement that appeared to me to be desirable both for the purpose of preserving the foundations from injury, and for maintaining the water only moderately deep at and in the immediate neighbourhood of the spots which were in general used by the bathers. At the Pyri ghat, the water is generally shallow, but in many places below this point, it is so deep at the lower ghats as to be not only impassable, but actually dangerous for those who frequent them. At these spots the narrow space between the water and the buildings is a bar to their utility as bathing places for crowds of people. It was proposed, therefore, to make use of the shingle taken from the excavation in filling in these deep and dangerous holes at the foot of the ghats, and to restrict the depth of the water along the whole face of the river side of the town to $1\frac{1}{2}$ or $2\frac{1}{2}$ feet. This narrow strip of shallow water, stretching along the whole face of the buildings both above and below the Pyri or main ghat, would during the annual fairs offer facilities for ingress and egress which do not at present exist; the deep pools which now render bathing dangerous would be removed; and independently of the advantages thereby gained to the community, additional security would be given to the buildings. To those who are acquainted with Hurdwar at the period that I am alluding to, I need hardly observe, that the pilgrim in his ablutions at the Pyri ghat is prevented from going to the right or left by the uncertain depths of the water; he must either retrace his steps up the ghat, or cross the branch. The plan which has now been carried out, might be still further improved by establishing a barrier—

an iron railing, for instance—at a distance of 150 feet from and parallel to the ghats, so as to prevent all possibility of accident from the bathers wandering into the deep and rapid part of the channel.

The main current will necessarily be on the opposite side of the branch, and the bathing places will be restricted to comparatively still water. Under this plan, in fact, although neither the sanctity nor exclusiveness of the Pyri ghat will be interfered with in the smallest degree, the concourse of bathers will not, after their ablutions are completed, be necessitated either to force their way back again up the ghat, or to cross the river, but every facility will be offered for their escaping to the right or left, and reaching the town through the numerous roads and passages which connect the main street with the river face. The means of ingress and egress might be much improved by the local authorities of the district, the passages down to the water's side might be maintained open, and free from impediment in the shape of huts, shops temporarily projected from the walls, and the heaps of rubbish which are allowed to accumulate in native towns; wide roads or ramps might also be constructed both on the northern and southern extremities of the ghats; and, as a still further improvement, bridges of boats might be established across the stream, so as to connect the ghats with the opposite island, and keep up a free communication, which would be especially convenient at the time of the annual fair.

At the Gunes Ghat, the works which are immediately connected with regulating the canal supply, and delivering it into the main channel, have been constructed with due attention to economy; they consist of a bridge with ten bays or openings across the mouth of the canal, with shutters, each bay being 20 feet in width. A line of revetment connects this bridge with a dam, which is built across the branch, and furnished with sluices in its centre, and overfalls on its sides, for the purpose of passing off floods: the design is precisely the same, only on a larger scale, than the head works of the Jumna Canals, the principle being to maintain the supply which is brought down from the main river in a reservoir subject to regulation by a dam, the water sufficient for the canal supply passing down the canal channel through the regulating bridge, whilst that which is superfluous is allowed to escape through the dam sluices. During the rainy months, and when the supply in this reservoir exceeds that which is required, or at periods when a necessity occurs either for laying the canal dry, or for reducing its supply, the purposes of the works are inverted, the regulating bridge being either partially or perfectly closed, and the dam sluices being correspondingly opened; the dam in that case becoming the discharge and waste escape for the water. A full detail of the construction of these works will be given in its proper place; the works themselves, however, are figured in Plate XIV. of the Atlas. On the right and up-stream flank of the regulating bridge, an arched passage for the admission of the Bochna Nulla, one of the mountain torrents that I have before alluded to, is pierced through a line of revetment which extends upwards, and is terminated by a ghat or flight of steps resting on a sweep of revetment whereby an old native building is encircled and protected. The expense of these revetments and ghats became a heavy item in the expenditure; the protection, however, which they provided against the inroads of the stream, and the admirable security which they offered both to the inlet of the Bochna Nulla, and to the native buildings they were designed to protect, rendered their construction a useful appendage to the works. The ghats, moreover, as offering accommodation to pilgrims and others who visit Hurdwar and its sacred precincts, may be received by the Hindoo as some atonement for the liberties taken with the Ganges, as well as with the tutelary deity of the ghat upon the site of which these works were constructed. The Gunes Ghat of my original survey has now been converted into an extended line of stone steps washed by a running stream, and provided with convenient approaches for the accommodation for the bathing community. Near the site of these works is a house built for the European establishment, and other accommodation for stores and necessaries required for the use of the works. The regulating bridge over the canal, and a bridge which is built over the Bochna Nulla, afford the means of cross communication between the towns of Hurdwar and Kunkhul, this being further facilitated by the opening out of wide and efficient approaches to the towns themselves.

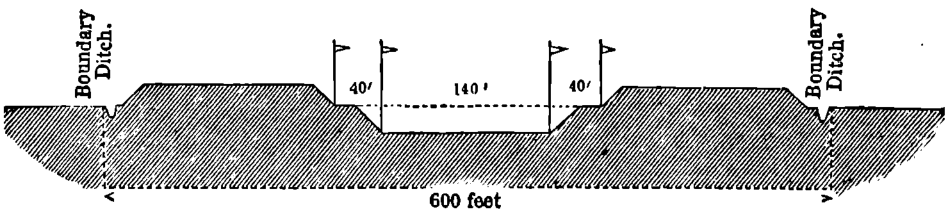
The depth of excavation at the point where the canal channel commenced, and upon which the regulating bridge was situated, was 22·83 feet; the upper 17 feet consisted of firm clay, which rested upon a stratum of shingle; the material derived from this excavation was used in forming an extended platform between the bridge and the right flank of the dam; and the shingle, at least that portion of it which was in sufficiently large boulders to render it serviceable, was used largely both in the foundations and in the superstructure of the works. At a date posterior to the completion of the regulating bridge, a great quantity of boulders was carried away to the different works which were situated in the neighbourhood of Jowalapoor and Bahadoorabad, and the esplanades in the neighbourhood of the dam and regulator were thus relieved from material which, useful as it was elsewhere, was a disfigurement in its original position, where it was deposited in mounds, occupying ground which would have been much improved by being perfectly level. At the period, however, when the water was admitted into the canal, and when the works at this point were completed, the esplanades in the neighbourhood had been cleared of all extraneous earth and shingle, and the difficulty of disposing of so much excavated matter, which in the first instance really appeared to be insurmountable, was by the good management of the executive officer completely overcome.

From the regulating bridge, the canal channel leaves the bed of the Ganges; at this point, therefore, the work assumes an entirely new interest; and as I write these chapters for the information and instruction of the juniors in the Canal Department, and for the benefit of those who may be hereafter called upon to design and to execute works of a similar nature, I shall not hesitate, at the expense of being thought by the general reader somewhat tedious, to enter into a full detail of the progress, and of the deviations from the original project which time and a better acquaintance with the nature of the mountain torrents that we had to deal with rendered necessary.

I think it better to avoid encumbering the text with the calculations upon which the excavation and works were based, and which were given in appendix to my Report of 1845; they will, however, be interesting to refer to when the designs of the completed works are fully comprehended; and as they are, in fact, the basis upon which the whole structure has been raised, not only as regards the canal viewed as a mere machine the parts of which ought not to be subject to disarrangement, but as the means of performing a certain amount of irrigating duty, the returns from which ought not to be liable to disappointment. The appendix in question has been transferred, as Appendix F., to the volume of tables, where it can be consulted by those interested in such details.

From the regulating bridge to a point 2 miles below it, at which a bridge connecting the towns of Kunkhul and Jowalapoor is situated, and throughout the whole of which the canal was carried through shingle, the slope of the bed was determined at 24 inches per mile; in advance of this bridge the soil was of a lighter description, and the slope was reduced to 18 inches, at which it continued onwards to Roorkee. The capacity of channel which was calculated on this slope was fixed at a bottom width of 140 feet, with slopes equal to $\frac{3}{2}$ of the depth of excavation. The section of the canal may be described by the following diagram:—

Diagram 2 A.



The section above figured, and the slopes above described, will be understood, therefore, as those upon which the works were begun, and upon which the whole of the channel, from the regulator at Myapoor to the high land at Roorkee, was originally projected.

With these remarks, as introductory to a proper understanding of the projected line of operations from the regulating bridge downwards, I now come to the detail of the channel from the bridge above mentioned to the spot where it is crossed by the Ranipoor torrent, to within a short distance of which the excavation had been completed as far back as 1846. The canal on this line runs parallel to, and within half a mile of, a low spur of hills which is thrown out from the Sewaliks; it leaves this spur by a gentle curve to the right, passing the town of

Kunkhul on its left, and, proceeding in a direction close to and south of the town of Jowalapoor, reaches the neighbourhood of the Ranipoor drainage at a distance of 5½ miles from the regulator. On the whole of this line the slope of the country extended from the hills towards the canal, and it was necessary to dispose of the drainage of this slope with as little interruption as possible to the excavated channel. There were three lines of drainage more or less defined, two of which were derived from the low spur of hills along the foot of which the canal was excavated, and the third was connected with the high levels above the town of Jowalapoor. It was proposed in the original project to adapt an inlet and outlet to the Lounda Leniwala torrent, which was the most remarkable one of the three; to give an inlet to the centrical or Kunkhul drainage, and allow the floods from this comparatively small line to expend themselves in the canal channel; and to get rid of the Jowalapoor drainage altogether, by taking advantage of the slope of the country, and turning it off to the Ranipoor valley, by which it was supposed that efficient relief would be obtained.

The Lounda Leniwala outlet was projected, not only as an escape for flood-water during rains, but to act as a supply head for the purposes of the town of Kunkhul; and as the fall from the point of the canal where the torrent left it to the bed of the Ganges, which was close at hand, was considerable, it was proposed to build corn-mills near the junction, and to maintain this outlet as a supply head for them also.

The Kunkhul drainage was an ill-defined hollow through which the canal excavations were carried; it was, however, of less importance than the former one. At Jowalapoor there were no marks of drainage at all; the flood-water appears to have swept over the country, and it was only when it found itself impeded by the canal embankments that it began to show vigorous signs of active hostility. In the early stages this hostility was confined to breaking through the embankments, and cutting its way into the canal by the formation of a deep ravine; subsequently, however, the floods effected a passage into the channel at the site of a bridge that was built opposite the town for the convenience of the inhabitants, and, in so doing, carried away a wing wall, besides doing further injury to the structure. Free and open passages had up to this time been excavated for the purpose of carrying the water to the westward, but as they did not answer their intended purposes, and as other views with reference to the drainage were then in contemplation, I determined on making an inlet opposite the town of Jowalapoor, for the purpose of receiving the drainage water from that line of country.

The experience that had been gained by the deliberate observation for a number of years of the discharges and effects of the Lounda Leniwala and Kunkhul lines of drainage had at this period thrown an entirely new light upon the method with which they also ought to be treated. The canal channel which, as I have before stated, was excavated to a point near the Ranipoor torrent, had for years received the whole of the floods from the above lines, with no further means of outlet than an opening which had been left in the embankments near Kunkhul. This opening showed no signs of having passed off extraordinary floods, and the only conclusion that could be arrived at was, that the flood-water of the Lounda Leniwala and of the Kunkhul lines of drainage expended themselves over a very contracted area of excavated channel in which they were completely exhausted. The inlet water, therefore, derived from these sources appeared to be of no great consequence.

For the protection, however, of the right embankment through which this drainage had to pass, it was thought advisable to build two masonry works for inlet; each of these were 50 feet in width, the design being similar in every respect to that which was built at Jowalapoor, viz., a flight of steps or ghats built to a sufficient height to retain the maximum high water in the canal, and strongly protected on the flanks to admit of the passage of the highest possible floods.

The *escape* on this line has been limited entirely to one point, situated just below the town of Kunkhul; this outlet will provide a head for irrigation for the village of Kutarpoor and others which lie on the right bank of the Ganges, and will give a supply to clusters of mills which it is proposed to establish on the lower side of the town of Kunkhul. By this arrangement the necessity for mills on the upper side, as projected in the original estimate in connection with the Lounda Leniwala, will no longer exist, and the inconvenience of having the old line of channel which now runs through the upper part of the town as an open watercourse, subject during floods to heavy and dangerous supplies of water, will be entirely removed. It is evident, in fact, that the proximity of a channel of this sort, liable to sudden and intermittent discharges of water, to a densely-populated town, is open to serious objections. From the arrangements now made, it will cease to act as a line of watercourse at all, and I have no doubt that in a few years all vestiges of its existence will be lost.

Between the Myapoor regulating bridge and the Ranipoor torrent, the following works have been constructed:—

Two bridges for cross communication—one at Kunkhul, the other at Jowalapoor, the latter including the works at the head of the navigable cut;

One outlet on the left bank, south of Kunkhul;

Three inlets on the right bank—Lounda Leniwala, Kunkhul, Jowalapoor.

The excavation on this line of channel, with the exception of that point where the Kunkhul drainage crossed it, and which was 990 feet in length, with an average depth of digging of 5 feet only, was very great: on 2 miles of its course it averaged 22 feet, elsewhere from 15 to 14 feet—the maximum depth being 25·08 feet from the surface. Throughout the whole line the soil was good, with a large admixture of clay, and, as I have before said, from Myapoor to the Kunkhul bridge the canal bed was executed in shingle.

The left bank has been formed into a wide and spacious roadway, which is continued from the Myapoor regulating bridge to the first-class choki at the Ranipoor Works. This road acts as a line of patrol for the Canal Establishment, and, in fact, is a good carriage-road for every purpose that could be required. The right bank, as will be inferred from the system of inlet which has been above described, is broken at three different points, and it has not been considered worth while to complete the line of communication by throwing super-arches over these inlets, or to make any arrangements for clearing and maintaining a passage along this bank further than will be provided by the interior berm. It is supposed that the scale upon which the works have been built for the admission of inlet water, and which is the result of twelve years of observation, will place the banks on the right of the canal out of all jeopardy.

The changes that have taken place in the distribution of works on that portion of the canal between the Myapoor regulating bridge and the Ranipoor torrent consist, it will be observed, of increased inlet to drainage water on the right, and to decreased outlet on the left. The causes for such changes have been described as arising from the observed quantity of flood-water in the Lounda Leni and Kunkhul lines being less than it was originally estimated, and from a disinclination to interfere with the town of Kunkhul by introducing into its precincts an element of such danger as an open channel subject to sudden and impetuous discharges of flood-water. The additional inlet of the Jowalapoor drainage was proved by deliberate and anxious experiment to be absolutely necessary for the convenience of the town. There were other reasons, which will be hereafter explained, why the relief of the country at this point and by the method adopted was considered to be expedient.

From the point of the canal where the excavation of 1846 terminated, or from a point situated immediately above the Ranipoor torrent, the line upon which the canal channel has been excavated and the works built, is one of very peculiar interest. It is that upon which the works have been subject to the greatest changes from the original design, and it is one where the circumstances under which the canal channel is brought in contact with torrents deserves the marked attention of all those who are interested in civil engineering under difficulties.

To enable me to place the details in any degree of perspicuity before the reader, it will be necessary to bring under review the whole of the country lying between the Ranipoor and Rutmoo torrents, including the drainage which gives rise to these torrents; to explain the project for passing the canal through this line of country, as designed in my Report of 1845; and to show the causes of the changes that have been made in that project during the execution of the works. The total length of canal channel, which will be embraced in this review, is equal to 8 miles.

By referring to Plate III. of the Atlas, which exhibits in the greatest detail the surface profile of the country, and which is, in fact, a contour of the whole of the land lying between the mountains and the canal, a good general idea of the circumstances under which the works were placed will be obtained. It is desirable that these general features of the country should be understood before the details of the canal operations are considered, as they exhibit peculiarities somewhat similar to those of the country passed by the line of the Eastern Jumna Canal, amongst which may be noted the very remarkable one of double slope, which may hereafter, in all probability, be taken advantage of with great benefit to the works. In the present instance, the slope in question proceeds from east to west, instead of from west to east, as it does in the drainage on the western water-shed, with which the Eastern Jumna Canal works are connected: in both cases, it has afforded the means of projecting a line of canal on slopes sufficient for the purposes required, and in both cases it has placed in our hands the ability of regulating the distribution of the flood-water. I have, in a former chapter, explained how beneficially this natural arrangement of slope, combined with topographical advantages, from which, I am sorry to say, the Ganges Canal works are entirely precluded, has been brought to bear upon the line of the Eastern Jumna Canal, in relieving its works from the effects of mountain torrents; and, although I see no probability of freeing the Ganges Canal works altogether from flood-water, in the way that the Muskurra on the Eastern Jumna Canal has been freed, by escapes into rivers, which are entirely unconnected with the works, we hold in our possession the means, as I before said, of regulating its distribution; and, as I have in some degree made use of the means thus placed in our power, it may be as well to lay some stress upon them here, preparatory to the detail which will follow.

The remarkable points in the country which I am about to describe, as connected with the canal works, were, 1st, the extraordinary slope upon which the mountain torrents (crossing the line at right angles to its course) passed onwards to the lower levels of the Khadir; 2ndly, the peculiar circumstances under which the beds of these torrents exhibited themselves, or, more properly speaking, did not in some cases exhibit themselves at all; and, 3rdly, the alluvial nature of the soil, with a disposition of spring water, which, as leading to complete drought in one, and complete saturation in another part of the line, was particularly inconvenient.

The line of canal, in proceeding across the Ranipoor torrent onwards to the Rutmoo, gains in departure from the hills considerably. At the point where it crosses the former river, the hills are at a distance of $2\frac{3}{4}$ miles; half way on its course, or at the point where it crosses the Puttri, it is $5\frac{1}{2}$ miles distant; and at the Rutmoo the distance was increased to 16 miles: this is a question of some importance in estimating the value of the flood-water.

It was proposed in my project of 1845 to adopt the dam system, as practised on the Jumna Canals, for all the torrents, the courses of which were intersected by the canal channel, to confine the masonry works to outlet only, to dispose of the superfluous fall of country by masonry descents, and to reach the Rutmoo dam by a gentle sweep from the termination of which the bearing on Roorkee would be in one uninterrupted line.

The country to be passed may be thus described. The Ranipoor torrent, which is the first defined line of drainage west of Jowalapoor, is directly connected with the mountains; its catchment basin may be estimated sufficiently accurately for our purpose at 45 square miles; from its debouche from the mountains to the point of intersection with the canal, the distance in a direct line is

$2\frac{3}{4}$ miles, which by the tortuous course on which the flood-water runs, may be increased to $4\frac{3}{4}$ miles: the total declivity of bed on this line is equal to 87′ 1·9″ or 18·34 feet per mile. In my original survey of 1839–40, I remark that at a point 4,800 feet below that where the canal intersects the line of the Ranipoor torrent, the water spreads over the surface of the country, leaving no trace of a defined channel; the average width of the bed of the torrent was at that time 100 feet; and borings which were carried on in the bed at the point where the canal works were to be constructed, showed at three different places that there was favourable soil at a depth of 14 feet from the surface; the borer, however, showed no signs of spring water at a depth of 40 feet; at half a mile to the west, and immediately on the edge of the high bank skirting the torrent, the level of the water in the Moongawala well was 60 feet from the earth's surface. The supersoil in the bed was pure sand; at the depth above mentioned of 14 feet, this was of a better consistency, and mixed very sparingly with small shingle; but to the extreme depths reached by the borer, the soil produced was merely sand more or less mixed with clay. Immediately at the point where the canal and torrent came in contact, the latter had within the last few years deserted its direct course towards the village of Surai, and had made an abrupt turn to the westward—on the bearing, it fact, upon which the canal was to be carried. This abrupt turn had excavated a deep channel close under the Moongawala well, the position of which at that period was one of great jeopardy; another equally sudden turn to the south had thrown the direction upon the village lands of Boungla, where the flood-water exhausted itself, leaving, as it is usual in such cases, fan-like deposits of sand. The site of the works was, therefore, at the head of a delta, the eastern branch of which ran in prolongation of the river's course on its approach to the works, and bore on the village and lands of Surai; the western turned off abruptly to the Boungla lands. The position determined upon for the dam was on the old or easterly branch, which, it appeared from the revenue surveys of 1835 (only four years before the date of my examination of the country), was the line of torrent at that period.

I have before noted, that the slope of the country from the debouche of the torrent, from the hills to the point of intersection of the canal channel, is 87′ 1·9″ or 18·34 feet per mile; below this intersection, on a distance of 2½ miles, the slope was 40 feet, or 16 feet per mile. The effective slope, or that in immediate contact with the line of canal, as shown by fig. 1 in the accompanying sections, was equal to 15½ feet per mile; one-third of the length upon which the section was taken being *above*, and two-thirds below the line of works.

The sill or flooring of the dam on this project was 12·725 feet below the surface of the bed of the torrent. The inlet was designed without masonry works of any description, and the outlet or dam on the left bank of the canal furnished a waterway over the pier-heads of 131½ feet in width, the sluice openings being 10 in number, and each of them 10 feet wide. I have before explained that, on the project of 1845, the works of which I am now describing, the slope of the canal bed throughout the Khadir was 18 inches per mile; it will, therefore, be understood that the different points of fixed level for the sites of dams are determined on this particular slope, the intervention of descents or falls for overcoming excess of slope being duly considered.

In advance of the Ranipoor torrent and its water-shed, the rapid fall of country which led to the valley of the Puttri torrent was overcome by descents in masonry of

8 feet each, either collected in one spot, or divided into two separate descents, as the levels of the actual line upon which the canal would be excavated might prove to be most convenient.

These descents were to be passed by lockage, for which provision was made in both plans and estimates.

The Puttri drainage, as I have formerly said, may properly be brought under two different heads, viz., that portion of it which was connected with the mountains, and which may be called the "Puttri proper," and a tract of country lying to the eastward in the neighbourhood of the town of Selimpoor, which, extending over an area of about 10 square miles, had its drainage confined within a distinct although ill-defined water-shed, consisting of grass and jungle land extending towards the mountains, by the water from which, excepting in very high floods, it was totally unaffected. The material difference that existed between the jungle drainage and that of the Puttri proper, was that its flood-water was entirely free from sand and silt; its course was marked by deep ravines and a well-defined section both to the north and westward of the town of Selimpoor. At a point about half a mile south of the town, no traces of this drainage were to be seen, the surface of the country was under cultivation, and there were no outward and visible signs by which a person who had confined his examination to the line of the canal alone, could have formed an idea of the nature of the drainage over which he was passing. At this point the project of 1845 gave a design for works similar, but on smaller dimensions, to those at the Ranipoor torrent, the water being admitted through the right embankment by an opening left for the purpose, and a masonry escape of 20 feet waterway being constructed on the left for passing the flood-water out of the canal.

The Puttri proper, which, like the Ranipoor torrent, is connected directly with the mountains, was marked at the point where the canal intersected its course by sheets of sand, elevated rather than depressed below the surface of the country, and with no signs of excavated channel; the channel, in fact, appeared to cease at about a mile above the point where the canal had to cross it, and at this point of cessation the sand was thrown over the surface of the country in the same fanlike expanse that had shown itself to me at Boungla and Surai when examining the peculiarities of the Ranipoor drainage. The catchment basin of the Puttri valley may be estimated at 80 square miles: from its debouche from the hills to the line of canal, the distance in a direct line is 5 miles. Its course, however, is an exceedingly tortuous one; its main branch leaves the hills considerably to the eastward, and after skirting the foot of the mountains, and gathering in its passage the drainage of the different valleys with which it comes in contact, it takes a direction almost due south, and with the exception of a few twists characteristic of this species of river, passes the line of canal on a tolerably direct bearing; the defined section which marks the earlier part of its course losing itself, as I have before described, over the surface of the country. On this tortuous course the distance between the points above mentioned may be estimated at $6\frac{1}{2}$ miles, the greater part of the country over which it passes being forest and uncultivated land. The total declivity of bed from the hills to the point of canal intersection was 179′ 6·5″, or 27·625 feet per mile. From this point to a distance of 11,500 feet south, where there are marks of the commencement of a well-defined although narrow section, the slope was 49·8 feet, or nearly 25 feet per mile. The effective slope, or that in immediate contact with the canal, as shown by fig. 2 in the accompanying sections, was equal to 25·41 feet per mile; one-third of the length on which the section was taken being above, and the remaining two-thirds being below, the line of works.

The sill or flooring of the dam on this project was 9·57 feet below the surface of the bed of the torrent; and the arrangements for inlet and escape were precisely of the same dimensions and projected on the same design as those at the Ranipoor works.

As a further means of disposing of the flood water of the Puttri valley, a dam and escape similar in every respect to that at the Selimpoor line of drainage was projected close upon and under the ridge upon which the town of Gurh is situated, this ridge being the westerly watershed of the Puttri basin.

The valley of the Puttri, therefore, was, under the project of 1845, provided on the left bank with three separate lines of escape; that on the east passing off the Selimpoor drainage, that on the west giving a relief to the floods from the high lands near Gurh, and a main centrical line provided for the especial purpose of the Puttri torrent itself. The total width of waterway that these three escapes afforded was 140 feet between the piers of the dams, with a flush passage over their pier heads of 178½ feet; openings of equal dimensions were to be left on the right for the admission of flood water.

On leaving the Puttri valley, and after crossing the ridge on which the town of Gurh and village of Saynibas were situated, at which point it was proposed to build a bridge for cross communication, the line of canal, as I have before noted, on a slope of 18 inches per mile, comes in contact with the Badshahpoor Nulla, a sharply cut ravine in which there was a perennial stream of water tributary to the Rutmoo River. The head of this nulla was situated at a distance of one mile north of the canal, and the level of spring water afforded a fair indication of the state of the springs in its neighbourhood; the canal bed crossed this stream at an elevation of 5 feet above the water's surface: there were no works estimated for on this drainage, the question of inlet or outlet being left an open one.

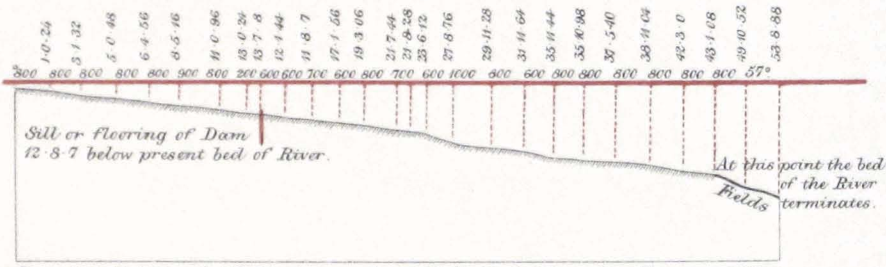
From this point the canal channel was to be carried on a gentle sweep upon the line of the Rutmoo River, the levels of which it reached by descents of masonry equal in extent and dimensions to those which were proposed at Bahadoorabad: at this point also a navigable line was projected round the falls for the passage of boats and rafts.

The Rutmoo River or Torrent, it will be understood from the foregoing description, runs on a level considerably below the high land on which the canal hitherto has been carried. The valley through which it takes its course is at the point of contact with the canal about a mile in width, bounded on the right by a steep and precipitous bank on which the village of Peeran Kulleeur, with its tombs and durgahs, are situated. The catchment basin of the Rutmoo Torrent may be estimated at about 126 square miles, 36 of which lie in and 90 at the foot of the mountains. The valley above the canal works receives the whole of the drainage from the Kansrao and Sukrouda Forests, combined with that which pours down from the mountains by the different ravines and passes on a length of 10 miles. Its watershed on the east is bounded by that which falls off towards the Puttri, and on the west by the slope which delivers the drainage upon the Solani River. The debouches from the hills of the torrents, which are thus tributary to the Rutmoo, vary from 10 to 16 miles from the canal works, the main or westerly line of drainage being the most distant. The greater portion of the country over which these tributaries

DIAGRAM III.

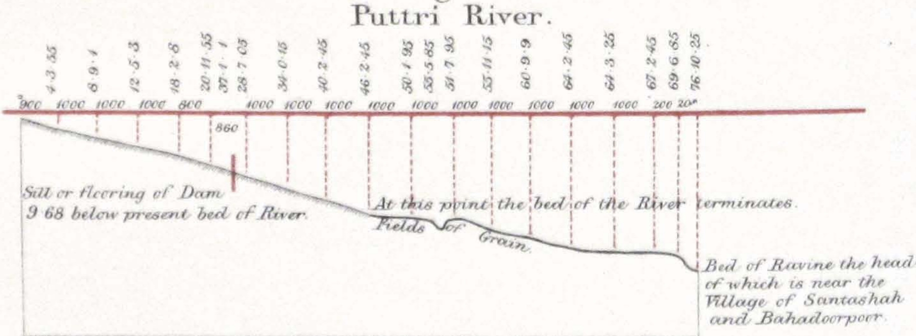
SECTION ON THE RANIPOOR, PUTTRI AND RUTMOO RIVERS, SHEWING THE DECLIVITY OF BED AS CONNECTED WITH THE GANGES CANAL WORKS.

Fig. 1.
Ranipoor River.



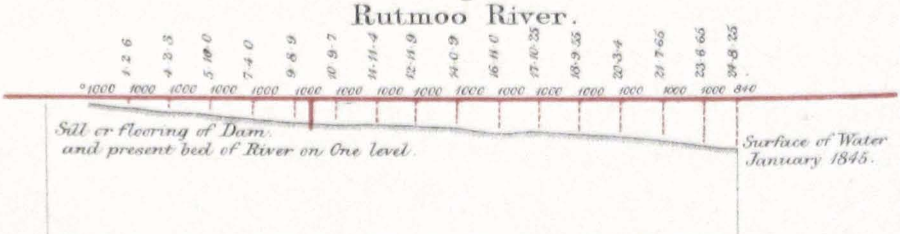
Length 3 M. 3 F. and 150 Yards. Total Fall 53·8·88 or 15·5 Feet per Mile.

Fig. 2.
Puttri River.



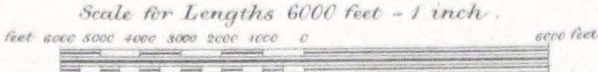
Length 3 M. 40 Yards. Total Fall 76·10·25 or 25·41 Feet per Mile.

Fig. 3.
Rutmoo River.



Length 3 Miles. Total Fall 24·8·25 or 8·23 Feet per Mile.

Scale for Lengths 6000 feet = 1 inch.



Scale for Depths 120 feet = 1 inch.

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take their course was, at the period of my original surveys, forest and grass jungle, the few villages that existed being mere hamlets, with a field or two in their immediate neighbourhood. From the point where the main branch of the Rutmoo left the hills to the bed of the river at the intersection of the canal line, the slope was 626′ 11·2,″ or averaging 39·18 feet per mile. Below the point in question this slope decreased, but the effective slope, or that in immediate contact with the works, as shown by Fig. 3 in the accompanying section, was 8·23 feet per mile, one-third of the length on which the section was taken being above and two-thirds being below the line of works.

The sill or flooring of the dam on the Rutmoo River coincided with the natural level of the bed, and the arrangements for inlet and outlet were on the same plan as those that I have before described, viz., masonry sluices on the left for the purpose of passing off, and an open breach through the right embankment for admitting flood-water. On the right of the valley a masonry drain was designed for carrying the water of the Bhuguleea (a little stream or nulla that runs at the foot of the Peeran Kulleeur bank) under the canal channel, so that inundation, which would necessarily arise where the course of the stream was interrupted by the canal embankments, might be prevented. Attention was also drawn at this time to the inundations consequent on the canal bed and that of the river being on one level. It was observed that under this circumstance the maximum head-water in the canal, which is proposed to be 10 feet from the sill of the dam, and therefore from the bed of the river, must stand in back-water, forming an inundation on the upper side of the dam, by which not only would a serious disfigurement arise to the works, but the rank vegetation consequent on inundation extending over such a large surface would, in all probability, affect the health of the neighbouring population, as it would inevitably provide a harbour for tigers and other vermin. The evils of a large inundated tract at this point were undeniable; and although I proposed a method for curtailing this evil, which was the least expensive that could be devised, I suggested at the time, that it was by no means improbable that during the operations in this valley other and perhaps better remedies might offer themselves. It was natural, in fact, to look to the system of tunnelling which had been proposed for the Bhuguleea Nulla as one equally appropriate to the relief of the Rutmoo inundation.

The works proposed in my estimate of 1845 for the Rutmoo River consisted of a dam with 40 sluices of 10 feet wide each, and flank sluices each 100 feet in width. The flush passage over the pier-heads, which were 10 feet above the level of the canal bed, was equal to 796½ feet.

A bridge for the purpose of regulating the canal supply, and for preventing the floods of the Rutmoo from passing down the canal, was to be constructed across the canal channel between the river and the Peeran Kulleeur ridge. The design of this work, with its arrangements for regulating the supply, was similar in every respect to that of the canal head.

Having now passed over in detail the country between the Ranipoor and Rutmoo torrents; having described the slopes of country over which the line of canal had to take its course; and having noted its relative position to the mountains; we may, in adverting to the different works which were proposed at this period for overcoming the difficulties which were offered by the mountain torrents, point out the comparative want of information that we possessed at the time in question, to that which we held at a later period. The surveys upon which the whole design of the Ganges Canal was based were made by myself, unaided by staff of any description, and were carried on at a time when my attention was divided by the responsibilities of other duties. These duties neither permitted a prolonged absence from them, nor of any interruption at all to the daily routine of office business. I was, therefore, necessitated to confine my views to the determination of a line for the canal, and to the examination of the torrents in their immediate connection with it—to the details, in fact, which are given *in extenso* in the report of 1845, from which the whole of the data I had at that time in my possession, and upon which the project was formed, are taken. This report is open to the perusal of all who may take any particular interest in the subject.

The valuable information which we have since gained by the numerous, and I am by no means disinclined to allow the fortunate, delays that have taken place in the prosecution of these works, has shown the character of the mountain torrents in a very different aspect to that in which they were originally displayed. The deliberate surveys and contour levelling which have been carried over the whole of the country between the hills and the line of canal, have thrown lights upon the subject of the drainage of which we were previously ignorant; and it is not too much on my part to claim some indulgence for a design projected on limited data, and unaided by those advantages which time and experience have since accorded to us.

In recapitulating the works above described, it will be observed that the section of the canal channel was continued on the same dimensions as are shown in diagram 2A, page 133; the slope of the channel was maintained at 18 inches per mile, with a superfluous fall of

32 feet, disposed of in masonry descents; that the cross drainage was to be effected by gaps left in the right bank for the admission of flood water, and by masonry works, with sluices adapted to escape, attached to the left.

The total amount of water-way which was allowed for escape under this project was equal to 1,106½ feet, distributed as follows:—

Ranipoor Torrent		131½	feet above pier heads.	
Puttri Torrent .	East . .	23½	ditto	Total, 178½
	Centre .	131½	ditto	
	West . .	23½	ditto	
Rutmoo Torrent		796½	ditto	

It must also be remarked that the canal bed came in contact with the torrents under the following circumstances:—

Ranipoor	Torrent bed	12·72 feet above the canal bed.	
Puttri	ditto	9·57	ditto.
Rutmoo	ditto	on the same level.	

and that the projection of the levels of the canal bed, and the position of the falls or descents of masonry, had been devised, not only with a view of reducing the difference of level between the canal bed and that of the mountain torrents to a minimum, but restricting the excavation of the channel to moderate depths, and thereby escaping the springs that showed themselves on the country between the Puttri and the Rutmoo valleys. The bridge between Synibas and Gurh was the only work for cross communication that was contemplated on this line of the canal.

An attentive perusal of the above recapitulation, with the matter that has preceded it, will, with plate No. 3 of the Atlas before him, put the reader in a position to form his own opinion as to the value of the inductive reasoning which led to an extensive revolution in the method originally adopted for dealing with the Ranipoor and Puttri drainage. This involved a material change in design for the disposal of the flood water; modifications to the disposition of slope in the canal bed; and, in some cases, an increased capacity of channel.

The views which I entertained on the subject of the effects of the Ranipoor and Puttri torrents upon the channel of the canal at the point of contact, may be best shown by an extract taken *verbatim* from my report of 1845. After explaining the position of the Ranipoor masonry dam, and other points with regard to levels with which I have before made the reader acquainted, I observe :—" The masonry work being completed (or during the time of its progress, if labourers are to be procured in sufficient abundance), the excavation for the escape at the dam-tail ought to be commenced. This, I propose, shall consist of a channel 50 feet wide, with its bed formed on a declivity of 24 inches per mile, which, with reference to the actual slope of the surface of the country, will, at about 6,000 or 8,000 feet south, deliver the escape into the lowland, draining itself into the Ganges in connection with the Puttri River; the width of channel proposed will be sufficient to enable the stream to adapt itself to its own wants, by clearing out a passage suited to the body of water which will be passed over the dam. North of the dam," and to this point I would draw particular attention, " and up the course of the Ranipoor Rao, the bed of the river will be deepened, so as to meet the level of the canal bed on an inclined plane, the base of which shall be half a mile. I propose that the width of this excavation should be 40 feet. It may be assumed that during floods the canal which crosses this river at right angles, and which will receive in the first instance all the water which comes down the river, will hold from 6 to 10 feet of water in depth; so that a considerable backwater will be present to receive the floods that come down the rao, and the meeting of the flood with the canal back-water will, in the case of the depth being 6 or 10 feet, take place at a distance from the line of the canal and the masonry dam. The wear and tear of the bed of the rao, owing to this alteration of its levels, will necessarily lead to the removal of sand and silt, all of which will be borne forwards in the direction of the canal. A portion of this will necessarily pass off through the sluices of the dam; but owing to the canal stream meeting that of the rao at right angles to its course, a portion will be projected into the canal channel; the dams and escapes which are situated lower down the line will, however, in some measure act as a relief to this inconvenience; and the closing of the regulating bridge south of the dam on the Rutmoo River will, in all probability, act as the means of efficiently scouring the canal channel through the sluices of the dam at that point. It is to be understood that, with the exception of the periodical floods which usually occur during the rainy months only, the beds of these raos are perfectly dry. The silt therefore obtained from these sources is merely an occasional evil."

The plan of the inclined plane or rapid by which the water from the torrent was to be admitted into the canal channel was evidently a crude and imperfect one; it brought into direct contact two slopes on extreme declivities, and was, in fact, the introduction of an evil in somewhat of an exaggerated form like that with which experience had made us acquainted elsewhere. It will be understood, however, from the extract above given, that the body of water and current which the canal was supposed to deliver at right angles to that of the rao, would project a great portion of the silt forwards in the canal channel, out of which it would find an exit from the lower escapes, whilst the remainder would pass over the outlet made expressly for its passage. The remedy, however, was in itself one of great inconvenience, to say the least of it, and it was one that had sufficient objections to render any dependence upon it a matter of very questionable propriety.

On my return from England, and re-assuming charge of the works early in 1848, the whole question of the drainage on this line of country was one of the first that occupied my attention; the foundations of the Ranipoor dam or outlet were at this time in progress, and by the month of July of that year had been completed. During the progress of these operations, and during the rains of 1848, the floods were passed round the works by well-protected embankments; and it was at this time that the enormous accumulation of sand which these embankments led to, became an object of prominent observation. The floods during the rains of this season had been numerous, and in the month of July one of the heaviest that had been experienced, poured down the river; the protective arrangements to the masonry works, however, did their duty efficiently.

After the rains of 1848, the Ranipoor River, and the drainage connected with it, were subjected to a more detailed examination than they had hitherto experienced; and in the month of February, 1849, after drawing the attention of the Government to the acknowledged imperfections of the admission of the rao water into the canal channel, by an inclined plane excavated through the bed of a sandy river, I pointed out the only remedy that appeared to me to be available, viz., the substitution of a masonry overfall for the inclined plane, by which the levels of the Ranipoor bed would be in some measure retained on their original level. The advantages anticipated by this plan were—

1st. Great relief to the canal channel from silt and gravel, from the influx of a torrent running on a sandy bed under a great slope.

2nd. Security to the embankments in the neighbourhood.

3rd. Advantage to the cross communication of the country, by retaining the bed of the rao or river on the higher level, by which means the road between Hurdwar and Saharunpoor, which lies immediately on the north of the canal, would be maintained passable during the year.

The actual state of the works at this particular point were, on the date above noted, as follows:—The excavation of the canal channel was in progress across the bed of the rao, a bar of earth having been left across the channel at the point immediately above that where it came in contact with it; the flooring and foundations of the dam were laid bare, and the escape channel was nearly completed; the foundations of the inlet to which I have above alluded were in progress, and a sufficiency of material had been collected to complete the work. In a report at this period, I concluded my remarks by observing, that "I look confidently to seeing the whole of these works completed (with the exception of the dam piers, the completion of which is postponed) before the next rains. I am anxiously desirous that such should be the case, that we may in these works gain some practical experience, and consequently useful hints, for the execution of the works on the Puttri drainage, the site of which is a few miles below the Ranipoor Rao."

The design of the inlet (plan and section of which will be found in Plate No. XV. of the Atlas) was a plain perpendicular drop of 10 feet, with a reservoir at the foot to receive the water; the flanks were well protected by masonry wings, which were covered on the ends, resting on the embankments by piling; the sill of the overfall was 2·72 feet below the level of the bed of the river, the height of the drop being designed with reference to the estimated high water-mark in the canal, which, agreeably to the project, was 10 feet.

The whole of these works were completed before the rains of 1849, with the exception of the piers in the centre of the dam waterway. The escape from the dam had been entirely cleared out on a width of 51 feet, with a slope of bed equal to 4·75 feet per mile, and bunds or embankments had been thrown across the canal channel, both above and below the works, so that the torrent might be confined to its own course, and not be allowed to interfere with the canal excavation on the right or left. Under these circumstances the works were opened for the passage of the river.

That the effects upon these works, which I am now about to describe, may be fully understood, I may observe in this place, that the slope of the inlet was equal to 10·33 feet in a length of 1,400 feet, or 38·95 feet per mile; whilst that from the tail of the inlet, along the line of escape which had been provided for it, was equal to 4·75 feet per mile, or 6·12 in 6,800 feet; the width of the torrent might be, on an average, 100 feet, whilst that of the escape was 51 feet only.

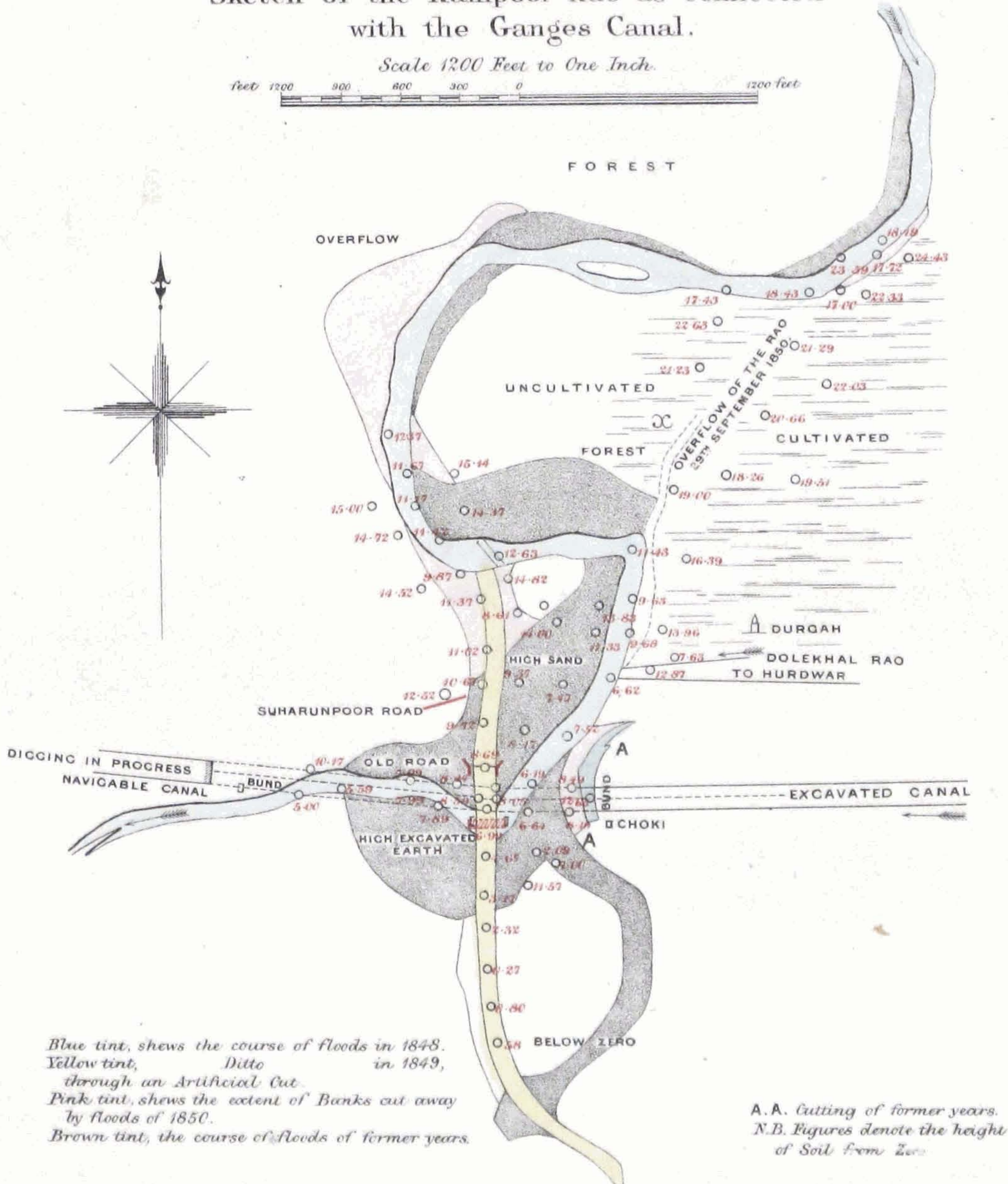
After a flood which occurred on the 19th June, 1849, the canal bed at the foot of the inlet had upon it a deposit of 3 feet of sand; light floods occurring on the 25th and 26th of the same month raised this deposit 2 feet, making a total depth of sand at the foot of the inlet equal to 5 feet. During the month of August following, a succession of floods still further added to this accumulation of deposit, until, at the termination of the rains, neither dam nor inlet (with the exception of the upper portion of the flanks of the latter) were visible; they were, to all intents and purposes, buried, and the bed of the river had formed itself on a natural slope, entirely independent of the works which we had constructed for its accommodation. A perfect detail, both in plan and section, of the state of the Ranipoor Torrent, before and after the rains of 1849, will be found on the opposite page. The results, in the very rapid extent of deposits, were by no means anticipated; the slope upon which the escape was designed was, it will be observed, very considerable, and although the comparative width of this escape was small, and might, in some degree, add to the evil already existing of the capabilities of inlet and discharge not being in equilibrium, either in slope or capacity of channel, I considered that the nature of the current acting upon a soil of a light and sandy description, would, by widening out the artificially excavated channel, dispose, in some measure at least, of these difficulties. It was not overlooked that deposits would necessarily take place upon the line of channel south of the masonry inlet, but it was considered that these deposits would be of a nature, that would render their periodical removal a matter of very little difficulty; and that, in fact, when the canal was opened, and the cross current which it would give rise to came into action, that the interference from these deposits would be of no consequence at all.

Now the effects that are above described are by no means dissimilar to a re-disposition of sand on natural slopes which occurred in the Nogong River, one of the torrents connected with the Eastern Jumna Canal; and as the case in question is exceedingly illustrative of the changeable nature of these sandy beds, and of their disinclination to be interfered with, I shall make no apology for introducing the subject here.

The Nogong dam is a masonry building, constructed across the bed of a torrent, which has a catchment basin of about 56 square miles, 25 miles of which are moun-

Sketch of the Ranipoor Rao as connected with the Ganges Canal.

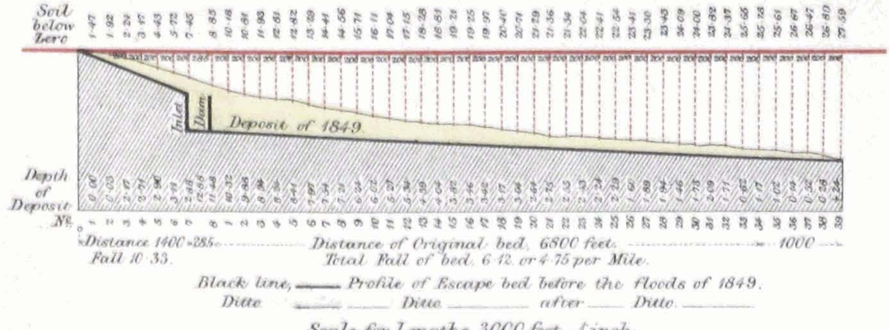
Scale 1200 Feet to One Inch.



Blue tint, shews the course of floods in 1848.
Yellow tint, Ditto in 1849, through an Artificial Cut.
Pink tint, shews the extent of Banks cut away by floods of 1850.
Brown tint, the course of floods of former years.

A.A. Cutting of former years.
N.B. Figures denote the height of Soil from Zero.

Section on the Ranipoor Escape, shewing the levels of the bed before and after the Rains, 1849.



Distance 1400 = 285. Fall 10·33. *Distance of Original bed, 6800 feet. Total Fall of bed, 6·12, or 4·75 per Mile.* *1000*

Black line, Profile of Escape bed before the floods of 1849.
Ditto ——— Ditto ——— after ——— Ditto.

Scale for Lengths, 3000 feet = 1 inch.

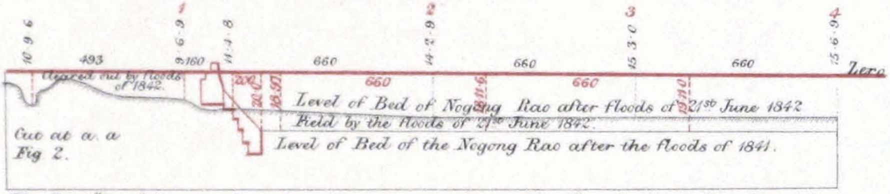
Scale for Depths, 60 feet = 1 inch.

Copied by Kadir-Bukhsh, 27th August 1853. London: Smith, Elder & Co. 65, Cornhill.

DIAGRAM V.

Fig. 1.

Section across the Dam down the Bed of the River.



The Bed "Zero" line in the above Section represents the True level of the Canal bed and that of the River in 1828-29 when the Nogong Dam was constructed.

Fig. 2.

Survey of the Nogong River as it existed after the destruction of the Dam. Shewing the Canal Stream turned down its new course into the Belka Cut a. a... a. a. Bund built after the destruction of the Dam to turn the Canal Water into the Belka Cut.

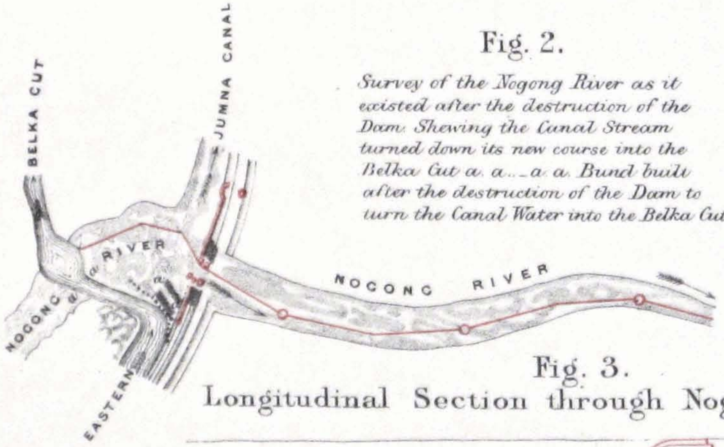


Fig. 3.

Longitudinal Section through Nogong Dam (Old).

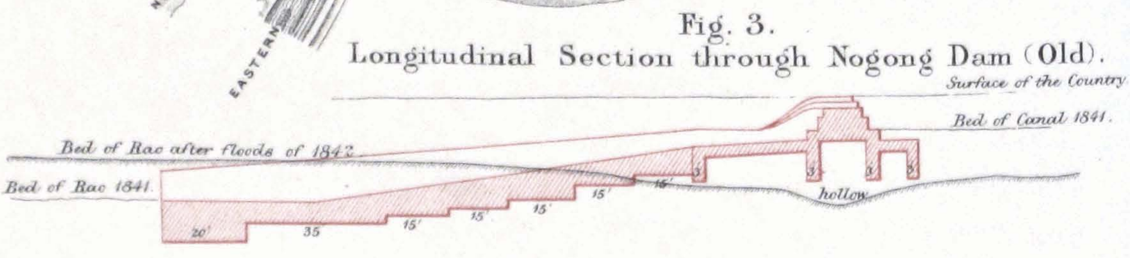
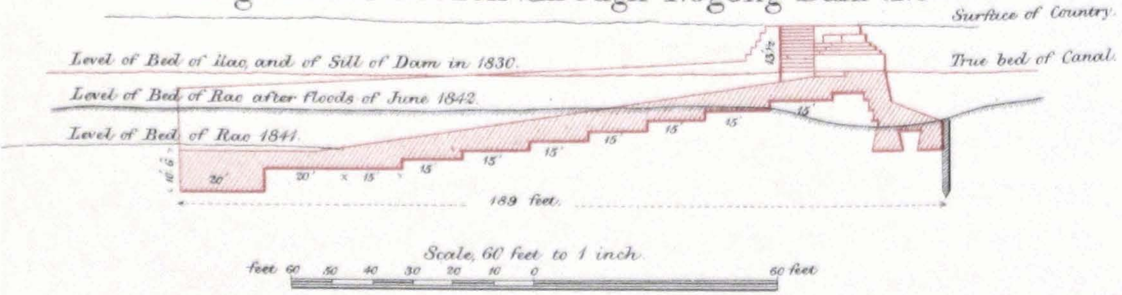


Fig. 4.

Longitudinal Section through Nogong Dam (New).



London: Smith, Elder & Co. 65, Cornhill.

tain, and the remainder open forest and jungle country lying at its foot. The dam itself is situated at a distance of 7 miles from the hills, and the slope of the bed of the torrent at the point upon which the building was constructed was $11\frac{1}{2}$ feet per mile. There were twenty-four sluices, of 7 feet width, adapted to the centre of the river's course; the eight centrical ones having their sill or flooring 2 feet, and the side ones having their sills 4 feet, above the bed of the river. The piers of these sluices were from the bed of the river 6 feet in height, and above this point the floods passed over the dam in one unbroken sheet of water.

At the time that this work was constructed, in 1828-29, the bed of the river, at the point where the dam was built, and both above and below it, was one uniform slope, with a section of 8 or 9 feet in depth from the surface of the country. (See diagram 5, figure 4.)

From the rains of 1830 to those of 1834, a constant succession of retrogression of level upon the masonry tail of this work took place. In the rains of the latter year a portion of the tail apron fell, and a new tail was constructed, partly of masonry and partly of timber and boulders, flanked by hurdles and fascines. This new tail was made on a slope adapted to the depressed level that the bed of the river had at that time assumed at and south of the tail of the dam.

At the commencement of the rains of 1841—that is to say, eleven years after the dam was constructed—the total width of the tail apron, which had annually been receiving an accession of material, was 80 feet on its transverse section. Year after year extensions had been made, and, as it was hoped, addition had been given to its stability. Early in the rains of 1841, however, a very heavy flood came down the Nogong River: the water, in its passage over this fearful rapid of boxwork (the bed of the river south of the tail being at this time 21 feet *below* the sill of the dam) turned the piling and hurdle work on the left flank, carried away that portion of the tail in its immediate proximity, and was only checked in its career of destruction by the masonry platform, over which it fell in an uninterrupted cascade of at least 15 feet in perpendicular height. The injury was of such magnitude, and the accident had occurred at a period when a succession of floods during the three following months were certain, that there was neither time nor material available for doing anything, further than making a moderate repair; and the only prospect that offered of preventing irreparable injury, was by passing off flood-water down the canal channel, and, if possible, putting the dam out of use for the rest of the season. It so happened that during the rest of the rainy season of 1841 the floods that came down the river were passed down the canal channel with the greatest ease, and, in so far, our arrangements were crowned with the most perfect success.

By a concurrence of unforeseen failures in the manufacture of materials, and chiefly in the deprivation of European superintendence, arising from sickness, the new works which, during the following cold weather, had been in progress for the protection of the tail, were only imperfectly finished when the rains of 1842 set in. These rains commenced with unusual violence; and on the 23rd of June a heavy and continued fall of rain, confined, it appeared, to the upper part of the Doab, led to the whole of the rivers connected with the Jumna being flooded to an enormous extent. The coffer dams, built for the protection of the sluices at the Nogong works, were either not or only partially removed; the floods swept over the works, which were imperfectly indurated, and carried away the whole of the centrical portion of the dam, leaving the side revetments standing, with a gap between them of 150 feet in width. (*Vide* diagram 5, fig. 2.)

This removal of an obstruction to the course of the current led to an entire revolution in the bed of the river; the abrupt step which I have before described as formed at the tail of the dam by a successive retrogression of levels was entirely obliterated; the bed of the river, after the flood had ceased, had assumed one uniform slope, and there was a deposit over a portion of the masonry tail (that, from the lowness of its position, had not been affected by the action of the flood water), of no less than 12 feet in depth of sand. A careful inspection of the plans and section of the Nogong River, with the different levels that the bed occupied—1st, at the period when the works were constructed; 2ndly, at a period antecedent to the occurrence of the accident, when the retrogression of the levels on the tail had arrived at their maximum; 3rdly, the state of the bed after the accident (*vide* diagram 5, fig. 3)—will be suggestive of interesting reflections on the nature and circumstances under which our canal works are placed in connection with these mountain torrents.

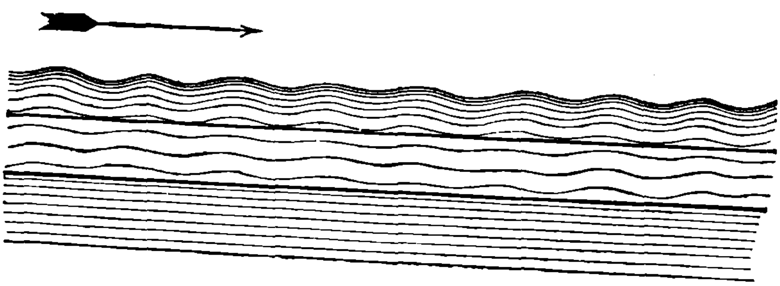
In comparing the effects at the Ranipoor with those at the Nogong works, we see, in the first case, an open and capacious inlet, with its sill placed 2·72 feet below the natural bed of the river, or at such a depth that the action of the current passing over the surface in its natural state would not in any way have interfered with it; in other words, that the regimen of slope and soil would not, by the intervention of the inlet, have been interrupted. We see the torrent pouring its waters over this inlet upon a lower line of levels, artificially excavated as an escape, the slope of which was reduced far below that which nature had designed for it. In the case of the Nogong dam, the sill of which was on the natural surface of the bed of the river, and consequently destructive to the regimen of the flow of current over a sandy bed, we see a torrent pouring its waters over an escape upon a depressed line of levels as much opposed to its natural distribution, as that on the artificially excavated outlet for the Ranipoor River; we see the obstruction of this dam on the Nogong River violently removed, and no sooner does Nature assert her own influence, than she at once returns to her uniformity of slope. There can be no reason for doubting that, although our experience of the effects of this accident at the Nogong dam only pointed to that of one rainy season, a succession of floods would, by a succession of deposits, have restored the bed to its original levels, as shown by the upper line in the section; precisely in the same way, in fact, as the succession of floods at the Ranipoor Rao acted in the restoration of the levels to their natural uniformity.

The question might, perhaps, have been one of degree in so far that the proximity of the Ranipoor works to the mountains, and the excess of slope upon which the torrent runs at the point of intersection with the canal, would have effected in one season that which, under peculiar circumstances, both in distance from the hills and reduced slope of the torrent, might not, in the case of the Nogong excavations, have been effected in many years. In both these cases, the natural effects arising from artificial causes appear to me to be very much the same.

The consequences of building masonry dams and platforms across the beds of mountain torrents running under circumstances like those of the Muskurra and Nogong Rivers, had, in both cases, proved that a retrogression of levels, and an attendant deepening of the bed of the river upon their lower side, were inevitable. Both these rivers run in well-defined sections, and their beds were considerably below the surface of the country. The slopes upon which the beds were maintained (in the case of the Muskurra 9½ feet per mile, and in that of the Nogong 11½ feet per mile), were clearly dependant on a natural regimen which admitted of an equability of deposit of moving masses of sand. The effects of destroying this regimen by placing a bar of masonry, or a bar of any material whose substance was more rigid and of a denser nature than the material that formed the bed of the river itself, might naturally be expected to result in a disarrangement to the uniformity of deposits below the bar, and in a power of wear and tear upon the bed given to the current at that particular point which, without any counteracting medium, the extreme slope of surface rendered unavoidable.

To explain my views on the above question, let us refer to the following diagrams, showing a portion of the course of a mountain torrent flowing over a sandy bed.

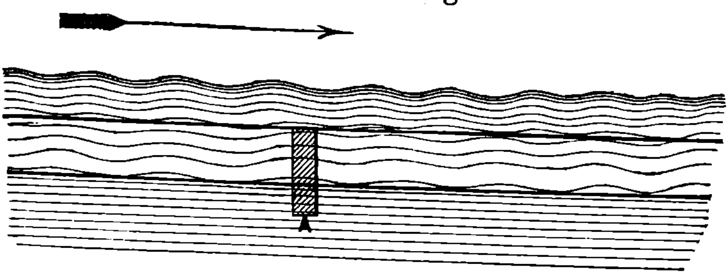
Diagram 6.



From the above diagram it will be understood that during the action of a torrent, the upper surface of the bed is under a forward movement; that the whole mass of sand of which the supersoil of the bed is composed is dislocated and torn up by the violence of the current; and that during floods, the sand and water are carried forward in a headlong course to the lower levels, where the former is either deposited by lateral inundations, or by meeting with levels running on a diminished slope; or, as is frequently the case with the torrents in the north-west, by its joining the great rivers, in the advancing volume of which its sands are engulfed. The above is a representation of the torrent in its natural state; and its action upon the sandy bed, as above shown, is, I believe, undisputed.

Repeating the above diagram, and introducing the disturbing element caused by a bar of masonry, or by the Nogong and Muskurra Dams, the position of which is effectively shown in the diagram, we appear to arrive at the following conclusions:—

Diagram 7.



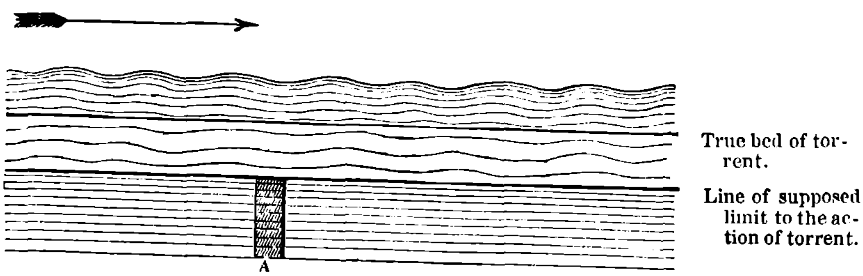
True bed of torrent and level of dam silt.
Line of supposed limit to the action of torrent.

1st. That the interposition of the bar A must necessarily act as a disturbing element in the uniform advancement of the sand; and that at this particular point, during the periods when floods are running, the tendency of the current in its full depth to rise over the bar A, leads to an increased velocity on its down-stream side, which must more or less influence the action of the current on the bed; and that this element, small as it may be, but connected as it is with the obstacle presented by the bar to the uniform progress of the sand, places the bed of the river on the down-stream side of the bar, under an entirely different regimen to that which exists on the up-stream side, and that this difference of regimen is in favour of a wear and tear upon the bed of the river below the bar.

2nd. That in the case of the dams on the Muskurra and Nogong Rivers, during the eight and a half or nine months when the beds of the torrents are dry, the leakage through dams, and the discharges of escape water, can only act in carrying matter forward ; and the slopes upon which this advanced movement is effected are on such an exaggerated scale, that the wear of bed and consequent retrogression of levels are inevitable.

Another and a third representation of the above diagram is illustrative of the effects upon the bed of the torrent, when the sill of a dam or bar of masonry is placed even with or below the line marked as that of "the supposed limit to the action of the torrent;" and its introduction here, as illustrative of matter that will hereafter follow, is convenient.

Diagram 8.



The sill of the dam A is here supposed to be below the semi-fluid matter in motion, and beyond the influence of the action of the current ; its existence, therefore, is harmless as far as disarranging causes are concerned, and as it in no way affects the natural habits of the river, its admission under any form or shape is legitimately safe, and this safety increases with the depression of the sill below "the line of supposed limit to the action of torrent."

The extraordinary accumulations of sand which were attendant on the floods of the Ranipoor and Puttri Torrents, with which we had to deal on the Ganges Canal works, and the action which they appeared to exert on the surface of the country, opened out new considerations as to the method of dealing with them. The alignement of the Ganges Canal came in contact with these torrents at points high upon their courses, and in regions where, in escaping from confined channels, they poured over the surface of the country, sheets of sand. Across these extensive areas the line of canal had to pass under the difficulties of its bed levels, being in one case 12·725 and in the other 9·57 feet below the surface. The circumstances under which the Jumna Canals came in contact with their torrents, were in no way coincident. The line of the Ganges Canal, on its course between the Ranipoor and Rutmoo Torrents, was literally (unless some other means than those originally devised were projected) a catch drain of very imperfect dimensions for the silt brought down from the mountains by the periodical floods.

It was evident, in fact, from the experience that we had gained by observing the Ranipoor works during the floods of 1849, that the quantity of sand annually brought into the canal channel, under the projected plan of works, would be enormous, and that an influx of silt equal in extent to that of 1849, if to be annually expected in each of the two torrents referred to, would not only lead to the greatest expense and annoyance hereafter, but that in the working of the canal the evil would be unbounded.

The only efficient remedy that suggested itself for overcoming the difficulties arising from these silt-bearing torrents—namely, passing the floods over, instead of through, the canal channel—was one which, from the enormous expense attendant upon its adoption, and from the time and labour that would be required to complete it, was naturally open to reasonable objection: it implied excavation from the low levels in the Rutmoo Valley back to the Puttri, through the heart of the springs (which I have before described as existing in the Badshahpoor Nulla), on a distance of no less than three miles. It implied a similar operation, under more favourable circumstances, with regard to springs on a line of upwards of a mile to the Ranipoor Valley, and it necessitated a total and complete redistribution of the masonry works, and, what was of equally material consequence, it implied also a complete rearrangement of the drainage. The plan of passing the Ranipoor and Puttri Torrents over the canal might be compared to a design for disposing of the Nogong and Muskurra Rivers over the Eastern Jumna Canal by a similar process, in which the low levels of the Belka falls in one case, and the low levels of the Bobyl and Nugla falls in the other, would be carried back to points in the canal channel above those of its intersection with the courses of the torrents.

Before any determinate measures could be recommended so seriously affecting the amount of the original estimate, as the remedy to which I have just alluded would lead to, it was necessary to examine, with a mind as unprejudiced as possible, the existing causes and effects of the sand deposits, bringing to this examination our experience on the Jumna Canals, combined with that which we had so lately gained in the case of the Ranipoor Rao, and thus deciding the general question as to the method that could be best adopted for meeting the difficulties of the Ganges Canal works in their existing state of progress.

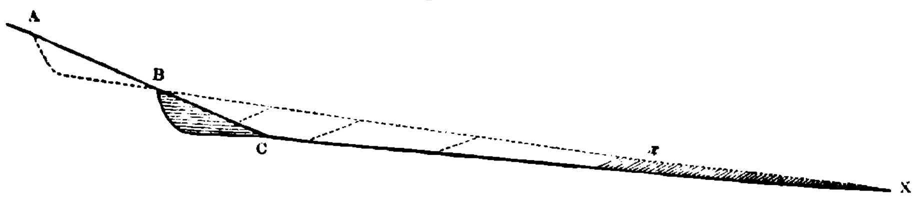
The question was thus brought within defined limits, and it appeared to me to resolve itself into the following argument:—

The natural law by which the phenomena alluded to were guided, was to be explained on the principle which was well known as operating on artificial lines of canal, both in these provinces and elsewhere, where the early part of the courses of the channel runs on extreme slopes through deep sections excavated through a light sandy soil, and on beds inadequate to withstand the attrition of the current. The phenomena here alluded to have been too practically exhibited on the Eastern Jumna Canal to require any further consideration; they are, in fact, an exhibition of that law in nature which makes running water regulate its own course and its own declivity; this, in running rivers, being most apparent in tortuosity of direction; in artificial lines (where tortuosity is prevented by embankments) in an adaptation of the bed or declivity of channel by deposits of silt to the regimen due to velocity of current.

The Eastern Jumna Canal affords a good exhibition of the law in artificial lines.

The upper, or northern, portion of this canal was excavated on an excessively steep slope, in a light and sandy soil; the lower, or southerly, portion on irregular and moderate slopes, and through good, firm soil. The results of this distribution of slope were, after a very limited period, shown in a manner represented by the following diagram, where the line A B C X shows the original

Diagram 9.



bed upon which the canal channel was excavated, and the dotted line B x X the slope which the current adapted itself to.

The process by which the new slope was arrived at is thus explained. The velocity of the current led to an abrasion of the bed at B C, as represented by the shaded portion of the diagram. The soil thus abraded was carried forward until, by a decrease of the velocity of the current, arising either from diminution of slope or from decrease of volume, the water was no longer able to retain the matter in suspension, and at the point x the first deposit established itself; in the rear of this deposit a stillness of water, added to the causes before-mentioned, led to further deposits, and by a gradual, but very evident process, the whole space X C B x was filled by deposits retrograding from X to B, as shown by the dotted lines.

A further retrogression of the wear and tear at A in the canal bed, led to a deposition again in advance of the point X, with an after process corresponding in every respect with that before explained; this continued until the retrogression at A was put a stop to by the intervention of masonry works built for the purpose. For the particular object of the present argument, there is no necessity to carry the explanation further, but it is sufficiently illustrative of the effect of silt-loaded waters, running on irregular slopes in an artificial and embanked channel.

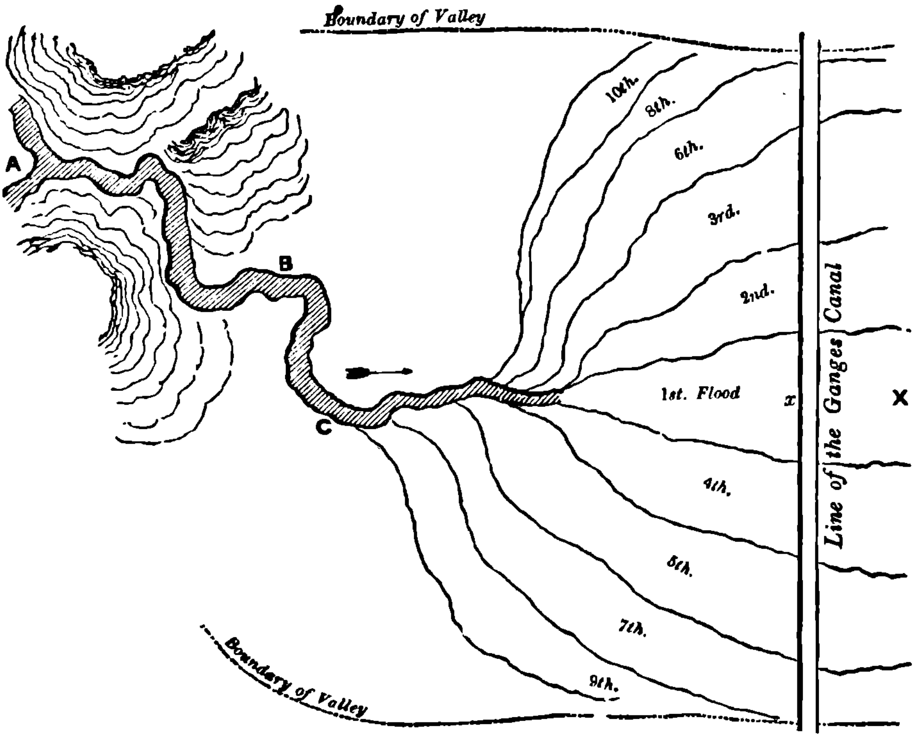
We will now consider a case where the channel has no embankments, and where the water perpetually loaded with silt flows over the surface of the country.

It is clear that the precise point x, at which the deposition commences, is necessarily determined by the power of the water to carry silt forward; in an embanked channel this power will act to a considerable extent and on long lines, checked only by a decrease of volume (arising, in irrigation canals, from expenditure on watercourse heads), or by decrease of the slope. In lines not embanked, the water, from spreading over the country, is immediately subjected to a reduction of velocity, and, consequently, has an immediate inclination to get rid of all heavy matter by deposition: the point x will, therefore, in this case, be situated closer to the field of abrasion; at any rate, *it will exist* at some point or other in the course of the river, and, as I have before shown, at that point where the velocity of current is inadequate to hold matter in suspension.

Whether, therefore, the channel is embanked or not, the same laws operate in both cases; the same ends are obtained by a process similar in every respect, although under different circumstances.

In the following diagram, using the same letters as before, is represented, in plan or map, the surface of a

Diagram 10.



country where the channel has no embankments, and where the water, perpetually loaded with silt, flows over it; A C having a steep slope, and C X a comparatively moderate one.

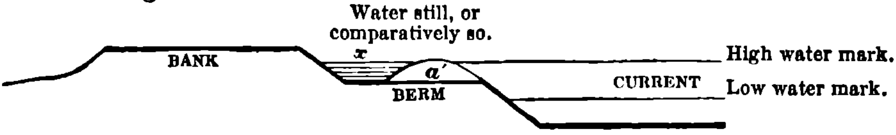
The line of river from C to x would run on a tortuous course, spreading and throwing up to the right and left slight deposits, as may be observed in the region of all alluvial rivers,* on its gaining the surface of the

* Where a silt-bearing river separates into two branches, either at different angles to the main stream, or on different slopes, that branch having the least slope, or at the greatest angle, will have a tendency to silt up. It is thus with the outlets and escapes from our canals, which being on a less slope than that of the main line, and in most instances being at right angles to it, have always a tendency to silt deposits at their mouths; so also at Cattle Ghats, and at still places on the right or eft of the stream.

To see this in a practical point of view, look at the Rajbuhas, or main lines of water-courses on the Jumna Canals, and the periodical clearances of silt which they require ; the deposits in these Rajbuhas never extend more than one or three quarters of a mile from the main stream ; from a rapid deposit of coarse sand at the point of departure, they dwindle off to that of the finest mud; the whole progress of a deposit may be observed, studied and understood by any person who will from the Rajbuha head walk down its course.

In silt-bearing rivers, the waters of which, during floods, spread over the country to the right and left, the water, on leaving the main current, immediately has a tendency to deposit the matter suspended in it, the disposition of the deposit depending upon the gravity of the matter in suspension. This deposit is exhibited in a talus sloping outwards, and away from the river. Any person travelling along the Jumna Canals, where the height of the surface water is very variable, and where the water is loaded with silt, will observe the deposit on the berms, and may even see the action in progress, thus:—

Diagram 11.



a' being the silt deposit, and x either a trifling stream or standing water.

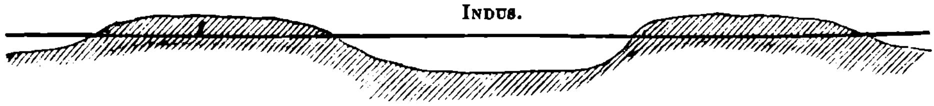
The same is apparent in the Khadir lands of our mountain torrents, only on a larger scale, the hollow x being invariably exhibited in either nulla or marsh at the foot of the high land skirting the valley. The same is seen in the high steppes of the Ganges and Jumna (which, although now far removed from the action of the river, which has excavated for itself a course on a lower level), where a nulla or marsh invariably exists, as the representation of x: this is clearly seen in the country where, unshackled by any channel or section, the water, by spreading, would lose all power of holding matter in suspension, the deposits would take the form as represented at *x*, terminating in a fan-shaped field of silt, which would assume a convex form (as may invariably be observed in deposits of this sort), and would exhibit the remarkable appearance which is so recognizable in the Ranipoor and Puttri Torrents, where the bed of the river, after the rains, is on a higher level than that of the neighbouring country.

I have by dotted lines shown the limits of the basin in which the floods are supposed to act, the tendency of such action being undoubtedly to raise the surface of the valley; the course of the preceding year could not, from its elevated position, be that of the next; this next flood would throw out another fan of sand laterally situated to

Gosainwala marsh, and in others in that neighbourhood in the Eastern Doon, as well as in the lower flats of Bhogpoor, and similarly situated land on the Jumna.

On the Indus the most magnificent exemplification is shown of the same law, where for a mile on each side of the river's course the land is elevated, whereas the surface of the distant country is below that of the water of the river. The following section of the Indus, for which I am indebted to my friend Major W. E. Baker, of the Bengal Engineers, is literally that of an artificial canal with embankments, the latter being composed of silt deposited during inundatioms.

Diagram 12.

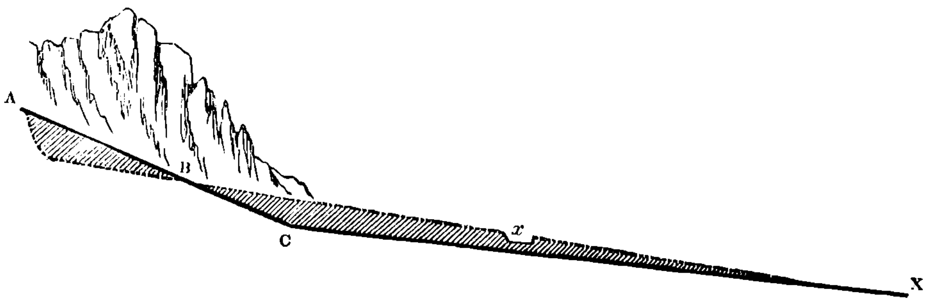


The fan-like and convexical form which deposits assume, when silt-bearing water, running on a steep declivity, escapes from its channel and spreads over the surface of the country, is too conspicuously shown at points on the Eastern Jumna Canal, where fractures have taken place in embankments much elevated above the surface of the country to have escaped the attention of men in the Canal Department; but the rationale is too clear to require further explanation, when the effects of deposit depending on the velocity of the current, and the gravity of the suspended matter, are taken into consideration.

that of the preceding year, and so on annually, as figured in the diagram, until a deposit similar to that at *x* would be distributed over the whole surface of the valley. This would, it may naturally be supposed, lead to the same action as was before described as occurring on the artificial line of channel, with consequences precisely the same, and, to use the words of a former paragraph, by a gradual and very evident process, the whole space, X C B *x*, would be filled by deposits retrograding from *x* to B, as shown by the dotted lines in diagram 9.

Now, let us consider that in the case of the Ranipoor and Puttri Torrents (which strictly deserve that name from their being perfectly dry, excepting during floods), and the deposits of sand which occur at that part of their course where the canal comes in contact with them; the letters A B C of diagram 13 represent the Sewalik Hills,

Diagram 13.



with their steep slopes, having a perpetual tendency to degradation, from the quantities of shingle and sand which are carried out of them during every flood; and that B X is the tract at their foot through which the Ganges Canal takes its course, as represented by the depression at *x*. Now repeating the diagram as a representation of a longitudinal section through the map in diagram 10, we have the Ganges Canal at the point *x* excavated *in* the deposit, and actually in the position of a catch drain, for the reception of all the detritus brought down from the hills A B.

It is a point, moreover, most especially worthy of attention, that the very fact of the above two rivers being torrents, and not perennial streams, is greatly in favour of deposits at their immediate debouche from the mountains. The floods are, in fact, spasmodic disgorgements of heavily silt-laden water spreading over the surface of country, and frequently losing themselves by absorption and other causes before they reach the rivers to which they are properly tributary.

Under the above view of the question it appeared to be impossible that any works, constructed on the principle of passing flood-water through the canal, could (situated as I have described the works to be both in position and level) be free from very extensive deposits of sand, nor would it have been practicable to maintain the escape from the canal, and in the direction x X, as open and efficient channels, without annual and most extensive clearances. Having arrived at these conclusions, and being justified by the results of the floods of 1849 on the Ranipoor works, I considered that the following facts were established :—

1st. That the canal channel, under the project of 1845, would be subjected to greater deposits of sand than were before anticipated.

2nd. That, consequently, the annual outlay for getting rid of the inconvenience would be very heavy.

3rd. That the whole state of the question gave me legitimate grounds for incurring increased outlay, where the object to be attained was one of such immense importance in ultimate economy.

It may be hardly necessary to observe that, in illustrating the above argument, both the diagrams themselves and the descriptions, as far as time is concerned, are exaggerated in every sense; that the time occupied, when nature is not interfered with, in gaining the results to which I have drawn attention, runs through an infinity of ages; that thousands upon thousands of years have been expended in gaining the configuration of the earth's surface, as it now exists in the region upon which the canal takes its course; that the process is so slow that human life and human intellect are incapable of appreciating it. But degradation of matter is certain. The Sewalik Hills, which are now such an ornamental feature of our world, will, in the course of time, dwindle to nothing: their substance has been for ages, and will be for another succession of ages, undergoing dispersion over the earth's surface. The land at the foot of the Sewalik Hills is, year after year, rising in surface as the hills themselves fall to pieces; and although the immeasurable periods at which great changes take place are not matters to be considered in human undertakings, a steadily proceeding cause like that alluded to above, in which there is a perpetual tendency to deposit, assured me of the correctness of the results at which I had arrived, in maintaining the course of the canal and that of the hill torrents distinctly separate.

In recommending, therefore, that the course of the Ranipoor and Puttri torrents should be carried over that of the Ganges Canal, I observed that if the phenomena attendant on the regimen of the slopes of the mountain torrents at that particular point of their course where they came in contact with the canal works, were as I had stated, it was evident—

1st. That it would be an evil of the first magnitude to let these torrents, with their silt, enter the canal channel.

2nd. That if a super-waterway for the passage of the torrent is made of sufficient width, there will be no tendency to wear and tear on the water passing from the masonry super-passage to the soil of the surface of the country.*

3rd. That as there is no tendency at this particular point to a retrogression of levels, the torrent may be carried over the canal with perfect security.

The advantages of passing the floods over the canal were, in every respect, undeniable: they resolved themselves into the following:—

1st. Utter freedom to the canal channel from silt, and the evils arising from the contact of two streams meeting each other at right angles.

2nd. Freedom from all the wear and tear of channel necessary on the admission of the torrent into the canal bed.

3rd. Freedom from the anxiety of opening and shutting sluices, and regulating the escape at the dams.

4th. Freedom from all establishment for working the dams, and a consequent reduction of a large permanent establishment necessary for their maintenance.

On the other side was the enormous additional expense, which it was hoped would in a great measure be neutralized by the ultimate saving on establishment, silt clearances, and general repairs.

In my letter of the 12th of April, 1853, the arrangements depending on the improved project were thus stated:—

" Super-passages, therefore, for the torrents will be constructed on the main channel at the Ranipoor and at the Puttri Raos. In the first case, the first fall at Baha-

* It was not meant, by the expressions above used, that there would be no tendency to excavation at the immediate tail of the work; but that this excavation would be a mere local evil, subject to being filled in, more or less, on the subsidence of floods, and not one affecting the downward levels of the escape.

Fig. 1.
Plan of the Ganges Canal.
From the Ranipoor to the Rutmoo River,
Shewing the position of the Works as originally projected
in 1845.

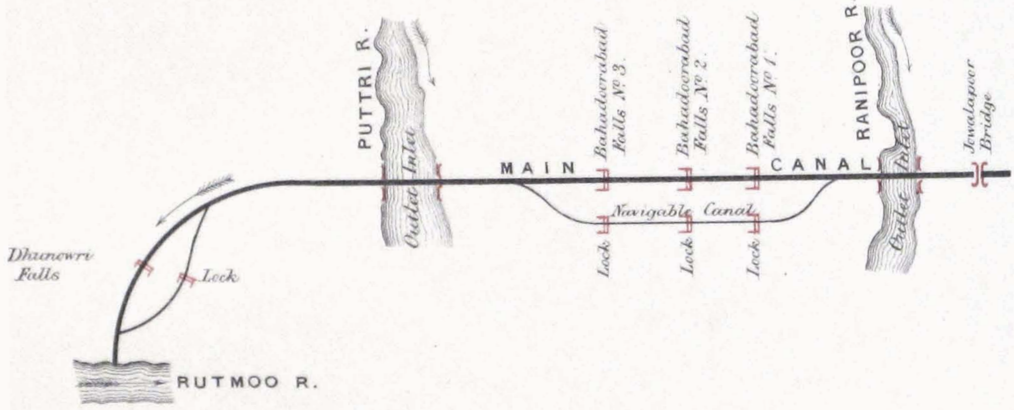
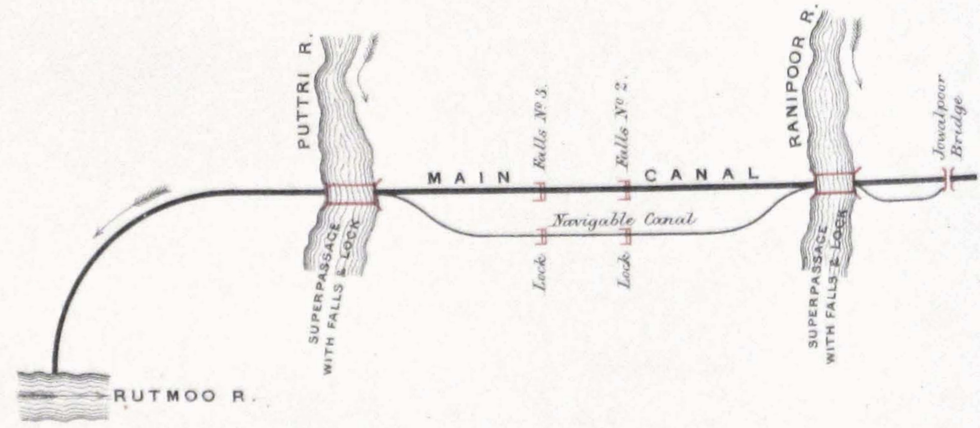


Fig. 2.
Plan as above
Shewing the position of the Works as projected in 1850.



On no Scale

London: Smith, Elder & Cº 65, Cornhill.

DIAGRAM XV

TRANSVERSE SECTIONS OF THE GANGES CANAL AT THE POINT WHERE THE RANIPOOR (TORRENT) RIVER CROSSES IT.

The dotted lines -------- represent the direction of the Stream in the Ranipoor River under the different plans proposed.

Fig. 1.
Agreeably to Project of 1845.

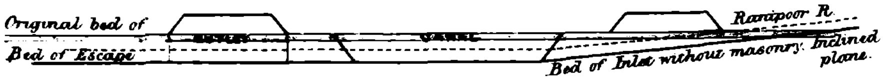
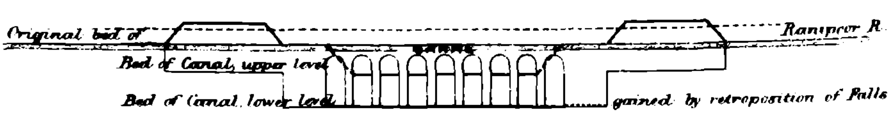


Fig. 2.
Agreeably to Modification of 1849.

Fig. 3.
Agreeably to Project of 1850.



On no Scale.

doorabad will be moved back to a distance of 5,748 feet (1 mile and 468 feet); in the second case, the Dhunowri Falls, which in the original project are situated on the left bank of the Rutmoo River, will be moved back to a distance of 15,630 feet (3 miles nearly); in other words:—

"1st. The first Bahadoorabad Falls and Locks and the Ranipoor Inlet and Outlet of the original project, will become one work.

"2nd. The Dhunowri Falls and Locks and the Puttri Inlet and Outlet will be united."

The general design of the works, arising from this change of disposition of slopes and method of dealing with the cross drainage, will be very clearly understood by a reference to the accompanying outline, which shows the details of the works from the Jowallapoor Bridge to the Rutmoo torrent, both on the project of 1845 and on that which has just been explained of 1850 (*vide* diagram 14).

With these outlines, as well as with the transverse sections (*vide* diagram 15), explanatory of the different methods of passing the torrents over the canal channel, before him, the reader will without difficulty be able to comprehend the precise nature of the change that had been effected, and the position of the different works as they have been actually executed.

With regard to slope, the bed of the canal, on the sill of the Falls No. 1 at Ranipoor, was maintained on its original level. The falls, which were nine feet in perpendicular descent, although constructed in the form of an ogee, delivered the water on a channel 143 feet wide, with a slope of bed equal to 1·052 per mile, and extending on a line of 9,742 feet to the sill of the No. 2 Bahadoorabad Falls. A descent of 9 feet at this point, delivered the water on a channel 170 feet wide, with a slope of bed equal to 1·3 feet per mile, and extending on a line of 2,696 feet to the sill of the No. 3 Bahadoorabad Falls; a descent again at this point of 9 feet delivered the water on a channel of 160 feet wide, with a slope of bed equal to 1·2 per mile, and extending on a line of 11,963 feet to the sill of the No. 4 Puttri Falls; from this point, where the last masonry descent occurs, the water is delivered on a slope of 1·21 feet per mile, which terminates on the flooring of the Dhunowri Bridge.

It will be observed, therefore, that the uniform slope of 18 inches, which was designed in the project of 1845, was very considerably reduced, the reduction having been gained by giving an additional twelve inches to each of the masonry descents. To meet this reduction of slope, however, additional width was given to the channel from the tail of the Ranipoor to the head of the Puttri works, south of which the interruptions which were met with from springs led to a modification of the dimensions which were elsewhere put into practice.

The direction of the canal was, in many respects, similar to that of the original project. Both at the tail of the Ranipoor and at that of the No. 3 Bahadoorabad Falls, however, there was a change of direction of $5\frac{2}{3}$ deg. to the right. With the exception of these changes, the canal was carried on a direct bearing to the village lands of Dhunowri. Here a curve on an angle of $62\frac{1}{4}$ deg. tangential to the line of channel on its approach to Dhunowri, and to a direct line bearing upon Roorkee, delivered the canal on the Rutmoo River. At this point the gentle curve upon which the line of canal was, in the project of 1845, brought down upon the Rutmoo River, was, for reasons to be explained, hereafter rejected; the more abrupt turn, with sides well protected by masonry revetments, being preferred.

The soil through which the excavation was to be carried was of a light description, but by no means unmixed with clay; shingle in small quantities was met with here and there, and as far as the head of the Puttri Falls no spring water interfered with the excavation. The retro-position of the first set of falls led to excess of digging of 9 feet in depth on a length of 5,748 feet, with its attendant increase to the dimensions of slopes. From the head of the Puttri Falls, however, to the Rutmoo River—on which, by the proposed plan, an excess of depth of 13 feet on a length of 15,630 feet was to be excavated—the difficulties arising from spring water were very great. The detail of these difficulties will be found in its proper place, when the canal excavation is brought under general review.

The passage of the Ranipoor Torrent over the canal is obtained by throwing arches over the lower levels of the falls, the waterway of which was divided into eight parallel descents of 25 feet in width, with a passage of 19 feet in width on the left for the navigable channel. The inlet and dam which had been already built were embedded in the side walls or abutments of this new building, so that the masonry of the old works was disposed of in the most economical way. The super-passage, which rested on the arches thrown over the bays of the falls, has a clear waterway of 200 feet in width, with all the necessary appliances for its protection on the ingress and egress of the torrent.

The Bahadoorabad Falls, No. 2 and No. 3, which are situated immediately below the Ranipoor works, are provided with a waterway of 200 feet each, in eight bays of 25 feet each. Below the No. 3 falls, and on the right of the canal, the Selimpoor inlet (which is constructed exactly on the same design as that built at Jowalapoor) admits into the canal channel the drainage which I have before described as unconnected with the hills, and subordinate to that of the Puttri. The width of waterway of the Selimpoor inlet is 150 feet.

The Puttri superpassage, which is 300 feet in clear width of channel, is arranged, with reference to the falls and navigable channel, precisely in the same way as that before described at the Ranipoor works. All the necessary appliances for its protection from the ingress and egress of floods have been carefully adopted.

On the right of the canal, at a point 10,804 feet below the Puttri works, an inlet, with a waterway of 50 feet in width, has been constructed for the purpose of admitting the stream and floods of the Badshahpoor Nulla. The design of this work is similar to that which has been universally adopted for inlet purposes.

The Rutmoo dam is approached by well-protected masonry revetments, for the purpose of securing a safe change of direction to the course of the canal on its approach to the river. The river is crossed by both inlet and outlet, and is cut off from the works on the Peeran Kulleeur ridge by a regulating bridge, constructed on the same scale, and fitted with the same apparatus, as that at the canal head at Myapoor.

This bridge gives the means of cross-communication over the canal on the right bank of the Rutmoo River; whilst a plain bridge, which has been built across the revetted portion of the canal channel on its approach to the Rutmoo, gives the means of cross-communication on the left. The dam is fitted with sluices, which give a waterway of 600 feet; over the pier-heads, which are 10 feet above the bed of the canal, the works afford a flush escape for flood-water equal to 800 feet in length.

The distribution of escape from, and inlet to, the canal channel from the Myapoor regulator to the Rutmoo dam, as designed in the estimate of 1845, and compared with those which have been adopted on the explanations of 1850, may be thus described :—

—	1845.		1850.	
	Inlet.	Outlet.	Inlet.	Outlet.
Lounda Leni Wala . . .	20	20	50	—
Kunkhul	10	—	50	20
Jowalapoor	—	—	100	—
Ranipoor (inlet free) say . .	131½	131½	—	—
Selimpoor ditto say . .	23½	23½	150	—
Puttri ditto say . .	131½	131½	—	—
Gurh ditto say . .	23½	23½	—	—
Badshahpoor	free	free	50	—
Rutmoo	796½	796½	800	800
Totals .	1,136½	1,126½	1,200	820

In other words, in the early project the whole of the drainage to the right was to be passed off by escapes equal in width to 1,126½ feet; whereas in that of the latter date the whole of this drainage, minus 500 feet in width, is passed off through 820 feet of opening. The new project does, in fact, therefore, give an escape of 829 + 500 = 1,320 feet, or 193½ feet *more* than that originally contemplated.

It is questionable whether the amount of drainage which, on the project of 1845, was admitted *into* the canal by apertures left in the embankments, would not have affected the canal supply passing down upon the Rutmoo dam to an equal, if not greater, extent than the numerous inlets which have been latterly designed. The admission, however, of so much water without any apparent escape for it, as is given at the Lounda Leni, Jowalapoor, Selimpoor, and the smaller inlets, is a more palpable evil; it is, nevertheless, more so in appearance than in reality, the breadth of inlet by which, in the

N 2

foregoing table, the amount of volume has been estimated, having been given to facilitate the ingress of floods over an expanded surface, and thereby to relieve the canal channel, as much as possible, from the effects of a confined and contracted waterway.

With a view, however, to meet the contingency of an overloaded canal channel, the embankments on the left, and immediately opposite the inlet at Selimpoor, have been omitted, so that on any extraordinary rise of high water the flood may pass over. The expedient is an awkward one, as in so doing the navigable channel, which runs parallel, although at some distance from the canal on the left, would be swamped. The cost, however, of the restoration of this line of channel would be trifling to the damage that might otherwise be inflicted on the main line of works; and, after all, the contingency of floods of this sort occurring is one that is hardly to be expected, although it is better to be prepared than otherwise.

The navigable canal channel, which, in the original project (*vide* the sketch which has been given in a former page, diagram 14, fig. 1), left the main canal at a distance of 4,000 feet from the head of the falls, and re-entered it at a point below them, has, in consequence of the reprojection of the drainage works, been considerably modified, and very greatly improved.

The head of this channel now (diagram 14, fig. 2) leaves the canal on the left bank immediately *above* the Jowalapoor bridge, of which the works form a component part. By placing the head in this situation we hold the means in our power of preventing rafts and craft of any description that may pass down the canal from coming in contact with the descents or cataracts, as they may be called, by which one superfluous slope has been disposed of, and we thereby give an increased security to the navigation.

After leaving the Jowalapoor bridge, the line runs parallel to the canal, and reaches, by a masonry channel brought down by a gentle curve, a lock with a drop of 9 feet, situated on the left, and forming the left bay of the Ranipoor superpassage.* After passing the lock, the masonry channel goes off in another gentle curve, and delivers the water on an excavated channel running parallel to, and at a distance of 900 feet from, the line of the main canal. On this portion of its course the descent of country which is passed in the main canal by No. 2 and No. 3 falls, is overcome by locks of 9 feet drop each; the navigable channel on its approach to the falls and superpassage of the Puttri Torrent enters a masonry channel, which meets the superpassage, and passes the descent in the same way as I have described at the Ranipoor works.

At this point the navigable line rejoins the parent stream.

The arrangements made for the passage of boats at the Ranipoor and Puttri works are in every way adapted to security. The masonry channel—which, at these points on the navigable line, is entirely separated from the stream of the main canal (with which, excepting for lock and supply purposes, it has no connection whatever), not only renders the approach to the superpassages and the de-

* At the head of the lock chamber at the Ranipoor superpassage, the masonry channel is divided into two; that one the right, which is 16 feet in width, giving the drop for lock purposes; the other, or that which is situated on the left, which is 10 feet in width, continuing on the upper levels under the superpassage, for the purpose of supplying mills for grinding corn at Bahadoorabad. At the intersection by this channel of the curve of the navigable line, which is situated directly below the superpassage, a crossing is effected by an aqueduct, from whence it proceeds to a cluster of mills, which are constructed on the site of the No. 1 locks of the project of 1845. By taking advantage of the means at my disposal for establishing a channel for the water under the superpassage of the Ranipoor Torrent, I was able to get efficient head supply for the mills, which could not well have been obtained otherwise.

scent to the locks convenient, but places boats and rafts in their passage out of all danger.

I may here remark that the progress of these extensive works which the changes involved, was greatly facilitated by the use of water conveyance from the canal head downwards, and in the cheap and ready supply of boulders or river stone which this mode of conveyance introduced on the works. The canal excavated for this purpose was a mere channel 10 feet wide, formed in the bed of the main canal, and carried a supply of water brought down from the branch of the Ganges, which passes under the town of Hurdwar.

My original intention was to have kept this an open line for the supply of material to all the works as far as those on the Rutmoo River, for which it was in the highest degree appropriate ; circumstances, however, prevented the carrying out of this intention to its fullest extent, and the advantage of water-carriage was limited to a supply of material for the Ranipoor and other works which were subsequently constructed. The benefits gained, however, by this limited use of the canal were great, and, in lieu of the difficulties and delay in land-carriage, of the highest importance. The introduction, moreover, of a constant supply of water on the surface of a country where the springs were at great depths, was not only a great convenience to the workpeople in providing water for the purposes of cooking, drinking, &c., but it kept up a constant supply for the brick-fields, thereby facilitating the manufacture of bricks : and, finally, what was in my estimation of infinitely greater value and importance, it provided an unbounded supply for the bricklayers in laying the bricks into the work with mortar thoroughly mixed, and with bricks and mortar thoroughly moistened. This ready, although artificial, supply of water, in fact, enabled us to meet a want at the Ranipoor, which, at the Solani and

Puttri works, the water from surface-springs naturally provided for.

The works from the Ranipoor to the Rutmoo torrents consist of—

1st. The Ranipoor superpassage, with a waterway of 200 feet in width, connected with falls No. 1, having a drop of 9 feet in the bed of the canal.

2nd. The falls No. 2, with a drop of 9 feet.

3rd. The falls No. 3, with a drop of 9 feet.

4th. The Selimpoor inlet, 150 feet opening.

5th. The Puttri superpassage, with a waterway of 300 feet in width, connected with falls No. 4, having a drop of 9 feet in the bed of the canal.

6th. The Badshahpoor inlet, 50 feet opening.

7th. The Rutmoo dam and inlet, with escape of 800 feet, and a bridge for the purpose of regulating the canal supply, and of cutting off the canal stream from its passage onwards towards the Peeran Kulleeur excavation and the Solani aqueduct, together with a bridge for cross-communication north of the works.

8th. Line of navigable canal from the Jowalapoor bridge to the tail of the Puttri superpassage.

From the Rutmoo regulating bridge to the high land of the Doab, the canal runs in an uninterrupted straight line, passing *between* the village of Peeran Kulleeur and the Durgah, *between* the villages of Bajooheri and Mahewur, and reaching the high land immediately to the east of the town of Roorkee; from thence, by a curve to the left, which commences at the terminal point of the aqueduct, the channel proceeds in a straight line to the Assoff-nuggur falls, at which point the first division terminates.

The deviations from the original design on this portion of the canal's course (laying aside building details, which will be referred to in their proper place) consist entirely in a reduction of the slope of the bed. The original plan was, as I have before said, to continue the slope, in an uninterrupted line of 18 inches per mile, from the Ranipoor works to the flooring of the Rutmoo regulator. This slope has been considerably modified, and a similar modification has been practised in advance; the bed slope of the canal having been, on the line which we are now describing, reduced to 15 inches per mile; that is to say, from the flooring of the Rutmoo regulator to the flooring of the Roorkee bridge there is a declivity of bed equal to 1·25 feet per mile.* Onwards to the sill of the falls of Assoffnuggur (to which point it is necessary to continue the series, to bring under review the effectively operative slope on the aqueduct works), the fall on a distance of 21,202 feet is equal to 4·4 feet, or 1·095 feet per mile. The section of the canal on its transverse axis corresponds with that given in detail, under the head of "Excavation." In a general way, however, it coincides with that figured in diagram 2.

On leaving the regulator, the canal channel, on a length of 5,000 feet, passes through the Khadir or low land of the Rutmoo River; it then enters the Peeran Kulleeur ridge, an elevated tract of land which I have before described as extending from the steep slopes near the town of Kheeri, and terminating at Peeran Kulleeur, where it overlooks the Khadir lands, either in abrupt precipices, formed by the inroads of the Rutmoo Torrent, or in undulating raviny slopes, considerably elevated over the low country which lies on three sides of it. The length on which the canal take its course through this ridge is equal to 10,700 feet; the mean depth of excavation being 31 feet, and the maximum 37 feet. At the point opposite the village of Peeran Kulleeur, a masonry bridge, with a waterway of the same dimensions as those of the Jowalapoor and Kun-

* For detail, see p. 189.

khul bridges, viz., 165 feet, has been constructed for the convenience of the high road between Saharunpoor, Imli, and Hurdwar. This bridge connects the village with the temple tombs and reservoir attached to the Durgah, and gives accommodation to the multitudes that assemble, during the months of March and April, at a fair held at this place, which, although on the high road to the head-quarters of Brahminical faith, is purely Mussulman. The section of the canal at the point where the bridge is constructed is, with the exception of that at Gurh and Synibas, the deepest on the whole line of works, the perpendicular depth from the bridge roadway to the flooring on the canal bed being equal to 37 feet. There are flights of steps arranged on its up-stream side, for the purpose of providing the community with means of access to the canal water. There are also side or towing-path passages to this bridge; the left one being the line of railway communication between Roorkee and the Rutmoo works. This work is entirely built of brick masonry, and its foundations were in some measure interfered with by springs.

On the approach of the canal channel to the villages of Bajooheri and Mahewur, the line is crossed by a hollow, which is connected with an extended line of ravine, running back to the distance of 3,000 feet into the high land which constitutes the Peeran Kulleeur ridge. The drainage of this line passed through the hollow which is intersected by the canal, and fell into the Khadir, close under the village of Bajooheri; this drainage has been got rid of, by making an artificial cut from the hollow on the right of the canal, and giving an escape for the water to the west of the village of Mahewur.

From the point above described, the works of the Solani aqueduct commence, the hollow in question having, on both sides of the canal, channels of escape built in connection with the aqueduct terminus, and formed through the embankments. These channels are in width 100 feet, with masonry floorings and flanks; they are filled in with soil of a light description, and are hardly to be recognized, excepting in the projecting steps of masonry which form their flanks; their especial object is to relieve the aqueduct in cases of extreme emergency, and their uses will be fully described hereafter. From these "blind" escapes, as they may be termed, the down-stream flank of which rests on the upper terminus, the canal passes the Solani valley in a channel whose base is 150 feet in width between revetments, designed in the step fashion, as used by the natives of India in their ghats or bathing-places. At a point, not altogether centrical, and nearer Roorkee than Mahewur, the Solani River is passed by a series of fifteen archways, 50 feet in width each. The level of the flooring of the aqueduct which crosses the river, and upon which the canal water is carried, is 24 feet above the bed of the Solani, which runs below it; and this 24 feet may be considered the maximum difference of level between the bed of the canal and the surface profile of the valley, on the whole length upon which the aqueduct passes.

The total length between the extremities of the termini is 15,687 feet, or 2 miles 7 furlongs and 507 feet, of which that portion of the bed which passes over the Solani River, and which is 932 feet in length, is of masonry, and the rest of earth. Cattle ghats and bridges of cross-communication act as the terminal features of this aqueduct.

From the lower extremity or terminus at Roorkee, the canal channel passes on the high land of the Doab to the Assoffnuggur falls by rather an abrupt curve, projected to the left on a radius of 6,617 feet; this curve commences immediately on leaving the masonry of the aqueduct, and on its concave or right side is protected by a revetment of masonry which continues on a length of 3,200 feet. The whole distance from the aqueduct terminus to the sill of the falls of Assoffnuggur is 21,202 feet in length; and the actual slope of bed from the flooring of the terminal bridge at Roorkee to the sill of the falls is 4·4 feet. The transverse section of channel corresponds with that before figured in diagram 2.

The reduced slope upon which the channel runs, between the bridge at Roorkee and the sill of the Assoffnuggur falls, has been designed with a view of protecting the bed of the channel in its course over the Solani valley. The flooring of the aqueduct itself, which is 3,404 feet on the up-stream side of the Roorkee bridge, and which, to correspond with the slope of 15 inches per mile, ought to have been laid 8 inches above that of the bridge, is laid on the same level,* so that on this point, as well as on the whole line of the aqueduct channel, there will be a tendency to back water, and, consequently, to a relief from the action of the current upon the bed. The arrangement of the slopes which I have just described will be best understood by a reference to the longitudinal section of the works in this neighbourhood. They appear to be eminently advantageous to the interests of the works in this rather delicate part of their course, over a long line of depressed valley.

It will be interesting at this point, and before closing my remarks on the works of the first division, to show at one view the effective slopes of the channel. These slopes, although somewhat irregular in detail (an irregularity which has been designed for specific objects), are

* Actually 2 inches below by proof levels.

on long lines very distinctly marked, and as easily divided by the constant recurrence of masonry descents. These descents lead to abrupt changes of level, and to series of slopes quite independent of each other. These long lines or series may be thus tabulated :—

Locality.	Length.		Fall.
	Miles.	Feet.	Ft. In. 10ths.
From the Ganges to the head of the falls at Ranipoor	7	4,839	32 9 4

The detail of the above slope may be thus given :—

Locality.	Length.		Fall.		
	Miles.	Feet.	Ft.	In.	10ths.
From the Ganges to the flooring of the Myapoor regulating bridge . . .	2	4,190	24	0	0
From the flooring of the Myapoor regulating bridge to the flooring of the Kunkhul bridge	1	4,347	3	8	0
From the flooring of the Kunkhul bridge to the flooring of the Jowalapoor bridge	1	4,155	2	9	8
From the flooring of the Jowalapoor bridge to the sill of the Ranipoor falls	1	2,707	2	3	6
Total	7	4,839	32	9	4

With the exception of the lower 4 miles, the whole of this distance is passed on beds of shingle and boulders; that portion of it which extends from the Ganges to the Myapoor regulator being an old cleared-out bed of the river, permanent and compact, and composed of shingle mixed with the largest description of boulders. The effect, therefore, of the forward movement of material in equalizing the slopes on this extended line will, it may be supposed, be a very gradual process; the nature of the bed, however, gives a security to its efficient maintenance.

LOCALITY.	LENGTH.		FALL.		
	Miles.	Feet.	Ft.	In.	10ths.
From the tail or lower level of the falls at Ranipoor to the head of the No. 2 falls	1	4,462	1	11	3
From the tail or lower level of the No. 2, to the head of the No. 3 falls	1	2,696	0	8	0
From the tail or lower level of the No. 3, to the head of the No. 4 falls . .	2	1,403	2	8	7
Totals	4	3,281	5	4	0
From the tail or lower level of the No. 4 falls, to the sill or head of the falls at Assoffnuggur	12	5,240	15	6	1

The detail of the series last given may be thus explained:—

LOCALITY.	LENGTH.		FALL.		
	Miles.	Feet.	Feet.	In.	10ths.
From the tail or lower level of the No. 4 falls to the flooring of the Dhunowri bridge	3	249	3	8	3
From the flooring of the Dhunowri bridge to that of the Rutmoo regulator	3	1,429	0	5	5
From the flooring of the Rutmoo regulator to that of the Peeran Kulleeur bridge	1	1,393	1	2	9
From the flooring of the Peeran Kulleeur bridge to that of the Mahewur bridge	1	3,349	2	3	7
From the flooring of the Mahewur bridge to that of the masonry channel over the Solani River .	2	614	3	6	9
From the flooring of the masonry channel over the Solani River to that of the Roorkee bridge . .	2	3,404	Rise 0	2	0
From the flooring of the Roorkee bridge to the sill of the Assoffnuggur falls	4	82	4	4	8
Totals as above	12	5,240	15	6	1

The composition of the soil through which the canal channel runs from the Ranipoor works downwards is, on the first part of its course, or as far as the head of the Puttri falls, decidedly light and sandy; in advance of this, there is a great admixture of clay, and the excavation through the ridge of Peeran Kulleeur, the greater part of the soil from which has been carried out to form the banks in the Rutmoo valley and the earthen portion of the Solani aqueduct, was made through alternate strata of soil more or less sandy, and unmixed clay, similar to that which is produced in old ponds and reservoirs. The same species of soil existed on the opposite and Roorkee side of the valley, the Solani having clearly worn its passage through a series of horizontal beds, which formerly extended from Roorkee to Peeran Kulleeur.

Both the bed of the Solani aqueduct, and the embankments which are constructed in rear of the masonry side revetments to which they form a backing, are formed, therefore, of soil of a very mixed nature. Great care has been taken in its consolidation, and it is supposed that an upper layer of boulders, which will be gradually deposited on the earthen portion of the channel, will, in the course of time, secure the permanency of bed which is desired.

I may observe, in concluding this section, that although the demand for irrigation on the tract which has been described, is comparatively of little general importance, there are lands lying high on the right bank of the Ganges, in the neighbourhood and *within* the limits of the Puttri forests, that will derive extraordinary benefits from the introduction of water. For the accommodation of these lands, heads for irrigation have been provided, both at Kunkhul and from the mill reservoir at Bahadoorabad; and, although I have not thought it expedient to build heads for irrigation at other points, the means of irrigation can very easily, and certainly with greater practical advantages, be provided hereafter.

II. *The country from Roorkee to Nanoon marked by great declivity of fall in the surface, and by its connection with Bhoor or tracts of sand-hills.*

It was necessary, to enable me to bring the slopes of the canal bed and their effects upon the Solani aqueduct fairly under review, to include in the first section that portion of the high land extending for four miles from Roorkee to the sill of the Assoffnuggur falls. The inclusion is a matter of no importance, but it is as well to keep it in consideration when defining the limits of country so topographically different as that which properly belongs to the first and second sections.

From the uncertainty that exists as to the amount of water which will be taken for irrigation in the Khadir, and the means that (from its proximity to the Ganges River) we have of restoring any quantity of water that may be so taken, without interfering with the calculated supply for the lower regions, we may consider that at the head of the section, on the description of which we are about to enter, the supply of water is equal to 6,750 cubic feet per second, or to that which is the theoretical quantity assumed for the canal supply from the Ganges River, without loss or detriment from either natural or artificial causes. At any rate, as this is the specific quantity upon which the capacity of channel, and means for irrigation, have been provided in advance of Roorkee, it is necessary, for a perfect understanding of the subject, that the above quantity should be not only admitted into the canal and delivered on the high land above mentioned, but that its existence should be admitted by those who are either directly or indirectly interested in the truth and value of the calculations. The quantity lost or consumed in irrigation between the head and the Assoffnuggur falls will be comparatively small, and is, practically speaking, of no material importance. To leave it out of consideration is, however, essential to my argument.

The length of canal which is included in the section under description, or that from Roorkee to the village of Nanoon, is 160 miles; its direction, both on the project of 1845, and on that which (arising from a redistribution of the branches south of it) was afterwards determined on, is in every respect similar. Considerable modifications to the slope of bed, and to the capacity of channel, arising partly from this reduction of slope, and partly from the redistribution of the supply for irrigation, have led to changes in the works, but the direction of the canal alignement is alike in both cases.

The project of 1845 gave throughout the whole of this section an equable slope of bed equal to 18 inches per mile, the superfluous slope being disposed of by four descents of 8 feet each, in masonry falls situated at Boodpoor (Muhmoodpoor), Bailra, Jaoli, and Chitowra: the waterway at each of these falls consisted of six bays, each of 25 feet wide, or a total of 150 feet. For the passage of these descents, lines of navigable channel, separate from the main canal, were designed, the departure of which from the canal, and the point of admission into it again, were situated as far as possible out of the influence of the increased rapid depending on the proximity of the falls. These lines also were fitted with locks, for the convenience of ascent and descent of boats and rafts in their passage along the canal; and the bridges were designed with towing-paths, situated under the left arch, in prolongation of the berm, which acted as a towing-path on the whole line of the excavated channel.

At a point near the 50th mile of the course of the main canal, and near the town of Jaoli, a branch was to be taken off from the left, for the purpose of irrigating the lands lying between the East Kalli Nuddi and the Ganges River; and at the 110th mile it was proposed to take off another branch on the right, for the irrigation of lands in the neighbourhood of Tuppul, in the Alligurh district.

The original project, therefore, which will be perfectly understood from the above short explanation, consisted in the section under review of—

1st. A line of canal, with a declivity of bed on an uniform slope of 18 inches per mile.

2nd. Four masonry descents of 150 feet each in width of waterway, and with a drop of 8 feet on each descent, for the purpose of overcoming the superfluous slope.

3rd. A branch for the irrigation of the Futtigurh district, situated on the left bank of the canal, and at the 50th mile of its course with a masonry head at the point of departure from the main canal.

4th. A branch for the irrigation of the Bolundshuhur and Tuppul country, situated on the right bank of the canal, and at the 110th mile of its course, with a masonry head at the point of departure from the main canal.

5th. Bridges, situated on an average of every 3 miles, adapted in waterway to the section of the canal, at the particular point where they were constructed, and fitted with towing-paths under the left arch, and in prolongation of the line of berm.

6th. Three escapes, two of which, situated at Aboo's

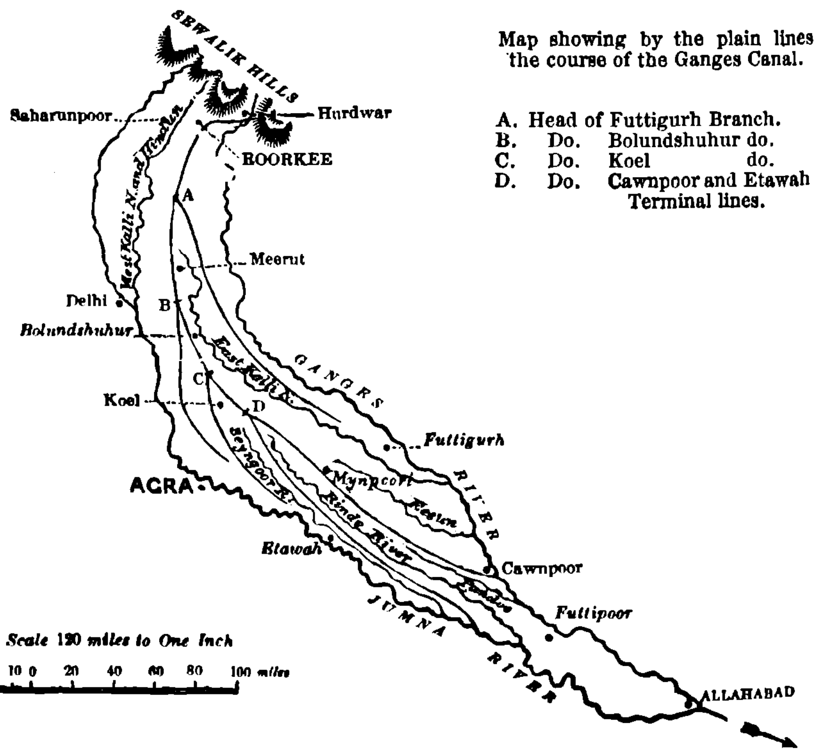
Canal, and at Janni Khoord, at the respective distances of 62 and 69½ miles on the course of the canal, were to deliver the waste water into the West Kalli Nuddi; and one, situated at the 141st mile, to throw the waste water into the East Kalli Nuddi, at a point opposite the town of Khoorja. Each of these escapes had a waterway of 60 feet in width, divided into six openings of 10 feet each.

To render the detail above given more distinct, and to enable the reader at once to comprehend the design for the capacity of the main channel, as well as that for the distribution of the supply throughout its whole course from Hurdwar to its junction with the main rivers, I shall here give, in juxtaposition, a skeleton outline of the project of 1845, and that which was determined on in my letter to Government, No. 1,653, of the 15th January, 1850; that, in fact, upon which the works have been executed. The introduction of these diagrams here with a few prefatory remarks derived from the above letter, although in some measure anticipating the matter of the section that lies in advance of Nanoon, will enable the reader to form a comprehensive view of the causes which led to the changes above that point.

It will be recollected that there were considerable doubts expressed at an early period of the history of this canal, whether the directions of the branches as laid down in the original project through the Cawnpoor district, were those best adapted for distributing the benefits of canal irrigation. The project above referred to, placed the main line in a position running parallel to, and on the left of, the Rinde River, until it reached the Jumna, near the village of Jar; from this main line a branch was conducted to the Ganges at Cawnpoor. From the point of departure of the Cawnpoor branch, the data upon which the estimate of the main canal had been drawn up were merely conjectural; the country, it is true, had been examined by me both in cross section and in a line of longitudinal levels, bearing upon Futtipoor and Allahabad, but the precise line upon which operations were contemplated had not undergone detailed examination, a process hitherto confined entirely to the country upon which the branch to Cawnpoor was to be executed; on both lines, however, and especially on that which runs parallel to the Rinde, the Cawnpoor district, through which they took their course, was under a high state of cultivation, this being especially the case on the country to the left of the Rinde River. To the right of this river, however, and between it and the Jumna, the condition of the country was remarkably different; from the great depth to which wells had to be carried before spring water was reached, irrigation was unknown or only partially known in the Ghatumpoor, Kora, and Jar pergunnas, a tract of country lying at the junction of, and between the Rinde and Jumna, and covering an area of about 400 square miles. As a general rule, whether from difficulty in procuring irrigation from wells, or from difference in the quality of the soil, there could be no question that the state of the lands lying to the right was inferior in an agricultural point of view to that of those on the left; the agricultural population was on both sides of the river in every respect the same; the cause of the difference, therefore, was clearly traceable to a want of advantages on one side of the river which were enjoyed by the people on the other; to a want, in fact, of the means of irrigation which in the North-West Provinces are the soul of agriculture.

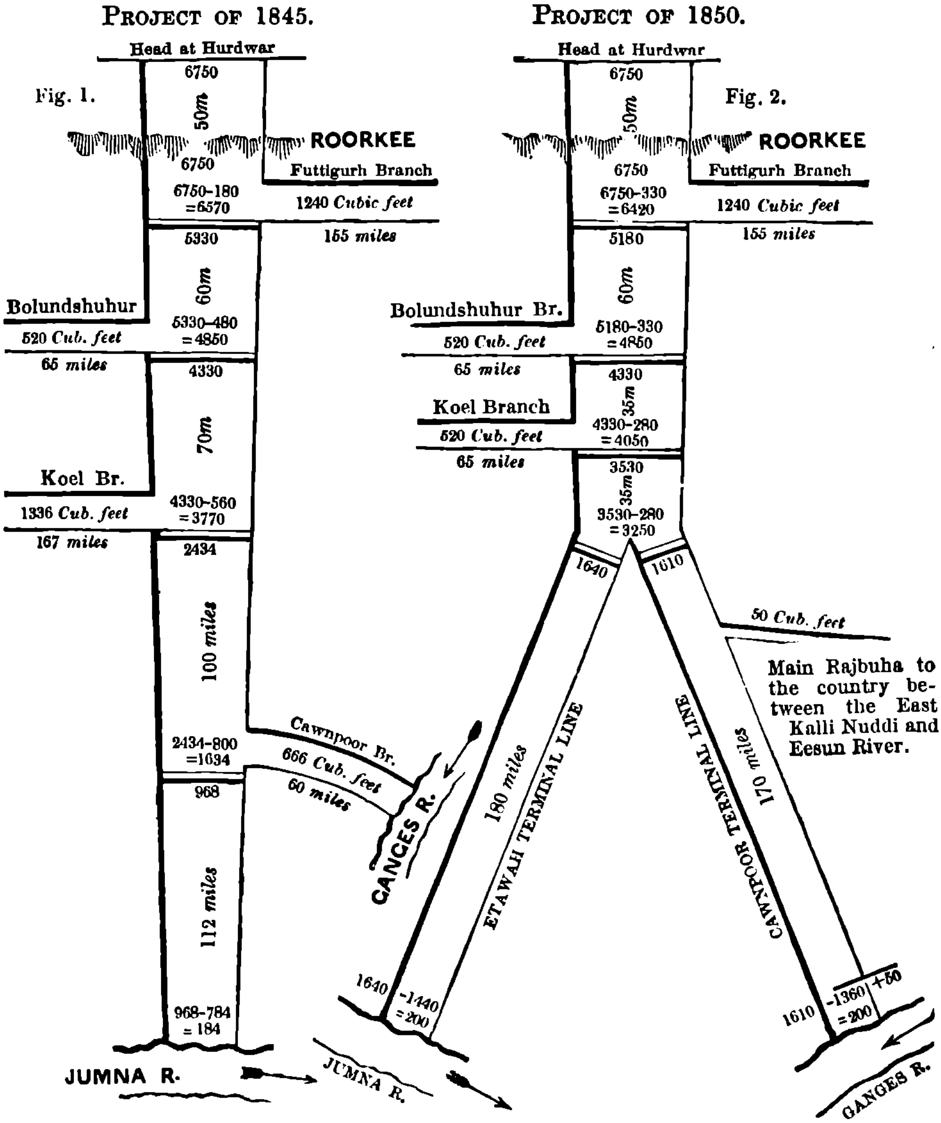
Under the above considerations, and with results before me derived from detailed surveys and levels of the lands lying to the left of the Rinde, which were by no means satisfactory; after a personal examination of the lands in question; correspondence with the revenue civil officers connected with the district; and after having entered freely into the subject with various persons, all of whom were more or less interested in the detail of our operations; the design of keeping to the left of the Rinde River was abandoned, and the canal in its lower portion was laid out in directions more adapted to the demands of the country, and to the economic application of the water for agricultural purposes. This will be better understood by the following diagram, which is a reduced map of the country upon which the Ganges Canal works were projected.

Diagram 16.



In illustration of the above, the following skeleton outlines will place before the reader the detail of distribution of supply which the above changes necessitated.

Diagram 17.



It may be hardly necessary to enter into an explanation of the above figures; they depend, however, upon the 2nd axiom of the prefatory remarks on the calculations upon which the original project was based, viz. that from the results of the Delhi and Doab Canals, "800 cubic feet per second, constant, is a fair supply for irrigation for 100 miles in length of a canal," and "that that portion of the canal extending from Hurdwar to the village of Nusseerpoor (27½ miles in length) may be considered as removed from the influence of irrigation, from its passing through Khadir land in the early part of its course, and deep digging immediately above Nusseerpoor."

The canal, *e.g.* on its reaching the regulator at the head of the Etawah branch (*vide* Fig. 1), contains a volume of water equal to that which it held on leaving the Bolundshuhur regulator minus eight cubic feet per mile of the distance between these two works; or, as is above shown, it holds 4,330 cubic feet $- \overline{70 \times 8'} = 3{,}770$ cubic feet. From this amount 1,336 cubic feet is abstracted for the purposes of the Etawah branch, the residue, viz. 2,434 cubic feet per second, passes on to the lower districts.

It will be seen from a comparison between the diagrams above shown, that at this period of our operations, it became necessary to remodel the line of canal in all its extent, especially from the head of the Koel branch, or from the 145th mile downwards; to use the words of the letter to which I have before referred, "The chief feature of the alteration is this, that the main canal is continued in one trunk to the 180th mile, to the village of Nanoon, in the Alligurh district, at which point it separates into two branches, one bearing direct upon Cawnpoor, and the other going to the right of the Rinde River. The first falls into the Ganges at Cawnpoor, the latter into the Jumna above the junction of the Rinde. Above the fork, in addition to the Bolundshuhur branch, a line will leave the main trunk for the purpose of irrigating the country in the neighbourhood of Koel, Hattras, Ferozabad, and a portion of the Etawah district; this line has been designated the Koel Branch. The tract between the East Kalli Nuddi and the Eesun, will be partly irrigated from a point below the fork by a rajbuha, to which theoretically fifty cubic feet per second have been given, and partly from the Cawnpoor branch by aqueducts over the Eesun, the latter being a question for after consideration and design, when the canal is in working order."

The above is a digression, but its introduction at this place will simplify in a very great degree the explanation of matter directly connected with the section of works now under review.

One of the first points that attracted my attention on rejoining the canal works early in 1848, was the result of the excavations, as far as they had been carried on the high land from Roorkee downwards. With the exception of well-marked tracts of bhoor, or sand-hills, the superficial soil was good, in some places of a very tenacious quality, and its general character was equal to that which we had met with in the excavations on the Eastern Jumna Canal lying on similar parallels; this character, however, proved to be entirely deceptive, the good soil merely overlaid sand; and throughout the whole course of the excavations, this sand had been laid bare to an extent that rendered the question of the slope of the bed and the design of the different masonry works, as originally proposed, matters for serious consideration. The slope of 18 inches per mile was under any circumstances excessive; but its maintenance on a good soil, aided by artificial expedients, was by no means considered to be an impossibility, or likely to involve expenses of an extraordinary nature; this could by no means be the case when the water was brought in direct connection with sand, or with the lighter varieties of soil that the admixture of sand leads to; nor could the design for the masonry works be considered appropriate to a channel where, although the surface of the bed might exhibit some trifling signs of durability, every foot in depth of excavation for laying in the foundations plunged deeper and deeper into sandy soil. The necessities for modification not only in width of waterway, but in depth and solidity of foundations, became, under this evil, apparent; and, although, from the advanced state of some of the works in the neighbourhood of Munglour and Liburheri, a re-disposition of slope became somewhat inconvenient, as necessitating an alteration of work which had already been done, I determined at once to remodel the whole of the slope on a reduction of 3 inches per mile from the Roorkee Bridge to Nanoon, to increase the waterways of the bridges and falls, and to provide for all the contingencies which the connection of sand and springs with foundations, and the protection of works under such circumstances, called for.

With a view to putting the above intentions into immediate execution, and as the levels on the whole line had been accurately determined, a point (to which I have before alluded, viz. the sill of the Assoffnuggur falls) was fixed upon, from which an entirely new series of slopes was to be commenced.

Assoffnuggur was convenient as affording a good and commanding head from whence to begin our lines of irrigation; it was conveniently situated to brick manufactories, and it was precisely the point on the course of the canal from whence under any circumstances the Nusseerpoor irrigation would have derived its supply. The site of the Assoffnuggur Bridge, which was originally intended as a line of country cross-communication, was fixed upon, therefore, as the starting point for the new series of levels; a descent of 8 feet in masonry was here established, and its upper platform or sill (before described as fixed determinately with reference to the works on the Solani aqueduct) was made a zero, from whence the new levels were to be carried.

The reduction of the slope of the canal bed from

18 to 15 inches per mile led to an increased number of falls to enable the superfluous slope of the country to be disposed of; these falls were dispersed throughout the whole line, but their succession was more rapid in the Saharunpoor, Mozuffurnuggur and Meerut districts; whilst on the remaining seventy miles the profile of the country forming part of the districts of Bolundshuhur and Alligurh, corresponded in a great degree with that of the new levels of the canal bed, until it reached the neighbourhood of the flats, on which the Rinde and Eesun rivers took their rise: at this point a somewhat abrupt descent in the surface of the country led to a corresponding descent in the canal levels.

The project under this revised plan consisted of an uninterrupted slope of 15 inches per mile, with masonry descents at the following places:—

Assoffnuggur	Descent of	8	feet	200	feet waterway
Muhmoodpoor	Ditto	8	"	200	"
Belra	Ditto	8	"	200	"
Jaoli	Ditto	8	"	200	"
Chitowra	Ditto	8	"	200	"
Sulawar	Ditto	8	"	150	"
Bhola	Ditto	8	"	150	"
Dasna	Ditto	8	"	150	"
Pulra	Ditto	5	"	100	"
Simra	Ditto	5	"	100	"

a total declivity of 74 feet being overcome by masonry. The waterway on these falls, it will be observed, had been increased, while the substructure and foundations generally, but especially at Assoffnuggur and Muhmoodpoor, were of necessity carried to excessive depths to obviate the risks of accidents from the nature of the sand in which they were embedded, and these depths further required that the masonry should be proportionally augmented in dimensions.

Additional waterway was obtained by removal of the towing-paths, which obstructed portions of the left bays of the bridges as they were formerly designed, and by substituting in some instances for the structure of solid masonry a pathway under the arch supported on an open timber framework; in others, a towing-path passage was constructed through the wing walls of the bridge, and in prolongation of the berm or towing-path of the excavated channel; but in all cases throughout this portion of the canal, where the works were connected with sand, both bridge and fall floorings were covered in front and rear by aprons of heavy material, consisting either of blocks of kunkur or of brick masonry, protected by lines of sheet piling; the flanks, moreover, of all these works were well protected by lines of piles.

The above will explain the alterations which had been made in the bed slopes of the canal, and the method that had been adopted in overcoming the difficulties of superfluous fall. We now come to the topographical features of the country, with a detail of the different works that have actually been constructed; and that this may be more distinctly placed before the reader, I shall divide the description into sections, commencing at the head of the high or bangur land at Roorkee.

The canal, after its passage across the Solani River and its arrival at Roorkee,* makes a turn to the left, and continues on a bearing almost due south for a distance of about 20 miles, until it reaches the neighbourhood of Belra; on this line it runs parallel to and between the high bank overhanging the Khadir and the Seela Nulla, a shallow depression that acts as a tributary to the West Kalli Nuddi. The position of the canal with regard to these two natural boundaries is by no means centrical. As a general rule it is nearer the high bank, and in the vicinity of Noornuggur, Dimat, Kumbhera, and Toghulpoor approaches to within $1\frac{1}{4}$ mile of the edge of the

* 19th to 40th mile.

Khadir: throughout the whole of this tract the surface is marked by undulating ridges of sand, either skirting the edges of the rivers or throwing out ramifications transversely; but in every case where they appear, they diversify the aspect of the scenery, barren as it is, and unrelieved either by the presence of foliage, or excepting during the rainy months by the slightest appearance of verdure. The line of canal crosses three of these ridges; the first almost immediately after leaving Roorkee; the second in the neighbourhood of Toghulpoor; and the third near Belra; although this tract of country is intersected by sand ridges, as I have above described, and marked by extensive areas of land on which rain crops only are planted, it is by no means an ill-cultivated nor a poorly populated region; there are numerous large towns, well wooded with mango and other fruit trees, indigenous to this part of India, in the vicinity of which the cultivation is very extensive, but the whole is what is designated Burani, that is to say, dependent on rain for fertilization; the wells, which vary in depth from 66·36 to 24·71 feet, are too deep for agricultural purposes, and it is only now and then, when small patches of garden-land lie in the proximity of ponds or natural hollows, that the rain-water collected in them is used for the purposes of irrigation.

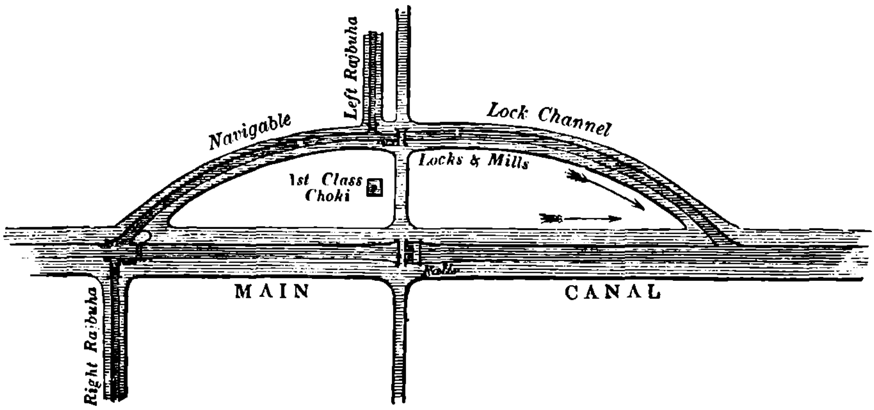
The slope of the surface of the country on the 20 miles running from Roorkee to Belra, may be estimated at 46 feet, or 2·3 feet per mile; as a general rule, there is a transverse slope from the edge of the bank to the bed of the Seela Nulla, but the intermediate land upon which the canal takes its course is sometimes nearly horizontal; this is especially the case at Roorkee, as well as at Toghulpoor and Belra, where the high land lying between the bank on the east and the sand ridges which run parallel to the canal on its west, has very little variation in profile; the line of canal, however, although keeping as closely as possible on the backbone of the country, must, as will be understood from the transverse slope before mentioned, interfere in some degree with the local drainage; this has been remedied in the neighbourhood of Munglour and Liburheri by a cut made into the Khadir of the Ganges, and it will be evident from the position in which the works are situated, high above the low lands which run within a few miles of them, that inconvenience arising from want of drainage can only be attributed to a want of channels of escape for the making of which nature has provided every facility. On the approach of the canal to Belra, it takes up its proper position on the watershed of the country.

The depth of excavation throughout the whole of the channel from Roorkee to Belra, is greater than that of the calculated maximum high water of a full canal supply excepting in the neighbourhood of Toghulpoor, where a depression of the country on a length of 4,900 feet has led to embankments; the minimum depth of excavation on this depressed line is equal to 4·18 feet.

The works on this line consist of—

1st. The Assoffnuggur falls, with a waterway of 200 feet over the sill or waste-board, a navigable channel which leaves the main line of canal at a distance of 3,500 feet above the falls on the left, and runs parallel at a distance of 1,000 feet, rejoins the main canal again 4,000 feet below the falls; the head of this line is protected by masonry works, with flank revetments on each side of the main canal, fitted with iron rings and appliances for the establishment of a bridge of boats over the main stream; the object of this bridge being partly to prevent craft passing down the canal from coming within the influence of the overfall, partly to give a line of cross-communication, and partly to give head-water to both the navigable channel and to a rajbuha or main watercourse head which is situated immediately above it on the right bank. Locks with a bridge, the axis of which corresponds with that of the bridge over the falls, are constructed on the navigable channel for the convenience of passage, and above the locks and connected with them is the rajbuha head, for the irrigation of the country on the left. Corn-mills are attached to the waste channel of the lock-chamber, and a first-class choki is built in the island, formed by the main and navigable channels. For a full description of these works, the atlas, and the chapter devoted to the details of construction, must be consulted; but the introduction in this place of the following diagram will exhibit to the reader the general lining out of the works of this description throughout the canal.

Diagram 18.



2nd. Bridge at Munglour with a choki building of the second class: this bridge has 3 bays of 55 feet each, with a roadway of 18 feet, and has attached to it, both on the up and down stream flanks, flights of steps for the convenience of the native community.

3rd. Bridge at Liburheri with a choki building of the 2nd class on the same design as that at Munglour.

4th. Bridge at Mundowli, the foundations only of which have been built.

5th. Falls and works at Muhmoodpoor, similar in every respect to those at Assoffnuggur.

6th. Bridge at Dimat, similar in every respect to that at Munglour.

7th. Bridge at Toghulpoor, with a choki building of the 2nd class, on the same design as that at Munglour.

8th. Falls and works at Belra, similar in every respect to those at Assoffnuggur, with exception to the choki, which is of the 2nd class, and of the tail jetties, which are built on the original design (*vide* Plate XXVIII. of Atlas).

9th. Bridge at Belra, with a choki building of the 1st class.

In advance of the village of Belra,* the line of canal makes a slight turn to the right, increasing in distance from the high bank of the Ganges, and gaining a more central position between that bank and the low lands connected with the West Kalli Nuddi; this inclination to the right or to the westward increases on its approach to the town of Khutowli, immediately north of which, and to the eastward, it passes the heads of the East Kalli Nuddi, which from henceforth separates the canal from the Ganges River. The distance between the East and West Kalli Nuddies at this point is about 8 miles, through which the canal passes very nearly centrically.

The features of the country throughout the above tract, which extends for 20 miles, are not unlike those which I have before described; there is much Bhoor land, and to the west of the line, and between it and the valley in which the West Kalli Nuddi runs, there are a succession of ridges; the excavations, therefore, both for the channel and for the foundations of the

* 40th to 60th mile.

masonry works, were sandy throughout; brick soil was with difficulty met with, and the early completion of the numerous and extensive masonry buildings on this line may be placed to our success in collecting bricks from the extensive ruins of Chitowra and other old towns, which are the remnants of a period when the Mozuffnuggur district was governed by Zabitha Khan's family.

The longitudinal slope of country over the 20 miles above referred to is 32 feet, or 1·6 foot per mile; the transverse slope is from west to east, but the line of canal runs high, and is well situated with regard to the watershed.

From a point at the 50th mile of the course of the canal, a branch for the irrigation of the country lying between the East Kalli Nuddi and the Ganges, leaves the main line on its left, or east bank; at the period that I am writing (1853), nothing has been done further than the preliminary surveys, lining out, establishing bench marks or fixed points of level, and (as far as supervision can be provided for it) brickmaking. The detail of the project for this line will be found elsewhere.

To the eastward and at the village of Untwarra, which is situated nearly opposite the 60th mile of the course of the main canal, the East Kalli Nuddi rises. Tanks or large ponds have been excavated at its immediate head, which during the hot months of the year are perfectly dry; this line of drainage, which ultimately forms a very extensive river, is immediately below these tanks a mere shallow, ill-defined nulla, running through low, grassy, and untidily cultivated lands; it gradually, however, expands, and at a point in its course at some distance above the town of Bolundshuhur it becomes a perennial stream, running in a wide and well-marked valley, which continues increasing in size and importance until passing under the ruins of Kanoge it reaches the Ganges, near the village of Muhdeepoor, in the Furruckabad district. As this river runs parallel to the Ganges Canal through the greater part of its course, and is a receptacle for a good deal of its escape water, its influence on the works, as well as on the drainage connected with them, gives it an important place in the history of the canal.

The depth of excavation of the canal channel from Belra to Khutowli is sufficient for all the required purposes. The maximum depth from the surface of the earth to that of the water in wells during the cold weather is by observation equal to 67·69 feet, the minimum 29·22 feet.

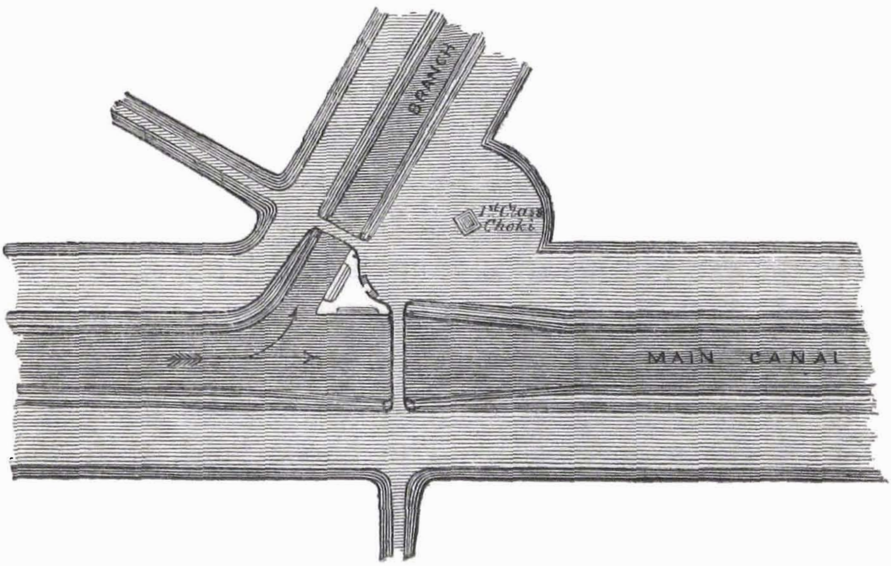
On the 20 miles above described, and from the bridge at Belra the following works have been constructed :—

1st. Bridge at Bhopa, on the same design as those which have been before described, with a waterway of 165 feet, and a 2nd class choki.

2nd. Falls and works at Jaoli, corresponding in every respect with those at Assoffnuggur, with exception to the choki building, which is of the 2nd class.

3rd. Head of the Futtigurh branch : this work consists of a bridge with nine bays, of 20 feet each, over the main canal, and a bridge of four bays, of 20 feet each, over the head of the branch, connected by a line of curved revetment, resting upon a redan-shaped platform, which projects its acute angle towards the point of separation of the main stream and the branch ; the sides of this redan consist of flights of steps, or ghats, which are approached from the higher levels by stairs centrically placed on the curved revetment; both these bridges are fitted with shutters and planks, and the necessary appliances for regulating the water. A 1st class choki is attached to these works, its site within the angle formed by the departure of the branch having been established on a line bisecting the angle of separation of the two streams; the following diagram represents the lining out of these and other similar works on the whole line of canal.

Diagram 19.



4th. Bridge at Dukheri, with towing-path arches in the flanks, and a choki building of the 2nd class; the waterway 165 feet in width, consisting of three bays of 55 feet each (*vide* Atlas, Plate LI.)

5th. Bridge at Jansuth, similar to that at Dukheri; but roadway 20 feet wide; 2nd class choki attached.

6th. Falls and works at Chittowra, similar in every respect to those which have been before described.

7th. Bridge at Surai, similar to that at Dukheri, and a 2nd class choki attached.

The course of the canal* proceeds direct from the heads of the East Kalli Nuddi and Khutowli, until it approaches

* 60th to 80th mile.

the town of Sirdhunna, where it inclines a few degrees nearer to the south, thereby avoiding contact at the most exaggerated part of the ridge with a line of sand-hills, which curve partially round the northern side of the town. The East and West Kalli Nuddies form the eastern and western boundaries of the canal tract, the line itself, however, keeping somewhat nearer the latter. The West Kalli Nuddi, in the latitude of Sirdhunna, has joined the Hindun River, which, by its westerly course, and by a consequent departure from the bearing upon which the East Kalli Nuddi runs, places the canal on a wider field, the transverse distance between the two rivers being at this point equal to 14 miles. The slope of the country on this section of 20 miles is 29·5, or 1·47 foot per mile; the transverse width varies from 8 to 14 miles, and the slope, which tends slightly to the east, does not militate against the effective position of the canal (that being, so far as the regularity of alignement would admit of it, fairly on the water-shed). The bhoor land, with well-defined sand-hills, is conspicuous on the westward; and near Sirdhunna the canal crosses a ridge which intersects the country lying north of the town; the soil, however, through which the canal channel is excavated, is of a better description than that which had before been met with, although it is still light, and, in the region of the foundations of the works, almost pure sand. The Hindun as well as the East Kalli Nuddi, have, by this time, become formidable rivers, with deep sections, and widely extended valleys or khadirs. Immediately opposite the town of Khutowli, and on the right bank of the canal, at a point 62 miles from the head at Myapoor, is the Khutowli, or No. 1, escape, connected with the West Kalli Nuddi by an excavated channel of 60 feet in width at its head; the distance from the canal at this point to the river is 3¾ miles, and the difference of level from the bed of the canal to that of the river is 29·21 feet; the width of waterway for the passage of waste water is 60 feet, divided into 10 openings of 6 feet each (*vide* Atlas, Plate No. XXXVII.) Across this line of escape channel, and at a distance from the canal of 6,024 feet, the main western rajbuha is carried over an aqueduct, connected with a bridge of cross-communication, to the floor of which a masonry descent, for the purpose of overcoming 8 feet of the superfluous fall, is attached; it is not intended to anticipate the natural effects of retrogression of levels on this escape channel by building further works; it has been considered more economical to watch the effects of the current, and to apply remedies, when such appear to be necessary. As this escape is the most northerly one of those situated on the high lands below Roorkee, its position is one of decided interest.

At the 69th mile, and not far from the village of Jowalagurh, the canal channel intersects the ancient canal of Mahomed Aboo Khan. This old work has been described in the early part of this paper; marks of excavation commence at two points on the West Kalli Nuddi, the most northerly one near the village of Rampoor, the other from Furreedpoor, a village lying about six miles to the south; these two lines form a junction on the right, and afterwards proceed in an oblique direction across the canal to the head of the Khodara (one of the numerous tributaries connected with the East Kalli Nuddi), which passes through the cantonment of Meerut. At this point of intersection, No. 2 escape, equal in dimensions to that at Khutowli, has been built, and a channel excavated on the old line of Aboo's cut towards Furreedpoor, on the West Kalli Nuddi. The distance from the canal to the river is equal to 7 miles, and the difference of level from the bed of the canal to that of the river is 23·93 feet; the width of waterway and arrangements for its passage by the western rajbuha, with those for anticipated retrogression of levels, are the same as in the case of the No. 1 escape at Khutowli. At the site of this work is a 2nd class choki for the accommodation of the requisite establishment; its situation, however, is 7,960 feet distant from the Uturna bridge, and, therefore not so conveniently placed as if it had been in immediate connection with a passage of cross-communication.

The depth of excavated channel on the line from Khutowli to Sirdhunna is sufficient for all canal purposes. The maximum depth from the surface of the earth to that of water in wells is, by observation, during the month of May, 44·63 feet, and the minimum 14 feet.

On the 20 miles above described, and from the bridge at the village of Surai, before noted, the following works have been constructed:—

1st. Bridge at Khutowli, on the high road between Meerut and Saharunpoor, on the same design as that at Munglour, but with a roadway of 24 feet in width. There are ghats or flights of steps on the down-stream face of this bridge, and the up-stream side is protected by curved wings.

2nd. No. 1, or Khutowli escape into the West Kalli Nuddi, with 60 feet waterway, divided into 10 sluices of 6 feet each.

3rd. Bridge at Sutheri, similar to those at Dukheri and Jansuth, with a waterway of 165 feet, divided into three arches of 55 feet each, and 2nd class choki.

4th. Falls and works at Sulawur, similar in every respect to those which have been before described, but with a width of waterway reduced to 150 feet.

5th. No. 2, or Aboo's escape into the West Kalli Nuddi, with 60 feet waterway, divided into 10 sluices of 6 feet each, with a 2nd class choki attached.

6th. Bridge at Uturna, similar to that at Sutheri, with 2nd class choki attached.

7th. Bridge at Sirdhunna, roadway 25 feet in width, similar to that at Khutowli, with ghats or flights of steps built precisely on the same model: attached to this bridge is a 1st class choki.

8th. Bridge at Nanoon, with 150 feet waterway in three arches of 50 feet each; roadway 25 feet, with side towing-path arches (*vide* Atlas, Sheet No. LII.) Ghats are attached to the down-stream side of this bridge, and near the bridge is a 2nd class choki.

9th. Bridge at Jutpoora, on a similar design to that at Nanoon, but without ghats, and the roadway is only 18 feet wide; near the bridge is a 2nd class choki.

10th. Bridge at Pooth, similar (excepting the roadway, which at this bridge is 20 feet in width) to that at Jutpoora, with a 2nd class choki attached.

From the point at which the last section terminates* to Jullalabad and its neighbourhood, which embraces the 20 miles of canal course in advance of that before described, the canal proceeds on the same bearing as before until it reaches the village of Sewal Khas; at this point a series of curves on radii of from three to five miles commence, for the purpose of meeting the watershed of the country, which henceforth takes a direction more to the east; these curves continue to a point below Jullalabad, near the village of Raoli. The canal on the 20 miles to which this description is confined, passes on its left the towns of Meerut, Begumabad, and Jullalabad, the former with its military cantonments being situated at a distance of 8 miles from the nearest point of the alignement; on its right are Dholuri and Moradnuggur, the latter lying within a short distance of the canal.

* 80th to 100th mile.

The width of country over which the canal passes, measuring transversely across the canal between the East Kalli Nuddi and the Hindun River, is at Sirdhunna 15½ miles; this increases in advance, until at Jullalabad the above two rivers are separated by a width of 26 miles; at Sirdhunna the canal runs centrically between the above boundaries, being separated from the East Kalli Nuddi by the Khodara Nulla, which at this point is a mere shallow depression; as it advances, however, it keeps nearer to the Hindun, from which at one point of its course, opposite Dholuri, it is separated by a distance of only 4 miles; the cause of this close approximation to the Hindun chiefly arises from the interposition on the east of the Choiya Nulla, a tributary like the Khodara, before described, of the East Kalli Nuddi. The Choiya Nulla rises at a point about 3½ miles to the east of the canal on the latitude of Meerut; it takes a southerly direction nearly parallel to that of the canal, and joins the East Kalli Nuddi, after running through a course of 30 miles, at a point about 9 miles below the town of Hapoor, between which and the canal the Choiya Nulla passes; its character is precisely the same as that of the East Kalli Nuddi: in the early part of its course, an ill-defined straggling nulla, running through land ill-cultivated on its edges, and, excepting in the rainy months, perfectly dry; in the latter part, and on its junction with the river to which it is tributary, carrying a sluggish stream through a deep section, with a valley more or less extended. All these nullas are of this character; from their heads, which generally receive the drainage of extensive flats of country, they proceed on their course, becoming gradually deeper and wider, until they reach the main river to which they are tributary. The direction of the main line of canal, therefore, is in a great measure dependent on this nulla, and the lowlands which lie contiguous to it.

The slope of the surface of the country is about 35 feet, which averages 1·75 foot per mile; in a transverse direction, the inclination is towards the east, but in such a small degree that it is hardly perceptible; the line of canal, in fact, is distinctly on the high ridge at the village of Janni Khoord, and it proceeds onwards to Jullalabad on the same elevated position. The country over which the works are carried between Sirdhunna and Jullalabad is, on an average taken from six measurements from the surveyor's returns, 43 feet above the bed of the Hindun, and 32 feet above that of the East Kalli Nuddi: the Choiya, or river which intervenes, having from the neighbourhood of Bhola (at which point its heads are on a level with the country) obtained a depression of 16 feet. Cross sections, taken by myself in 1840, showed that the land at Janni Khoord was 45·925 feet above the bed of the Hindun River, and 3·33 feet above that of the Choiya, at a point 2 miles from its head; a cross section at Jullalabad proved that the bed of the Hindun was 47·54 feet, and that of the Choiya 24·64 feet, below the country on which the line of canal was to be carried; the Choiya, therefore, had, in passing from the latitude of Janni Khoord to that of Jullalabad, accumulated a total fall of 21·31 feet, which, as the distance is 14 miles, is equal to 1·52 foot per mile.

The country through which we are now passing is very highly cultivated, a remark that may apply to the greater portion of that lying south of Khutowli. Between Sirdhunna and Jullalabad the sandy and bhoor tracts are more subdued than they have been previously; the canal excavation is, generally speaking, carried through a good supersoil, with sand lying beneath it.

With the exception of 7,100 feet in length of channel opposite Moradnuggur, where the excavation is shallow, the minimum depth being only 5·61 feet, the bed throughout is sufficiently deep to hold the maximum supply of water; and on that portion where a deficiency of depth has led to heavy embankments, these works are so massive and wide that no danger from breakage, nor evil from the percolation of water, need be at all anticipated.

At the village of Janni Khoord is a third escape (No. 3), connecting the canal with the Hindun; this work has a waterway of 60 feet, divided into 10 sluices of 6 feet each; its dimensions, both in masonry and capacity of channel, are precisely the same as those of No. 2, at the site of Mahomed Aboo's Canal, and the arrangements for the passage of the West Rajbuha, and the retrogression of bed levels, are projected on the same design. The distance from the canal to the Hindun at the point where the escape is built is equal to five miles, and the difference of level between the bed of the canal and the bed of the river is 38·06 feet.

The maximum depth from the surface of the country to that of the water in wells, by observations during the month of March, is, on the 20 miles above described, equal to 37·91 feet, and the minimum 21·52 feet.

From the Pooth bridge downwards the following works have been constructed :—

1st. Falls and works at Bhola, similar to those which have been before described, but with a waterway over the falls of 150 feet in width, as at Sulawur. There is some deviation from the original design in the lining out of the navigation channel, arising from the village of Bhola interfering with the alignement; in other respects the works correspond in every way with those which have been before described.

2nd. No. 3, or Janni Khoord Escape, similar in every respect to the works at No. 2, or Mahomed Aboo's Escape; waterway 60 feet, in 10 sluices of 6 feet each.

3rd. Bridge at Janni Khoord, similar in design to that at Pooth (Atlas, Plate No. LII.), with a 2nd class choki attached to it.

4th. Bridge at Nugla, with a 2nd class choki, both of them similar to that at Pooth.

5th. Bridge at Newarri, similar to that at Pooth, but roadway only 18 feet wide, with a 1st class choki attached.

6th. Bridge at Sounda, similar to that at Pooth, but roadway only 18 feet wide, with ghats on the wings both on the up and down stream sides, with a 2nd class choki attached.

7th. Bridge at Didowli, similar to that at Pooth, but with roadway only 18 feet wide, with a 2nd class choki attached.

8th. Bridge at Moradnuggur, similar in design to that at Pooth, but having a roadway 25 feet wide, and with ghats on its down-stream side, corresponding in design with those which have been built at Khutowli and Sirdhunna (Atlas, Plate LII.). To this bridge a 2nd class choki is attached.

A further distance of 20 miles,* the first portion of which is in continuation of the curve which I have before described as commencing at Sewal Khas, takes us to the neighbourhood of Sikundrabad, a town situated in the Bolundshuhur district; the curve terminates at a point near Dasna, from whence, up to the 120th mile, the canal pursues its course in an uninterrupted straight line. Its direction, which from Sirdhunna to Jullalabad inclined rather to the west, or to the Hindun side of

* 100th to 120th mile.

the Doab, on this section takes an opposite course; from the point near Dholuri—in fact, where the canal and the Hindun River approach to within four miles of each other, the canal takes an oblique direction across the country towards the East Kalli Nuddi, from which, at a point a few miles below Sikundrabad, it is only two miles distant. Throughout the whole of this line the canal tract has for its boundaries the Hindun on the west, and the Choiya, and latterly the East Kalli Nuddi (after the junction of the Choiya with it), on the east. At a point almost directly at right angles with the line of canal at Sikundrabad the Hindun joins the Jumna; and the low lands or khadirs of these two rivers, which from Delhi and Ghazioodeennuggur downwards are united, extend over a surface varying from four to thirteen miles in width, and thereby very considerably reduce the area of the high land in immediate connection with the canal.

The slope of the surface of the country on the line over which the 20 miles from Jullalabad to Sikundrabad passes is 33·34 feet, or 1·66 foot per mile; the width may be estimated on an average at 26 miles, including the land cut off by the Choiya on the east, and the khadir lands of the Hindun on the west; the surface is, in a general point of view, flat, or broken by irregularities unworthy of any particular consideration; the direction of the canal, however, is high, and on a cross section from the Hindun, *viâ* Ghazioodeennuggur, Dasna, Galund, Habul and Kumalpoor, to the Choiya Nulla, it crosses at the highest point of the profile, near the village of Galund, that point being elevated 40·7 feet above the Hindun, and 15·58 feet above the Choiya.

It was on this line, and from a point in the canal near Moradnuggur or Jullalabad, that in my first report, written in 1840, I pointed out the probable advantage that might be derived from carrying a line of navigable canal to the Hindun River. With a view to ascertain the capabilities of the Hindun, I had measurements (transverse) in width and depth taken at every thousand feet in length, from the bridge which crosses the river at Ghazioodeennuggur to its junction with the Jumna, near the village of Dunkoor. These measurements, which were taken in the month of April, showed that with the exception of one part of the course of the river, near the village of Gojur, where the depth of water varied from 1·4 to 1·3 foot, the average depth might be estimated at between 3 and 4 feet, on a width varying from 50 to 190 feet. The total distance between the Ghazioodeennuggur bridge on the Hindun, and the junction of that river with the main Jumna, was 30¼ miles, the course being exceedingly tortuous, and on its whole length passing through khadir land. A tabulated statement (appendix G) of these measurements will be found in the volume of tables attached to this paper. With lockage of 35 feet, or thereabouts, a line of still water might be carried from the canal to a point on the Hindun below the bridge at Ghazioodeennuggur, by which means a direct line of water communication would be obtained between the Ganges at Hurdwar and the Jumna. In the report in which this subject was alluded to it was remarked, that the uses of such a canal "in the mere introduction of timber and forest produce would be of infinite importance, as enabling the Delhi and Agra markets to be supplied direct from the forests which lie in the vicinity of the Ganges at its debouche from the mountains."

The country is throughout richly cultivated, and the soil of a better description than it was in the bhoor or sandy districts; sand, however, is still an attendant on all excavations exceeding a few feet in depth, and the occurrence of spring water at shallow levels was in some cases a matter of great inconvenience, especially at the falls and locks, where it was considered advisable to lay the foundations at a depth below spring-water level. Throughout the whole of the distance, however, extending from Jullalabad to Sikundrabad, the depth of excavation is sufficient to carry the full canal supply.

At, or near, the 110th mile, and near the village of Duhurra, the Bolundshuhur branch leaves the canal on its right bank; this branch is intended for the irrigation of the different purgunnas that lie on the edge of the Jumna Khadir, Jewur, Dunkoor, Tuppul, &c.; it crosses the lowlands, in which the heads of the Putwai Nulla are situated, to the eastward of the village of Kot, and from thence proceeds onwards between that nulla and the Karoon River, another line of drainage, which rises in the neighbourhood of Parpuh, a village which is situated on the left of the main canal. The works which are attached to the head of this branch are (with the exception of the reduced widths to waterway, adapted to the particular position in which they are situated, and to the calculated discharge of water necessary for the branch supply), similar in detail and in design to the Futtighur branch headworks, before described; the regulator over the canal at this point has eight bays of 20 feet each, and that of the branch has a waterway of 50 feet, divided into one centrical bay of 20 feet, and two side bays of 15 feet in width each.

The depth of spring-water from the surface of the earth is, throughout the above line of 20 miles, much the same as it was in the Khutowli neighbourhood, its maximum, on a number of observations taken at different villages during the month of February, being 40·65 feet, and the minimum 22·65 feet, measuring from the surface of the earth to the surface of the well-water.

From the Moradnuggur bridge the following works have been constructed :—

1st. Bridge at Noorpoor, similar to those before described (*vide* Atlas, Plate LII.), with a 2nd class choki attached.

2nd. Falls and works at Dasna, similar in every respect to those at Sulawur and Bhola, and with the same width of waterway.

3rd. Bridge at Peepulheri, three arches of 45 feet each; 20 feet roadway, with ghats on both the up and down stream sides, and a 2nd class choki attached.

4th. Bridge at Raoli, similar to that at Peepulheri, but without ghats: a 2nd class choki attached.

5th. Bolundshuhur branch headworks.

6th. Bridge at Nidhowli, with three bays of 45 feet each, with ghats and rajbuha and inlet heads (*vide* Atlas, Plate L.), with a 2nd class choki.

7th. Bridge at Jarcha, similar in every respect to that at Nidhowli, with a 2nd class choki attached.

8th. Bridge at Geesoopoor, of the same description and design as that at Nidhowli, with a 1st class choki attached.

The use of kunkur, which had been confined either to building in beton or concrete, or to filling in at the tails and other points near bridges and falls, where protection was required, became on this line of works the staple material for building, not only foundations, but superstructure. The works from the Bolundshuhur branch head downwards, with the exception of bridge arches, have been built almost entirely with kunkur, which is procurable from quarries in the neighbourhood. The material, although variable in compactness, and requiring in use some circumspection, is undoubtedly one of a very superior quality; and perhaps one of its greatest recommendations was its extraordinary abundance, which enabled the executive officer to carry on without interruption the whole of the bridges and works at a period when bricks were literally not procurable: and when, had it not been for the occurrence of kunkur quarries, the failures in the brick manufactories would most undoubtedly have necessitated an entire stoppage to the works. The subject of building in its details, however, will be entered upon hereafter; the fact of kunkur being used is merely alluded to here, from its being a remarkable feature in the progress of the works, and in the resources of the country.

The next 20 miles* bring us to the neighbourhood of Khoorja, a large town situated on the Grand Trunk Road, and at a distance of 2 miles on the right of the canal: at this point we are 140 miles from the head at Myapoor.

The Kuroon River, to which I have before adverted, as rising in the neighbourhood of Parpuh, passes off in a southerly direction, increasing in departure from the East Kalli Nuddi as it advances in its course; in its natural features it resembles in all respects the Choiya, as before described, and after a course of 90 miles joins the Jumna, near the village of Shahdurra, in the Agra district, at a point just below the town of Agra. The Kuroon River passes to the east of Sikundra, and to the west of the town of Khoorja, at a distance of 4½ miles, and proceeds onwards by the towns of Khyr, Hussungurh, Mudsan, and Saidabad, to its junction with the Jumna.

The line of canal, therefore, in its passage through this portion of the Bolundshuhur district, after crossing the lowland in which the heads of the Kuroon are situated, runs between that river and the East Kalli Nuddi: at their widest points of separation they are only 7½ miles

* 120th to 140th mile.

distant from each other, whilst immediately opposite the town of Bolundshuhur, which is built on the high land overlooking the valley or khadir of the East Kalli Nuddi, the width does not exceed $4\frac{1}{2}$ miles. The canal alignement passes within $1\frac{1}{4}$ mile of the town of Bolundshuhur, and, throughout the whole of the 20 miles which I am now describing, runs parallel to, and at a distance of from 5 to $1\frac{1}{2}$ miles from, the East Kalli Nuddi. In the early part of its course its direction is in prolongation of the straight line from the Bolundshuhur branch head, but at the 127th and 131st miles there are curves on radii of 15,414 and 21,300 feet, bringing the line to bear on a westerly direction, and at the 139th mile a curve of the former dimensions to give it a direction towards the east; these curves are adapted to the general direction of the high land and the watershed, as well as to open country unconnected with sites of houses or villages. The low land which lies at the head of the Kuroon, and which is intersected by the canal in the vicinity of the 120th mile, has not been considered of sufficient importance to call for additional works; nor from the experience that we have had since the canal has been dug and its embankments have been made, does there appear to be any necessity for them.

The slope of the surface of the country on its longitudinal section is 28·5 feet or 1·42 feet per mile, and transversely it inclines from the East Kalli Nuddi towards the Kuroon, or from east to west. The country is richly cultivated throughout, although intersected by bhoor or sand-ridges in the neighbourhood of Khoorja. The canal excavation is through a tolerably good soil, with the exception of those portions of it which are connected with the sand; the soil *below* the bed is of a light and not very satisfactory description; the depth of excavated channel, however, is sufficient for the high water supply, and in this respect is well adapted to the purposes for which it is intended.

A cross section taken by me from the East Kalli Nuddi at Bolundshuhur to the Kuroon River, showed that the surface of the country on which the canal takes its course is 22·33 feet above the bed of the former and 6 feet above the bed of the latter. A similar section taken transversely across the country at the town of Khoorja, showed that the East Kalli Nuddi was 24·83 feet, and the Kuroon 10·5 feet below that of the canal line; the distance longitudinally between these two sections being equal to 11 miles.

The only works on this line are bridges, which have been built on the same design as those before described in the former section from the Bolundshuhur head downwards; at the crossing (at Wullipoora) of the high road between Allygurh and Bolundshuhur, the ghats, which are universally attached to the bridges, are more extended in length, and greater conveniences are provided for approaching the water for the purposes of bathing, but in other respects the appended rajbuha heads, inlet, towing-path, passages, &c., are precisely similar. The following is an enumeration of the bridges from the 120th to the 140th mile :—

1st. Bridge at Sunowta, with ghats, rajbuha and inlet heads, similar to that at Nidhowli (Atlas, Plate L.), with a 2nd class choki attached.

2nd. Bridge at Pukkana, similar in every respect to that at Nidhowli, with a 2nd class choki attached.

3rd. Bridge at Dumkoura, 135 feet waterway, in three bays of 45 feet, with ghats on the down-stream side (Atlas, Plate L.), and 1st class choki attached.

4th. Bridge at Urrowli, with ghats, rajbuha and inlet heads (Atlas, Plate L.), 135 feet waterway, in three bays of 45 feet each; roadway 25 feet broad: a 2nd class choki is attached to this work.

5th. Bridge at Wullipoora, with ghats, rajbuha and inlet heads (Atlas, Plate L.), waterway and roadway are the same as at Urrowli; with a 2nd class choki attached.

6th. Bridge at Mamun, similar in every respect to that at Nidhowli, with a 2nd class choki attached.

7th. Bridge at Uchuhja, similar to that at Dumkoura, with 2nd class choki attached.

At the Urrowli Bridge, the high road between Bolundshuhur and Delhi, and at the Wullipoora Bridge the Grand Trunk Road in its route from Khoorja to Bolundshuhur, cross the canal; at both these points increased width to the bridge roadways has been given, and at the latter one, additional length of bathing ghat also. Throughout all this line of works kunkur has been the staple material for building purposes.

The depth of wells on the usual recorded measurement, viz. from the surface of the earth to the surface of the water, is on a maximum 36 feet, on a minimum 15 feet throughout this section.

From the 140th to the 160th mile, the direction of the canal continues on a straight line,* maintaining its course in proximity to the East Kalli Nuddi, which opposite to the 160th mile takes a considerable curve to the eastward, regaining its position with regard to the canal alignement a few miles south. The width between the two rivers (East Kalli Nuddi and Kuroon), which in the latitude of Khoorja is about 11, is at this lower point 24 miles; the country is well cultivated throughout, and its slope longitudinally is 27·73, or 1·38 foot per mile; transversely the slope of the country is from east to west, but the canal runs on a high level, and keeps well to the watershed: opposite the village of Gungowli the line comes in contact with sand-ridges, through which it is

* 140th to 160th mile.

carried; in other respects the soil is good, although in excavation, sand and a lighter species of soil show themselves in increasing abundance below the levels of the canal bed. On this line the channel is somewhat shallower than the high-water mark of the canal calls for; the deficiency has been made up by embankments, of such a nature as to preclude any accident or lead to inconvenience to the country; the earth for this purpose has been procured from the surface on the outside of the canal boundaries, and necessary measures have been taken to secure these excavated areas from deposits of water.

Where the canal runs on the 160th mile, the surface of the country is 15·62 feet above the bed of the Kuroon and 25·33 feet above that of the East Kalli Nuddi.

At the 143rd mile, at the village of Moonda Khera, No. 4 escape is situated: this work, which in waterway is equal to 60 feet in ten sluices of 6 feet each, is attached to the up-stream side of the Moonda Khera Bridge, with its head well protected by masonry revetments, constructed in the step form, as that most convenient for the purposes of approach to the water; this escape is connected with the bridge by long lines of steps laid out in the form of an ogee curve, and forms with the different inlets and rajbuha (or main watercourse) heads, a very complete and very handsome mass of building; its situation is directly opposite, and to the east of the town of Khoorja, for the convenience of the population of which these extensive ghats were especially constructed. At this point, and intermediate between the escape and the bridge, is a 1st class choki building, the site being intended as one of the main stations on the line of canal.

The escape channel, which is excavated on a width of

50 feet, is cut out to the valley of the East Kalli Nuddi; the difference between the escape flooring and the bed of the river being 16·74 feet on a distance of 9,500 feet. Here, again, as was explained in the escape channels towards the West Kalli Nuddi, the arrangements for the passage of the main line of rajbuha will be designed in connection with a bridge of cross-communication and a descent in masonry; further operations with regard to retrogression of levels from the bed of the East Kalli Nuddi being postponed until the practical effects of wear and tear by retrogression have exhibited themselves; in preparation, however, for this circumstance, material has been collected, so that the means for counteracting the evils will be at a moment's notice available.

At the 149th mile, the Pulra falls deliver the whole body of the canal water on a level 5 feet lower than that on which it has been running. This work consists of five bays of 20 feet each, giving a clear waterway of 100 feet; the general design of the work being the same as that which has been before described. The works at the head of the navigable channel, locks, mills, rajbuha heads, &c., are all built on the same design (*vide* Atlas, Plate XXX.)

Three miles below the Pulra falls, and close to the 152nd milestone, the Koel branch leaves the canal on its right. The works at the head of this branch are on the same design as those at the Bolundshuhur branch head before described; the regulating bridge over the canal having a waterway of 120 feet, divided into six openings of 20 feet each, and that across the head of the branch having 50 feet waterway, viz. a centre bay of 20 feet, with two side bays of 15 feet in width each, the works attached, with the choki of 1st class dimensions, are the same as before described.

The capacity of channel for the Koel branch is the same as that for the Bolundshuhur, the head discharge being estimated at 520 cubic feet per second.

The object of placing the head in the position in which it is situated, is to secure a line of channel as free as circumstances will permit for the low lands which lie to the south-east of Somna, in the neighbourhood of the fort of Alligurh and the town of Koel; these low lands or flats, which are very extensive, are connected with a good deal of the downward drainage of the country; the Rinde and Seyngoor, the former on the east, and the latter on the west, derive their head supplies from this neighbourhood: the Seyngoor, however, or that river which is most directly connected with the Koel drainage, and which at all periods of the rainy months acts as the escape from this particular part of the country, is the line whose heads it was the main object to turn, and this will be very tolerably effected, from the point which has been determined on; the fall or declivity of the surface of the country corresponding with that of the lower levels which the canal has gained by its descent over the Pulra falls.

The Koel branch will irrigate that portion of the country which lies between the Kuroon and the Seyngoor rivers. Its direction has not been accurately determined; but the transverse sections of the country which were obtained in the original surveys define the line with some degree of accuracy as bearing to the east, and close by the town of Somna, to the west of Koel, and onwards to the richly cultivated districts in the neighbourhood of Hattrass and Sasni.

In describing the Choiya and Kuroon, I have, in fact, explained the character both in its rise and progress of the Seyngoor River, which, as I have before mentioned, acts as the left or eastern boundary of the Koel branch. This river, which in the early part of its course takes a southerly direction, continues onwards inclining to the east; it runs through 190 miles of country, passing through the districts of Alligurh, Etawah, Mynpoori, and Cawnpoor, and joins the Jumna River in the latter district: this junction is effected near the town of Moosanuggur, at a point almost centrically situated between the two stations of Kalpi and Humeerpoor, which lie on the opposite or right side of the river. The increasing width and depth of section that I have noted as characteristic of the rivers in the Doab, lead, in consequence of the great length of the Seyngoor, to its becoming a very formidable river, running through deep and raviny ground, on the latter part of its course and on its approach to the Jumna: it is a line which is very intimately connected with the Ganges Canal works, as providing a boundary to the tract upon which the Etawah branch runs; and in this point of view is one well deserving of attention when considering the design which has been adopted in laying out the main lines of irrigation.

The works on this section, or from the Uchuhja Bridge downwards, are as follow:—

1st. Moonda Khera works, consisting of a bridge of three bays of 45 feet each, rajbuha heads, inlets, ghats and escape No. 4 into the East Kalli Nuddi, with a 1st class choki attached (Atlas, Plate XXXVII.)

2nd. Bridge at Suhenda, with a waterway of three bays of 45 feet each, with rajbuha heads, inlets, and ghats, with a 2nd class choki attached.

3rd. Pulra falls and works, the falls having a waterway of 100 feet in width, divided into five bays of 20 feet each. Head to navigable channel, locks, and other works precisely similar to those before described (Atlas, Plate XL.)

4th. Koel branch head works, similar to those at the Bolundshuhur branch head, the waterway of the branch regulator being 50, and that of the main canal regulator 120 feet in width. To these works a 1st class choki is attached.

5th. Bridge at Daoopoor, with a waterway of three bays of 40 feet each. Rajbuha and inlet heads, ghats, and a 2nd class choki attached.

6th. Bridge at Birowli, similar to that at Daoopoor, with a 2nd class choki attached.

7th. Bridge at Dubthulla, similar to that at Daoopoor, with a 2nd class choki attached.

In advance of the 160th mile,* the alignement continues direct to the neighbourhood of the village of Simra, at which there is a curve on a radius of 20,000 feet, which brings the canal on the direct bearing of the head works of the Etawah and Cawnpoor terminal lines, and of the villages of Nanoon and Rajoopoor, between which these head works are situated; at this point, which is 180 or $180\frac{1}{5}$ miles from the regulator of the canal head at Myapoor, the main trunk of the Ganges Canal terminates; the spot is marked by a solitary Tar or Fan palm-tree (*Borassus flabelliformis*), the last of its race that shows itself on the works, and, with the exception of a few plants scattered sparingly in the Saharunpoor and in the districts between it and Nanoon, almost the first specimen of this species of palm which exists in these northern latitudes.

The slope longitudinally of the surface of the country from the 160th mile is 26·86 feet, giving an average per mile of 1·34 foot: its transverse slope tends towards the westward from the East Kalli Nuddi to the Kuroon, and ultimately, as the canal proceeds onwards, to the heads of the Seyngoor River. The canal alignement is, in fact, kept as near as possible to the East Kalli Nuddi, so that it may avoid the low tracts in which the Seyngoor drain-

* 160th to 180th mile.

age commences, and in the neighbourhood of Hurdooagunj the canal, which passes between that town and the East Kalli Nuddi, approaches to within $1\frac{3}{4}$ mile of the latter. In defiance, however, of this close approximation to the above river, the depth of canal excavation is on a considerable length insufficient for the high-water supply; embankments have been made to meet the required height from earth excavated from the outside of the boundaries; the consolidation of which, together with the magnitude of their proportions, will secure the country from any liability to accident; the measures which have been taken to secure efficient inlet, also, will, it is to be hoped, relieve the neighbourhood from inundation. There was so much earth required for these lines of embankment, that the usual method of taking a superficial foot in depth over large areas was utterly impracticable, from the distance to which earth would have to be carried; I therefore determined on the excavation of a series of tanks at fixed distances from the canal boundaries, as well as from each other, of dimensions in squares or oblongs adapted to the cubic content of earth required for the canal works: it struck me that compactly formed and deep tanks or reservoirs might hereafter be of great use in catching supplies of drainage water, and of adding their quota to the irrigation of the fields in the neighbourhood: the depth to which these reservoirs are dug will prevent the accumulation of water reeds, and the rank vegetation that usually attends shallow pools. At any rate, the necessity (should the speculations on their use as machines for irrigation hereafter be accomplished or not) of keeping them clear and free from malarious appendages, may be considered a duty attendant upon the supervision of the works.

The width of country between the East Kalli Nuddi and the Kuroon at the 160th mile of the course of the canal is 24 miles, and it continues very nearly on this width to the 180th mile, or to the branch heads at Nanoon; here, however, the intervention of the Seyngoor River, which has at this point of its course arrived at a well-defined section, reduces the width to 10 miles, over which the canal runs intermediately, the works being situated exactly on the highest ground, and midway between the two rivers.

At the point where the canal passes the town of Hurdooagunj, the surface of the country is 22·33 feet above the bed of the East Kalli Nuddi, and 18·84 feet above that of the Kuroon, at points at right angles to the canal channel.

The country throughout the whole of these 20 miles is well cultivated, excepting in the plains in the immediate neighbourhood of the heads of the Seyngoor; there is a good deal of irrigation from wells, the maximum depth of water from the surface of the earth being 49 feet, and the minimum 16 feet.

Near the village of Simra, and at the 163rd mile of the course of the canal, the water is let down to the lower levels by another set of falls, similar in every respect to those before described at Pulra: this abrupt descent is, as in the case of the Pulra one, equal to 5 feet in perpendicular height, and it completes the great step of country which is met with on the approach to the heads of the Seyngoor and Rinde, which flow towards the right to the Jumna, and to the Eesun, which passes off to the Ganges on the left. The navigable cut, with its arrangements for the departure of vessels from the main line, its locks, mills, and rajbuha heads, are precisely similar in design to those figured in the Atlas, Plate XXX.

Near the village of Kasimpoor, which is situated about 3 miles below the Simra falls, an escape, No. 5, into the East Kalli Nuddi, similar in dimensions to that at Moonda Khera, viz., 60 feet waterway, divided into ten sluices of 6 feet each, is built in connection with the bridge, on the same design, and with an excavated channel of 50 feet in width, precisely as has been described at the Moonda Khera works; the distance between the canal at the Kasimpoor escape and the East Kalli Nuddi is 20,577 feet, and the total fall between the escape flooring and the bed of the river is 21·35 feet. The plan which has been before described for getting over the difficulties of excess of slope in the bed of these escape channels will be practised at the Kasimpoor works; and the method of passing the eastern rajbuha across the escape channel will be in every respect similar to that which has been adopted before.

The head works of the Etawah and Cawnpoor terminal lines are in design like those at the branch heads before described; the main trunk channel, on its approach to the heads, however, bears on a line which bisects, or which divides into two equal parts, the angle of departure of the two branches; this angle is equal to 43 degrees, and the main line meets it on an angle of 158½ degrees. The design of this particular lining out of the works is, that the current of the main line shall meet the branches on its right and left under precisely similar circumstances, so that as far as capacity of channel, slope of bed, and direction is concerned the supply of each branch shall correspond; this correspondence is further maintained by the regulating bridges over the head of each being of the same dimensions, viz., of 100 feet waterway, divided into five bays of 20 feet each. The supply of each branch, therefore, although laid down as equal, can be regulated in any way that it is desired, through the medium of the regulating apparatus; in cases where such is required, in fact, one or other of the branches can be laid entirely dry; any surplus water being passed off at the escapes at Kasimpoor or Moonda Khera.

The Grand Trunk Road between Cawnpoor and Allygurh crosses the line of canal over the regulators at these heads. The position is one of great importance, and as a main canal post has a 1st class choki attached to it.

The works on this section, or from the bridge at Dubthulla, downwards, may be thus enumerated:—

1st. Falls and works at Simra, similar in every respect to those at Pulra (*vide* Atlas, Plate XL.)

2nd. Kasimpoor works, consisting of a bridge of three bays of 40 feet each in waterway, rajbuha and inlet heads, ghats, and escape No. 5 into the East Kalli Nuddi, with a 1st class choki attached.

3rd. Bridge at Burotha, with a waterway of three bays of 40 feet each; with rajbuha and inlet heads, ghats, and a 2nd class choki attached.

4th. Bridge at Machooa, similar to that at Burotha, with a 2nd class choki attached.

5th. Bridge at Chungeri, similar to that at Burotha, with a 2nd class choki attached.

6th. Bridge at Sheka, similar to that at Burotha, with a 2nd class choki attached.

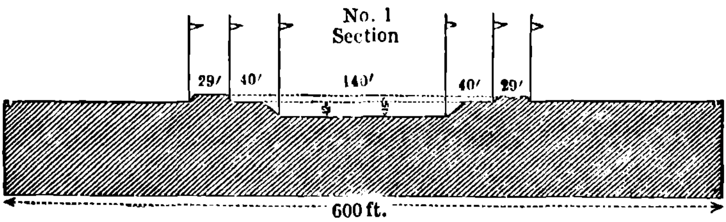
7th. Nanoon head works, similar to those before described at the heads of the other branches, but with the regulating bridges having a waterway of 100 feet each, divided into five bays of 20 feet each; a 1st class choki being attached to the works.

As noted in the works throughout the Bolundshuhur district, the staple material for building has been kunkur, the use of bricks being confined to arches and to those works where kunkur was not procurable.

The works at Nanoon, which are situated at the down-stream extremity of the main canal, are the terminal point of the section included between the entrance upon the high land at Roorkee, and the fork at which the Etawah and Cawnpoor branches separate. I have given in the above detail as full a description as possible of the profile and extent of country over which the canal passes, and it will be observed from this detail that the arrangements which have been made for the different subordinate lines or branches provide the means for irrigation on the whole length and breadth of the country from the Ganges on the east to the Hindun and Jumna on the west, and that the extraordinary declivity of profile which takes place on the early part of its course, enables us to gain the most efficient head supply for all the side lines, whether these are canals for the use of lands situated at great distances from the main channel, or whether they are rajbuhas or main watercourses for the irrigation of lands lying within a moderate distance.

The capacity of the channel from Roorkee to the head of the Futtigurh branch, or to the 50th mile of the course of the main canal, has not been increased from the dimensions laid down in my estimate of 1845; the minimum section being as follows:—

Diagram 20.



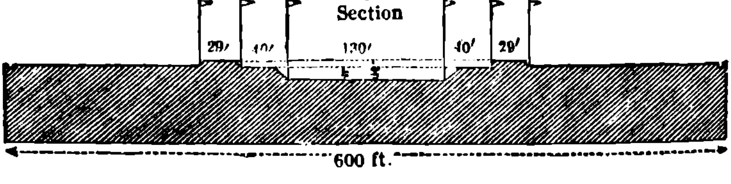
That is to say, the height of the top of the bank from the canal bed is 15 feet, and that of the berm from the canal bed is 12 feet: the latter is a constant quantity; and although it is exceeded in many places where the depth of excavation is very great, the depth of 12 feet for the trapezoidal portion, which is intended for the retention of the canal water, is always maintained; the height and width of the embankments vary with the amount of earth excavated from the channel, but the earth is always spread out, so as to form an even esplanade; and it is only at those parts of the canal, south of Togulpoor, for instance, where the depression of the surface of the country led to shallow digging, and consequently to an artificial formation of berms and embankments, that the minimum section is practically exhibited.

The width of waterway of the falls and bridges, however, has been increased from 150 to 200 feet, and the latter by the removal of the solid towing-path, which was projected into the stream, from 150 to 165 feet. The canal channel may be considered, as far as its bed is concerned, to consist entirely of sand, and a consequent wear and tear of slopes and sides, leading to a gradual extension in width to the earthen channel, may be anticipated.

It will be observed by referring to diagram 17, page 197, that the estimated maximum discharge at Roorkee is equal to 6,750 cubic feet per second, and that this supply, by the abstraction of 330 cubic feet per second for the rajbuha heads at the Assoffnuggur, Muhmoodpoor, Belra, and Jowli falls, to each of which 41¼ cubic feet per second have been allowed, and of 1,240 cubic feet per second for the supply of the Futtigurh branch, is diminished at the head of the canal regulator at that point to 5,180 cubic feet per second.

The regulator across the main canal at the Futtigurh branch head has, as has been before stated, a waterway of 180 feet in nine bays of 20 feet each. From the Futtigurh branch head the section of the canal is reduced to the following dimensions:—

Diagram 21.



And this is continued unchanged to the Khutowli, or No. 1, escape into the West Kalli Nuddi, in supersession of the gradual diminution in width to 121 feet, as it was designed in the estimate of 1845. The same remark applies here, as in all cases where a minimum section is given, viz., that much as the dimensions may be extended, they are never reduced below the figures above noted, and the three dimensions of 130, 40, 40, or the breadth of the rectangle, and the distances between that rectangle and the foot of the embankment slope on each side, are in all cases constant quantities. On this line the width of waterway of both bridges and falls has been retained at the larger dimensions above specified, and bridges with side passages constructed on the flanks, and in prolongation of the towing-path, or the berm, have been arranged for the convenience of traffic, as well as for the extension of the bridge waterway.

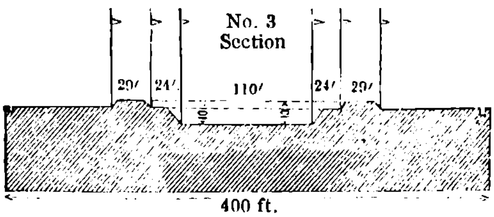
From the Khutowli escape, or from the 62nd to the 105th mile, the section of the canal is precisely the same as that above figured, excepting only that the width of rectangle is reduced from 130 to 120 feet; from the 105th to the 110th mile, or to the head of the Bolundshuhur branch, the width of rectangle is still further reduced to 110 feet; the section otherwise remaining the same, and the height of berm above the canal bed being never less than 11 feet. The canal on its leaving the regulator at the Bolundshuhur head, has to carry a supply equal to 4,330 cubic feet per second; the abstraction of water between that point and the Futtigurh branch being equal to 330 cubic feet per second for the supply of the rajbuha heads, and 520 cubic feet per second for that of the Bolundshuhur branch. I may here remark that from Roorkee to this point, or to the head of the Bolundshuhur branch, the water for the purposes of irrigation is taken from heads situated immediately above the masonry falls; of these heads eight are on the right, and eight are on the left of the canal; the supply of water allowed for these 16 heads is equal to that calculated (*vide* tables) for 82½ miles at 8 cubic feet per mile; the upper 27½ miles measuring from Myapoor downwards, having, for reasons before stated, been excluded from the irrigating districts: each of these 16 heads, therefore, has a supply per second equal to 41¼ cubic feet, delivered from the canal under the most advantageous circumstances of command over the country, and of facility for securing a regular supply. I consider that the means are so ample on this line for extending irrigation, that there will be nothing to prevent the passage of the West Kalli and the introduction of watercourses on the surface of the country above the junction of that river and the Hindun; the bridges and ramps of approach to the bridges on the West Kalli Nuddi may be the means of facilitating this object, but there can be no doubt that aqueducts built specifically for the purpose, would lead to returns sufficiently remunerative. The station of Hapoor and the stud lands, which are separated from the line of canal by the Choiya Nuddi, will be reached with probably greater facility by turning the heads of the Nuddi itself; but I believe that there is no intersecting river on this tract of the country, with the exception of the great boundary lines of the Jumna and Ganges, that ought to be looked upon as offering the slightest impediment to the passage of a rajbuha; with certain restrictions, depth of section in a river or ravine to be crossed, is a positive advantage; anxiety and trouble arise only in crossing those shallow tracts that give no depth of section at all, and thus render sub-passages necessary to prevent interference with the natural drainage; in such localities lines of rajbuhas, with their attendant embankments, are often sources of expense and care.

The waterway of the bridges continues on the dimensions as above specified, as far south as Sirdhunna, below which it is diminished to 150 feet, in three arches of 50 feet each; below the Dasna falls, this waterway is again reduced to 135 feet, in three waterways of 45 feet each. To meet the decrease of supply and the diminished capacity required, the falls from Sulawur downwards are reduced to 150 feet in width of waterway.

The waterway of the regulator on the canal, which is situated at and immediately below the Bolundshuhur head, is, as I have before mentioned, equal to 160 feet in width, in eight openings of 20 feet each; the advantages of giving capacious waterway in manageable openings at these regulators are great, as it relieves the channel from the wear and tear which would otherwise attend upon the working of the shutters under a contracted opening.

From the 110th to the 144th mile, the capacity of the channel of the canal is the same in width as described from the 105th mile downwards, the difference between the berm and bed level being reduced from 11 to 10 feet, it having been an object in this part of the course of the canal to reduce the maximum depth of the water to 8 feet; the section on this line is thus:—

Diagram 22.

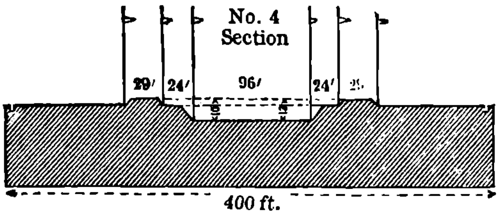


From the 144th mile, or from the down-stream side of the Suhenda Bridge, to the 180th mile, or to the Nanoon regulators at the end of the main line of canal, the width of the rectangle is gradually reduced to 80 feet, by a reduction averaging 10 inches per mile; the depth of trapezoidal channel being maintained in all cases at

10 feet, so that there may be a clear 2 feet above the high-water mark.

At the Koel branch head the width of the canal channel is represented by the following section :—

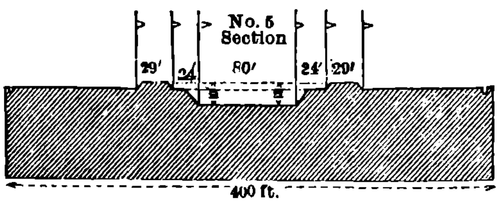
Diagram 23.



The discharge at that point being equal to 3,530 cubic feet per second, the regulator over the canal having a waterway of 120 feet in width, in six openings of 20 feet each.

On the channel reaching Nanoon, and immediately above the separation of the two branches, its capacity is shown by the following section :—

Diagram 24.



The theoretical discharge on the arrival of the water at that place being equal to 3,250 cubic feet per second.

I may remark that, from the 110th mile downwards, the regularity of the berm at a height of 10 feet above the canal bed has been maintained with great uniformity; the reason why the same regularity was not carried out in the channel above this point, was from the extraordinary depth of digging at parts where the channel came in contact with the bhoor land and the sand-hills, and the great expense that would in consequence have attended a reduction of the berm to one uniform level; at this period of our operations, and with so much experience to guide us, I am not sure that it would not have been better, as it certainly would have improved the look of the work, had the berms been constructed on a level parallel with that of the canal bed; in all cases, however, they have been sloped off on long lines, so as to render the irregularities as little apparent as possible, and in no case have they been made less in height than that designed, and as shown in the minimum sections figured in the above diagrams.

The width of waterway of the bridges, from the 110th to the 180th mile, has been maintained on two uniform dimensions, viz., of 135 and 120 feet, the former having three bays of 45 feet each, and the latter three bays of 40 feet each. My object in keeping to these two sizes was to give the greatest possible relief to the water in its passage through the bridges, and to simplify the construction, by which both time and expenditure were saved; the design of these bridges is the same as those before described, with towing-path arches in prolongation of the towing-path of the berm (*vide* Atlas, Plate L.) The Pulra and Simra falls have a waterway of 100 feet in width, and are so well protected, that the water will, I have no doubt, pass over them with as little obstruction as could be desired.

With the exception of the Dumkoura and Uchuhja bridges, where the application of outlets for irrigation did not appear to be desirable, every bridge, from the Bolundshuhur head downwards, has two rajbuha heads attached to it, one on each side of the canal (*vide* Atlas, Plate L.) The channels of these heads are made 10 feet wide, for the purpose of giving full scope either for the escape of water, or for the fixing of modules or other apparatus that may be at any time designed for the purpose of regulating the discharge; the width and height of these openings, as they have been now built, will, I hope, place it beyond possibility that they can require enlargement, which would of course involve a pulling down and reconstruction of the channel; a reduction to the size of the present waterway can be easily managed by building up and diminishing the size of the opening. In every case, however, the sill or flooring of the rajbuha channel is laid 2 feet above the bed of the canal, and of the flooring of the bridge to which it is attached; the object of this arrangement being to secure the passage of at least 24 inches in depth of the canal supply, and, by these means, to give water to the country in advance, which, had the zumeendars in the upper districts the power to drain off the canal to its bed, would, in case of drought, and when the competition was great, have in all probability no water at all. This point, it will be observed, has been particularly attended to in the irrigation outlets above the heads of the falls; the Assoffnuggur and Dasna, which are the two extremes, and have to maintain a supply for a long line of country, have their sills constructed on a level with the canal bed, by which every advantage will be gained in the supply of the rajbuha lines, whereas those which lie intermediately have their sills raised on a higher level, *i. e.*, one foot above the bed of the canal, so that water equal in amount to that depth may pass onwards for the irrigation of the lower districts.

I do not consider that the close proximity of the East Kalli Nuddi on the left of the canal is to act in the smallest degree as a limit to the extent of irrigation from the raj-buhas or heads lying on that side; by the use of masonry piers, and open sheet-iron channels stretched across them, the river can be passed without any difficulty, and the valley itself is easily overcome by an earthen embankment; the latter would in no instance exceed in dimensions some of the raised channels which have been built in connection with the rajbuhas on the Eastern Jumna Canal; that at Rundole, for instance, which is upwards of a mile in length, and with the bed of the watercourse raised 18 feet above the level of the valley. The East Kalli Nuddi will, therefore, be no impediment to the irrigation of the country lying on its left bank.

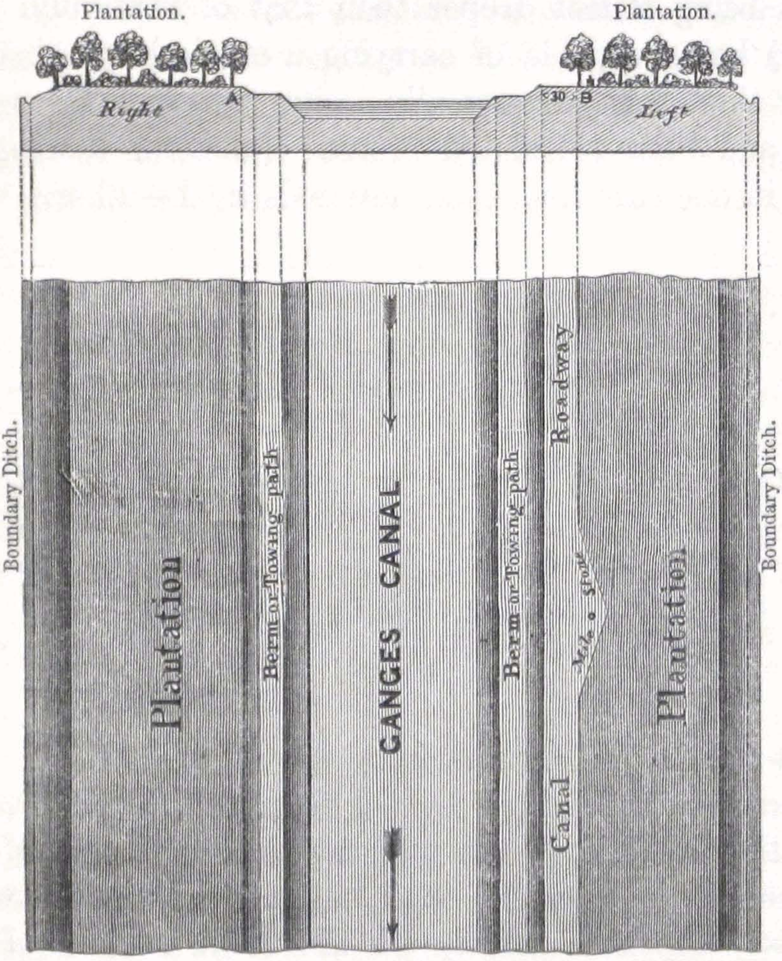
With a maximum theoretical depth of water on the different sections of the canal channel, as figured in the above diagrams, the discharges will be as follow; the actual capacity of the channel (from the circumstance of its being 2 feet deeper than that of maximum high water) being capable of carrying a much larger body of water than that theoretically assigned to it. The values of R and *b* are calculated on even numbers, ·5 being the limit in one case, and even hundreds in the other.

Section.	Value of R.	Value of *b*.	Sectional Area in Feet.	V in Feet.	Discharge.	
					Theoretical.	Required.
No. 1	107·0	4,224	1,500	4·04	6,056	6,750
" 2	96·5	4,224	1,251	3·83	4,794	5,180
" 3	85·4	4,224	944	3·60	3,400	4,330
" 4	84·0	4,224	832	3·57	2,972	3,530
" 5	82·0	4,224	704	3·53	2,484	3,250

It will be understood, from the method of disposing of the earth which is excavated from the canal channel, that the breadth of the esplanades on the top of the embankments, where these embankments exceed in width 20 feet, depends entirely on the cubic content of the excavated channel. With the exception of detached portions equal in total length to 9 miles, the whole of the banks from Roorkee to the 180th mile at Nanoon are much in excess of the minimum dimensions; they frequently occupy the whole space between the berms and the canal boundaries, and in this case offer a fine open esplanade for the purposes of roadway.

The maintenance of a line of roadway, both for convenience of communication, and for the purposes of patrol, is a point that has been anxiously looked to; this road is in some measure connected with the plantations, which are intended to occupy all the spare space between the canal boundaries that is not required for other pur-

Diagram 25.



poses. The general design and object of these plantations, whether for forest or for fruit trees, is explained in the volume of Tables.

The foregoing plan and section exhibit the lining out of the road, at a point where it comes in contact with a milestone; these stones are numbered from the Myapoor regulating bridge, in a continued series to the end of the main canal at Nanoon; they are, it will be observed, situated away from the road, in a platform kept clear for their especial purpose; they consist of a square prism of stone embedded in a cylindrical mass of masonry, the top of which acts as a bench mark, and the figures engraved on the stone, independently of the mileage, give the exact depression of that particular point from the flooring of the regulating bridge at Myapoor.

On the preceding diagram the width of the bank is supposed to be much greater than that laid down as a minimum dimension; in fact, as it really is on the greater part of this section of the canal, the road is here 20 feet wide, with an additional 10 feet between it and the plantations, so as to prevent the passage being interrupted by boughs of trees; the road by these means actually maintains a width of 30 feet; it has a slight slope internally, so that all drainage may flow away from instead of towards the canal channel, and there is a low edging of earth carried along the crest of the interior slope, for the purpose of preventing the action of the water from destroying its uniformity.

The above rule applies equally to banks of minimum dimension, the plantations being limited to a line B drawn in rear, and on the low ground, at the distance of 30 feet from the crest of the interior slope; platforms of earth connected with and equal in height with the embankment, are in this case raised for the accommodation of the milestones, should such happen to occur on these narrow lines of roadway. In the sandy tracts the surface will require some species of metalling, but in other parts the plain soil will be sufficiently even, and of sufficient durability, to admit of its being kept in order. This road is situated on the left or east side of the canal, when the direction runs from north to south, as by these means the plantations give shade to the roadway in the earliest and hottest part of the day: the road is specifically for the canal establishment and for canal purposes, and is not maintained as a public line of communication.

The section given in diagram 25 will show the exact limits to which the plantations are carried, and the limits of annual clearance from grass, jungle, and other nuisances that might impede the flow of the water; the lines marked A B define the portion in the vicinity of the stream, that it is proposed to keep perfectly clear from jungle: within these limits no trees are to be allowed on any account whatever; beyond them the whole space up to the canal boundaries is devoted to plantations of forest trees. I may observe, that with a desire to secure good shade to the roadway, I have planted a row of mango-trees on the line marked B, throughout the whole length of the canal. These trees at present are 100 feet apart, but when they have taken root, and are fairly in progress of growth, it is proposed to put in an intermediate tree of the same useful and ornamental quality; there is some difficulty in the establishment of this species of tree, as it is a martyr to the whole tribe of the white ants, who attack it with remorseless severity; it requires care and attention in being well watered during the dry weather, and it is much benefited by shade in the earlier periods of its career; for these reasons I have restricted the number to a moderate proportion, so that the gardeners who are in charge of the different plantations may not be overwhelmed with their duties in securing the growth of this single line, the advantage of which, 20 or 30 years hence, will be duly appreciated by those who have to travel along the Ganges

Canal works. It must not be understood that the mango-trees above referred to are *grafts;* they are the common country mango, which grows to its natural size, lofty in height and wide in its stretch of ramification. The plantations of "grafted mangoes" are confined entirely to orchards situated near the 1st class chokies, or main station points of the different districts, which are on an average (with the exception of those built for specific purposes at falls and other large works) about 12 miles apart from each other.

The works on this section were divided into two portions, which have been carried on under the titles of the 2nd and 3rd divisions. The 2nd, commencing at a point below the Assoffnuggur falls (above which the works, as I have before described, are included in the northern division), and terminating at the 110th mile, or at the departure of the Bolundshuhur branch, was commenced under the executive management of Captain A. D. Turnbull, of the Engineers, who, in December, 1847, was relieved by Lieutenant E. Fraser, of the same corps. On Lieutenant Fraser's departure on medical certificate to England in October, 1850, Mr. Frederick Read, the senior assistant in the division, assumed charge of the works, and under this gentleman's management, the division has been brought to its present state of completion. The Futtigurh branch, the works of which have not yet been begun, is included in the 2nd division.

The 3rd division, or that from the 110th to the 180th mile, including the terminal works at each extremity, have been begun and completed under the supervision and management of Mr. Philip Volk. Both the Bolundshuhur and Koel branches are included in the 3rd division.

III. *The country from Nanoon to the Ganges and Jumna rivers, marked by a deficiency of fall in the surface of the country, and by its connection with the Rinde, Seyngoor, Pandoo, and other rivers, which drain the flat lands of the centrical districts.*

This section includes both the Cawnpoor and Etawah branches or terminal lines, into which the main trunk is separated at the Nanoon works; it naturally, therefore, comes under two heads, and as the line which runs between the Eesun and Rinde is that of my original survey, and that which was explained in my report of 1845, I shall, in describing in detail the country below Nanoon, limit myself first of all, to the Cawnpoor or easterly branch, being that which is the connecting link between the canal head and the Ganges River. A few prefatory remarks, however, regarding the site taken up for the head of these branches, and the motives for fixing it at Nanoon, will render the details which follow much more distinct and interesting.

I have already referred to the Seyngoor and Rinde drainage, as having influenced in a great measure the direction upon which the main line is carried from the 152nd mile, or from the neighbourhood of the town of Somna downwards; this drainage shows itself in a very undecided and unmarked character, along a line of country passing Koel, Alligurh, Nanoon, Akrabad, and even to a point as far as the town of Sikundra Rao; the direction of this drainage inclines from the East Kalli Nuddi, towards the right of the canal line; in the neighbourhood of Sikrundra Rao, however, another series of jheels or extensive flats occurs, and from thence rises the Eesun River, a line of drainage which keeps to the left of the canal. In fixing, therefore, a point for the head of the branches, it was necessary, in such a labyrinth of watershed, to look to that which would give the greatest facilities for turning the heads of the different rivers; for passing between those of the Rinde and Seyngoor attended by the least possible interference with the natural drainage; and by reaching Sikundra Rao, and the country lying to the east of it, between the Eesun and Rinde, with as little interruption as might be to the cross drainage escaping between Akrabad and Sikundra Rao. The difficulties of this ground will be more clearly understood by a reference to the map (Atlas, Plate V.); the whole surface was carefully examined, and the site at Nanoon, a village situated 2 miles to the west of the town of Akrabad, was determined on as that most convenient for the required purposes; it enabled us to reach the high land stretching between the Eesun and Rinde, and upon which the Cawnpoor branch is directed, with moderate interference from country drainage; and it placed the Etawah branch on the ridge between the Rinde and Seyngoor, without any interference with their watershed at all. I believe that the position fixed upon at Nanoon for the head works of the terminal lines is the true one, and that by establishing the fork at that particular point, we have by the least amount of artificial aid left Nature to carry out her own operations unimpeded. The design for the slopes of the bed of these branches is in both cases precisely the same, in the early part of their course; the slope of 15 inches has been continued as far as the natural profile would admit of it; and when this ceases to be the case, the slopes are reduced to 12 inches per mile, the superfluous fall being overcome by masonry descents and lockage; the detail of this part of the work will be fully entered upon hereafter. For the reasons above specified, I shall commence the detail of the works below Nanoon by taking up those between the Rinde and the Eesun, and terminating in the Ganges River; this series of works is denominated—

THE CAWNPOOR TERMINAL LINE.

The total length of this branch from the Nanoon regulator to the terminus on the Ganges at Cawnpoor is 169 miles 3,700 feet. After leaving Nanoon, and after having overcome the difficulties of the flats and hollows between that place and Sikundra Rao, the channel proceeds in an easterly direction, keeping to the line of main canal of my original survey, and maintaining an almost direct course centrically between the Eesun and Rinde rivers, as far as the 98th mile at the village of Dingri; south of this point the Rinde River discontinues its parallelism with the Eesun, and proceeds onwards on a more southerly course; whilst the Pandoo River, the heads of which lie on the left of the Rinde, and in the neighbourhood of Subhud and Bandmow (villages situated to the south-east of Dingri), takes up the bearing which the Rinde has deserted, and continues on a course parallel to the Eesun River. At the 98th mile, therefore, the line of canal turns the heads of the Pandoo, and proceeds onwards, keeping to the left of that river, and between it and the Eesun, until it reaches the 139th mile; at this point, and on the left, the Noon, a line of drainage connected with the Ganges and the low land lying between Cawnpoor and Baitool, rises; keeping this low land connected with the Noon on the left and still maintaining its parallelism with the Pandoo River, the canal proceeds onward to the village of Barah, or to the 160th mile; from thence it takes a long sweep to the north-east, and, passing between the town and military bazaars of Cawnpoor, enters the Ganges River by a series of locks and falls.

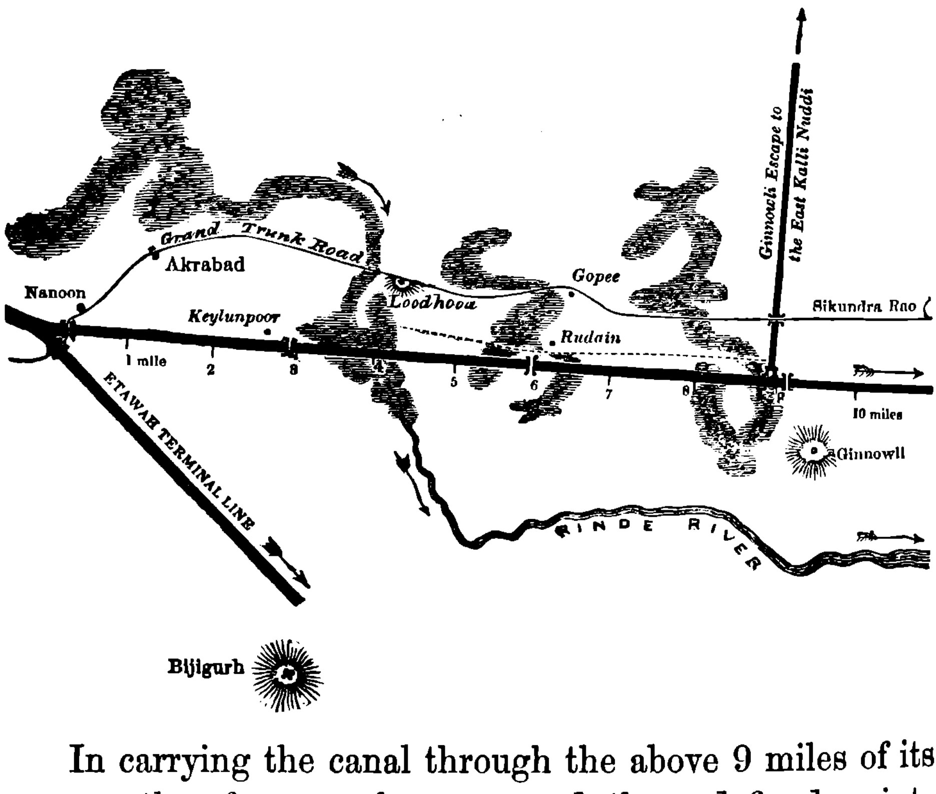
The above general outline will convey a tolerable idea of the position which the branch occupies, with reference to the Eesun, Rinde, Pandoo, and Noon rivers. I shall now take up the detail, on the system which I have before observed, of describing the works and the country over which they pass in specific distances of the course of the canal; on this plan, commencing at Nanoon, I shall take the first 30 miles, which brings us to the high road between the towns of Eyta and Agra, and the villages of Guddunpoor and Sawunt Khera, which lie on opposite sides of the canal.

With the exception of a slight curve,* which gives the canal a direction to the south of the town of Sikundra Rao, the bearing throughout the whole of the 30 miles from Nanoon to Sawunt Khera is almost due south-east. At points near the 4th, 6th, and 9th miles, and before its arrival at Sikundra Rao, the line of canal crosses low country, which is connected with the heads of the Rinde, that at the 4th mile, near the village of Loodhooa, being the most distinct, and traceable to a set of shallow depressions which lie on the north of Nanoon; from these jheels or hollows the drainage appears to pass round on the north of Akrabad, keeping to the west of the village of Loodhooa; it then crosses the line of canal, and sweeping round the village of Kunnukpoor, in a defined line of watercourse, assumes under that shape the name of the "Rinde." The true Rinde may be considered as that above described, originating in low jheels north of Nanoon. This line of drainage appears to be the most connected of the series; its indistinctness, however, excepting by actual instrumental levelling, may be understood by its exceeding shallowness: the maximum depth of the main hollows which lie near Nanoon is only 3 feet below the surface of the neighbouring country, whilst in its course round Akrabad and Loodhooa it does not exceed 12 inches in depth. At the 6th mile, and near the villages of Gopee and Rudain, the hollow is of the same character in its immediate junction with the canal,

* 1st to 30th mile.

and the drainage appears to pass off towards the Rinde without any perceptible depression. At the 9th mile, the hollow bears some resemblance to that described as crossing the canal at the 4th mile, but it is less extensive, although evidently connected with a quantity of uneven ground near the high village of Ginnowli, lying on the right of the canal, and under which the water passes off to the Rinde. The following diagram gives a representation of the drainage above mentioned :—

Diagram 26.



In carrying the canal through the above 9 miles of its course, therefore, we have crossed three defined points over which the drainage towards the Rinde River naturally runs; on this length of canal there are three bridges, situated at Keylunpoor, Rudain, and Ginnowli, each of which is provided with masonry inlets; these bridge inlets, however, are constructed more with a view to prevent the accumulation of water by the interference of the bridge approaches with the drainage of the country than to relieve the drainage of the country itself; my object in all cases having been to turn rain-water away from the canal into the rivers lying on the right or left, so that the canal line may be perfectly free and unincumbered: the inlets at the bridges, therefore, would give little relief to the country lying on the left, which had thus been cut off from its natural means of drainage. To obviate the difficulties of our position in this neighbourhood, an escape channel has been excavated from a point above the Ginnowli Bridge, or that which is situated on the lowest levels, to the East Kalli Nuddi, and cuts have been made connecting the different hollows in the 4th, 6th, and 9th miles, with the escape channel; the drainage, therefore, will pass down parallel to and on the left of the canal, and find an escape in the channel above described. The distance from the canal at Ginnowli to the East Kalli Nuddi is 11 miles, and the escape channel joins a ravine near the village of Chokra, lying on the right bank of that river; the difference of level between the sill of the escape at Ginnowli and the bed of the East Kalli Nuddi is 28·67 feet, or 2·42′ per mile. The excavation has from motives of economy only been carried to a width of 10 feet, as the wear and tear of the current will, it is supposed, widen it sufficiently for all practical purposes. Advantage has been taken of the necessity which arose for excavating the channel and for connecting the drainage with the East Kalli Nuddi, to build an escape head from the canal channel, with 18 feet waterway, immediately above the Ginnowli bridge; we have, therefore, the means, during the whole year, of using this escape channel for canal purposes, as well as for those of country drainage. As the channel in question crosses the Grand Trunk Road, the bridge required for the purposes of this road has been built with a waterway of 30 feet in width, so that there may be ample space for the passage of the water, and also for any increased width to the present excavated line, which may follow on the passage of flood water. One advantage, and by no means a small one, of establishing a canal outlet in connection with this channel is that, if such should be necessary, an occasional scour can be given by passing a current of canal water down it.

From Ginnowli, the canal passes onwards on the same bearing, leaving the town of Sikundra Rao on its left at the distance of a mile; in the neighbourhood of this town, encircling it in fact, are numerous shallow depressions, in which the Eesun River, which henceforward becomes our left boundary, has its origin; these depressions, with a profile of country very irregular (and as I have described elsewhere, when pointing out the peculiarities of these Doab rivers, so marvellously unobservable, from their shallowness, that the irregularities are only to be traced by the levelling instrument), continue onwards parallel to, and as it may be said fringing, the line upon which the canal runs as far as the 24th mile, at which point, and in the immediate vicinity of the village of Jinwar, we come in contact with one of them, which, by being extended farther to the south, forces us to cross it, under the disadvantage of much heavy embankment.

This hollow, ordinarily termed the Jinwar Jheel, lies due east and west; it is in the form of a horseshoe, with its toe resting on the village of Jinwar, which is on its western extremity. The extent of this horseshoe surface is about one square mile, and its maximum depth below the country in its neighbourhood is 6 feet. The canal channel passes through it on its full extent, and from having been more or less filled with water during the period that the works have been in progress, some annoyance has been experienced in the embankment operations; its character, however, as a jheel holding a perennial supply, which was that given to it by native report, failed in the cold weather of 1853, when I found it dry or very nearly so, a circumstance that may have arisen from the canal excavations, although the channel was completely cut off from the expanse of the jheel itself by heavy embankments. It will be understood from the above description that a considerable portion of this hollow, lying to the right of the canal, is cut off from its connection with the Eesun, and consequently from its natural line of escape; this has been remedied by excavating a channel from a point on the extreme east of the portion so cut off, towards the Rinde River, and by these means relieving the country from any ill effects caused by our interference with the jheel (see diagram No. 28); the cut thus made is in length 15,250 feet, with a bottom breadth of 5 feet, its average depth being about $8\frac{1}{2}$ feet, and I have no doubt that it will act in the most efficient way in relieving the country. The Eesun River, which, in the neighbourhood of the Jinwar Jheel, lies at a distance of about 2 miles from the course of the canal, turns off abruptly to the left on its approach to the village of Roostumgurh; and at the 30th mile of the course of the canal, and below the point where the high road between Eyta and Agra crosses it, the river and the canal are separated by a distance of 5 miles, whilst immediately eastward of the same point and of the village of Sawunt Khera, the canal comes in direct contact with the hollows of the Rinde, the tortuosities of the course of which are here very remarkable; its course in fact at the point in question is directly at right angles to that of its general alignement; it passes from west to east between the villages of Sawunt Khera and Gillowli.

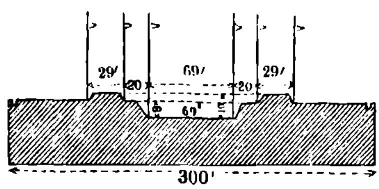
The strip of land over which the canal runs between the Eesun and Rinde rivers is exceedingly narrow; its maximum width is only 7 miles, and at the village of

Murgaon, or on the 22nd mile, the width does not exceed 2¼ miles. The surface slope of the country from Nanoon to Sawunt Khera, *i. e.*, on a line of 30 miles, is 42·35 feet, or an average per mile of 1·41 foot. The bed of the Eesun, or rather the country at the heads of that river, in the early part of its course, is on a higher level than that of the Rinde; as the rivers advance, however, and where they obtain a more defined section, the true relative position of the drainage exhibits itself at the 30th mile; a cross section from the Eesun to the Rinde shows that the bed of the former is 5·44 feet below that of the Rinde, and the latter river maintains its elevation above the Eesun throughout the whole length of its course afterwards.

The section of the canal at the 30th mile is shown in the following diagram, the width of rectangle, which at the Nanoon regulator was 80 feet, having, by a gradual reduction of 4·12 inches per mile, been diminished by 11 feet.

Diagram 27.

Section at the 30th mile.



The depth of canal water, which on its approach to the Nanoon regulators had been retained at 8 feet, has been, by an extension of width to the excavated channel, reduced to a maximum of 6 feet in the branches below them, the berm being maintained uniformly throughout the whole line at 8 feet in height, or on the principle which has been adopted on the whole work, at 2 feet above the high-water mark. The remarks which I have before made on minimum section apply to the above diagram; excess of earth from the channel excavations being used in widening the bank to the rear.

The average depth of digging on the line from Nanoon to Sawunt Khera, or on the first 30 miles of the Cawnpoor branch, is as follows:—

From	1st to 10th mile	=	6·53	feet.
„	10th to 20th „	=	7·75	„
„	20th to 30th „	=	4·10	„

The soil is good, though much mixed with reh (soda), especially in the neighbourhood of Sainthra. On the up-stream side of the Guddunpoor Bridge, or at the 29th mile, there are traces of bhoor, or sand-hills; but generally speaking, the soil is harder and better than it has been found in the upper divisions. The canal bed throughout the 30 miles included in this section is excavated on a slope of 15 inches per mile.

At the Keylunpoor Bridge flooring there is a drop of 24 inches, the canal bed on the down-stream taking up the lower level; the drop was necessary, to avoid the heavy embankments that would have been required in advance, had the canal bed been retained on the higher levels. Locks and a navigable channel have been designed for the purpose of overcoming the difficulty, and of facilitating the passage of boats; but the experience which we have obtained in observing the efforts of these canals (these artificial rivers rather) to determine their own slopes, by the natural arrangement of silt deposits, has led me to defer the construction of the works for the purpose of passing boats round this descent, until we can see the consequences of admitting water, and the effects of a running canal upon the soil over which it passes. *A priori*, the very circumstance of a sudden reduction of slope from 15 to 12 inches would lead to silt deposits, and to an equalization of the slope of the canal from a point considerably above that where the change in the amount of level takes place, to one many miles below it; and as I believe that this *will* take place, and as I do not calculate on any very immediate demand for navigation, after the water is first admitted, I have considered that it would be unwise to hurry on the execution of works, the uses of which may be problematical. The observation of a few years will at any rate settle the question, and will determine whether my anticipations are true or not; if they are not true, the navigable canal and locks can be constructed at a future period.

The maximum depth of wells, measuring from the surface of the earth to that of the water, is, by observation in the month of October, equal to 32 feet, the minimum equal to 16·5 feet.

The following masonry works have been built on this line:—

1st. Bridge at Keylunpoor, with a waterway of 99 feet, in three arches of 33 feet each, 20 feet roadway, and flank towing-path arches, with ghats, rajbuha heads, inlets, and 2nd class choki attached.

2nd. Bridge at Rudain, similar to that at Keylunpoor; roadway 18 feet wide, with 2nd class choki attached.

3rd. Bridge at Ginnowli, similar to that at Keylunpoor; roadway 18 feet wide, with an escape of three openings of 6 feet each, with 2nd class choki attached.

4th. Bridge at Burramai, three arches of 33 feet each, 20 feet roadway, with flank towing-paths, and ghats on the down-stream.

5th. Bridge at Sikundra Rao (Poordilnuggur), same as at Keylunpoor, with a 1st class choki.

6th. Bridge at Jirowli, similar to that at Keylunpoor; roadway 18 feet wide, with a 2nd class choki attached.

7th. Bridge at Junsoi, similar to that at Keylunpoor; roadway 18 feet wide, with a 2nd class choki attached.

8th. Bridge at Tuttarpoor, three arches of 32 feet each, roadway 20 feet, with ghats, rajbuha, and inlet heads, flank towing-path arches, and a 1st class choki attached.

9th. Bridge at Bundi, three arches of 31 feet each, roadway 18 feet, with ghats, &c., and a 2nd class choki attached.

10th. Bridge at Guddunpoor, three arches of 30 feet each, roadway 20 feet, with ghats, rajbuha, and inlet heads, and a 2nd class choki attached.

Block kunkur has been extensively used in all the above works, excepting in the arches, the material for making which has been confined to brick.

From the bridge at Guddunpoor,* over which the high road between Eyta and Agra passes, to the bridge at Singpoor, which is directly opposite the town of Mynpoori, and is a point on the high line of communication between that town and Etawah, the distance is 35 miles. The line of canal continues on the same course, and on the same bearing as it did in approaching Guddunpoor, making a slight curve to the left on coming near Singpoor, to accommodate itself to the general alignement of the Rinde River, between which and the Eesun River it runs very centrically; on its reaching the neighbourhood of Mynpoori, however, it bears more upon the Rinde, and opposite the villages of Suthnee and Dhulleeppoor, or at the 64th mile, it passes within a quarter of a mile of that river.

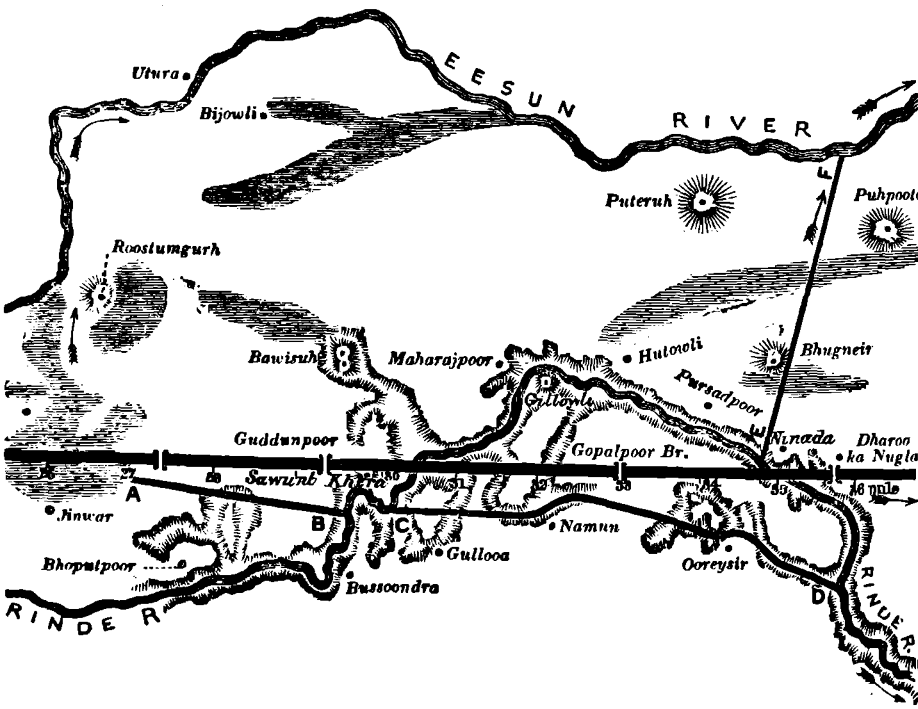
I have before remarked that in the neighbourhood of the 30th mile, and on the down-stream side of the village of Sawunt Khera, the line of canal comes in direct contact with the course of the Rinde; the intersection of these two lines was unavoidable; it takes place at two

* 30th to 65th mile.

points, the canal forming a chord 4 miles in length, to an arc represented by that portion of the river's course which is cut off; the perpendicular or versed sine of this arc is about 1½ mile.

The following diagram will show the position of the works in this region, including those connected with the Jinwar Jheel:—

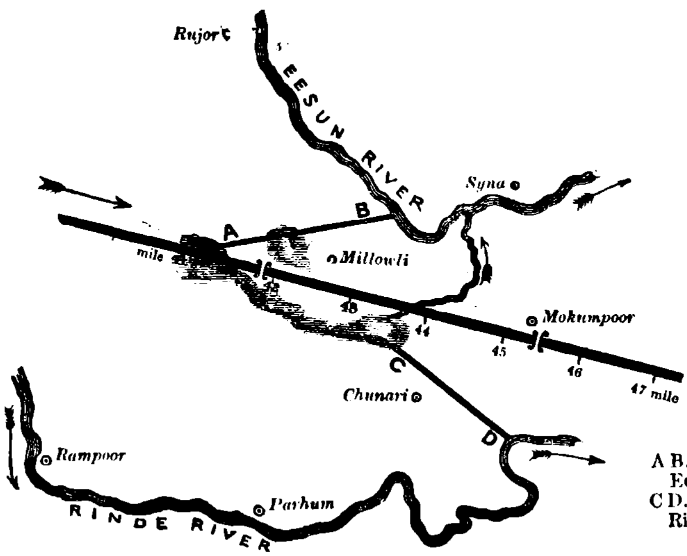
Diagram 28.



The methods adopted both in the case of the Jinwar Jheel, the drainage of which flows towards the Eesun, and in that of the passage of the Rinde above described, are precisely similar: the Ooreysir cut, C D, will maintain the continuous flow of the Rinde drainage in its natural direction, keeping to the right of the canal; whilst the cut, A B, from that portion of the Jinwar Jheel which is separated from its natural line of escape towards the Eesun by the canal embankments, will carry off all its spare water to the Rinde.

Those portions of the Rinde hollows which lie on the left of the canal have been connected with the Eesun by the cut E F, leaving the higher levels between the villages of Kundpoor and Ninaoli, of similar dimensions to those before described. This cut is in length 21,513 feet, with a slope of bed equal to 1·386 foot per mile. The slopes of the rivers at this part of their course are small, and it is possible that the high water in the Eesun, during floods, may maintain a back-water inundation in the Rinde hollows in the neighbourhood of Gopalpoor for a longer period than is desirable; this may be relieved by further cuts entering the Eesun at a lower point of its course; and I may observe that the inlet at the Gopalpoor Bridge, as well as that at Dharoo ka Nugla, will afford relief to the extent of their waterway. This part of the canal, however, is one which, as far as drainage is concerned, will require careful watching, and an energetic application of remedies adapted to the circumstances of the case.

Diagram 29.



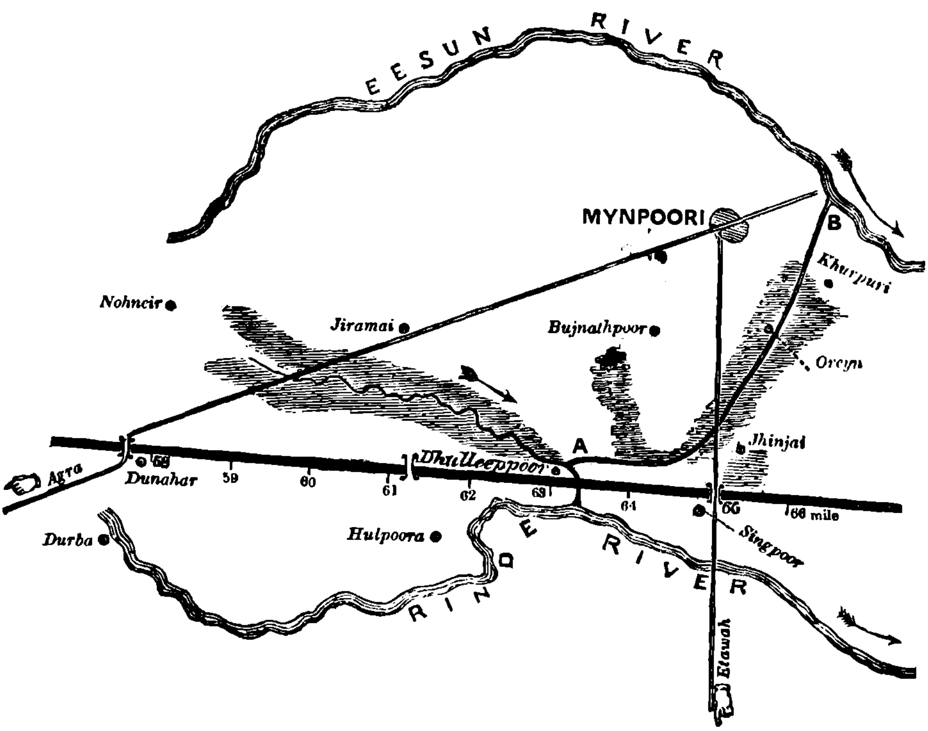
A B. Cut into the Eesun.
C D. Cut into the Rinde.

At the Gopalpoor bridge, which is situated in the segment formed by the canal and the old bend of the Rinde, a 1st class choki post has been established, with a view to the proper supervision and maintenance in efficient order of the different works in this neighbourhood.

From the Dharoo bridge, or from the point where the canal a second time intersects the Rinde River, the line passes onwards without any interference with drainage, until it reaches the 41st mile; both at this point, and at the 44th mile, a series of hollows connected with the Eesun river is crossed, a portion of its drainage being cut off entirely; the preceding diagram represents the lining out of the drainage at Mokumpoor and Millowli, with the measures that have been taken to restore it to its proper equilibrium.

From the 44th to the 65th mile, or to the end of that portion of the canal which I am now describing, the line passes over a country tolerably free from drainage; at the 49th mile, on the up-stream side of the works at the Nugureea Bridge, an escape into the Eesun River is established. At this point, the distance from the Eesun is 9,000 feet, and the slope from the sill of the escape to the bed of the river is equal to 5·42 feet, or on an average of 3·18 feet per mile. This escape has a water-way of 30 feet in five sluices of 6 feet each, and the channel has been excavated on a width of 30 feet. This channel will be the means of disposing of the water which collects on the lands east of the villages of Oosneyda, Koonchul ka Nugra, &c., as well as of that with which the canal comes in contact at the 47th mile; the drainage is comparatively small, but it will be entirely relieved by the escape channel. Between the 51st and 52nd miles, however, at the village of Dhunni ka Nugla, some hollows connected with the Eesun River are crossed, and that portion of them which has been cut off has been relieved by a cut of a mile in length made into the Rinde; the drainage at this point, therefore, is effectively provided for. At the 64th mile also, and at a point where the canal comes in close proximity to the Rinde River, drainage which rises in the neighbourhood of Nohneir crosses the line of canal. This drainage has been conducted into the valley of the Eesun by a cut A B, as shown in the following diagram :—

Diagram 30.



The strip of land lying between the Eesun and Rinde, upon which the canal takes its course, consists of a series of narrow necks, connecting expanses of a width never exceeding 9 miles, the necks themselves being in some cases (as at the 49th and 54th miles) not more than 2 miles in width. At the Singpoor Bridge, and at right angles to Mynpoori, the width between the two rivers is equal to 6¼ miles, and the canal passes within 1 mile of the Rinde.

The slope of the surface of the country from the 30th to the 65th mile is equal to 43·48 feet, or an average equal to 1·24 foot per mile. Cross sections at the following points show the relative position of the beds of the Rinde and Eesun to each other:—

41st mile, bed of Eesun,		4′ 8″ below that of Rinde.	
49th do.	do.	7·65′	do.
*57th do. at Nohneir	do.	9·7′	do.
65th do.	do.	15·46′	do.

The bed of the Eesun, it will be observed, increases in depression below that of the Rinde as it advances in its course; the Eesun, in fact, at Mynpoori is a perennial river (supplied by springs which rise on its approach to the town from Nohneir), running through a very extensive valley; its value during floods may be estimated by the waterway of the bridge which is built across it on the high road between Cawnpoor and Agra; the bridge consists of two bays of 30 feet each in width, connected to the high road by raised embankments or ramps of approach; this waterway is in all probability somewhat contracted, as the bridge appears to have been injured by a flood as far back as the 21st August, 1833, but it has nevertheless done its duty for a period of 20 years, and although its wings and superstructure require modification, to meet the improved and well-raised approaches that have been lately made, the bridge itself as far as waterway is concerned would most likely be sufficient for all practical purposes.

The necessity, however, for using the Eesun as an escape from the Ganges Canal works, in consequence of the slopes and capacity of the channel of the Rinde being insufficient, will render an enlargement of the waterway of the Mynpoori Bridge necessary, and in this case the opportunity might be taken of carrying into effect the alterations recommended in 1833 by Colonel John Boileau

* On a cross section at this point, the bed of the East Kalli Nuddi, near the villages of Beegumpoor and Khirni, is 24·5 feet below the bed of the Rinde. The East Kalli Nuddi, in the month of April, when I took the section, had water in it running slowly and sluggishly and full of weeds; the width of surface was 115 feet, and the greatest depth 3 feet 2 inches: both the bed and the banks in the neighbourhood were sandy.

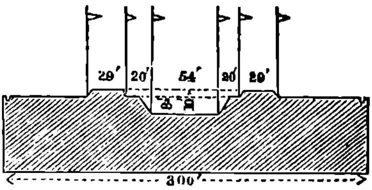
of the Engineers, in increasing the waterway; instead, however, of giving an additional width of 70 feet, I would give three additional arches of 30 feet in width, two on the north, and one on the south of the present building, giving five arches of an uniform span, and, if possible, I would make the roadway over it horizontal.

The bridge over the Rinde at Kulhore has a waterway of {Spring of Arches 121½ feet / Foot of Piers 111 feet} divided into 3 bays of {40½ feet / 37 feet} each, without any appearance of valley or running stream, which the Eesun possesses to the great and apparent fertilization of the country in its immediate neighbourhood.

The section of the canal channel at the 65th mile is as follows:—

Diagram 31.

Section at the 65th mile.



A gradual reduction having taken place in the width of the rectangular channel equal to 1·28 foot in every 3 miles. The minimum dimensions are here retained in the same way as formerly; the height of berm or towing-path above the bed of the canal being made of one uniform height of 8 feet; and where there was excess of earth beyond that required for the minimum section, the earth in excess was thrown in rear of the embankments, so as to increase as much as possible the width of the esplanade or roadway.

The average depths to which the channel has been excavated, between the 30th and 65th miles are as follows:—

From the	30th to the 40th mile,	7·21 feet.	
Do.	40th to the 50th do.	6·94	„
Do.	50th to the 60th do.	6·60	„
Do.	60th to the 65th do.	7·02	„

The soil continues on the whole of this line of the same tenacious quality, occasionally mixed with kunkur, as it was on the section before described; judging from the effects of rain-water which during the progress of the works lodged in the channel, it is only slightly absorbent; and throughout its whole course the influence of reh efflorescence is markedly observable; this reh efflorescence is characteristic of the whole line of the Mynpoori district, through which the canal is carried; it shows itself more or less on the surface, influencing in a great degree the extent to which cultivation is carried, and in many parts of the excavated channel it shows itself at depths considerably below the level of the ground. The brick manufactories have suffered greatly from the soil being impregnated with this most destructive alkali, and the consequences have been in many cases altogether fatal to the manufacture of bricks, whilst, on the whole line, there has been a difficulty in procuring this species of material, which has been unknown in the northern districts. The slope of the canal bed throughout the 35 miles included in this section is 15 inches per mile.

The maximum depth from the surface of the country to the surface of the water in wells is equal to 28·8 feet, and the minimum 18·2 feet, the observations having been made in the month of October.

The following works have been constructed below the bridge at Guddunpoor:—

1st. Bridge at Gopalpoor, three arches of 30 feet each, 18 feet roadway, with ghats, rajbuha, and inlet heads, and a 1st class choki attached.

2nd. Bridge at Dharoo, three arches of 29 feet each, 18 feet roadway, with ghats, rajbuha, and inlet heads, and a 2nd class choki attached.

3rd. Bridge at Kylai, similar to that at Dharoo, but with a roadway 20 feet wide; a 2nd class choki is attached to this work.

4th. Bridge at Kooreet, three arches of 28 feet each, 18 feet roadway, with ghats, rajbuha, and inlet heads, and a 2nd class choki attached.

5th. Bridge at Mokumpoor, three arches of 28 feet each, 18 feet roadway, with ghats, rajbuha, and inlet heads, and a 1st class choki attached.

6th. Bridge at Nugurreea, three arches of 28 feet each, 20 feet roadway, with ghats, rajbuha, and inlet heads, and an escape, with a waterway of 30 feet on the up-stream side of the work. A 2nd class choki is attached to these works.

7th. Bridge at Puchowur, three arches of 27 feet each, 18 feet roadway, with ghats, rajbuha, and inlet heads, and a 2nd class choki attached.

8th. Bridge at Kuraoli, three arches of 27 feet, 18 feet roadway, with ghats, rajbuha, and inlet heads, and a 2nd class choki attached.

9th. Bridge at Dunahar, three arches of 26 feet each, 25 feet roadway, with ghats, rajbuha, and inlet heads, and a 1st class choki attached.

10th. Bridge at Roostumpoor, three arches of 26 feet each, 20 feet roadway, with ghats, rajbuha, and inlet heads, and a 2nd class choki attached.

11th. Bridge at Singpoor, three arches of 26 feet each, 20 feet roadway, with ghats, rajbuha, and inlet heads, and a 2nd class choki attached.

In all the above works kunkur has been very extensively used; the succession of failures in brick manufactories, and the consequent scarcity of bricks, would, in fact, have delayed the completion of these works, had it not been for the presence of kunkur quarries, which fortunately abound in the districts through which the canal is now passing. The material is excellent, but it requires to be carefully selected; and in all cases the blocks which have been used in building, have been rigorously surveyed by the executive officer.

Continuing our progress on another 35 miles,* or from the 65th to the 100th mile, we reach the neighbourhood of Dingri and Rousa, two villages which are intimately connected with the lining out of the canal as proposed in my project of 1845.

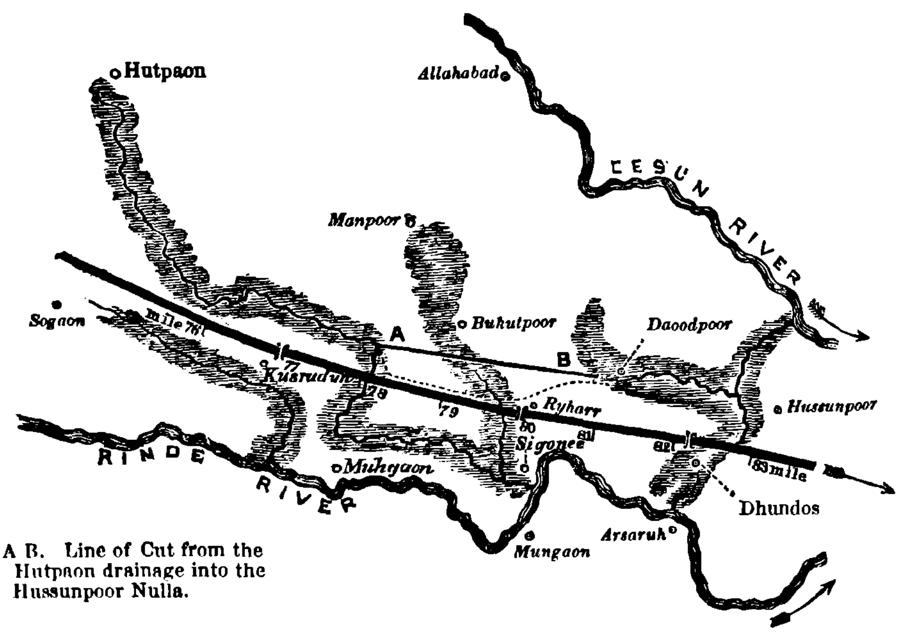
The direction of the canal after leaving the Singpoor Bridge is a few degrees more southerly than it was in the latter part of its course, the bearing being influenced by the course of the Rinde, to which on the whole line it runs in close approximation; in the neighbourhood of the village of Tireea, and at the 85th mile, at which point the line of canal and the Rinde come very nearly in contact, the former takes a slight curve to the right, and proceeds onwards in a straight line, upon the village of Dingri. The courses of the Eesun and Rinde rivers, throughout the whole of the 35 miles now under review, run on the most tortuous lines, although in a general way maintaining their parallelism to each other; the watershed of the Eesun River occupies the greater part of the intervening land, and in some cases stretches nearly to the Rinde; the canal line has been laid down with the greatest attention to this particular feature of the drainage, and it passes as directly upon the crest of the watershed of the two rivers, as a straight line could possibly do upon a tortuous one. From the 65th to the 78th mile, no drainage is crossed; the natural flow towards the Rinde on the right, and to the Eesun on the left, is unimpeded; on this line the village of Bhawunt, situated on a high mound to the left, and under which there are extensive hollows, is passed without the drainage in its neighbourhood meeting with any check or impediment. At the 78th and 82nd miles we come in contact with cross drainage, under circumstances of rather a peculiar nature; in the first case, a series of

* 65th to 100th mile.

shallow depressions, extending from the high mound on which the village and old fort at Hutpaon are situated, crosses the line of canal in progress to the Rinde; and in the second case we come (at the village of Dhundos) upon a well-defined crest of two nullas, one of which passes by the village of Hussunpoor into the Eesun, and the other runs into the Rinde, from the south of the village of Dhundos. This village is, in fact, built on the high land between these two lines of drainage, on a space of about 1,500 feet in width, over which the course of the canal has been directed. The hollows in this neighbourhood are, as is frequently the case throughout the Mynpoori district, converted into reservoirs for the purpose of irrigation; the remains of bunds or embankments have come under my observation as far back on the line of canal as the village of Nohneir, and in the hollows connected with the Rinde they are of constant occurrence. At the head of the Hussunpoor Nulla, and on the Hutpaon line of drainage, they are eminently conspicuous; their extent, however, is inconsiderable; at the period of my survey in the month of December there was no appearance of moisture in connection with them, and their uses are merely for watering crops during or immediately after the rainy months; it is questionable whether, after water is admitted into the Ganges Canal, the system of bunds on these hollows will be continued.

To remedy the evils arising from the interference with the Hutpaon drainage, a cut has been designed, for the purpose of keeping the flow of water to the left of the canal, and onwards to the Hussunpoor Nulla; the point at which this cut commences is taken on the deepest part of the Hutpaon hollows, opposite the 78th mile, or opposite to that point of the canal where the natural drainage is intersected; from this point a straight line of excavated channel, with a rectangular width of 15 feet and with a bed slope of 2 feet per mile, will carry the water off to the Eesun; on its course it will pass directly through the Bukutpoor hollow, leaving that village on its left; it will pass on the right, and close to the village of Sobhunpoor; and at the distance of 3 miles will meet one of the main heads of the Hussunpoor Nulla, under the village of Daoodpoor; two miles more of excavation and clearance through the Hussunpoor Nulla will give the water a free escape into the Eesun River, and give full relief to the country from Hutpaon downwards.*

Diagram 32.



A B. Line of Cut from the Hutpaon drainage into the Hussunpoor Nulla.

The preceding diagram will give a more accurate idea of the rivers, and of the position of the works in this neighbourhood, than I can convey in description.

* Economical considerations have led to a deviation from the above design, the water from the Hutpaon drainage has at the 78th mile been thrown into the left boundary ditch, which has been widened for its reception; this ditch at the 79th mile receives the drainage from Manpoor, and at the 79¾ mile of its course it is connected with the head of the Daoodpoor hollow, by a cut passing to the east of Ryharr; see dotted line.

From the 82nd to the 100th mile, the canal, although passing over a country intersected by jheels, hollows, and lines of drainage of every description, and at one point almost touching the Rinde River, pursues an evenly lined out course, without in any way interfering with either the drainage of the Eesun or Rinde.

On the up-stream side of the Tireea Bridge, and situated at the 87th mile, an escape head, with a line of escape channel into the Eesun River, has been constructed; this escape has a waterway of 30 feet, in five openings of 6 feet each, and is in design similar to those which have been built in the Bolundshuhur district; plan and section of this work will be found in the Atlas, Plate XXXIX. The difference of level between the beds of the Rinde and Eesun on a cross section taken on Tireea is 16·68 feet; the Eesun, as I have before remarked, running in all its course on a lower level than the Rinde. The two rivers are on this section characteristically represented, the section of the dry bed of the Rinde being 70 feet wide, well defined, and with a bed depressed about 10 feet below the level of the country; the Eesun, on the contrary, with a wide sandy bed, and with its banks scattered over with sand-hills, runs on an expanse of valley, green and fresh from its proximity to water. It is not, however, to be understood that the neighbourhood of the Rinde is barren; in many places, wheat crops exist in its very channel, its slopes are constantly covered with cultivation, but the difference between it and the region of the Eesun, in which there is a constantly running stream, and on the slopes of which water is found at short distances from the surface, is remarkable; the soil in the neighbourhood of the Eesun, moreover, is of a much lighter quality than that on the Rinde, the latter being in many cases a strong clay, and frequently much mixed with kunkur.

The distance between the canal and the Eesun at the point where the escape is built is 8,000 feet, and the difference of level between the sill of the escape and the bed of the Eesun is equal to 20·94 feet. The excavated channel is 30 feet in width, with a bed slope of 1·5 per mile. The object of my selecting Tireea as the site of an escape, and avoiding the line of the Hussunpoor Nulla, which in my original project was the first fixed upon, was the desire to leave the Hussunpoor Nulla, for the purposes of the Hutpaon drainage; the slope of this nulla, as well as that of the artificial cut to connect the Hutpaon drainage with it, is a good and a rapid one, and the advantages of scour which in the Ginnowli escape channel might be desirable, were of no moment at this particular point; in addition to this, there was a greater and more immediate relief at Tireea than there would have been on the Hussunpoor line.

The canal, throughout the whole of the 35 miles above adverted to, is confined between the natural boundaries with which it has been running parallel on its route from Nanoon; the Eesun and Rinde, which constitute these boundaries, pursue with regard to each other the same irregular, although generally speaking parallel, course; at one time approaching to within a short distance, and at another wandering off in the most exaggerated series of curves and tortuosities. At the 100th mile, the departure of the Rinde on a new line of bearing which separates it entirely from the Eesun River, gives an extension of width to the strip of ground over which the canal passes, which it has not had since its separation from the main canal; at this point the width between the two rivers is equal to 12 miles, seven of which are towards the Eesun River. With the exception of that part of the tract near the village of Tireea, where the above rivers come within 3 miles of each other, the average distance of separation from the 65th to the 100th mile may be considered as about 6½ miles.

On the surface of the country the slope from the 65th to the 100th mile is 39·15 feet, which is equal to 1·11 foot per mile, the canal runs upon the watershed between the two rivers as closely as possible, and, as before observed, in closer approximation to the Rinde than to the Eesun, a circumstance depending entirely on the position of the ridge or watershed. Cross sections at the following points show the relative position of the beds of the Rinde and Eesun to each other :—

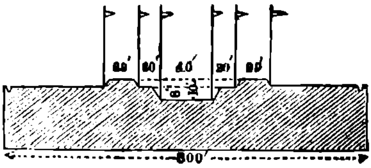
72nd mile,	the bed of the Eesun is	8·35 feet below	that of the Rinde.
82nd	do.	14·92 feet	do.
87th	do.	16·68 feet	do.
100th	do.	19·41 feet	do.

The gradual increase of depression of the bed of the Eesun below that of the Rinde is here, as on the last 35 miles, distinctly observable: the fact is deserving of notice, as it points out the Eesun River as one more capable of being useful in carrying off waste water from the canal than the Rinde, the slope of which, laying aside the tortuosity of channel which is common to both rivers, is ill adapted on this part of its course for the purposes of escape.

The section of the canal channel at the 100th mile is as follows :—

Diagram 33.

Section at the 100th mile.



A gradual reduction of ·4 foot per mile having taken place in the 35 miles just described.

At the 71st mile the slope of the canal bed, which had been continued at 15 inches, is reduced to 12 inches per mile, on which it is carried up to the 90th mile. At this point, and between the 90th and 102nd mile, I have, instead of giving a sudden drop, as at Keylunpoor, and continuing the slope in advance at 12 inches per mile, designed an uniform slope of 14 inches, giving to each mile an excess of 2 inches, thereby adopting in preference to the drop the form of an inclined plane.

The rule for disposing of excess of earth and for maintaining the different parts of the section are similar to those before described; the berm is kept at an uniform height of 8 feet from the canal bed, and the maximum height of water is 6 feet.

The average depth to which excavation has been carried is as follows:—

65th to 70th mile,	10·03	feet.
70th to 80th do.	7·11	do.
80th to 90th do.	7·7	do.
90th to 100th do.	7·86	do.

The soil is similar to that on the last section, the same adulteration by alkali, the same mixture with kunkur, either in the form of gravel, or detached pieces, or in tabular masses; and apparently retaining the same non-absorbent qualities. It will be understood, therefore, that the manufacture of bricks was here also a matter of serious difficulty; the absence of this material has, in fact, led to the reduction of our buildings to minimum proportions, and to the necessity of the strictest economy in the use of brick masonry; and had it not been for the quarries of kunkur, which have at detached points so conveniently, I may say providentially, offered themselves, the works in this division could not possibly have been completed at the early period that they have been.

The observed depth of wells is on a maximum 33·25 feet, and on a minimum 16·41 feet, the measurement being taken from the surface of the earth to the surface of the water in the month of October.

The following works have been constructed on this line of 35 miles and below the bridge at Singpoor:—

1st. Bridge at Putahar, two arches of 35 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

2nd. Bridge at Bhawunt, two arches of 35 feet each, 20 feet roadway, with ghats, rajbuha and inlet heads, and a 1st class choki attached.

3rd. Bridge at Sogaon, two arches of 33 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

4th. Bridge at Kussudh, two arches of 33 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

5th. Bridge at Ryharr, two arches of 32 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

6th. Bridge at Dhundos, two arches of 32 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 1st class choki attached.

7th. Bridge at Tireea, two arches of 31 feet each, 20 feet roadway, with rajbuha and inlet heads, and ghats attached. Above the bridge is an escape of five openings of 6 feet each. A 2nd class choki is placed between these works.

8th. Bridge at Futtipoor, two arches of 31 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

9th. Bridge at Mirzapoor, two arches of 30 feet each, 20 feet roadway, with ghats, rajbuha and inlet heads, and 2nd class choki attached.

10th. Bridge at Dingri, two arches of 30 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 1st class choki attached.

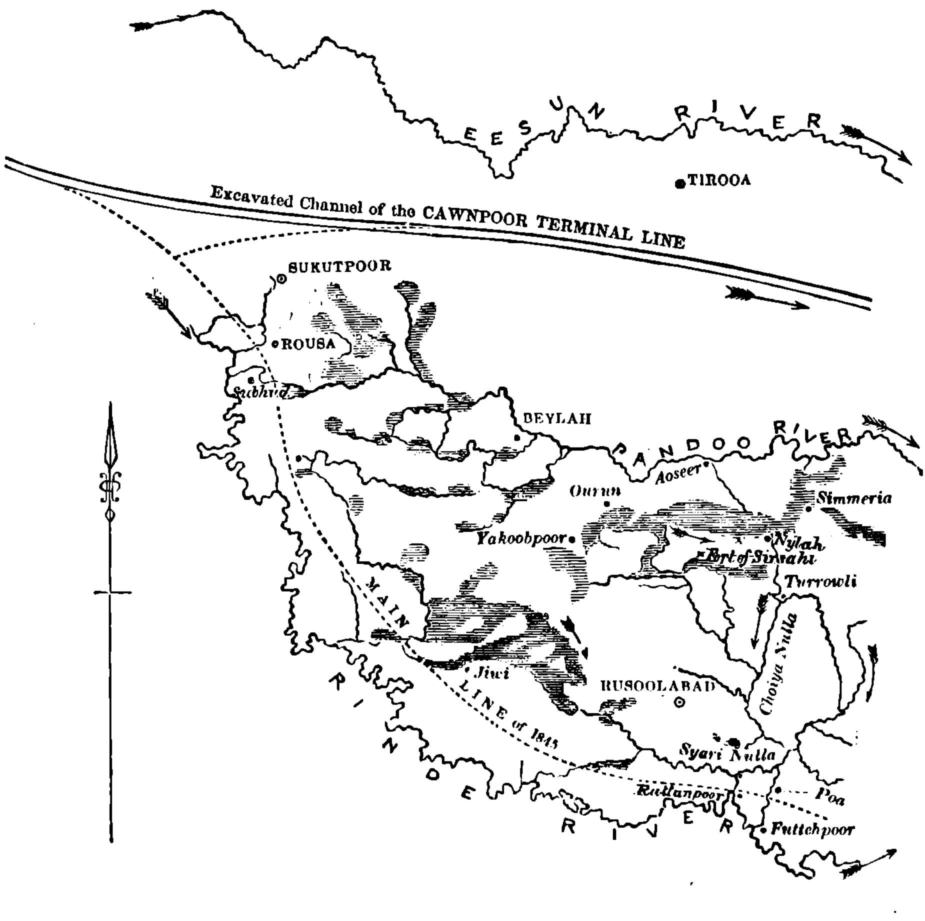
11th. Bridge at Sooreya, two arches of 30 feet each,

20 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

We are now at the point of the branch of the Cawnpoor line, from whence in the original project the main canal continued its course onwards, in one case towards Allahabad, and in the other keeping (agreeably to the third project of 1845) to the left bank of the Rinde River to the Jumna, near the town of Jar. This main line, as far as the village of Dingri, was precisely the same as that upon which the present branch has been carried. From Dingri, instead of proceeding straight onwards to Cawnpoor, the original line took a southerly direction, passing by the village of Rousa, and by these means escaped the heads of the Pandoo River, which are situated in this neighbourhood on the left and near the fort and village of Subhud. A branch to Cawnpoor, which was a component part of the project, left the main line at a point above the low lands which constitute the head of the Pandoo River, the site of departure being laid down in the map which accompanied the report as near the village of Rousa, although it was an open question as to whether the precise position for the head would be actually at the point so laid down or at any intermediate site between that place and the village of Dingri. The site at, or rather above, Rousa had been determined by me as that best adapted to the watershed of the country, as, by passing on the right of the towns of Turreen and Sukutpoor, the drainage, which rises at the former and passes off towards the Eesun, would have been avoided.

The village of Rousa is the key to the passage of that part of the Doab; by turning the heads of the Pandoo at this point, an open and uninterrupted passage is obtained onwards to Allahabad, and it would have been impossible by any other direction to have avoided interference with the actual courses of rivers. It is unnecessary now to enter into details further than to explain that there is a great inclination of the drainage of the upper part of the country, upon which the Pandoo takes its course towards the Rinde, and at a point near the village of Aoseer, situated upon that river, and at a distance of 17 miles from its head; the waters of the Pandoo *do* in very heavy floods escape to the south over a series of extensive flats, on which the high mounds and forts of Sirsahi, Simmeria, and Turrowli are situated; on these occasions

Diagram 34.



N.B.—The dotted lines show the direction taken by the main line of canal, on its course towards Allahabad on the left of the Rinde River and the Cawnpoor branch agreeably to the project of 1845.

The double line shows the true course upon which the canal and the works have been executed.

The arrows show the direction of the drainage.

the flood-water takes to the course of a well-defined nulla called the Choiya, and enters the Rinde near the villages of Poa and Ruttunpoor. In fact, on the triangle embraced by the Pandoo (which river runs from west to east), the Rinde and the Choiya, there is a tendency of the whole of the drainage to pass off to the Rinde; the natural line of watershed being close on the right side of the Pandoo, and as ill marked and badly defined as a watershed could be. The preceding diagram (p. 277) will render this explanation of country more distinct.

The main line of 1845, it will be observed, instead of maintaining the high course near the right of the Pandoo, and mixing itself with the shallows, and heads of the numerous lines of drainage between Rousa and Aoseer, kept to the left bank of the Rinde; and, instead of competing in detail with such a labyrinth of drainage as the above diagram, even will convey but an imperfect idea of, crossed it by aqueducts at points near the Rinde, where the sections of the nullas in which it was collected were deep and well defined, one over the Syari to the east, and the other over the Choiya to the west of the village of Ruttunpoor.

The relative levels of the Rinde and the Pandoo, and of the country included between them, on the line stretching from Rousa to Aoseer, are as follow :—

Bed of the Pandoo at Aoseer . .	27·7	feet	Above the bed of the Rinde under the village of Ruttumpoor, and at the junction of the Choiya Nulla.
near Turrowli . .	29·89	,,	
Koorsi . .	49·88	,,	
Yakoobpoor .	41·88	,,	
Ourun . .	41·77	,,	
Jiwi . . .	37·95	,,	

The above description of the early part of the course of the Pandoo River, and its relative levels with regard to the Rinde, and the country to the south and to the right of the line of the existing canal, will enable me to continue my narrative without interruption. I may observe, however, in the words of my former report and in recapitulation of what I have before said, that the Pandoo, which takes its rise from the low ground in the neighbourhood of Rousa, has its main sources at the junction of the Futtigurh, Etawah, and Cawnpoor districts; it runs parallel to, and north of, the Rinde River on a much higher level, and in the early parts of its course exhibits a section of small dimensions, with a declivity of bed not exceeding 10 inches per mile; during heavy floods, this river, to a point as far east as the fort and village of Aoseer, overflows its banks, and obtains relief by throwing its excess of water into the Rinde River, through a natural escape, commencing in the neighbourhood of Aoseer, from whence by Simmeria and Nyla, it is conducted by a series of jheels into a distinct line of nulla, which, under the name of the Choiya, joins the Rinde near Russoolabad. Nature, therefore, has placed the country between the Pandoo and Rinde at the point in question under the liabilities of flood from the former river. The section of the country from Aoseer on the Pandoo to the Rinde, at the village of Poa, taken down the course of the Choiya Nulla, shows that with high water in the Pandoo, under Aoseer, above six feet, the country on the right bank, or on that between the Pandoo and Rinde, would be flooded, and the escape water would pass off down the Choiya into the Rinde. The bed of the Pandoo under the fort of Aoseer is only two feet below the bed of the Choiya at the village of Turrowli, the land intervening not exceeding four feet in elevation above the bed of the nulla at the latter place. From the Pandoo at Aoseer, the zumeendars have excavated a ditch connecting the river with the jheels at Simmeria and Nyla, for the purpose of supplying water for irrigation to the lands of these latter villages. The Pandoo and Rinde may, therefore, be said to be both naturally and artificially connected with each other. I would refer, however, for further explanation to Plate No. IX. in the Atlas, in which the most detailed examination of this part of the country is exhibited.

Proceeding onwards from the 100th to the 135th mile, we reach the 1st class choki and station of Kukwan. On this line the direction of the canal is, as has been invariably the case during its passage between the Eesun and Rinde, regulated by the course of the rivers, maintaining its position as far as possible on the watershed; in the present case the bearing on its leaving the 100th mile is continued in prolongation of that which has preceded it for a short distance; it then takes a gradual sweep to the left, keeping to the right of, and close to, the high mounds and forts of Husseyrun, Bahosi, and Mujla; from thence the line proceeds onwards, still keeping on a curve bearing east, until it reaches a point about half way between the towns of Tirooa and Tutteea, where it takes a sweep round to the south, reaching the 135th mile at the village of Kukwan, which is situated at a distance of a mile from the Pandoo River. The canal on this section of its course forms an ogee curve, the lower point of which rests on the village of Kukwan; the object of this curve being to avoid the Pandoo drainage, and to thread one of the most intricate labyrinths of drainage that can be imagined; its intricacies will be best understood and appreciated by a reference to the map (Plate No. IX., Atlas).

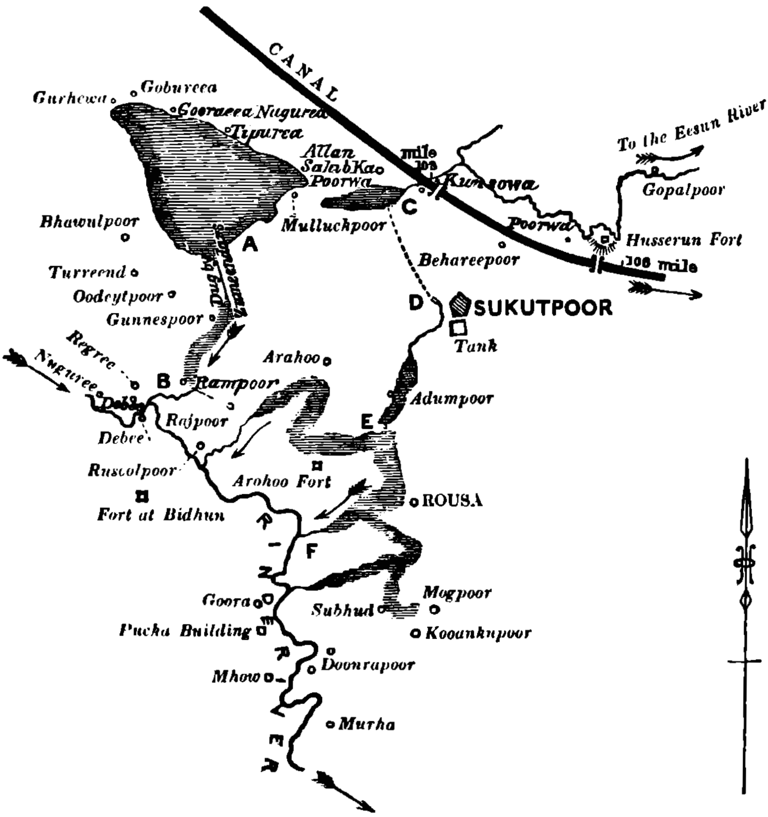
At the 102nd mile, the line of drainage, to which I have before referred as rising under the fort of Tureend, is crossed near the village of Kunsowa; the heads of this drainage show themselves in a triangular hollow of about 2¼ square miles in superficial extent, lying to the north-east of Tureend; its edge is situated within three-quarters of a mile of the canal, to which it lies parallel; and the centre of the hollow, or of the head of the drainage, is about three miles from the point of intersection with the canal at the village of Kunsowa; at its approach to this village it assumes the form of a tortuous and well-defined nulla, and its inclination towards the line of works is unmistakeable; from the deepest part of the Tureend Jheel to the bed of the canal at Kunsowa, the fall, in fact, is equal to 3·91 feet. This nulla continues its course, passing directly under and to the north of the fort of Husseyrun, from whence it takes a northerly direction to the left of the fort and mound of Lakh, and, after passing over an extent of about 10 miles, reaches the Eesun River at the village of Khurieapoor.

From the most southerly point of the Tureend Jheel, or from that which is in the closest approximation to the Rinde River, a cut has been made by the zumeendars of Gunnespoor, a village lying on the edge of a hollow connected with the Rinde, for the purpose of drawing off a portion of the Tureend Jheel water for irrigation; the length of this cut, which is a mere ditch, is about three-fourths of a mile; it meets a line of hollow, which extends for 1¼ mile from north to south, on the westerly edge of which the villages of Rampoor and Gunnespoor are situated; at a short distance from the former village a line of nulla runs into the Rinde.

The following diagram (p. 282) will explain the nature and position of the different points alluded to.

It is in taking advantage of the line here described, that I propose to relieve the canal at Kunsowa; the actual distance between the edge of the Tureend hollow and the heads of the nulla connected with the Rinde under the village of Rampoor is 2 miles; the cut for the purposes of drainage which is carried on the line of the zumeendars' ditch, and through the hollow lying to the east of Gunnespoor and Rampoor, including clearances in the bed of the nulla and jheel, may be estimated at 2½ miles in length, on a rectangular section of 15 feet in width; the slope from the point A to B is equal to 16·4 feet; the bed of the cut, therefore, has a declivity of 6·56 feet per mile.

Diagram 35.



The bed of the canal at the Kunsowa Bridge is 11·90 feet above that of the bed of the Rinde at the point where the Rampoor Nulla joins it at Debee: the distance as the crow flies being 4½ miles.

The inlet at the Kunsowa Bridge, which is 3 feet in width, will pass off any superfluous water that may (as it may be expected to do for some years at least) keep to the natural line of nulla. To secure, however, the most perfect available escape for the water that annually collects on the right of the canal, and in the neighbourhood of Tureend, a second cut, marked in the above diagram C D E F, has been made from the hollow, near Allan Sahib Ka Poorwa, to the line of drainage lying to the west of Sukutpoor, the whole of which flows towards the Rinde River. The general slope of the country on the right of the canal being towards the Rinde, there will, I imagine, be no difficulty in disposing of the Tureend drainage in the direction of that river.

From the 102nd mile the canal line passes onwards to the village and fort of Sooki with little or no interference with the cross drainage of the country. The great jheels or hollows lying to the left under the forts of Bahosi and Mujla retain their natural outlet towards the Eesun; and the country lying to the right in the neighbourhood of Sukutpoor, the fort of Mow, Ramnugger, &c., is drained without any sort of interference from the canal works into the Rinde.

At the fort and village of Sooki, however, which are built on one of the numerous high mounds for which this part of the Doab is remarkable, the canal at the 115th mile of its course comes in contact with a hollow of considerable dimensions; the alignement passes on its southern edge, and between it and the village, and there can be no doubt passes on the precise watershed between the Eesun and Pandoo at this particular spot. Here, however, as in the case of the Tureend Jheel before referred to, although the true slope of the country is towards the Eesun, and although the natural escape from the Sooki Jheel passes to the north, and close under the fort of Binnowra, the slope is so small and the hollows and jheels with which the line of escape is connected are so entangled, that had it not been for the most intricate instrumental examination of the country, I question whether the true watershed could have been discovered; as in the Tureend Jheel also, here are two cuts made by the zumeendars from the southern face, one on the west, and the other on the east of the fort of Sooki; the former leading the water from the Sooki Jheel into a long line of hollow, over which a bund or embankment has been thrown for the purpose of forming a reservoir for irrigation; the latter for the supply of a set of hollows lying to the eastward, over which there is a series of bunds applicable to the same purpose, and all of them put to use annually during the rainy season.

Both the cuts above mentioned connect the Sooki Jheel with the slope towards the Pandoo River; they run, in fact, over the watershed: and it will be interesting to the reader to refer to the map on which the detail of this particular part of the country has been introduced (Plate IX., Atlas), that he may understand the nature of this network of drainage.

In advance of the 115th mile, the canal passes over an even country until it reaches the 120th mile at Khyrnuggur; at this point it crosses a low tract which is on the watershed, leaving on the right a large hollow situated to the north, and under the fort of Khyrnuggur; and on the left a more extensive and more straggling depression of country lying to the south of the village of Goorowli, between that village and the line of canal. At the 121st mile, the canal crosses a piece of low ground which connects the Goorowli Jheel with the hollows that run under Khyrnuggur, and which ultimately join an extensive series of jheels, in the neighbourhood of the two forts of Junkut and Chungurwa, the water from which flows into the Rinde. The drainage from the Goorowli Jheel runs naturally to the Pandoo, and a cut 1½ mile long has been made to a nulla connected with the Eesun. The canal on its onward course sweeps round to the north of the forts of Junkut and Chungurwa, and the low ground which lies in this neighbourhood, and at the 126th and 127th miles reaches the village of Aima by crossing a piece of low ground which has been artificially connected with an extensive hollow lying on the left of the line under the mound and fort of Rouns. From this hollow under Rouns, the zumeendars have excavated two lines of ditches for the purpose of drawing off water to their dams and reservoirs lying to the south, and in the neighbourhood of Dooloo and Ruheempoor. Here, as in the instance before described of the Sooki Jheel, the watershed has been cut by channels for irrigation; over these, however, the canal line passes, separating the jheel at Rouns from the low land of Junkut and Chungurwa. The direction of the drainage from the neighbourhood of the fort of Rouns is towards the Eesun River, which lies at a distance of four miles, running in a deep valley, bounded by ravines, which are pierced in the direction of Rouns, by two lines of well-defined tributaries for the reception of the drainage. It is possible that the relief of heavy inundations near Rouns may be facilitated by an artificial cut,* made from that neighbourhood, or from the jheel itself, to the heads of these tributaries; but as the necessity for making it is not very clear at present, I have not included it in the operations which have been carried on during the progress of the works. I may remark, in this place, however, that, although the extension of artificial lines for the above purpose, not only here, but elsewhere, would undoubtedly add greatly to the relief of the country, by rapidly carrying off rain-water to the low boundary lines of the Eesun and Pandoo, we may, by so doing, cause considerable injury to the cultivators, who at present husband the supply for the purposes of irrigation, and are by no means

* This cut has been dug since this was written.

desirous of allowing the water to escape; in how far the introduction of canal water, and the system of regular irrigation thereby produced, may affect the system now in force by the cultivators, it is not easy to say; but it would be unwise to deprive them of their present means before we are able to insure a substitute; I do not, therefore, advocate any further drainage by artificial cuts than that which may be absolutely necessary for maintaining a natural equilibrium to the escape of flood-water.

From the 127th mile the direction of the canal pursues its curved course, keeping close to the drainage which runs towards the Pandoo River, and in this curved course running parallel to, and within a distance of 1½ mile from, the river. At the 133rd mile, and near the village of Munowa, it crosses on its watershed a branch of the Ourun drainage; this branch, which is connected with an extensive series to be hereafter described, slopes towards the Pandoo; but its dimensions are small, the water that passes off to the Pandoo is limited in quantity, and its connection with the Ourun drainage at all may possibly have arisen from artificial causes; at any rate, the drainage is not impeded by the canal, which passes onwards to the village of Kukwan without any further interruption.

The Ourun drainage, to which I have before referred, becomes of importance in its connection with the canal, with which (under the name of the Noon River) it runs for a considerable distance parallel; it requires, therefore, some explanation.

Ourun, which lies on the left, and to the north of the canal, is, like Sooki, Husseyrun, Yakoobpoor, and other places of that description, situated on a high mound—it might be called a mountain, did it not owe its existence to artificial causes. The whole country lying under the influence of the heads of these Doab rivers, and of the network of drainage which is their most remarkable feature, is studded with elevated mounds of this description; from the heads of the Seyngoor and Rinde throughout the Cawnpoor district, as far as the country over which the canal passes, these mounds are of constant occurrence; in the neighbourhood of the heads of the Seyngoor and Rinde, the forts of Bijeegurh and Awa are characteristic examples; in the country in the neighbourhood of the heads of the Pandoo, and at that point where the Etawah, Futtigurh, and Cawnpoor districts meet, they are numerous; they exist both on the Jumna and Ganges sides of the Doab, and in many cases are so extensive that it is difficult to imagine that they are artificial. Their origin may be traced to the most remote antiquity and to a period antecedent to that of recorded history. Originating in all probability in masses of earth piled up for the purposes of mud forts, they have from generation to generation received accessions of material from the country lying at their feet and in the decay and renovation of mud walls and habitations built under their shelter. The extensive and shelving hollows which invariably lie at the feet of these mounds are in themselves proofs of the ages that must have elapsed in bringing them into that condition. To the eyes of the present generation, these excavations show themselves in expanses of shallow jheel and wide-spreading lake, with no trace whatever of artificial origin.

It is not to be understood that the mounds to which I refer are mere conical elevations; in many cases (in illustration of which I may note Bawunt and Bahosi) they consist of ridges, ramifying from a centre, and rising from the surrounding country to a height not exceeding 120 feet. The forts and castles with which they are crowned are in the present day (with the exception of a few cases in which, like Awa, they have been retained as the mansion or palace of a native chief) in ruins; and the villages which from their elevated site are naturally attendant upon them, are in most cases at the present period clustered round and at the foot of the slopes; often, however, the mounds are deserted as at Tureend, and the village is altogether detached to a spot sufficiently elevated in the neighbourhood. I have no doubt that excavations in these mounds, although neither so interesting nor so productive as those on the banks of the Tigris, would add greatly to the elucidation of their early history; very extensive foundations, built entirely of blocks of kunkur, are frequently laid bare by the action of the rain-water; in a variety of cases, pieces of Hindoo sculpture, terraces, and remains of munduls or Hindoo temples, the architecture of which differs widely from that of the present day, have been found; and at Bahosi a figure about 4½ feet in length, in deep relief, of Hunooman, carved in large masses of kunkur, has by some enterprising person been rescued from its obscurity, and placed erect in a building designed apparently for its especial protection.

There can be no doubt that these mounds and the excavations from which they have originated, have in a great measure influenced the drainage of the country, as they most undoubtedly have, in some degree, determined the position of the canal works; the description, therefore, above given, may not be considered altogether discursive; topographically and archæologically speaking, they are of very great interest.

Ourun, with its mound, fort, and attendant hollows, may be considered as lying at the head of an extensive line of drainage, which, keeping to the left and to the north of the canal, reaches the village of Nurrooa, and thence proceeds onwards to the Ganges under the name of the Noon River. The hollows connected with Ourun extend to the north of that village to a distance of three miles, and in the direction of the fort of Rouns, to which I have before alluded, and are only separated from that line of drainage by a tract of country of 1½ mile in length; the levels of this tract are of no great elevation, and it is by no means impossible, therefore, that during heavy falls of rain, and when inundations arrive at their maximum, the superabundant water from the country in the neighbourhood of Rouns passes off down the Ourun drainage, and ultimately reaches the Ganges by the Noon River; it is under this idea that I would recommend, should the above speculations be correct, or should the Rouns Jheel give any trouble, that a cut be made connecting that jheel with the heads of the Ourun drainage.

From Ourun the drainage which lies on the left at the distance of half a mile from the canal forms two distinct lines of depression, that on the west passing by the villages of Ajmuthpoor and Gurhewa, and approaching the line of canal within a quarter of a mile near the Nurooa Jheel; and that on the east passing the forts of Sulempoor and Futtipoor at a distance of two miles from the canal; the fort of Futtipoor being isolated by two transverse lines of hollow, which connect the east and west series of drainage. The two parallel lines above described meet at the village of Luchmunpoor, situated about a mile to the left of the canal at its 141st mile, and from thence in a tolerably well-defined nulla the drainage passes off on an easterly direction, leaving the villages of Bakurgunj and Gowri on its right; near the village of Indhunna it joins a nulla with somewhat of a larger section, which is called the Noon; this river rises in the latitude of, and about 4 miles east of, the village of Munowa; it constitutes, in fact, a third to the two parallel lines, which I have above described, into which the Ourun drainage separates in its course between

Munowa and Nurooa; its heads, however, are distinct from those of Munowa, being separated by an elevated tract of a mile in width.

From Indhunna the drainage, under the name of the Noon, passes away in a south-easterly direction, parallel to the course of the Pandoo River, and at a distance of about five miles from it; the depression of country increases with great rapidity as it advances, and in the neighbourhood of the Grand Trunk Road, at Chobipoor, the Noon and one of its tributaries are crossed by two bridges; that which spans the larger river having a waterway of 58 feet, in three arches, one of 30 feet and two of 14 feet span; the other having a waterway of 30 feet in one arch of 30 feet span. The river enters the Khadir or low land of the Ganges, after running a course from Ourun of 26 miles, at the village of Birheeya.

With the exception, therefore, of a point at the 113th mile, where the Ourun drainage escapes over a narrow neck of hollow into the Pandoo at Munowa, and thereby is intersected by the canal, the whole of the drainage to the eastward is directed towards the Noon and its tributaries; the canal is in consequence carried over a country high and dry, and under these favourable circumstances it reaches the village of Kukwan at the 135th mile.

Immediately above the Kukwan Bridge an escape head of 30 feet waterway, in five openings of 6 feet each, has been built for the purpose of giving an outlet into the Pandoo River; this work is on the same design as those which have gone before it, and the apparatus for the management of the sluices is precisely the same; the width of excavated channel is 30 feet, and its length is 5,550 feet. The difference of level between the sill of the escape and the bed of the Pandoo is 11·99 feet, or 11·4 feet per mile. At Kukwan is a 1st class choki and a main station attached to the escape.

Throughout the whole of the 35 miles above described, the line of canal passes intermediately between the Pandoo and the Eesun, the Rinde in advance of the 100th mile of the course of the canal having passed away to the south, and the Pandoo having assumed the place of that river in its parallelism and propinquity to the Eesun. The strip of land through which the canal passes between the Eesun and Pandoo averages 10 miles in width, its narrowest point, in the latitude of Rouns, being only 6½ miles.

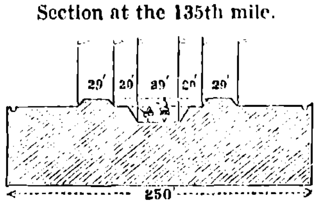
The slope of the surface of the country from the 100th to the 135th mile is equal to 35·18 feet, or on an average of 1·005 foot per mile. The canal runs on the watershed as closely as the regularity of alignement would admit of; it rather inclines to the Pandoo, and its general direction is determined by the bearing of the rivers. Cross sections at different points show the relative levels of the beds of the Pandoo and Eesun to each other as follow :—

10th mile between Bahosi and Indurgurh	Pandoo above Eesun	22·81 feet.
32nd mile at Ourun	Do.	23·89 feet.

The section of the channel at the 135th mile is thus :—

Diagram 36.

Section at the 135th mile.



A reduction of 11 feet in width of rectangular channel having taken place in the last 35 miles. The disposal of excess of earth has been arranged on the same plan as before described; the berm has been formed on one uniform height of 8 feet from the bed of the canal, and the maximum height of high water is still maintained at 6 feet.

The bed slopes of the canal channel have been (with exception to the first two miles, which have a slope of 14 inches per mile) made on one uniform level of 12 inches per mile, and the average depth to which excavation has been carried is as follows :—

100th to 110th mile,	7·15 feet.
111th to 120th do.	11·16 „
120th to 130th do.	7·65 „
130th to 135th do.	7·18 „

The soil is hard and tenacious, and, as far as I can judge, of a very non-absorbent quality; it is similar in all respects to that which I have described as existing on the last section.

The observed depth of wells throughout this length of 35 miles is on a maximum 36·5 feet, and on a minimum 13 feet, the measurements being taken from the surface of the earth to the surface of the water.

The following works have been constructed in advance of the Sooreya Bridge :—

1st. Bridge at Kunsowa of two arches of 30 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

2nd. Bridge at Husseyrun, similar to that at Kunsowa, but with a roadway 20 feet wide ; a 2nd class choki is attached.

3rd. Bridge at Bahosi, similar in every respect to that at Kunsowa, with a 1st class choki attached.

4th. Bridge at Goonaha, similar in every respect to that at Kunsowa, with a 2nd class choki attached.

5th. Bridge at Oomurda, similar to that at Kunsowa, with a 2nd class choki attached.

6th. Bridge at Sookhi, with a waterway of 50 feet in two arches of 25 feet each, roadway 15 feet wide, ghats, rajbuha and inlet heads, and a 2nd class choki attached.

7th. Bridge at Khyrnuggur, similar to that at Sookhi, with a 2nd class choki attached.

8th. Bridge at Aima, similar to that at Sookhi, with a 1st class choki attached.

9th. Bridge at Barrapoor, similar to that at Sookhi, but without ghats, rajbuha heads, or choki.

10th. Bridge at Bidhun, 50 feet waterway in two arches of 25 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

11th. Bridge at Ootha, similar to that at Bidhun, with a 2nd class choki attached.

12th. Bridge at Munowa, similar to that at Bidhun, with a 2nd class choki attached.

13th. Bridge at Kukwan, waterway, ghats, rajbuha and inlet heads, same as at Bidhun, roadway 20 feet wide; an escape of 30 feet waterway, and a 1st class choki, are attached to these works.

From the station at Kukwan,* or from the 135th mile, the Cawnpoor branch continues on another length of 35 miles, at the termination of which it falls into the Ganges River.

The direction of the line which continues on the same curve as that upon which it reached the Kukwan station is carried to the south, and clear of the Ourun drainage; at the 139th mile it takes a sweep to the right, passing (at the 156th mile, near the village of Koorsaoli) equidistantly between the high banks of the Ganges and the Pandoo rivers. From thence, on a gradually increasing curve, with the high banks of the Ganges still on its left, the canal crosses the high road between Kalpi and Cawnpoor, at the village of Khujoori, and the Grand Trunk Road near

* 135th mile to end.

the village of Duknapoor; it meets the Cawnpoor cantonment, on the boundary that separates it from the city; along this boundary the canal passes, and after crossing a portion of cantonment land, reaches the lower levels of the Ganges River, in a fall of 45 feet, in five drops of 9 feet each. The line of canal throughout the whole of the 35 miles which I am now describing, passes on a series of curves, threading the intricate drainage which intersects this portion of the Cawnpoor district; these curves have in fact continued uninterruptedly from the 100th mile downwards, and have, generally speaking, been laid out with great correctness, and on as long radii as possible; the general aspect of this portion of the course of the canal will be best understood by referring to Plate IX. of the Atlas.

From the 135th mile, which is the point upon which this section commences, down to the 144th mile, the channel proceeds uninterruptedly, and unimpeded by drainage of any sort; it passes within a quarter of a mile of the Nurooa Jheel, which lies to the east, opposite the 138th and 139th miles, running parallel, and at an equal distance, as far as the village of Kumalpoor. At the 144th mile, near the villages of Hunsa ka Nawada and Bakurgunj, the line crosses a small hollow, connected with the Ourun drainage; by this intersection a portion of the Ourun drainage of about one mile in length is cut off; this will be thrown into the Pandoo, if necessary, by a cut* made from the right of the canal to that river; the amount of drainage, however, so cut off is inconsiderable, and it is very questionable whether any steps will be required for its relief; this is a point, amongst others, upon which I should be disinclined to

* This cut has since been made; it is 5 feet wide at bottom. The villagers cut through the canal banks, afraid that their village would be injured.

spend money, until an experience of a few years proved the necessity of it.

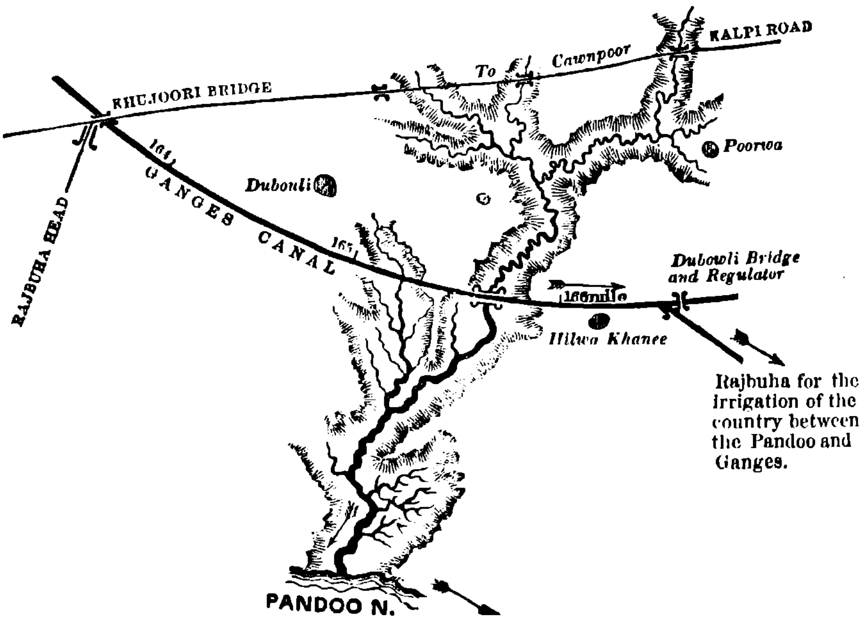
From the 144th to the 164th mile, the line passes over a high country uninterrupted by drainage until it reaches the neighbourhood of the village of Dubowli, at which point it comes in contact with a hollow connected with the Pandoo River; this hollow is crossed by a set of works combining the passage of the hollow by an aqueduct with a free waterway for its drainage, and a series of outlets for escape from the canal; these works are, in fact, the regulating head of the canal on its approach to the Ganges, and are the commencement of a series of works, connected with the lockage into the river, and with the irrigation of the country which we leave on the right, and which terminates at the junction of the Pandoo with the Ganges.

The Dubowli drainage, which is crossed by the works above alluded to, is of no further consideration than that, without making a great and a very awkward détour, the canal line could not have been carried in any other way than it has been; the site, however, is peculiarly applicable to the demands which the Cawnpoor works called for, for escape in their neighbourhood; and the position of the hollow with reference to its proximity to the Pandoo, and the capacity of both for the purposes of carrying off the escape-water, are circumstances in every way favourable to the uses for which they are required.

The following diagram will explain the relative positions of the canal, the Pandoo, and the country with which we come in contact in the neighbourhood of Dubowli.

The extent of country lying on the left of the canal, and which comes under the influence of the Dubowli drainage, does not exceed one square mile; its boundaries are well defined, and the waterway for its drainage, consisting of three passages equal in width to 6 feet each, which pass under the canal, will be quite sufficient for its relief. The escape from the canal channel consists of six waterways of 6 feet each, three on each side of the canal, and so arranged that their escape-water shall fall upon the lower levels under every advantage for the rapid passing off of the water. The difference of level between the bed of the canal and the bed of the sub-passages for the Dubowli and escape drainage is on its up-stream side equal to $6\frac{1}{2}$ feet; the beds of these sub-passages having a slope equal to 2 feet in 107 feet. From the up-stream edge of the sub-passage to the bed of the Pandoo River there is a fall of 21·91 feet on a distance of 9,000 feet; the average slope, therefore, is equal to 12·85 feet per mile. The nulla from the works towards the Pandoo will be straightened and cleared out to a width of 15 feet, and every facility will be given to the escape of both drainage and escape water.

Diagram 37.



Immediately in advance of the Dubowli escape and drainage works is a bridge for the convenience of the village; to this bridge a regulating shutter is attached at a point just below the head of a rajbuha, with a waterway of 10 feet in width, which is intended for the head of supply of irrigation for the tract of country lying between the Pandoo and Ganges; this supply will not, therefore, be cut off when the shutter is closed for the purposes of the Dubowli escape, or at periods when it becomes necessary to prevent the canal supply from proceeding onwards towards the works at Cawnpoor. The supply for irrigation under these circumstances will in no way be interfered with, and the rajbuha itself will, in addition to its uses as a line for irrigation, act to the extent of its capacity of channel as an escape. These works at Dubowli, in which I include both the escape heads over the line of drainage and the regulating bridge with its rajbuha head, will, I anticipate, place in the executive engineer's hands a perfect control over the water during flood periods, and enable him at a moment's notice to lay the channel which passes through Cawnpoor perfectly dry.

In advance of the above works and at the 168th mile, the canal is crossed at the village of Duknapoor by the Grand Trunk Road from Allahabad to Delhi; the bridge at this point is without rajbuha heads, and is built on a skew at an angle of 65 degrees; the direction of the canal on this line has been advancing on a gradual curve from due east to north, and on the latter bearing it proceeds nearly on a straight line from the Duknapoor Bridge direct to the Ganges River.

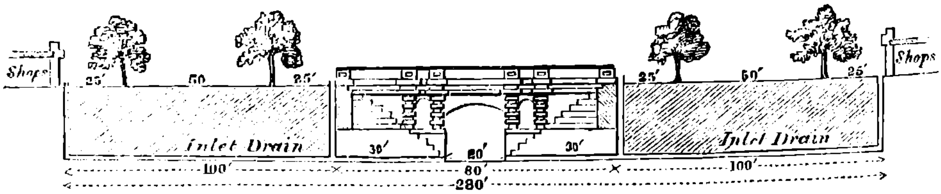
At the distance of 800 feet in advance of the Grand Trunk and the bridge at Duknapoor the line of canal, in passing a collection of brick-kilns which lies on the edge of the town of Cawnpoor, reaches the cantonment boundary; on this boundary, and for a short distance separating the cantonments from the town, the line of canal proceeds onwards, passing through a portion of the cantonment land, on a straight, or very nearly a straight, line until it crosses the "course-bridge," or that bridge which intersects the main cantonment drive; from thence it takes a slight curve to the left, and, by a series of drops of 9 feet each, gains the levels of the great river.

It is a characteristic feature of the profile of the ground on its approach to one at least of the banks of the rivers in the Doab, that there should be a gradual rise of surface; this is universal on the left bank of the Jumna, as well as on the left bank of the Rinde at all points with which the canal works have been connected; it was remarkably shown in the surveys of country on the lines of canal which were originally proposed towards the Jumna, both at Allahabad and Jar, and in both cases the amount of depth of digging which this increasing elevation of surface as it approached the banks of the river led to, was one great cause of the expense attendant upon these lines. On the Cawnpoor branch, which I am now describing, this peculiarity is as prominently marked as it was elsewhere, and on the last 18 miles of its course the excavation, which, throughout the Cawnpoor district, had averaged 8 feet in depth, increased to from 10 to 16 feet, the latter dimension being that on which a considerable portion of the channel was excavated; the depth of digging on the line which passes through Cawnpoor was on an average 12 feet, through a soil that was hard and tenacious at the surface, but sandy below; it became necessary, therefore, to design a series of works that would maintain the channel in efficient order, prevent the falling in of slopes, and retain the water within accurate and well-defined limits; it was also a matter of consideration to render this portion of the canal, which was so directly connected with a large and populous town, ornamental as well as useful, to relieve the bridges and works for cross-communication, which were necessarily numerous, from the extreme and rigid simplicity which had been adopted elsewhere; to give means of approach to the water by ghats or staircases, and to provide every reasonable accommodation to the community in wharfage and quays for the purpose of loading and unloading merchandise. An extensive system of inlet connected with the drainage of the country lying in its neighbourhood was also one of the leading features in the proposed improvements.

For a proper understanding of the works which have been constructed in the town of Cawnpoor, Plate XLIV. of the Atlas must be consulted. In a general way, however, they consist of a double line of revetments on an upper and lower level, with bridges for cross-communication; opposite each main street these bridges form the canal into a series of bays, which terminate on the approach to the head of the locks; from thence the series of works continues to the river, each lock having its passage for cross-communication, and its quays for the landing of goods. The terminus which faces the river has been designed in extensive ghats or flights of steps situated on the right and left of the entrance into the lock chambers; these ghats are backed by domed pavilions, constructed on native models, and the descent from the upper levels which is gained by a double line of steps is flanked by pedestals for the reception of sculptured figures emblematical of the great river. The plan and elevation of this terminus are designed as closely as possible to meet the habits, and accord with the tastes, of the native community; and as its architectural character is intended to harmonize with the town and ghat scenery lying in its neighbourhood, a departure from the usual routine of building on European models, which are perhaps neither so picturesque, nor so well adapted to river scenery, as those of India, may be excusable.

To effect a passage for the canal through that portion lying on the boundary of the town of Cawnpoor, which is denominated General Gunj, a good deal of house property had to be purchased; the property was entirely limited to that on cantonment ground, for which no ground-rent was paid, and the tenure upon which it was held was that common to all lands belonging to a military cantonment, viz., that it was reclaimable at any period, on proper remuneration being rendered for the buildings which had been erected upon it. In the present case the value was determined by a committee of military officers, which was assembled for the specific purpose, and the award in money was paid summarily by the executive engineer in local charge of the works; there were fortunately on the area upon which the line of canal fell, no buildings of any importance. A mosque which came within the boundary has been allowed to remain, and as much indulgence in this respect as could be allowed with reference to the projected lining out of the works was uniformly granted. The width of ground between the two lines which were fixed upon as the canal boundaries was determined at 280 feet, and the general design for laying out this ground will be understood by the following diagram, showing a transverse section on the line of clearance:—

Diagram 38.



The canal channel, as it will be observed, runs centrically through the space lying between the boundaries, having on each side a clear esplanade or roadway equal to 100 feet in width. These roadways are flanked by the town and cantonment buildings, which it is proposed to lay out in lines parallel to the canal, and with façades of uniform street architecture: lines of mango-trees planted at a distance of 60 feet apart will divide the esplanade into a centrical carriage road of 50 feet in width, flanked by open avenues for foot-passengers; I have selected mango-trees for the purpose of these avenues, because they give the best shade of any tree indigenous to this part of the country; I have rejected the neem (*Melia azadirachta*), which, in the Cawnpoor district, is a tree of the most umbrageous and noble character, because it is not from choice planted by the natives in the vicinity of their towns and residences; it is not, moreover, a fruit tree, nor does it produce the depth of shade which is so peculiar to that from the mango.

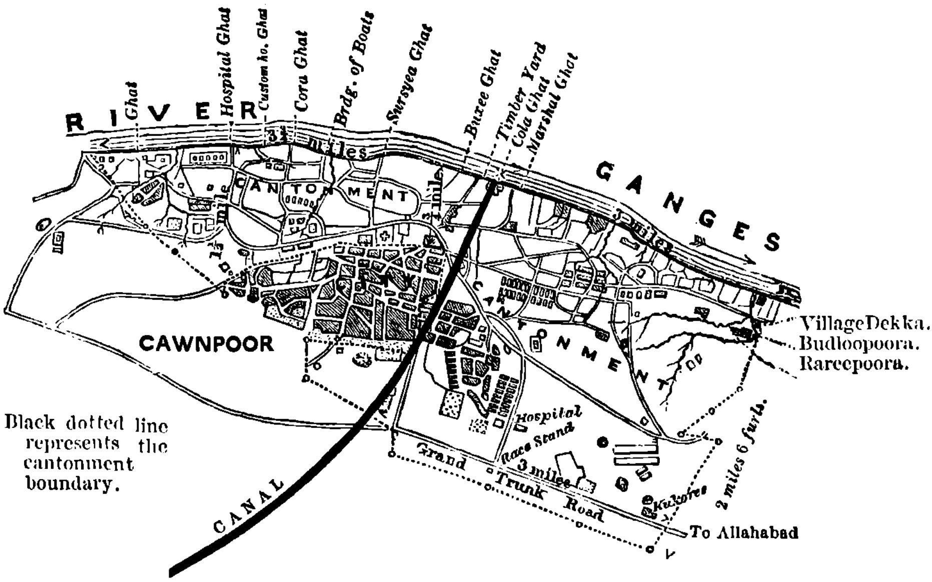
The design for drainage is shown in the above section. The esplanade slopes in a very small degree towards the façade, at the foot of which is a drain which receives not only the rain-water that falls on the esplanade, but that which falls on the streets running at right angles to it; this drainage passes off by perpendicular wells (or bombas, to use the native expression), which are situated at distances along the line, the wells themselves being connected with underground channels (as shown in the above section), which pass the water off to the canal; bombas of a similar description are placed in the rear of the revetment parapet. The bombas, or man-holes (as they are adapted to admitting a man or boy for clearance), are protected at the top by a wall or parapet; they are in fact mere copies of similar works which may be seen stretching across the country in the neighbourhood of Delhi; the remains of extensive sewerage and of underground channels for which the old city was celebrated.

The numerous inlets from the town and its neighbourhood will, it is expected, introduce large volumes of water into the canal below the Dubowli escapes, and between them and the heads of the locks; to remedy this inconvenience, an escape with two sluices of 6 feet in width each has been constructed in connection with a ravine which, under the name of the "church nulla," passes off to the left, and ultimately reaches the Ganges River. This nulla, which is in fact a mere ravine, and only loaded with water during the rainy season, will, I imagine, be greatly benefited by occasional scours, and by its being converted into a well-regulated channel, kept under proper supervision.

The above description of the works in Cawnpoor will, I believe, give a fair idea of the design upon which they have been constructed. They have occupied ground formerly encumbered by houses and huts, encircling pools of stagnant water, and connected with every species of filth and want of ventilation; they have been the means of not only getting rid of the pools and ponds which came within the region of the canal boundaries, but of filling in others, and of levelling and equalizing the ground in the neighbourhood; ravines and hollows by no means adding either to the salubrity or to the appearance of the place have been filled in, and their space has been occupied by roads, esplanades, or buildings; mills for grinding corn have been constructed in connection with the locks; means have been given by the locks for raising boats from the Ganges to the higher levels, and thereby, for unloading their cargoes in the immediate vicinity of the town; facilities for bathing, which have never before existed, have been introduced into the very heart of a densely populated city; and, perhaps, one of the greatest improvements which the works have led to is the advantage derived from ventilation by the opening of a centrical line of broadway, or promenade, with its attendant conveniences of shaded avenues.

The military cantonment of Cawnpoor, the boundaries of which at the present time are of a very irregular description, may, by the agency of the canal works, be placed on a more compact footing. I have before stated that the canal, on passing a series of brick kilns, and on its arrival at Cawnpoor, comes in contact with the boundary separating the town from the military cantonment;

Diagram 39.



this boundary, however, is continued along the edge of the town which lies parallel to, although at some distance from, the banks of the Ganges; the cantonment lands, therefore, separate the town from the river by a narrow irregular strip varying in width from ½ to 1½ mile, and extending as far as 3 miles up-stream to a point on which the ordnance magazine is situated; this long strip of land is occupied by barracks and parade grounds of the different corps, both European and native; and as it will be understood from the above description is crossed by the line of the canal on its approach to the river. The canal, in fact, divides the cantonment at a narrow neck where its width between the town and the river is three-quarters of a mile. The preceding diagram, which gives an accurate representation of the lines of the boundaries of the military cantonment with reference to the town of Cawnpoor, will be suggestive at once of the facilities which the canal works offer for remodelling the cantonment boundaries, should such be considered at any future time advisable.

The alteration which I would propose, and which, in fact, cannot help striking the eye of any one who looks at the present struggling nature of the cantonment, and the extreme inconvenience of its existing boundaries with reference to the town, is simply to remove the whole of the corps which are now cantoned on the left, and on that strip which separates the town from the river, to the right of the canal line; to make the canal line the western boundary of the cantonment; and to give up to the civil authorities the whole of that narrow strip which now separates the town from the river. By these means the cantonment would be compact; its police arrangements would be infinitely less complicated than they are at present; and its connection with the town would be cut off by the well-defined, broad, and open esplanade through which the canal runs. Whether the inconveniences of removing the troops from the west to the east, and the sacrifice of so much barrack room and public property, would militate against the above arrangement, I am unable to say: it is a fact, however, that very extensive barracks and public buildings are now lying on the east of the canal line deserted, in consequence of the reduction of the Cawnpoor force; these barracks and these buildings are therefore available, and their existence is somewhat in favour of the removal of the troops to that side of the canal. At any rate, by reducing the extent of the cantonments, which, in consequence of the great reduction of the military force, is more than half occupied by people utterly unconnected with the army, from its present unmanageable length of six miles to a more compact dimension of three (which, moreover, is infinitely more in accordance with the wants of the force in its present strength), the Government would, in addition to the advantages already pointed out, gain a very considerable accession of most valuable land, the return from which would repay them over and over again for any sacrifice that might be made in the desertion of public buildings, or in the expense of the removal of troops.

The canal in its passage through the last 35 miles of its course keeps, as I have before described, on the high ridge which separates the Pandoo from the Noon and the Ganges rivers; in the early part it runs in close proximity to the Ourun drainage, its direction onwards being guided by the course of the Pandoo, and by the low land of the Noon, which, at the villages of Purtabpoor and Koorsowli, approach to within 2½ miles of each other. On this high land the canal takes its course, leaving the Noon, which enters the Ganges to the south of Bithoor, and proceeds onwards parallel and close to the Pandoo River, to the point where it comes in contact with the Dubowli drainage; from thence it takes a turn towards Cawnpoor, deserting the course of the Pandoo entirely; the latter river continues onwards in a south-easterly direction to the boundary of the Cawnpoor and Futtipoor districts, upon which it passes to the north, and joins the Ganges River on the boundary of the Bindki and Sarh Suleempoor purgunnas; from the point whence the Dubowli drainage enters the Pandoo to the junction of that river with the Ganges, the course of the Pandoo may be estimated as running, in all its tortuosities, on a length of 40 miles: its course is parallel with the Ganges, and the two rivers in their progress from Cawnpoor and to the point of junction enclose a tract of highly cultivated country of about 25 miles in length, by an average of 8 miles in breadth, or a superficial area of 200 square miles; all of which will come under irrigation from the rajbuha head at Dubowli.

From the village of Kukwan to the town of Cawnpoor, the strip of land between the Noon and Pandoo, along which the canal runs, is variable in width, but it never exceeds 6 miles. The fall of the surface of the country from Kukwan to that point on the high land at Cawnpoor from whence the slope towards the river commences, is 25·44 feet in a length of 33 miles, or ·78 foot per mile; between that point and the surface of the Ganges River, the distance being about 2 miles, the fall is equal to 56·58 feet.

Cross levels at different points show the relative levels of the bed of the Pandoo River with the country on the left, or with the low land in which the Noon and Ganges rivers run:—

Koorsowli—56th mile. Pandoo, below country where the canal crosses, 15·39 feet.

56th mile. Low ground of the Noon, at $1\frac{1}{4}$ mile from the canal, 13·5 feet.

Dubowli—64th mile. The bed of the Pandoo at the junction of the Dubowli drainage appears, by a cross section taken by Lieutenant Charles Hutchinson, of the Engineers, to be only 12·93 feet above the surface of the Ganges River, at a point under the old town of Cawnpoor, and near the village of Nuwab Gunj, immediately at the junction of the high bank of the Khadir with the running river.

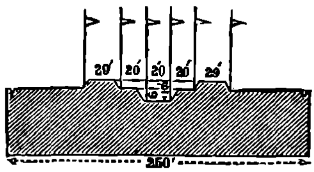
The level of the canal bed on the sill of the

Dubowli escape is 21·91 feet above the bed of the Pandoo River at the junction of the Dubowli drainage.

The section of the canal channel at the point where the Grand Trunk Road crosses the line near the village of Duknapoor is as follows :—

Diagram 40.

Section at Duknapoor.



The height of the berms from the canal bed having been reduced from eight to six feet from the Dubowli works downwards.

The bed slopes of the canal are maintained on a declivity of 12 inches per mile, and the average depths of digging throughout this section may be estimated as follow :—

135th to 140th mile . . .	6·32
140th to 150th " . . .	8·20
150th to 160th " . . .	9·76
160th to 170th " . . .	9·71

The soil from Kukwan downwards is of the same tenacious quality as I have before described it to be in all the excavations that have taken place in the Cawnpoor district; it is only in the deep digging on our approach to the Ganges River where we come in contact with sand.

The observed depths of wells, measuring as usual from the surface of the earth to that of the water, is on a maximum equal to 57 feet, and on a minimum equal to 14 feet.

From the bridge and escape at Kukwan, the following works have been constructed :—

1st. Bridge at Mudhoopoor, two arches of 25 feet each. Roadway 18 feet wide, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

2nd. Bridge at Koondun, of 50 feet waterway, in two arches of 25 feet. Roadway 15 feet, neither ghats nor choki are attached to this work.

3rd. Bridge at Tuktowli, similar in every respect to that at Mudhoopoor, with 2nd class choki attached.

4th. Bridge at Bhosan, of 30 feet waterway, in one arch. Roadway 20 feet wide, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

5th. Bridge at Juggutpoor, of 30 feet waterway, and 18 feet roadway; with ghats, rajbuha and inlet heads, and a 1st class choki attached.

6th. Bridge at Runjeetpoor, similar to that at Juggutpoor, with a 2nd class choki attached.

7th. Bridge at Hoorkapoor, similar to that at Juggutpoor, with a 2nd class choki attached.

8th. Bridge at Koorsowli, similar to that at Juggutpoor, with a 2nd class choki attached.

9th. Bridge at Barah, similar to that at Juggutpoor, with a 1st class choki attached.

10th. Bridge at Muswanpoor, of 25 feet waterway, in one arch. Roadway 15 feet wide, with ghats, rajbuha and inlet heads.

11th. Bridge at Khujoori, built obliquely on an angle of 37°, has a waterway of 25 feet, and a roadway of 20 feet in width; a rajbuha and inlet head is appended on the right, with a 2nd class choki.

12th. Escapes at Dubowli, with sub-passages for the drainage of the Dubowli Nulla (*vide* Plate, No. XLII., Atlas).

13th. Bridge at Dubowli, of 20 feet waterway, and

18 feet roadway; with head on the right, for the Jajmhow and Suleempoor irrigation.

14th. Bridge at Duknapoor, of 20 feet waterway and 25 feet roadway, carrying the Grand Trunk Road across the canal.

15th. Works at Cawnpoor:—

No. 1. Gunj Bridge.
„ 2. Ditto.
„ 3. Ditto.
„ 4. Ditto.
„ 5. Gunj or Mogul Serai Bridge.
„ 6. Course Bridge.
„ 7. Bridge between No. 1 and No. 2 locks.

All these bridges are on the same design as that at Duknapoor, and are connected together with revetments, ghats, quays, drainage inlets, &c., being placed intermediately between each bridge.

Five locks of 9 feet each in descent, with mills and escapes.

Terminal works at the river's front.

Having passed in review the detail of country, and works which have been constructed on the line of the Cawnpoor branch, from Nanoon to the Ganges River at Cawnpoor, I would here refer to diagram 17, fig. 2, and to the division of supply theoretically determined for the branches at their departure at Nanoon. It is better to retain the precise figures of this diagram, as by so doing the results will be more intelligible, and any excess or diminution in length to channels, which the actual working out of the project has shown, can easily be accounted for afterwards.

The actual head supply of the Cawnpoor branch, which is estimated at 170 miles in length, is 1,610 cubic feet per second; the expenditure of this supply is calculated as follows (an amount of eight cubic feet per second being allowed for each linear mile of the branch):—

Miles Linear.		Cubic Feet.		Total.	
170	×	8	=	1360	cubic feet for irrigation as per rules laid down in table.
				50	cubic feet additional, for the purpose of giving supply to the section of country lying between the Eesun and East Kalli Nuddi.
				200	cubic feet per second retained as surplus for the purposes of navigation.

I have in the detail above described figured the transverse sections of the channel at different points on its course, the breadth (*i.e.* of the rectangular figure to which slopes equal to the depth of digging are given), is on leaving the Nanoon regulator 80 feet; this breadth is, on the next 100 miles gradually reduced to 40 feet; from thence to the 162nd mile, the width is reduced to 20 feet, by a diminution of one foot in every three miles, until it arrives at the Muswanpoor Bridge; on this measurement it proceeds onwards to the works at Cawnpoor.

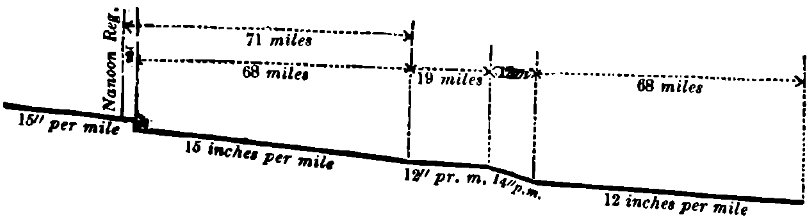
The capacities of the different channels on the sections above given are as follow:—

Section at	Value of R.	Value of $\frac{1}{b}$.	Sectional Area sq. feet.	V in Feet.	Discharge.	
					Theoretical.	Required.
1st mile	64	$\frac{1}{4224}$	516	3·113	1,606·3	1,610
30th "	63	$\frac{1}{4224}$	450	3·088	1,389·6	1,370
65th "	61	$\frac{1}{4224}$	360	3·038	1,093·7	1,090
100th "	58	$\frac{1}{5280}$	276	2·613	721·2	810
135th "	51	$\frac{1}{5280}$	210	2·448	514·1	530
Duknapoor	51	$\frac{1}{5280}$	156	2·448	381·8	264

It will be observed by the above table, that the slope of the bed varies; that in the early part of its course it continues at 1·25 foot per mile, and from that onwards it is diminished to 12 inches per mile. The change is an admitted evil, but from the profile of the surface of the country, it was unavoidable; the outline of this surface has in fact led to the necessity of very inconvenient drops, or sudden changes of level, by which means only we were able to retain within moderate limits the height of the canal embankments on the low tracts which occur in advance. These drops interfere greatly with navigation; they lead to very nearly as much expense in lockage as the falls on the main canal, and they require a navigable channel equal in extent to that of similar works on the main trunk line. The first drop of this description, which occurs on the Cawnpoor branch, is at the third mile, at which point the Keylunpoor Bridge is situated; on this bridge flooring there is a fall of 24 inches, the advantages of which, in taking up a lower line of levels for the canal bed, will be duly appreciated in considering the position which the canal bed would have held with reference to the surface of the country had such a depression of bed not been carried into execution (see Atlas, Plate V.) At the 90th, and between that and the 102nd mile, there is a similar depression equal to 24 inches, the difference of level being gained by an uniform addition of slope to the canal bed lying between these two limits; it will be seen that the excess of level on the 12 miles alluded to merely adds 2 inches per mile to the originally projected slope of the bed.

We have in the two cases above mentioned a perpendicular drop of two feet and an inclined plane, whose base is equal to 12 miles, with a similar drop; it will be interesting to observe the effects that the current, with its deposits, will have in the region of these two depressions. At the 71st mile, however, a general reduction of the slope of the bed from 1·25 foot per mile to 12 inches leads to a still further departure from uniformity in the levels of the Cawnpoor branch, and tends in itself to produce a silting up, and a series of deposits at, and in the neighbourhood of, that particular point where the diminution in slope commences. The canal bed, in fact, may be represented by the following diagram, showing the varieties of slopes in an exaggerated degree :—

Diagram 41.



There can be no doubt that this irregularity will, in the course of time, be remedied by a natural arrangement of deposits, which will, on the principle before explained, reduce the line to one uniform slope, adapted to the particular regimen of the flow of water; and I hold so strong an opinion on this question, that (as I have explained when describing the works which are estimated for at the Keylunpoor Bridge) I have not deemed it necessary to go to the expense of building works for lockage, or for the convenience of navigation, trusting to the abrupt changes in the levels being obliterated by deposits.

The difficulties arising from failures in brick manufactories, in procuring material generally, and, what was of equal inconvenience, of procuring labourers throughout the whole of the time that the Cawnpoor branch works have been in progress, were matters that reduced the executive officers in charge of the works to every shift that could be devised for reducing both the amount of labour and the demand for material to a minimum. I have before explained, that the soil in all the centrical parts of this line of canal was not good for brick-making; this evil, however, was in some measure remedied by the presence of kunkur, which was procurable in great abundance, and in many places of excellent quality; kunkur, therefore, not only took the place of brick, wherever the failures in making the latter had rendered such necessary, but it was used largely instead of soorkhi (pounded brick) in admixture with lime.

To reduce the expenditure of material to the lowest possible limit, Lieutenant Hodgson, the Executive Engineer, found it convenient to carry on a system of gradual reduction of waterway to the bridges corresponding with that of the excavated channel; by this much material was saved, although great additional work has been given to the executive. It may appear strange, that either a saving in time or a saving in money can be contemplated in building a set of bridges whose waterway shall remain on a maximum dimension; in building ten bridges of 50 feet waterway, instead of ten bridges varying from 50 to 40 feet in width; but under the circumstances in which we are placed with regard to establishment, and under our inability to obtain more than perhaps one or two good mistrees (head bricklayers) in a line of 100 miles, with European supervision given at long detached intervals, there can, I believe, be no doubt that ten bridges, built uniformly on one dimension, without variation either in plan or elevation, would be completed in a shorter time, and be built cheaper, more correctly, and better, than were the plan and elevation of every one different. In quantity of material, however, the latter plan is an economical one, and it was for the saving on this item that the change from my original design was made. The following list of bridges, with their waterways, as explained in my estimate of 1850, placed in juxtaposition with those actually built by Lieutenant Hodgson, will be explanatory of the changes that have taken place in this particular part of the project:—

Bridges divided into varieties agreeably to Estimate of 1850.				Bridges built by Lieutenant Hodgson.			
Number of Bridges.	Number of Bays.	Width of each Bay.	Total Waterway.	Number of Bridges.	Number of Bays.	Width of each Bay.	Total Waterway.
		Feet.	Feet.			Feet.	Feet.
9	3	33	99	7	3	33	99
7	3	30	90	1	3	32	96
7	3	26	78	1	3	31	93
5	2	33	66	2	3	30	90
12	2	30	60	2	3	29	87
7	2	25	50	3	3	28	84
9	1	30	30	2	3	27	81
8	1	25	25	3	3	26	78
				2	2	35	70
				2	2	33	66
				2	2	32	64
				2	2	31	62
				8	2	30	60
				11	2	25	50
				6	1	30	30
				2	1	25	25
				9	1	20	20

The design of the buildings is similar to that which has been used in the lower part of the main canal (*vide* Atlas, Plate L.) The main arches are flanked by towing-path passages in prolongation of the berm and towing-path of the excavated channel; irrigation or rajbuha outlets are attached to every bridge, with the few exceptions noted in the detail, and the heads of these outlets, which are situated immediately above the bridge, are protected by lines of revetments and steps, the length of which depends upon circumstances: at common village bridges, these revetments are restricted to 60 feet in length; in the vicinity of bridges connected with high roads, with the main lines of cross-communication, or with escape heads, they are prolonged indefinitely; the maximum length, however, in no case exceeds 350 feet. In some cases ghats have been built on the down-stream side of bridges, and, as a general rule, the means of approaching the water have been given in every case, where by so doing the convenience of the people could be in any way increased.

The escapes have been established as nearly as possible at a distance of 40 miles apart, and, in consequence of the insufficiency of the channels of the Rinde for receiving waste water, have down to the 88th mile been connected with the Eesun River; the heads of these works are in all cases on the up-stream side of bridges, near which they are situated, and are on the plan represented in Plate XXXIX. of the Atlas. The sites of these works are at Ginnowli, Nuggureea, and Tireea into the Eesun, and at the Kukwan Bridge into the Pandoo River. The Dubowli outlet, which passes its water into a tributary of the Pandoo, being considered as a component part of the Cawnpoor terminal works, is not included in the above enumeration of escape channels.

I have explained, when describing the rajbuha heads on the main line of canal, the object that I had in retaining their sills or floorings on a level higher than that of the bed of the canal itself. The system has been put in practice throughout the whole line of the Cawnpoor branch, by which means a certain supply of water will be forced down to the lower divisions. In the line extending from the foot of the Dasna falls to the Nanoon regulators this height of sill has been uniformly maintained at 24 inches above the canal bed; the same height has been continued to the 30th mile of the Cawnpoor branch, or to the rajbuha heads at the Guddunpoor

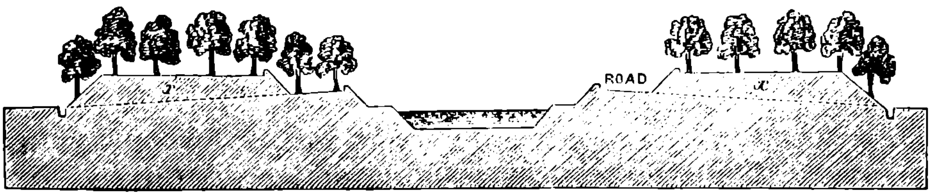
Bridge; from this point, as far down-stream as the 90th mile, or to the Futtipoor Bridge, the sill has been reduced in height to 16 inches. From the 90th to the 150th mile, or to the Runjeetpoor Bridge, the sill has been reduced to 8 inches; from thence to the canal terminus the sills or floorings of the irrigation heads are on the same level as that of the canal bed. Small as the supply may be that this arrangement ensures to the lower divisions, it is a certain one; and one that cannot possibly be interfered with by the most extreme demand for irrigation in the upper districts; in fact, it is the only method by which the irrigation heads at the tails of these long lines of canal could meetwith a certain supply, and the only device by which I could secure irrigation to that section of country lying between the Ganges and Pandoo rivers, for which the Dubowli head, which is the terminal one on the Cawnpoor branch, is specifically built.

In addition to the sill arrangements above noted, the width of the rajbuha heads, and the consequent capacity for discharge, has been reduced as the line of canal advanced in its course, so that the relative discharge from these heads might be in some degree proportioned to the decreased volume in the canal itself: on this principle the 10 feet wide heads, which from the head of irrigation at Assoffnuggur continued throughout the main line, cease at the 30th mile, or at the Guddunpoor Bridge of the Cawnpoor branch; from thence the heads are diminished to a width of 6 feet, on which dimension they are continued to the Dubowli rajbuha head, which is the last of the series. The head at Dubowli, however, is, as I have before explained, constructed on a width of 10 feet, with its sill on a level with the canal bed, so that the country which is dependent on that head for its irrigation may derive every possible advantage from local circumstances.

The design of the channel, with its berm or towing-path and its embankments, is very similar to that which has been executed on the main canal; the towing-path is on the Cawnpoor branch reduced to 8 feet in height from the canal bed, to meet the decreased high-water mark, and on that portion of the line which is connected with the works at Cawnpoor, or from the Dubowli regulator, this height is again reduced to 6 feet, the towing-path being with few exceptions maintained on a level parallel with that of the canal bed; the exceptions to which I refer are when the digging is unusually deep, in which case the towing-path has a gradual rise, and is adapted to the profile of the country, but on such moderate and uniform slopes, that the absence of the parallelism before alluded to is neither inconvenient, nor is it a disfigurement to the general appearance of the section.

The road, which is constructed and designed on the same principle as that which has conducted us down to Nanoon, is continued along the Cawnpoor branch on the left bank, to the terminus on the Ganges. The width between the boundaries, however, is in some places too narrow to admit of the earth which is excavated from the channel being spread out on one uniform and at the same time moderate height. In these cases, therefore, the superfluous earth has been formed into an elevated platform in rear of the roadway, the section of the canal under these circumstances being as follows:—

Diagram 42.



x x showing the position in which the superfluous earth is placed. The roadway on this section is limited to a width of 20 feet clear of the edging or small ridge of earth which is carried along the top of the interior slope, has a slight slope to the rear, and the rain-water is carried off to the boundary ditches by channels which are made through the raised platform *x* at distances of 500 feet apart; the facility of procuring kunkur will enable these drains to be protected from wear, and the outer ditches will carry away the water to the inlets which are built at each bridge in connection with the rajbuha head channel.

Milestones on the same plan as that before described and placed in the same relative positions to the roadway are continued from Nanoon to the Cawnpoor terminus; they are numbered from the Nanoon regulator downwards in one continued series; these milestones act as bench-marks, and are intended to have the precise level from the flooring of the Myapoor regulator at the canal head engraved upon them. The plantations are throughout this branch similar in every respect to those on the main canal; the species of forest tree is confined as far as possible to that which is indigenous to the district through which the excavation is carried: in those parts where the keekur (*Acacia Arabica*) grows more luxuriantly than other trees, the keekur is selected as the staple wood for the plantation; where the neem (*Melia azadirachta*) thrives with greater luxuriance, the neem has been selected, and by these means, a more rapid and a more certain growth to the trees in the plantations has been secured. In all cases, however, the line of mango-trees to which I have before adverted, as likely to be of such great benefit to the roadway in providing shade, and of such great ornament to the banks from its size and extent of foliage, is maintained as a part of the plantations.

The accommodation for the establishments and for the chain of station-posts is on the same scale as that on the main line, viz., 1st class choki buildings at distances of about 12 miles apart, with 2nd class chokies at each of the intermediate bridges; the plan of these buildings is given in Plates LIV. and LV. of the Atlas. The design of all these chokies is uniform as well as the position in which they are placed relatively to the bridges and the line of canal. Deviations from this uniformity have occurred in two instances; the Bahosi 1st class choki having been built on a mound at some distance from the left bank, and that at Barah having been placed on the right bank of the canal, at a distance from the bridge, and in a situation somewhat inconvenient for its purposes; so inconvenient do I consider the position of this choki building, that in preference to continuing its repair and maintenance, I would recommend that another choki be built near the Barah Bridge and on the site that was originally intended for it. At each of the 1st class chokies a mango graft plantation will hereafter be established, on the same plan as has been adopted on the main line, and on the same scale as has been so successfully carried out on the Eastern Jumna Canal.

The works on the Cawnpoor branch were, up to the 31st of August, 1852, separated into two portions, which went under the titles of the 4th and 6th divisions: Lieutenant Hodgson, of the Engineers, holding the executive control of that portion extending from Nanoon to Sooreya, equal in length to 100 miles; and Lieutenant C. W. Hutchinson, of the Engineers, having the supervision of the remaining 70 miles, including the works at Cawnpoor. On the 1st September and 6th December, 1852, Lieutenant Hutchinson and his assistant resigned their situations, and proceeded on medical certificate to England and New South Wales, leaving the works without any engineer supervision whatever; the opportunity, therefore, was taken to break up the 6th division, the existence of which in such a limited form was perfectly accidental, and to place the whole of the Cawnpoor branch under Lieutenant Hodgson's control. The works, therefore, of the Cawnpoor branch have, since the month of September, 1852, been carried on by that officer, who, aided by Lieutenant Lamb, of the Regiment of Artillery, and by Lieutenant E. Willoughby, of the same corps (the latter, having been placed in charge of the works at Cawnpoor, retaining his regimental duties), has brought the works to a state of completion that I had at one time hardly anticipated. Lieutenant Hodgson's success under very great difficulties has been highly satisfactory; and although the completion of the works at the terminus by the time that the canal is opened will not crown his efforts, the works themselves will be as far advanced as circumstances would admit of under a demand for bricks, which far exceeded the supply procurable from the brick manufactories. The difficulties of procuring bricks at Cawnpoor as elsewhere, however, have depended in a great measure on failures in brick burning, a misfortune before alluded to, and which was in all probability quite unavoidable.

THE ETAWAH TERMINAL LINE.

The total length of this branch from the Nanoon regulator to the terminus on the Jumna is 175 miles. It leaves the regulator at an angle of 21½ degrees, corresponding with that of the departure of the Cawnpoor branch; and after passing the fort at Bijigurh, at which it takes a sweep, bringing it in direct parallelism with its sister branch, and with the course of the Rinde River, it proceeds onwards in the same direction on a length of 65 miles; at this point, or at the village of Gangsi, it makes a turn to the right, leaving the Rinde and keeping clear of the heads of the Ahneea and Phoora, two rivers which join the Rinde in one connected channel under the village of Bhimwanmow. Avoiding the drainage connected with the above two rivers, the line regains its parallel direction to the Rinde, which it maintains from the 116th to the 145th mile. At this point a comparatively sharp turn to the right, near the village of Gujehmow, not far from the town of Ukburpoor, clears the heads of the Noon, a river that, rising near Ukburpoor, takes a course almost parallel to the Rinde. From thence the canal, passing to the right of the Noon, reaches the Jumna River, at the village of Futtiabad, eight miles east of the town of Moosannuggur.

From the above general description it will be understood that the Etawah terminal line, throughout its whole course, runs to the right of the Rinde River, keeping as much as possible out of the influence of the tributaries and drainage which are connected with it. The Seyngoor River, the heads of which lie in the neighbourhood of Koel and the town of Bijigurh, throughout its whole course maintains a parallel direction to the canal flowing on its right, so that, in fact, the Etawah branch, from its head at the Nanoon regulator to its terminus in the Jumna, passes between the Rinde and the Seyngoor rivers on a course as equidistantly marked out, as the position of the ridge or watershed would admit of.

The line upon which these works are carried was only touched upon by me, in my original surveys, in a series of levels which was carried to the south of the town of Koel, and which, in an onward course by the forts of Bijigurh, Deori, and Awa, terminated at the town of Gihror, from whence it crossed the Rinde, at the village of Durba, to Nohneir and the East Kalli Nuddi, as connected with the branch which now runs to Cawnpoor. My surveys, therefore, with the exception of fixing certain points of level, were of no practical importance.

In the cold season of 1845–46, Mr. Dodsworth, the surveyor of the Ganges Canal works, was deputed to report upon the country lying between the Rinde and the Jumna rivers. He was directed to commence from a fixed point or bench mark, which I had established on a tomb at the village of Umurpoor, near Koel; from this bench mark a series of cross sections was to be taken at every 5 miles, keeping the Rinde as the left and the Jumna as the right boundary; and upon this series of cross sections he was to establish a longitudinal line of levels, so as to determine as closely as possible the watershed between the Rinde and Seyngoor.

Mr. Dodsworth's surveys were completed in the cold weather of 1847–48; they had been carried out in the fullest detail as far as instrumental work was concerned; and the information which they conveyed enabled me to frame a very accurate estimate of the line upon which a branch for irrigation ought to be carried.

With Mr. Dodsworth's maps in hand, Lieutenant Whiting, of the Engineers, who was appointed to the executive charge of the Etawah branch, denominated the 5th division, commenced his surveys in the cold weather of 1849–50: these surveys, independently of verifying the results of Mr. Dodsworth's levels, placed upon paper the whole of the drainage between the Rinde and the Seyngoor, in all its intricacies and ramifications; exhibited the position of the different jheels and hollows forming the heads of the tributaries, and the lines connecting them with the above rivers; and traced out a course for the canal, which, maintaining itself on a fair and regular alignement, runs as closely as possible on the watershed.

This close examination into the minute detail of the cross drainage of the country, led to some deviations from the line which had been marked out in Mr. Dodsworth's map; and it was found convenient, from the exceeding intricacy of the drainage at the head of the Noon River, and the great extent of flats and hollows lying on the country over which it takes its course, to leave this river altogether on the left of the line of the canal, thereby deserting the tract of country situated between the Noon and the Rinde, upon which the towns of Jar and Ghatumpoor are situated. The canal, therefore, passes through the westerly portion of the Ghatumpoor Pergunna, or that lying on the right of the Noon, leaving the easterly portion, or that bounded by the Rinde, Jumna, and Noon, to be irrigated by rajbuhas, by which it is both approachable from the bridges above Ukburpoor, by turning the heads of the Noon, and more directly, by lines of watercourse carried over the valley of the Noon River.

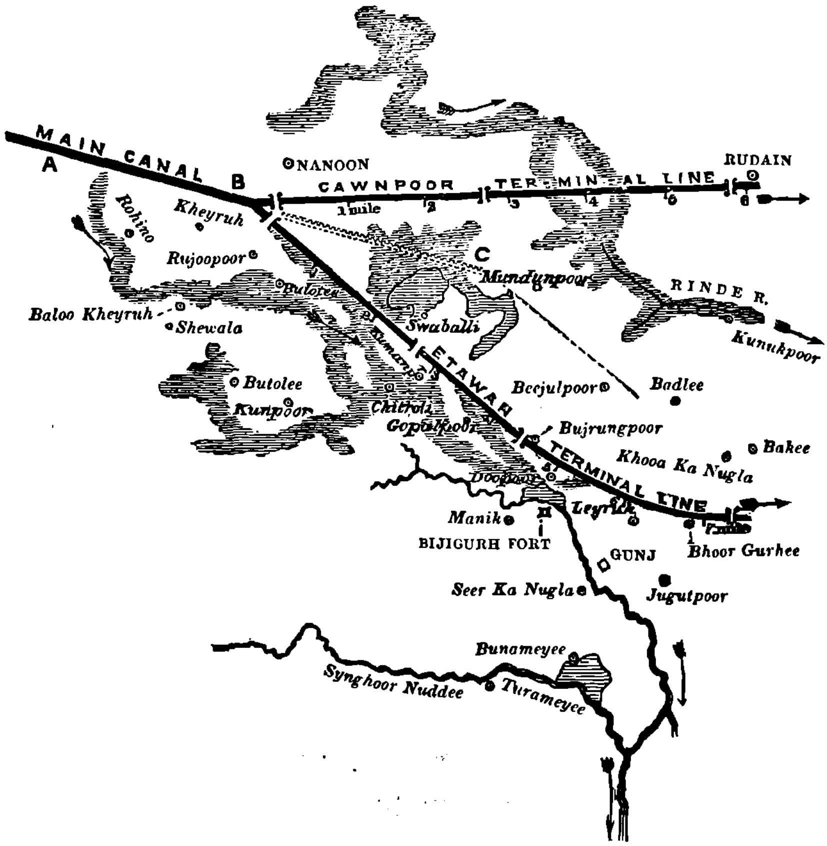
It will be understood from what I have written in the early part of this chapter, that the surveys of this tract of country were completed previously to the commencement of those of the main and Cawnpoor terminal lines south of Meerut. An engineer officer, however, was not appointed until late in the year 1849, and it was not until the cold weather of 1850–51 that ground was broken, and that a commencement was made in bridge and choki building. The 3rd, 4th, and 6th divisions, or those including the last 70 miles of the main canal, and the Cawnpoor branch, were, therefore, at this period two years in advance of the 5th or of the Etawah division, a circumstance that will account for their advanced state of progress at the period when I left the works.

I shall now bring under review the works and the country over which they pass, in a detail similar to that which has been followed on the Cawnpoor branch, commencing with the first 30 miles, or those which lie between the head at the Nanoon regulator, and the bridge situated opposite the town and fort of Awa.

In describing the course of the Cawnpoor terminal line on its leaving the Nanoon regulators, I have in some measure explained the peculiarities of the slopes of the country at that particular point, its connection with the heads of a very extensive system of drainage, and the cause which led to the Nanoon station being fixed upon as that best adapted for the site of the heads. It will be unnecessary, therefore, to advert to the drainage of the Rinde River, the marked and main heads of which clearly lie to the north of Nanoon itself, further than to draw attention to a tract of country lying around the village of Swaballi, which is so closely connected with the drainage, both of the Rinde and of the Seyngoor, that not even the levelling instrument, nor the most detailed and determined examination of its profile, could lead Lieutenant Whiting or myself to any further conclusion than that the drainage was common to both rivers; there was the slightest possible tendency in excess of slope towards the Rinde; to the Rinde, therefore, the Swaballi drainage has been consigned, and the line of canal, on its leaving the regulator at Nanoon, passes to the west of that village, separating its drainage entirely from that of the Seyngoor. I have no doubt that the determination of the alignement will prove to be correct, and that the hollows about Swaballi will pass off their superabundance of flood-water to the Rinde. The following diagram, however, will place the topographical features of this part of the country still more distinctly before the reader; it gives both the Cawnpoor and Etawah lines as they are connected at Nanoon with the drainage of the Rinde and Seyngoor rivers.

The three points, A, B, and C, were those from among which we had to select the best adapted for the head of the terminal lines; and the election fell on that

Diagram 43.



which was centrically situated, as having the twofold recommendation of being well suited for the site of the necessary buildings, and admitting at the same time of our giving favourable directions to the terminal lines themselves. The election, in fact, lay between the heads marked B and C; as that from the point A would have thrown the canal in contact with the hollows and flats in the region of the Bijigurh Fort. Between the positions of B and C, as sites for public buildings, there could be no question that the preference should be given to B; and as the results of our levelling operations had shown sufficiently clearly that the Swaballi drainage was connected with the Rinde, there could be no doubt that preferable as it was as a site for a public station, it was still more so as that for the heads of the terminal lines, which, by being separated at this point, would have the least possible connection with the cross drainage of the two rivers.

The Etawah terminal line, therefore, passes Swaballi to the west, and proceeds onwards, touching the heads of some drainage connected with the Seyngoor, in the neighbourhood of the fort of Bijigurh; the contact is very slight, occurring at the 4th mile near Bujrungpoor, and at the 5½ mile near the village of Doopoor; the country is exceedingly flat throughout, so much so, that on the right of the canal, as it passes by the fort of Bijigurh, which lies at a distance of half a mile, the eye wanders over sheets of waste and uncultivated plain, the whole of which throws its drainage into the Seyngoor River. As far as the fort of Bijigurh, the line of canal is carried on a bearing almost due south; from thence, however, it takes a turn to the left, proceeding onwards in a south-easterly direction, running parallel to the Rinde, as well as to the Cawnpoor terminal line; at the 10th mile, the canal comes in contact with a hollow in the neighbourhood of the village of Jao, over which it passes under the inconvenience of heavy embankments, but with little interference with drainage; at the 12th mile, another hollow, but small, as compared with that at Jao, is crossed under similar circumstances; the canal, in fact, at the above two points, is fringing a line of drainage that passes into the Seyngoor under the town of Juleysur. On its onward course, and between the 17th and 23rd miles, or between the villages of Jureyra and Roodurpoor, the canal crosses the heads of a third line of hollows, which is also connected with the Juleysur Nulla. Opposite the village of Pilkutra, which lies on the right of the line, these hollows extend to a distance of about a mile, and as far as the village of Gadri, which lies equidistantly between the canal and the Rinde River, the whole of this series consists of straggling lines of low ground, which appear to be connected with jheels or deep ponds lying under Pilkutra and the village of Nooh, the latter hollow being again connected with drainage which passes off to the Seyngoor, by the towns of Mustafabad and Jusranuh, considerably to the east and opposite the 40th and 50th miles of the course of the canal. The portion of the low land, however, which is thus cut off from the drainage leading to the Seyngoor, will by artificial cuts be connected with the course of the Rinde, and by these means be as efficiently drained as they would be otherwise. From Pilkutra, the line turns slightly to the left, sweeping round by the villages of Keyrara and Guhrana, between which it passes to the village of Soonari, from whence it continues on a bearing similar to that on which it arrived at Pilkutra. The sweep above alluded to enables the canal to pass the heads of the Seyngoor drainage, which run up to the fort of Awa, and its neighbourhood, and it passes between this and the Kureyra and Muhobutpoor hollows, which fall into the Rinde, with the slightest possible interference with the slope of either of the rivers; the watershed is in fact most closely followed on all this line, and with the exception of an intersected portion of low land connected with the Seyngoor, which lies between the 29th and 31½ miles immediately on the approach to Soonari, the canal passes over high land, more or less cultivated; the portion of hollow which has been thus cut off will, it is supposed, be relieved by a cut into the Rinde, which lies within a distance of a mile or a mile and a half from it; it is naturally connected with a system of drainage which stretches over the country between Awa and the canal, and which passes off to the Seyngoor by the Mustafabad line of nulla before alluded to.

The width of country between the Rinde and Seyngoor, upon which the canal takes its course, expands as it approaches the fort of Awa; on its leaving Nanoon, and at the Bijigurh fort and Gunj, the distance between the two rivers does not exceed 5 miles; at the 30th mile, and on a cross section at Awa, the distance has increased to $12\frac{1}{2}$; the watershed lies close upon the right bank of the Rinde, upon which the canal runs, at a distance of about $2\frac{1}{4}$ miles from that river. The slope of the surface of the country from Nanoon to the village of Soonari, or to the 30th mile, is 44·86 feet, averaging 1·49 foot per mile, and the relative position of the beds of the Rinde and Seyngoor to each other will be understood from the following table. This table has been deduced from the sheets of levels taken by Mr. Dodsworth, and as it includes the Kuroon (a river with which the main canal runs in connection, in its passage through the Bolundshuhur district), and the Jumna River, at the point where the Kuroon joins it, the relative levels of each will be interesting.

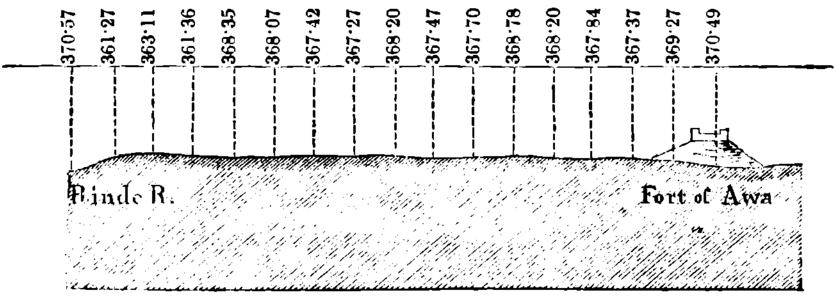
—	Below the Rinde River.							
	Mudsan.	Seyngoor Bed.	Kurgaon.	Eyta.	Augwar.	Chuteysur on edge of Jumna.	Kuroon.	Jumna.
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
A Cross section east of Bijigurh, 10th mile	—	3·36	—	—	—	—	—	—
Do. Hussayn, 15th mile . . .	—	5·66	—	—	—	—	22·00	—
Do. Patna, 20th mile	—	7·70	—	—	—	—	35·25	—
Do. Nooh & Juleysur, 25th mile	—	5·09	—	—	—	—	44·05	—
Do. Awa, 30th mile	0·61	7·58	above 4·70	above 5·65	above 0·94	4·15	71·3	71·3
							Junction of	

With reference to the last section, I may observe, that Mr. Dodsworth appears to have taken the low line of nulla, and expanse of flat lying on the immediate north of the fort of Awa, as the Rinde River, whereas this nulla and these shallows are in fact, as I have before shown, the head of a line which runs by the town of Mustafabad, into the Seyngoor. Lieutenant Whiting's levels, taken on a cross section between the Awa hollows and the Rinde (the distance being $2\frac{1}{4}$ miles), give the following results, using the figures of Lieutenant Whiting's series. The site of Lieutenant Whiting's station at Awa must have been close upon that which was taken up by Mr. Dodsworth.

Awa station	370·49
Bed of Rinde	370·57

And the result, as showing that there is only a difference of 0·8, is curious; it is very characteristic, however, of the profile of the country connected with the heads of these rivers, and of the difficulties that attend upon canal engineering when they have to be dealt with. Nothing could have been more natural than the error into which Mr. Dodsworth fell, and it is possible that had he extended his cross section in prolongation of the line upon which he was working, and had come upon the Rinde itself, he would have considered that he had come in contact with the Eesun River. The profile of the country lying between the Awa hollow and the Rinde, and across which the line of canal passes, is shown in the following diagram:—

Diagram 44.



The point at which Mr. Dodsworth's cross section on

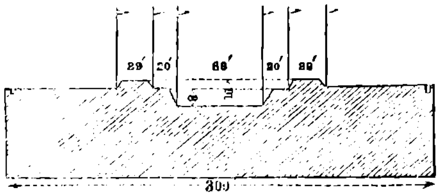
Awa meets the Jumna River is, at its junction with the Kuroon River, about 2½ miles below the Taj at Agra; the levels shew the surface of the water of the Jumna in the month of December. Appended to the levels of the different points immediately connected with the beds of the rivers, are those of the villages with which the cross section came in contact; throughout the whole line between the Rinde and the Jumna, the maximum difference of surface does not exceed 6 feet, and that only on very short distances.

It will be observed, from the table above given, that the course of the Rinde is on a higher level than that of the Seyngoor, which runs, relatively to the Rinde, much in the same way that the Eesun does, as described in a former paragraph. The heads of the Seyngoor, however, as it will be understood from what has gone before, take their rise on a country situated on higher levels than that of the Rinde, in the same way as those of the Rinde rise on a higher level than those of the Eesun.

The section of the canal channel at the 30th mile is as follows:—

Diagram 45.

Section at the 30th mile.



The width of the rectangular section having been reduced in the 30 miles, from 80, which was that upon which the excavation is commenced, to 68 feet.

The slopes of the canal bed are on one uniform series of 15 inches per mile.

The rule with regard to minimum dimensions is maintained here as elsewhere, that of the height of the berm or towing-path being 8 feet from the canal bed, and that of the top of the embankment 10 feet.

The average depth to which digging has been carried on the above line is as follows :—

From the	1st	to the	10th mile,	6·30	feet.
„	10th	„	20th do.	8·97	„
„	20th	„	30th do.	7·13	„

The soil is good and tenacious, and occasionally mixed with kunkur; the alkali, to which I have referred as existing in such large quantities, and over such extensive surfaces in the Mynpoori district, is prevalent; particularly so, on the plains in the neighbourhood of Bijigurh and Awa; in other respects the soil appears to be favourable, of a non-absorbent quality, and therefore well adapted to the retention of water.

The depth of wells on a measurement from the surface of the earth to the surface of the water is on the

Left of the Canal Line.		Right of the Canal Line.	
Maximum . . .	29 feet.	Maximum . . .	78 feet.
Minimum . . .	15 „	Minimum . . .	15 „

The following works have been constructed on the above section of the Etawah terminal.

1st. Bridge at Chitrowli, three arches of 33 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

2nd. Bridge at Bujrungpoor, similar to that at Chitrowli, with a 2nd class choki attached.

3rd. Bridge at Bijigurh, similar to that at Chitrowli, with a 2nd class choki attached.

4th. Bridge at Jao, three arches of 30 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 1st class choki attached.

5th. Bridge at Lodipoor, similar to that at Jao, with a 2nd class choki attached.

6th. Bridge at Kutai, similar to that at Jao, with a 2nd class choki attached.

7th. Bridge at Seetapoor, similar to that at Jao, with a 2nd class choki attached.

8th. Bridge at Pilkutra, similar to that at Jao, with a 1st class choki attached.

9th. Bridge at Nooh, similar to that at Jao, with a 2nd class choki attached.

10th. Bridge at Ooreyri, similar to that at Jao, with a 2nd class choki attached.

11th. Bridge at Guhrana, three arches of 30 feet each, 18 feet roadway.

12th. Bridge at Soonari, three arches of 26 feet each, 18 feet roadway, ghats, rajbuha and inlet heads, and a 2nd class choki attached.

From the 30th we continue our course as far as the 65th mile,* or to the village of Gangsi, at which the canal changes its direction to the right, and discontinues its parallelism as well as its propinquity to the Cawnpoor branch.

The direction of the course of the canal on its leaving the Soonari bridge is south-east, and it reaches Gangsi by a gentle curve, on a bearing almost due east; it keeps to the high land near the Rinde, to which it runs parallel, and at a distance of about 2 miles.

The width of country between the Rinde and Seyngoor is at Soonari 12½ miles; in the neighbourhood of Gangsi and Durba, or at the 65th mile, this width has gradually diminished to 5 miles, the drainage towards the Seyngoor running in many places close up to the edge of the Rinde, adjoining the right of which is the watershed.

I may here observe, that, from the Nanoon regulator, the Cawnpoor and Etawah terminal lines run parallel to each other as far as the 65th mile, at which point they

* 30th to 65th mile.

separate, the one passing off to the Futtigurh and Cawnpoor districts, the other proceeding on towards Etawah. On these 65 miles of their course, their maximum distance from each other is $5\frac{1}{2}$ miles; their minimum distance is 4; at the point of departure near Gangsi they are $4\frac{3}{4}$ miles apart. The Rinde River runs equidistantly, although on its own straggling course, between them. On this line, therefore, the drainage of the river is directly limited by the canal works to a basin which on the measurements above given equals 65 miles in length, on an average width of $4\frac{3}{4}$ miles, or to a superficial area of $308\frac{3}{4}$ square miles; both the branches of the canal, however, run so closely upon the natural watershed of the Rinde, that with the exception of that portion extending to the north of Nanoon, and lying on the left of the Cawnpoor terminal line, the natural boundaries of the basin, and the artificial ones now given by the two lines of canal, may be considered as sufficiently coincident to enable us to determine the actual volume of flood-water that may be expected to pass at the village of Durba; there is no necessity for entering upon the question here, but it is one that may be of importance, when estimating hereafter the value of this flood-water, as convertible to useful and economical purposes.

In taking up the details of the country over which the canal passes, and on leaving the Soonari bridge, the drainage towards the Seyngoor, which I have described as rising in the neighbourhood of Awa, runs on the right and parallel to the canal, at a distance of about $2\frac{1}{2}$ miles, until it reaches the 41st mile, or the village of Peydhut, which lies $2\frac{3}{4}$ miles due north of the town of Mustafabad, under which the drainage in question passes off by Jusranuh to the Seyngoor. At two points only, viz., at the 36th and 37th miles of the course of the canal, the works come in direct contact with cross drainage—the first near the village of Kuttana, where a hollow of no importance connected with the Rinde is crossed; the second near the village of Deywa, from which onwards as far as Peydhut, the canal line fringes a succession of shallow depressions, which are connected with a large jheel that lies to the south of that village, and which is on the slope of the Seyngoor River: with these two exceptions, the canal from the 30th to the 41st mile passes over land tolerably well cultivated, and altogether free from marked drainage. A cross section taken from the Rinde to the branch of the Seyngoor, under the town of Mustafabad and passing by the village of Peydhut, shows that the Rinde at this point is—

2·01	feet	below the Mustafabad hollow.
6·86	,,	below the Peydhut hollow.
10·83	,,	below the surface of the ground over which the canal passes.

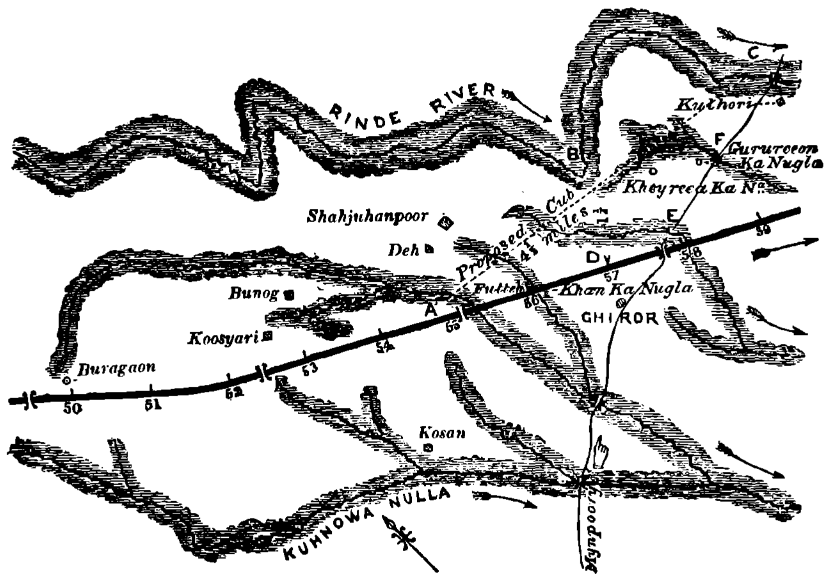
From the 41st mile the canal continues uninterruptedly, passing close by the villages of Puteekra, Burragaon (at which there is a tower, denoting one of the station points of the meridional series of Colonel Everest's measurement of the great arc), and Koosyari, all of which are on the left of the line, until it reaches the village of Futteh Khan Ka Nugla at the 55th mile; at this point, as well as at the 56th mile, the canal crosses drainage, which, uniting with the Kuhnowa Nulla, joins the Seyngoor at Kunukpoor; at the 58th mile, also, it crosses drainage, which joins the same river between the two villages of Ismailpoor and Nubbipoor.

No. 1 line, or that which is intersected by the canal at the 55th mile, rises in the vicinity of the village of Burragaon; it extends for about two milesto the left of the canal, collecting in its course (whichmay be estimated at six miles in length) the drainage from the country in the neighbourhood of Bunog, Koosyari, and crossing the canal at the village of Futteh Khan Ka Nugla.

No. 2 line, or that at the 56th mile, rises in the vicinity of Shahjuhanpoor and Deh, two villages situated at $1\frac{3}{4}$ mile from the point where the canal intersects it.

No. 3 line, or that at the 58th mile, rises in the same part of the country as that last described; its course before it reaches the canal is three miles in length. The value of the drainage here may be estimated by the waterway of a drain connected with the Grand Trunk Road, which crosses it, close to the Ghiror Bridge, at the 58th mile; the width of this waterway is three feet. The following diagram will make the above description more intelligible:—

Diagram 46.



Agreeably to the figures of Lieut. Whiting's series, the levels of the different points noted above are as follow:—

A	398·63
B	401·94
C	405·85
D	399·17
E	399·55
F	399·09

A cut made from A to the Rinde River at C will have a total fall of 398·63 – 405·85, or 7·22 feet, or, as the length of cut is 4½ miles, the slope of the bed will be equal to 1·6 foot per mile; it is proposed to make the channel 15 feet wide, so as to give a free and unimpeded passage, and it is hoped that by these means, the country from Burragaon along the left bank of the canal will be fully relieved. At the 61st mile, the drainage marked by the letter F in the above diagram crosses the canal in connection with another tributary of the Seyngoor, which joins that river near the village of Utta; the head of this line, which I call the Utta River, appears to consist of a large jheel under the two villages of Kheyreea and Gurureeon Ka Nugla, and situated on the west and between the Grand Trunk Road and the Rinde. From the Kheyreea Jheel to the point where the canal intersects the drainage at the 61st mile, the distance is 3¼ miles; a second cut will be required to carry away the water of this line to the Rinde. From the 61st mile, the line of canal, by sweepin ground to the left, escapes three extensive hollows or jheels, viz., those of Bidhowna, Oodhunna, and Soj, all of which, with a network of drainage, are left in open communication with the Seyngoor, which they join in one connected nulla under the village of Teyrah. The canal just touches upon low ground connected with this drainage to the north of Bidhowna, as well as to the north of the village of Gangsi, but the interference is of a nature offering no impediment either to the works or to the country.

At the Ghiror station, and attached to the bridge over which the high road between Mynpoori and Agra crosses, is an outlet into the Seyngoor; it consists of a waterway of 30 feet, divided into five bays of six feet each; the work forms a component part of the bridge buildings, and is connected to the bridge by a line of ghats (Atlas,

Plate XLV.) The distance between the canal at the escape and the Seyngoor River is $4\frac{1}{5}$ miles, and the difference of level between the sill of the sluice openings and the bed of the river is equal to 10·17, or 2·9 feet per mile, the excavated channel being 25 feet in width. Between the Ghiror bridge and the 65th mile, the rajbuha heads attached to the bridges on the left embankment will, in all probability, be connected with a main line of irrigation, which will be divided into two branches, one for the purpose of irrigating the country between the Rinde and the Phoora rivers, and the other for the irrigation of a similarly situated, although smaller, tract lying between the Phoora and Ahneea; to this, however, I shall refer more explicitly hereafter.

The slope of the surface of the country from the 30th to the 65th mile is equal to 38·18, or, on an average, 1·09 foot per mile. On this section, we come in contact with a sudden change in the level of the country, which appears to me to be one of the characteristic and marked features of this Doab, when approaching the heads of an extensive system of drainage. I have adverted to this change of slope elsewhere, especially when describing the country in the neighbourhood of Alligurh and Koel, at and near where the Rinde, Seyngoor, and Eesun take their origin; it is marked in the line of canal by the Simra and Pulra falls, by which the sudden variation of level is overcome by descents of five feet each, and at the Keylunpoor bridge it is represented by a drop of two feet; the surveyor, in fact, in his progress with the levelling instrument finds that he has suddenly made a descent, and that the profile runs entirely upon a new and different series.* In a general aspect, the country lying

* This complete change in the series of level to which I have adverted in the text, must not be confounded with local depressions which are occasionally met with under circumstances which are very

between the Ganges and Jumna has a surface with varied slopes, diminishing as it approaches the junction of the two rivers at Allahabad; it is separated into series of well-defined and sudden changes of levels, giving the profile an appearance of steppes, each of which is marked by its own peculiar drainage, and each of which defines, in a manner the most unmistakeable, the position of the watershed.

At the 49th mile, and on the approach of the course of the canal to Burragaon, the surface of the country, which has been continuing on a steady slope of about one foot per mile, abruptly takes up a level four feet lower, and proceeds in advance on a slope similar to that with which it arrived at the crest of the drop; this

liable to mislead. A good example of local depressions, extending over very wide surfaces, is shown on the tract of country between the Jumna and Ganges, near the town of Futtipoor; on the approach to which, and in the space of two miles, my levels showed a depression of 8·63 feet, with an unusual continued fall of country for five miles in advance; on the 6th mile, however, a rise took place, which restored the amount of fall to the original series on which the profile had existed previously to reaching the low land near Futtipoor. The following table, showing the amount of depression at each mile, will exemplify the interruption in the uniformity of slope, caused by the six miles of hollow above alluded to. From the 360th to the 382nd mile, or at a point close to the town of Futtipoor, the slope was 16·43 feet, or 0·746 foot per mile. From the 390th, or from the point where the hollow terminates, the slope continues at about 12 inches per mile, which, in calculating the levels from the 360th to the 410th mile, will be found to be the true average of the slope of the country.

360th mile	. .	526·59	feet from the zero point of my levels at Hurdwar.
382 ,,	. .	543·00	
383 ,,	. .	547·88	Sudden fall of 4·88
384 ,,	. .	551·63	Ditto 3·75
385 ,,	. .	553·08	Hollow
386 ,,	. .	555·08	
387 ,,	. .	558·76	
388 ,,	. .	555·58	
389 ,,	. .	550·74	level regained at one foot per mile.
390 ,,	. .	552·89	
400 ,,	. .	563·90	
410 ,,	. .	573·85	

sudden variation will be best understood by a series of figures which represent the depression of the surface at each mile below the zero point of Lieutenant Whiting's levels.

From the 39th to the 49th mile the slope of the surface of the country is 9·02 feet, or ·902 per mile. Thus—

39th mile	378·13
49 ,, ...	387·15
50 ,, ...	391·21
60 ,, ...	403·05

And the abrupt drop of four feet that occurs on the line between the 49th and 50th miles is not again recovered; from the 50th to the 60th mile, the country proceeds on an equable slope, on which it continues. Here the slope of the canal bed is reduced from 15 to 12 inches per mile, upon which it is carried to the Jumna: this change of slope occurs at the 54th mile.

The relative positions of the beds of the rivers, deduced from cross sections taken by Mr. Dodsworth, show the high course that the Rinde maintains over all the rivers lying on its right.

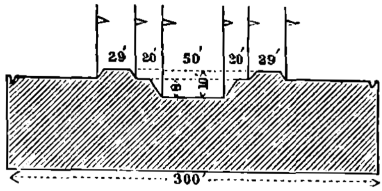
—		Below the Rinde.		
		Seyngoor.	Sirsa.	Jumna.
		Feet.	Feet.	Feet.
	35th mile	5·35	—	76·75
	40th ,, ...	3·66	7·57	77·62
Ferozabad	45th ,, ...	2·14	3·00	79·68
Jusranuh	50th ,, ...	4·01	1·66	83·75
	55th ,, ...	7·33	2·16	83·40
Kulhore	60th ,, ...	7·96	3·25	92·84
	65th ,, ...	12·63	4·45	94·56

z 2

The section of the canal channel at the 65th mile is as follows :—

Diagram 47.

Section at the 65th mile.



Spare earth being thrown in rear of the embankments on the plan which has been usually adopted.

The average depth of excavation is as follows :—

From the 35th to 40th mile . . .	6·75 feet.
„ 40th „ 50th „ . . .	9·80 „
„ 50th „ 60th „ . . .	7·25 „
„ 60th „ 65th „ . . .	7·94 „

The soil is good, partially accompanied by the alkali before alluded to, and occasionally mixed with kunkur; it appears to have all the non-absorbent or retentive qualities to which I have referred, as characterising the excavated channel in the Mynpoori and neighbouring districts.

The depth of wells, measuring from the surface of the earth to the surface of water, is—

On the Left of the Canal Line.		On the Right of the Canal.	
Maximum . . .	31 feet.	Maximum . . .	105 feet.
Minimum . . .	21 „	Minimum . . .	21 „

Continuing from the bridge at Soonari, the following works have been executed :—

1st. Bridge at Sooraon, three arches of 26 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 1st class choki attached.

2nd. Bridge at Kuttana, three arches of 26 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads attached, also a 2nd class choki.

3rd. Bridge at Jeyra, three arches of 26 feet each,

18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

4th. Bridge at Peydhut, three arches of 26 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

5th. Bridge at Kana Kowa, three arches of 26 feet each, 18 feet roadway, with rajbuha and inlet heads, ghats, and a 2nd class choki attached.

6th. Bridge at Puteekra, three arches of 26 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 1st class choki attached.

7th. Bridge at Burragaon, three arches of 26 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

8th. Bridge at Koosyari, three arches of 26 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

9th. Bridge at Futteh Khan Ka Nugla, three arches of 26 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

10th. Bridge at Ghiror, two arches of 33 feet each, 25 feet roadway, with ghats, rajbuha and inlet heads, and a 1st class choki attached; and connected with an escape head of 30 feet waterway.

11th. Bridge at Jurari, two arches of 33 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

12th. Bridge at Jowapoor, two arches of 33 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

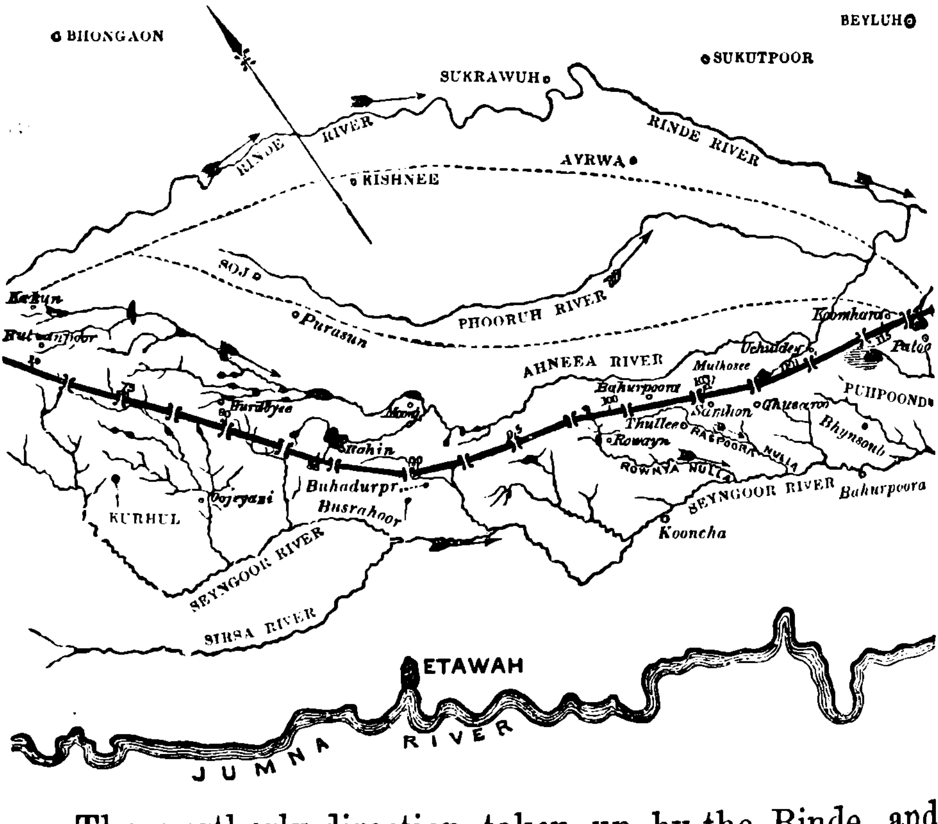
In advance of the 65th mile,* and continuing our progress to the 120th mile of the course of the Etawah branch, we, by making a turn round the village of Gangsi, escape the heads of the Phoora and the Ahneea

* 65th to 120th mile.

rivers, tributaries of the Rinde, which in one collected stream enter the last-mentioned river, near the village of Bhimwanmow.

The Rinde and the Seyngoor, which up to the 65th mile have been running in a direction nearly parallel, approach each other at that point within a distance of $5\frac{1}{2}$ miles, and afterwards gradually separate, the former taking a northerly, and the latter a southerly direction; their bearings are on a sweep which, on a cross section at the town of Ayrwa, places the two rivers at a distance of 23 miles from each other, an extreme distance which, in the neighbourhood of the 120th mile, and between the two towns of Puhpoond and Mungulpoor, is reduced to $12\frac{1}{2}$.

Diagram 48.



The northerly direction taken up by the Rinde, and the sweep that at this point of its course it takes to the left, touching near upon Sukrawuh, a town in close connection with the Cawnpoor terminal line, lead to a desertion of its watershed, the canal proceeding parallel to the Seyngoor River, and on the right of the Ahneea, a tributary of the Rinde. The Ahneea, in fact, from the neighbourhood of the 65th mile, and between the villages of Kakun and Gangsi, near which it rises, takes up the parallel course upon which the parent river had up to this point been running; and, in this respect, bears some resemblance to the Pandoo and Eesun, as described in a former part of this chapter.

The position of the drainage in this neighbourhood will be best shown by the preceding diagram.

The length of the Ahneea, from its heads to its junction with the Rinde, is 50 miles; that of the Phoora, 35: the former rises in a very extensively ramified series of hollows, of which that near the village of Kakun appears to be the most remarkable; and the latter rises in the vicinity of Soj. The superficial area of land included between the Ahneea and the Rinde may be estimated at 450 square miles, Soj, Kishnee, and Ayrwa being the principal towns, each of which give their names to purgunnas. The sections or spits of land, formed by these rivers, will receive their irrigation from the rajbuha heads, at and on the up-stream canal side of the Gangsi bridge; the course of the rajbuhas, for this purpose, being shown in the diagram by dotted lines. The tails of these rajbuhas are, in the above sketch, represented as falling into the canal again, after crossing the Ahneea by aqueducts, a design that might be carried out with great advantage, as it would admit of a continued supply being allowed to pass off from the canal above Gangsi, whilst at the same time a perfect command would be held over that supply, with the full power of cutting it off in cases of necessity.

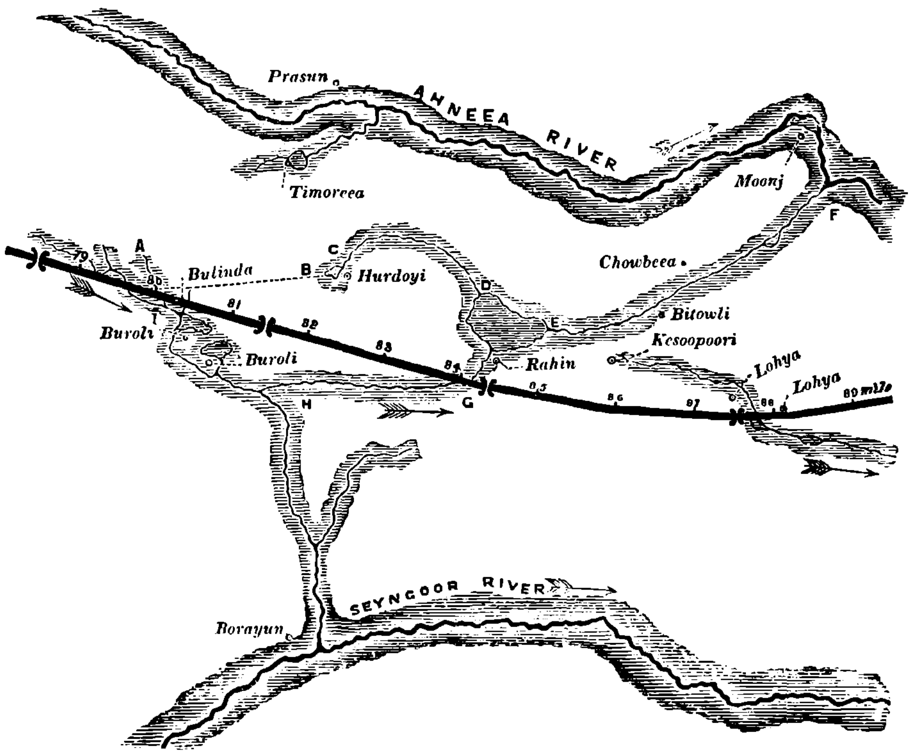
I may remark here that the Sirsa River, which, in fact, is a branch of the Seyngoor (which separates itself on the right from the main line, south of Juleysur, and near the town of Oomurgurh, in the Muttra district), rejoins that river at a point on its course lying between Kishnee and Etawah. The Sirsa passes on its left the towns of Shekoabad, Sirsa Gunj, and Justwuntnuggur; it can hardly be considered as having any influence on the works of the canal, excepting as far as relates to the course and direction of rajbuhas, but it so repeatedly crosses the line of Mr. Dodsworth's cross sections, and consequently takes so prominent a place in the tables, that its existence ought not to be passed over.

With this preliminary sketch of the country between the 65th and 120th miles, I shall proceed with the detail of the country over which the line of works has been carried.

The course of the canal, which at the 65th mile is on a curve having a radius equal to 20,000 feet, continues this course, passing the village of Gangsi, until it reaches the 68th mile. Immediately in the neighbourhood, and on the approach of the line to the village of Gangsi, a shallow tract of ground, connected with the hollows at Soj and Oodunna, is passed; it appears to offer no difficulty, and to cause no impediment to the drainage, which, however, can, if necessary, be carried into the Rinde, which by a sudden twist lies within a mile of the low ground in question. In advance of the 68th, the line passes over a high country as far as the 80th mile, coming in contact with a shallow of no importance, which occurs at the 73rd mile; it is one of the extreme heads of an extensive line of drainage that joins the Seyngoor under the village of Oojeyani.

At the 80th and 84th miles intersections of the drainage lying between the Ahneea and the Seyngoor rivers take place, under somewhat peculiar circumstances; as a line of uninterrupted hollows connects the two rivers, although at both points the natural slope most unmistakeably lies across the line upon which the canal crosses. The nature of the drainage will be best shown in a diagram.

Diagram 49.



The head of this drainage reaches the line at the point of intersection with the 80th mile, after having passed over about two miles of country running parallel to the canal; at this point, therefore, the canal embankments cut off at least two square miles of the catchment basin, which naturally belong to the Buroli jheels; at the 84th mile, again, the water, which during the high floods passed off from the Buroli jheels towards the great lake at Rahin, is diverted by the canal embankments from its natural line of escape. It is perfectly obvious that any interference caused by the canal works at the 84th mile can be easily remedied by deepening the line of hollows which communicate with the Seyngoor; the natural profile of the country points out this as the remedy; the fall from the 84th mile to the bed of the Seyngoor, under the village of Borayun, being (430·6 – 446·5) 15·9 feet, on a length including all the tortuosities of the course of less than six miles. At the 80th mile, however, the remedy is not so simple, the slopes of the country are by no means favourable, and it will be necessary to relieve the intercepted drainage by an artificial cut, two miles in length, extending from the low ground A to the Hurdoyi Jheel at B, and to clear out the low line of hollow connecting that jheel with the Rahin Lake. A portion of the rain-water collected on the left of the canal in the neighbourhood of the village of Bulinda, will undoubtedly escape into the inlets of the bridges and obtain relief to the extent of their capacity; the line of rajbuha, moreover, which will necessarily pass across the country in the neighbourhood, will not only receive a great deal of the flood-drainage, but will modify the natural watershed to such an extent, as to extinguish its existing boundaries. I have no doubt, however, that an efficient and well-cleared-out channel, not less than 15 feet in width, should be maintained on the line extending from the 80th mile by the Hurdoyi and Rahin jheels to the Ahneea River, on the line marked in the above diagram A B, C D, E F, and that channels of similar dimensions should be excavated on the right side of the canal from the 80th and 84th mile, or from the points marked I and G, to the junction of the natural hollows at the point H, from whence the nulla leading to the Seyngoor ought to be kept well open, so as to admit of a free passage for the drainage water.

With the works above specified, and with an annual inspection to secure their efficient clearance from either natural deposits, or from artificial bunds placed over them for the purposes of irrigation by the zumeendars, I see no reason why the difficulties of this part of the line should not cease altogether; the works, in fact, for obviating these difficulties will add greatly to the relief of the neighbouring country in the rapid removal of flood-water towards the Ahneea on one side, and towards the Seyngoor on the other.

In advance of the 84th mile, at Rahin, the canal runs on a course almost due south-east until it reaches the 88th mile, whence from the village of Lohya it bears more to the east, its course being influenced by the direction of the Ahneea River.

At the village of Lohya the canal intercepts a line of drainage running towards the Seyngoor, and at the point of intersection passes through a hollow which may be called the Lohya Jheel; the line of drainage alluded to rises at the village of Kesoopoora, between which and the point where it comes in contact with the canal the distance is two miles. I do not anticipate any inconvenience from the interruption to the drainage at this point; a portion of the rain-water will escape into the canal through the inlet at the Lohya Bridge, the rajbuha attached to which will in all probability carry off the remainder.

From the 88th to the 115th mile, the direction of the canal continues on a bearing tending easterly, over a high and well-cultivated country, keeping, with the following exception, entirely clear of drainage. At the 97th mile, not far from the village of Oomurseyra, it cuts off a portion of hollow connected with the low lands lying in the neighbourhood of Rowayn, a town on the right at a distance of a mile from the canal embankments; these low lands are drained by the Rowayn Nulla, a tributary of the Seyngoor, which enters that river near the village of Chowri. The portion of this drainage which is intercepted by the canal extends about half a mile, and has its origin in a jheel lying under the village of Chundelon Ka Nugla. No works have been designed for the relief of this hollow, nor is any necessity for them anticipated.

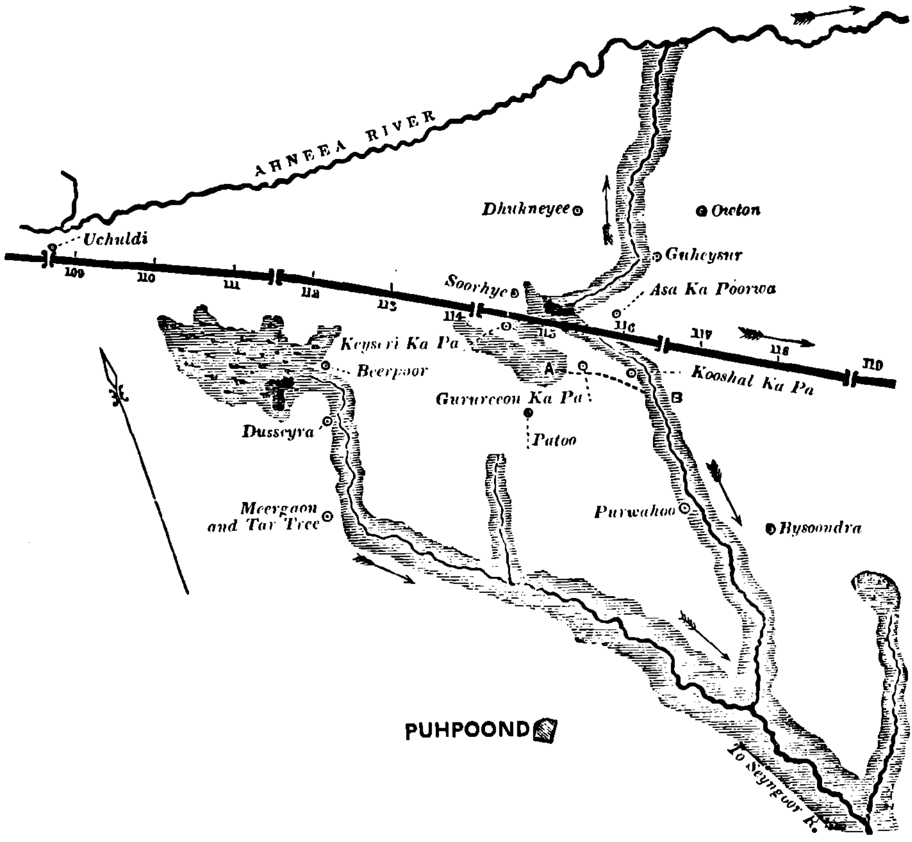
At the village of Munohurpoor and at the 106th mile, the line of canal which passes between that village and Gopalpoor skirts the edge of a large hollow, surrounded by villages which lie on its left; this hollow passes its flood-water off to the Ahneea River, by a line of nulla parallel to which the canal takes its course, as far as the village of Uchuldi. Under this village the Munohurpoor drainage forms a junction with the Ahneea, and the canal, which at this point runs within a quarter of a mile of that river, passes onwards in a sweep inclining to the right, over high land, until it reaches the 115th mile. The canal, in passing the village of Uchuldi and on its approach from the 109th mile, leaves on its right a very extensive hollow, which, as lying near the village of Beerpoor, I shall call the Beerpoor Jheel; this jheel is the head of a nulla which runs by the villages of Dusseyra and Meergaon (the latter marked by a remarkable tar-tree), and, leaving Puhpoond about 1½ mile to its right, joins the Seyngoor not far from the town of Oorya.

At the 115th mile the line proceeds on the watershed as closely as a straight line could do so on a crooked one; it appears, nevertheless, to intercept the drainage of a rather extensive hollow near the village of Keyseri Ka Poorwa, the position of which will be best understood from a diagram.

The low land at A, by the intersection of the line of canal, is isolated, and will in all probability require a cut from A to B for its relief. The diagram shows a very fair specimen of the intricacy of drainage and slope with which the canal at parts of its course has to contend.

From the 115th to the 120th mile the canal passes on high and cultivated ground to the village of Devipoora, the town and great trigonometrical station of Seyhud Khas lying about two miles on its right.

Diagram 50.



At the village of Mulhosi, which is situated at the 103rd mile of the course of the canal, an outlet, with a waterway of 30 feet, in five openings of 6 feet each, is designed for the purposes of escape into the Seyngoor River. The cut from the outlet will be directly at right angles to the course of the canal, and may either be carried into the bed of the Seyngoor, or, as the fall appears to be sufficient, it may terminate at the Rajpoora Nulla, a line that runs nearly parallel and north of the Rowayn Nulla, a tributary which has been before described as entering the Seyngoor under the village of

Chowri. A cross section taken from the surface of the country over which the canal passes, in a direct line, and on the course of the escape channel to the Seyngoor, shows that the bed of the latter is depressed to an extent of 34·05 feet, and that the beds of the two intermediate nullas, which would be intersected by a straight line of cut, are as follow:—

	Below surface of Country at the Canal.	Distance from the Canal.
	Feet.	Feet.
Rajpoora Nulla . . .	14·10	8,000
Rowayn " . . .	14·81	17,000
Seyngoor " . . .	34·05	20,000

For further remarks on this line, see Part III. chap. ii. sect. 3, under the head of Escapes.

The slope of the surface of the country, from the 65th to the 120th mile, is equal to 54·938, or on an average of 0·998 foot per mile. At the 72½ mile, a general depression of two feet in the surface of the country takes place similar to that which I have described as occurring elsewhere, especially at the 54th mile of the course of this line; this sudden change of levels at the 72½ mile, however, affects in no way the slopes of the canal bed, which are continued uninterruptedly at 12 inches per mile, although it acts so far beneficially as to reduce the depth of digging, which up to this point had been somewhat in excess, to that required for the height of the towing-path.

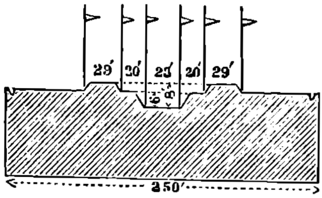
The relative position of the beds of the rivers, as deduced from Mr. Dodsworth's cross sections, will be shown by the following table, the plus or minus quantity in the table denoting the depths above or below that of the Rinde.

Distance in Miles from Nanoon on the Rinde.	Phoora River.	Town of Soj.	Ahneea River.	Village of Oomurseyra.	Town of Puhpoond.	Seyngoor River.	Sirsa River.	Town of Ajeetmul.	Town of Lukhnao.	Town of Etawah.	Ravine heads near the Jumna River.	Wells. Left of the Canal. Max.	Wells. Left of the Canal. Min.	Wells. Right of the Canal. Max.	Wells. Right of the Canal. Min.
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
70	...	...	...	...	...	−14·70	−0·30	...	...	...	−14·74	38	23	90	23
75	...	...	...	...	...	−10·45	−1·50	...	...	...	− 8·56	38	25	90	25
On Soj . . . 80	...	+12·24	...	...	...	− 9·68	−3·00	...	...	...	− 9·82	33	18	90	31
85	...	...	+10·68	...	...	− 7·47	−1·06	...	...	...	−10·94	35	24	90	30
On Etawah . 90	...	...	−10·23	...	...	− 9·72	...	...	...	+22·70	−22·27	40	29	90	35
On Oomurseyra 95	+12·11	...	−14·83	+19·84	...	− 9·99	...	...	...	...	−14·15	40	28	90	33
100	− 8·63	...	−16·64	...	...	− 9·71	...	...	+26·25	...	−16·93	40	28	90	30
105	− 6·33	...	−13·41	...	...	− 8·99	...	...	...	...	−21·25	32	24	105	30
On Ajeetmul 110	...	...	−12·46	...	...	− 4·70	...	+27·26	...	...	−27·20	27	22	77	26
On Puhpoond 115	...	...	...	...	+15·38	− 5·09	...	...	...	...	−29·30	32	20	72	25
120	...	...	...	...	...	−13·73	...	...	...	...	−26·29	37	...	80	37

The section of the canal channel at the 120th mile is shown in the following diagram:—

Diagram 51.

Section at the 120th mile.



The distribution of spare earth being arranged for as in former cases.

The average depth of excavation is—

		Feet.	
At the	70th mile	6·95	
			6·30 mean of 5 miles.
,,	75th ,,	4·90	
			6·44 ,,
,,	80th ,,	5·36	
			5·83 ,,
,,	85th ,,	7·56	
			5·23 ,,
,,	90th ,,	4·59	
			5·38 ,,
,,	95th ,,	6·40	
			5·92 ,,
,,	100th ,,	7·38	
			5·78 ,,
,,	105th ,,	9·41	
			6·88 ,,
,,	110th ,,	7·58	
			5·22 ,,
,,	115th ,,	4·71	
			6·58 ,,
,,	120th ,,	8·93	

The soil is very good, occasionally mixed with kunkur, which is, generally speaking, met with in small pieces, gravel like, seldom in masses, but all available for lime burning, for mixing with cement, or for metalling roads. The soil appears to be of the same retentive quality as that before described, and, as such, is especially favourable for the purposes of economizing the supply of canal water.

Oosur soil, or that with which the alkali is mixed, is met with here and there over the whole of the country through which the canal passes in its progress from the 65th to the 120th mile.

The maximum depth of wells is 105 feet, and the minimum depth is 18 feet, measuring from the surface of the earth to the surface of the water.

Continuing from the bridge at Jowapoor, the following works are designed for this portion of the canal :—

1st. Bridge at Gangsi, two arches of 33 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

2nd. Bridge at Nutaoli, two arches of 33 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

3rd. Bridge at Boojeea, two arches of 33 feet each, 25 feet roadway, with ghats, rajbuha, and inlet heads, and a 1st class choki attached.

4th. Bridge at Bussoo ka Nugla, two arches of 33 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

5th. Bridge at Tukrao, two arches of 33 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

6th. Bridge at Bulinda, two arches of 33 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

7th. Bridge at Burrowla, two arches of 30 feet each, 18 feet roadway, with ghats rajbuha and inlet heads, and a 2nd class choki attached.

8th. Bridge at Rahin, two arches of 30 feet each, 18 feet roadway, with ghats, rajbuha, and inlet heads, and a 1st class choki attached.

9th. Bridge at Lohya, two arches of 30 feet each, 20 feet roadway, with ghats, rajbuha, and inlet heads, and a 2nd class choki attached.

10th. Bridge at Budamyee, two arches of 30 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

11th. Bridge at Toreyeea, two arches of 30 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

12th. Bridge at Oomurseyra, two arches of 26 feet each, 18 feet roadway, ghats, rajbuha and inlet heads, and a 1st class choki attached.

13th. Bridge at Bahurpoora, two arches of 26 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

14th. Bridge at Mulhosi, two arches of 26 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and connected with which is an escape of 30 feet waterway; a 2nd class choki is attached to these works.

15th. Bridge at Munohurpoor, two arches of 26 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

16th. Bridge at Uchuldi, two arches of 26 feet each, 18 feet roadway, ghats, rajbuha and inlet heads attached, as also a 1st class choki.

17th. Bridge at Koomhara, two arches of 26 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

18th. Bridge at Kunahown, two arches of 26 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

19th. Bridge at Devipoora, two arches of 26 feet each, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 1st class choki attached.

20th. Bridge at Bijhye, two arches of 26 feet each,

18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

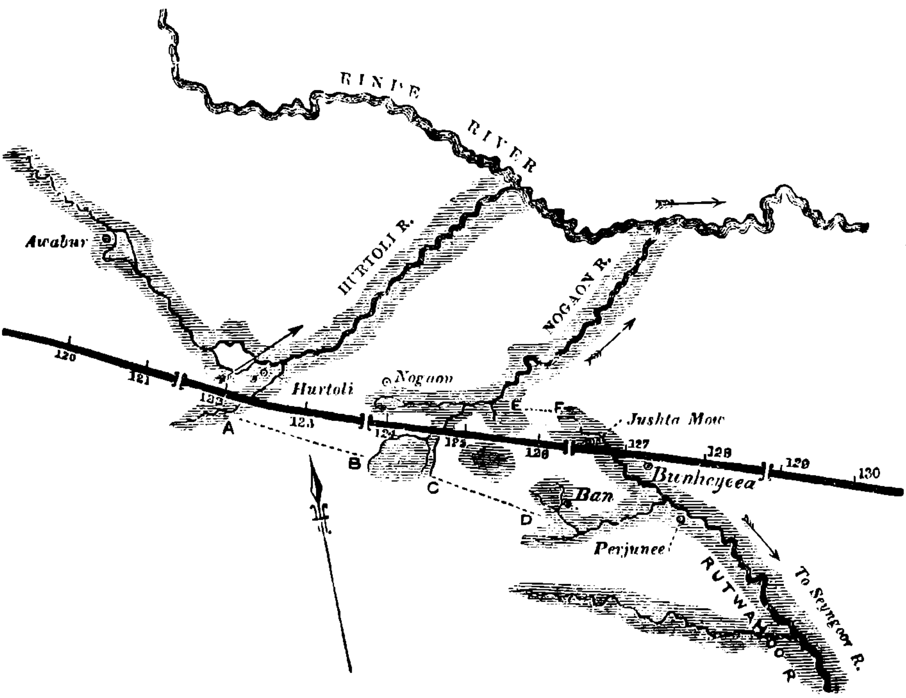
The last section terminated at the 120th mile at a point of the canal situated about five miles north of the town of Puhpoond, in the Etawah district. From this point, the direction of the alignement is in a general way in prolongation of that on which it reached the 120th mile, viz., about east south-east, or a few degrees nearer east; on this bearing it continues as far as the 142nd mile, or to the heads of the Noon River; from thence to the 145th mile, a succession of curves on a constant radius of 20,000 feet delivers the line on an entirely new bearing, deserting the course of the Rinde (which proceeds onwards to the town of Kora Juhanabad), and taking for its left boundary the drainage of the Noon River. This new bearing, which is to the south-south-east, continues to the 163rd mile, and to the neighbourhood of the town of Rawun; from this point another curve on a radius of 20,000 feet fixes a starting point (at the 165th mile) for an alignement which, running due south, delivers the canal water into the Jumna.

It will be understood, therefore, that the direction of the canal on that part of it which is above described, after running parallel to and between the Rinde and Seyngoor, as it has done from its head downwards, takes at the 145th mile, or thereabouts, a sweep to the south, passing round the towns of Ukburpoor and Rawun, leaving the Rinde River altogether, and entering the Jumna, bounded on its left by the Noon, and on its right by the Seyngoor.

The strip of country through which the canal passes between the Rinde and Seyngoor is at the 115th mile, or on a section taken at Puhpoond equal to 14 miles in width; at the 145th mile, or at a point between the villages of Roora and Tugaeen where the change of direction takes place, this width is decreased to 11 miles;

the line of the canal maintaining its position as closely to the watershed as possible, and running within four miles from the course of the Rinde. In its passage onwards, and in its course southward towards the Jumna, the line of canal takes up a more centrical position between the Noon and the Seyngoor (which are separated by a distance of about 11 miles), a circumstance entirely influenced by the watershed, and by the extensive and scattered drainage connected with the former river, not only at its immediate heads, but on its whole course, to which reference will be made in greater detail presently, when bringing under review the alignements as connected with the detail of cross drainage. To this review, therefore, we will proceed, the drainage connected with the hollows near Keyseri Ka Poorwa and Gururreeon Ka Nugla having been before described.

Diagram 52.



Leaving the villages above noted, the line of canal reaches the 141st mile, on a fine open and cultivated country, with less interference from cross drainage than has been usual on such a length of course; on this whole line of 26 miles, there are only three points, viz., at the 122nd, 124th, and 127th miles, where drainage is intersected at all, and the hollows cut off by this intersection lie so conveniently with regard to the Rutwahoo River, that any annoyance which may arise can be very easily remedied. A diagram, showing an outline of the country will be the most satisfactory method of conveying information on the detail of the intersections above alluded to. (*See* diagram 52.)

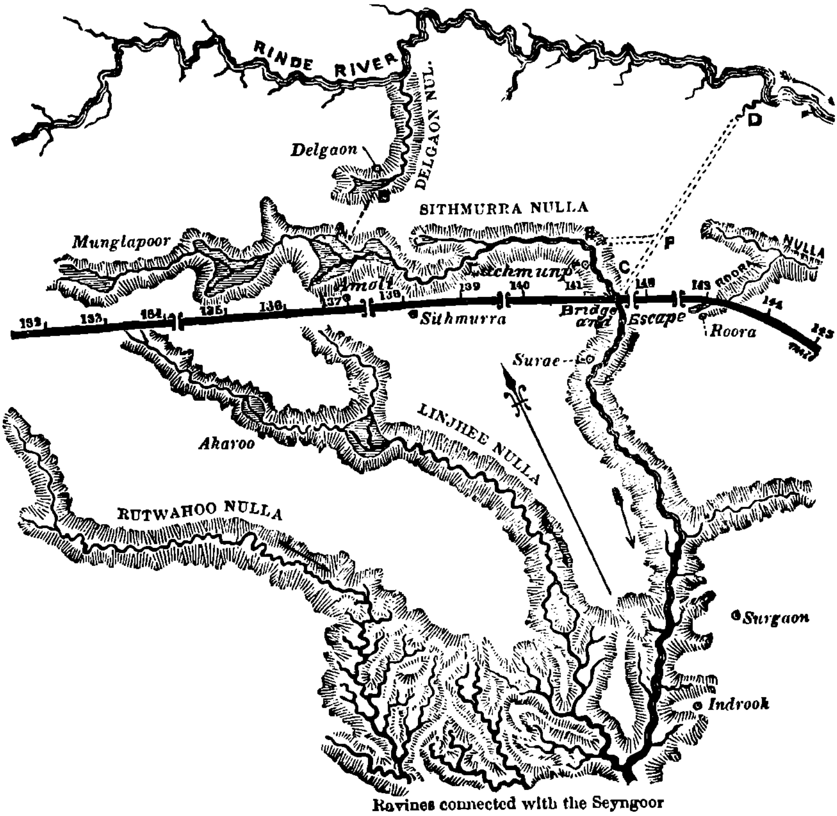
It will be observed, that the hollows which are cut off by the canal at the 122nd and 124th miles are portions of drainage connected with two distinct tributaries of the Rinde; to these I have, to facilitate reference, given names derived from villages lying at their heads. Both those portions of the Hurtoli and Nogaon tributaries which have been separated from their parent drainage, can be connected with each other and with the Rutwahoo, by cuts as above marked at A B and C D: the length from A to B is not more than two miles, and that from C to D does not exceed 1¼; a ditch that need not exceed 10 feet in width would lead to the complete drainage of the hollows. I may remark, however, that these lines of drainage look more formidable in a map than they are in reality, it is necessary to exaggerate in shade the lines of drainage when shown in a map, although such lines may be depressed only a few inches below the level of the surrounding country; our maps, too, represent by a shade the hollows as filled with water, a circumstance that naturally occurs only during heavy rains; many of the hollows, therefore, and the above amongst the number, which are described as being thus cut off and isolated, are depressions of such an inconsiderable amount, that in all probability no remedies will be required at all.

At the 127th mile, a portion of one of the heads of the Rutwahoo, lying in the neighbourhood of the village of Jushtamow, is cut off, and thrown on the left of the canal; the remedy for this, is to connect it with the drainage of the Rinde, by making the cut E F into the Nogaon Nulla; a cut the length of which will be considerably under a mile, will here also lead to a rectification of evil; the fact is, that the remedy in all these cases is exactly the same, although in one case it may be more expensive than it is in another; the direct and even line upon which the canal takes its course, necessitates intersection with the heads of drainage which are scattered about the surface, without the least regularity; as this direct line of canal, however, passes over the summit level of the country, and intermediately between rivers, the beds of which are considerably depressed, it is evident that a portion of hollow cut off from one slope may be turned into the drainage, passing off on the other, and that there ought to be no inconvenience to the drainage of the country from the introduction of a canal, or road, which has been conducted on the principles above mentioned.

At the 141st, or rather at a point between the 141st and 142nd miles, the line of canal, after running for 10 miles parallel, comes then in contact with the course of a tributary of the Seyngoor which I call the Sithmurra Nulla; this is the first serious impediment that the Etawah terminal line has met with, and it is in fact connected with a series of impediments which, in describing the heads of the Noon River, I shall enter upon very fully. At the point of intersection, the bed of the Sithmurra Nulla is 8 feet below the surface of the neighbouring country, its section is of considerable size, and its bed is 3 feet lower than that of the canal. The following diagram will render the description more distinct.

The Sithmurra Nulla, after leaving the point where the canal intersects it, passes off in a direction almost due south, and at a distance of seven miles, near the

Diagram 53.



Ravines connected with the Seyngoor

villages of Surgaon and Indrook, plunges into a mass of ravines, which are connected with the Seyngoor. At a point opposite the village of Amoli, at which the Sithmurra drainage has passed through five miles of its course, a cut marked in the above diagram A B will be made, connecting it with the heads of the Delgaon Nulla, which flows into the Rinde River; the difference of level between the two jheels of Amoli and Delgaon which will be thus joined together is exceedingly small—the jheels may be considered, in fact, as on one level; it will be necessary, therefore, in making the cut A B, to commence digging from the lowest point in the jheel A, and, if necessary, to extend the channel as far down as the junction of the nulla with the Rinde; I would make this cut 15 feet in width, and on as rapid a slope as the relative levels will admit of, by which means the whole of the drainage from the head of the Sithmurra River, as far down its course as the village of Amoli, will be disposed of.

At the point where the Sithmurra River crosses the canal, it is proposed to establish a bridge, attached to which is an outlet of 18 feet waterway divided into three sluices of 6 feet each; from this outlet a cut or escape channel will be directed towards the Rinde, on the line marked C D in the diagram; this cut will be made 30 feet in width, and will have a slope of bed equal to 1½ foot per mile. The Rinde at the point where the cut will join it has become a deep and wide channel, with a depression below that of the Sithmurra Nulla at C of at least 25 feet; and as the distance between C and D is 4½ miles, the slope will be most amply sufficient for the purposes of escape. By this artificial channel the Sithmurra Nulla, or that portion of it which remains after it has been deprived of its upper drainage, will pass off towards the Rinde, and that this may be more satisfactorily secured, a second cut E F, continued in prolongation of the line of river, will still further ease off the current during floods, and, at any rate, will prevent the water from collecting near the canal embankments at C, and in a great degree remedy the awkward and abrupt turn that the Sithmurra drainage would otherwise have, in passing off down the escape nulla. (For further remarks on this line, see Part III. chap. ii. sect. 3, under on the head of Escapes).

The plan upon which I have disposed of this drainage, is similar in principle to that which has been before described on the Cawnpoor terminal line at the village of Ginowli; at which point the heads of the Rinde are turned off to the East Kalli Nuddi by a channel connected with an escape, much in the same way as the Sithmurra drainage has been turned off at this point towards the Rinde.

From the 141½ mile, the canal curves round to the south, passing close to the villages of Roora and Tugaeen, which lie on its right, from thence it proceeds straight to the village of Nurhea, situated at the 149th mile, and lying between two extensive hollows, both of which are crossed by the line of canal, and both of which are connected with the Noon River, of which they are the ostensible heads.

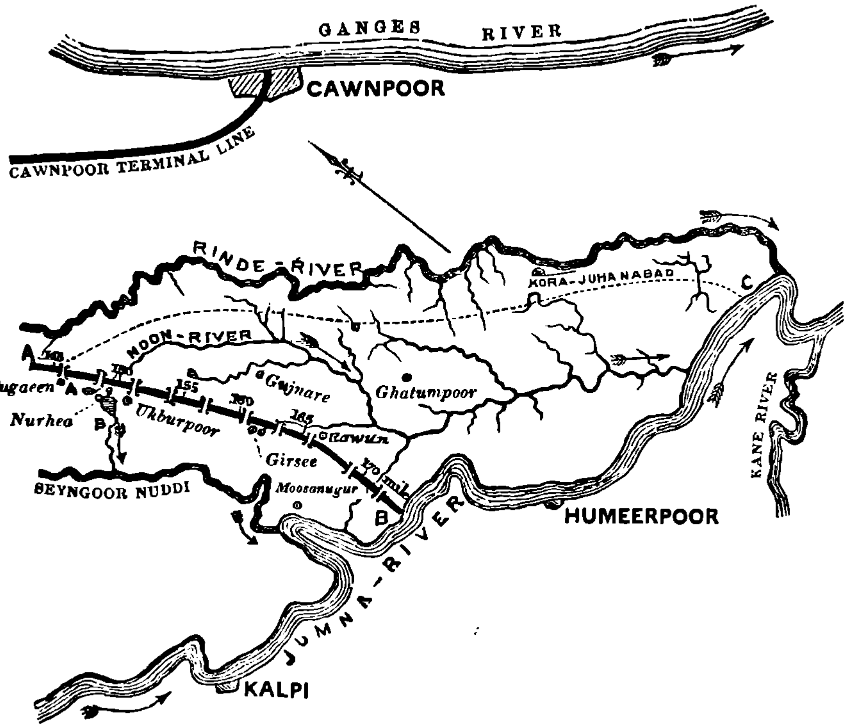
Both at the 143rd mile at the village of Roora, and at the 145½ mile at the village of Tugaeen, the canal comes in contact with the heads of nullas, to each of which I have given the names of the villages near which they take their origin; in neither case is the portion cut off of sufficient consequence to demand works for its especial drainage; should such, however, be found necessary, the slope of the country towards the villages of Surgaon and Indrook, which lie to the south-west and towards the ravines on the Seyngoor River, is sufficient to admit of the most efficient relief, at the smallest possible outlay.

We now reach the heads of the Noon River, and to these and to the river itself, I am desirous of devoting as much space as their importance on the terminal works of the Etawah line calls for.

The following sketch (p. 362) will exhibit at a glance the main topographical features of the country in which the canal, at this point of its course comes in connection with the Rinde, the Noon, and the Seyngoor rivers.

The great object to be accomplished, was to carry the line of canal to the east of the town of Ghatumpoor, so as to reach the high land in the vicinity of that, as well as of the neighbouring town of Kora Juhanabad; I have before, when discussing the capabilities of the land lying on the right and left of the Rinde River, described the advantages that the former would derive from irrigation,

Diagram 54.



as well as the superior claims that it possessed over that lying on the left of the river, which was highly cultivated, and flourishing under the effects of irrigation from wells, the average depth of which did not exceed 30 feet: whereas the land lying in the neighbourhood of Kora Juhanabad, Ghatumpoor, Gujnare, and Rawun was comparatively ill cultivated, without irrigation from wells (the depth of which precluded their being used for that purpose), and consequently without the means of giving fertility to soil which is in itself excellent; the purgunna of Ghatumpoor is in fact the least remunerative portion of the Cawnpoor district, and it was naturally the desire of the revenue authorities, as well as my own, to give it the full benefits of canal irrigation.

With regard to navigation also, it was very desirable that the canal terminus should be as little removed from the junction of the Rinde with the Jumna as possible; as the best and most efficient part of the Jumna for the purposes of navigation lies below the towns of Humeerpoor and Kalpi, and below the junction of the Kane and the Rinde rivers. This, although a secondary object, was one of the causes that led me to prefer a line that would pass between the towns of Ghatumpoor and Kora Juhanabad, and finally terminate in the Jumna close by the junction of the Rinde with that river.

Plates Nos. V. and VIII. of the Atlas give in detail the whole of the intricate and complicated drainage connected with the Rinde, Noon, and Seyngoor, at the point where the Noon River rises; the general lining out of which will be understood by diagram 54, which is drawn in sufficient detail to show the cause of my selecting a line which differs very materially from that which I had originally proposed.

In describing the Choiya, Pandoo, and other rivers, with which, during its course, the line of canal has come in contact, I have in fact given an accurate description of the character of the Noon River; the same shallow depressions, scattered over an extensive area, the same labyrinth of entangled nullas, and a similar irregularity in direction, are characteristics of the Noon, as they were of the before-mentioned rivers. I shall, however, describe the Noon in the words of the report of Lieutenant Johnstone, an officer of the Bengal Engineers, who was deputed to survey the country in the vicinity of Ghatumpoor, and to trace to their sources the lines of shallow connected with the river. Plate No. VIII. of the Atlas is the map which accompanied Lieutenant Johnstone's report.

"The Noon is a river which for the greater part of its course during six months in the year is but a small stream, although it collects nearly the whole drainage of the country between the rivers Rinde and Seyngoor. Forwards to the Jumna, into which it falls, it increases very considerably in importance and runs through a maze of ravines of a very formidable nature. It rises in a large jheel or series of jheels to the north of Ukburpoor, about seven miles above the point where it is first shown in the plan;* close to its source the level of the bed is about 40 feet above that of the Rinde, and about five miles distant from it. The level of the bed of the Seyngoor is not shown, but the country in the immediate vicinity of its ravines is about six feet below that by the Rinde and Noon.

"About five miles east of Ukburpoor, near the village of Tulounchi, is another large jheel from which springs the Nihar Nuddi, one of the principal feeders of the Noon; at the village of Nonunna it joins the main stream, which then proceeds in a more southerly direction, and near Tilhalia is at its greatest distance from the Rinde.

"By reference to the plan, it will be seen that, about three miles above the junction, the Noon approaches very close to the Rinde, while its feeders receive drainage from its vicinity: very shortly below this, the difference of level between their respective beds is reduced to about 20 feet.

"The double line on the plan shows the direction I should be inclined to recommend for the canal, were it decided that it should run between the Noon and the Rinde, though for various reasons, I am led to believe, a preferable line for the main canal, both on account of expense and difficulty of construction, would be found between the Noon and the Seyngoor; while a branch

* The direction of these lines of jheels is shown in Lieutenant Johnstone's map by the dots which have been entered from Lieutenant Whiting's surveys.

might be carried along the north side of the Noon for the supply of the country lying there.

"In the line marked out, it will be seen that several of the heads of drainage of the Noon are cut off; this I believe would be found unavoidable, but the great depth of the bed of the Rinde would, I think, render the difficulty of turning the small portion of drainage very inconsiderable. The Rinde during this portion of its course is environed by ravines extending nearly half a mile on either side.

"As the line advances, it approaches very near to the Rinde at the village of Burnoi, and along with the river takes a more easterly direction from that point. Near the crossing of the road from Ghatumpoor to Cawnpoor, it again intersects lines of Noon drainage, though the river itself is now many miles distant: here, in a large Oosur plain, is another of the Noon feeders, which drains the country for several miles. The line, from this crossing, follows the direction of the levels for some little way, and is in this place, and for some distance, on the ridge between the two lines of drainage. Farther down, near Passi Khera, it passes through a large jheel, from which, runs a watercourse into the Rinde; almost immediately on leaving its source, this nulla becomes an obstacle of a most serious description, and to cross it at all near the Rinde would be attended with considerable difficulties.

"The drainage below this becomes rather complicated, and the line almost immediately cuts off a portion of another large jheel, which, however, drains into the Noon. It then passes down to Juhanabad, and continues with very little deviation through a portion of country which I did not completely examine, though, from appearances in its vicinity and observations taken in crossing it, I am led to believe that it is very nearly on the highest ground; from the vicinity of Busseea, where my levels again approach it, its course is clearly marked out, and any deviation, right or left, would lead into a mass of jheels and ravines which bound it on either side."

Lieutenant Johnstone continues: "The line marked is the only one by which the Jumna can be approached, at this point, without passing through difficulties almost, if not quite, insurmountable; and even by this, I fear the fall into the river would be far from satisfactory. For several miles on either side of Barra, near which the proposed junction would take place, the Jumna flows almost in a straight line with its entire stream on the farther bank. Separated from this stream by tremendous ravines and a wide expanse of sandy bed, I fear that the construction of the canal, so as to admit of its being used for navigable purposes, would be found all but impossible; were this laid aside, the tail might be thrown into any of the numerous watercourses that cut the country in every direction.

"In concluding my description of the line laid down, I need only state that, throughout a very great portion of its course, it runs through wide plains of Oosur, with patches of cultivated land near the villages. The wells are, in most parts, very deep, and the supply of water limited, uncertain, and expensive, so that the necessity for some assistance is most apparent. This line has no very great difficulties to contend with, except at its junction with the Jumna, where they are of so serious a nature (if navigation is considered), that I should be inclined to recommend the canal being carried, if possible, in some other direction.

"If the main line were constructed on the south side of the Noon, it would be shorter by about 20 miles, and could, I believe, be carried on quite as high (if not a higher) level, and the turning of drainage would be attended with fewer difficulties, as the bed of the Seyngoor is laid down by Mr. Dodsworth 30 feet lower than that of the Rinde. The revenue survey maps, too, show a salient angle of the Jumna, which would appear to offer a most convenient point for the junction."

The consequences of Lieutenant Johnstone's operations were fatal to the project for carrying the canal on the Ghatumpoor line, which was clearly one of great difficulty, as far as navigation and its junction with the Jumna were concerned; whereas the direction pointed out by Lieutenant Johnstone, as lying between the Noon and Seyngoor, was not only with reference to the terminal works infinitely more convenient, but it possessed all the advantages of high level, which for the purposes of irrigation gave us a full command over the lands lying to the left of the Noon; there were, moreover, no impediments from drainage, as the low lands crossed near the town of Ukburpoor were not only in the immediate neighbourhood of the deep ravines which bordered the Seyngoor, but they were actually connected with them by a line of hollow.

The line, therefore, chosen by Lieutenant Johnstone, and which I have adopted, lies between the Noon and the Seyngoor rivers; it merely touches upon the Ghatumpoor purgunna on its extreme western boundary, but at the same time it holds a position which will ensure to the whole of the purgunna an ample supply of water for the purposes of irrigation. The means by which this may be effected are—

1st. By one main line of rajbuha occupying the course which Lieutenant Johnstone has laid down for that of the main canal at the Tugaeen Bridge, and at a point where it would not be interrupted by the Tugaeen Nulla. From the main line, branches would be thrown off for the irrigation of the different spits of land lying between the tributaries of the Noon.

2nd. By the ordinary rajbuha heads, which are constructed at each of the bridges between Sithmurra and Rawun; four of which, viz., those at Sithmurra, Roora, Ukburpoor, and Nurhea, in addition to that at Tugaeen, would give an aggregate width of waterway equal to 30 feet; and, as their levels are favourable, would be ample for any supply that the country could call for. In this case, the Tugaeen rajbuha would be joined by those from the Sithmurra and Roora bridges, and the collected water would pass on Lieutenant Johnstone's line; while the others, after providing irrigation to the country lying between the canal and the right bank of the Noon, would, in either one or two united streams (whichever might be found most convenient and most economical), be pushed over the Noon by aqueduct. The rajbuha heads, which are situated below that at the Ukburpoor Bridge, would be specifically devoted to the irrigation of the tract of country lying between the Noon and the high bank of the Jumna.

The facilities offered by the profile of the country, for either of these projects, is best shown by a reference to Lieutenants Whiting's and Johnstone's levels. The bridges to which I have referred above, are situated at points where the surface level of the country is as follows:—

1.	Sithmurra Bridge	487·75	feet.
2.	Roora ,,	484·08	,,
3.	Tugaeen ,,	486·04	,,
4.	Nurhea ,,	493·31	,,
5.	Ukburpoor ,,	493·95	,,
6.	Korari ,,	503·67	,,
7.	Jaffirabad ,,	503·46	,,
8.	Girsee ,,	508·19	,,
9.	Rhutgoan ,,	509·84	,,

The towns and principal points lying on the land between the Rinde and the Noon, which have to be reached from the above points, lie on the following levels :—

Ghatumpoor . . .	518·33
Gujnare . . .	510·80
Kora Juhanabad . .	522·83

The distance from the Sithmurra head to Kora Juhanabad is, along the line marked by Lieutenant Johnstone, about 40 miles; the fall of country, in this distance, is equal to 36·79 feet, or about 0·919 foot per mile.

From Ukburpoor to Gujnare, the distance is 9 miles, and the fall of country is equal to 16·85, or 1·87 foot per mile. From Gujnare to Ghatumpoor, the distance being 11 miles, the fall of country is equal to 7·53, or 0·68 foot per mile. The level point at Ghatumpoor, however, is taken on the north of the town, from whence, in the direction of Kora, there is a considerable fall. The town of Ghatumpoor itself lies on a level equal to 508·42, but the country slopes away on all sides. From the table above given, it will be seen that the points at Girsee, Rhutgaon, and Gujnare are nearly upon one level.

The change in the direction of the canal, therefore, which is so manifestly advantageous to the works both in construction and economy of expenditure, has not in any way deprived the Ghatumpoor Purgunna of the benefits of canal irrigation.

Having thus explained the disposition of the works in regard to the Noon River, I shall now proceed with the detail of those on the main line of the canal, which I left at the 149th mile at the village of Nurhea. The extensive hollows, which, by the intersection of the canal both above and below this village, are cut off from the slopes of the Noon, to which they naturally belong, will be drained into the Seyngoor, aided by a cut marked in the diagram A B, which will connect them with a line of low land commencing under the town of Ukburpoor, and continuing uninterruptedly to the ravine heads bordering the Seyngoor River.

From the 149th mile the canal pursues a course to the south-east, passing (between the 151st and 152nd mile) the town of Ukburpoor, which lies about half a mile on the right; at this point the high road, between Etawah and Cawnpoor, crosses the canal. To the 163rd mile the canal proceeds evenly over a high and well-cultivated country, passing the village of Girsee, which lies close to the right, and immediately opposite the 161st mile; at the 162nd mile, and about 400 yards from the village of Rhutgaon, which lies on the left, the canal crosses the head of the line of drainage which, as passing under the village, I shall designate the Rhutgaon Nulla; this nulla, after running through a course of about 8½ miles, joins the Noon near the village of Benda, and the high road connecting the towns of Moosannuggur and Ghatumpoor.

The head of this nulla lies directly under the village of Girsee, from whence to its intersection by the canal the distance is about a mile; it is not very clear whether the interruption to this line of drainage will be of material consequence, or whether it will require any remedy for its relief at all; should such, however, be necessary, a cut must be made from the low land near Girsee to the Seyngoor ravine heads lying about three miles to the south-west under the village of Jursen; a cross section on this line made by Mr. Dodsworth is by no means favourable, however, the ground in the neighbourhood of Jursen being three feet higher than that near the village of Rhutgaon. I have no doubt that an examination of the country lying between the villages of Girsee and the ravines which are situated near the Seyngoor, would lead to the discovery of a line well adapted to the purposes of escape.

From the 163rd to the 165th mile, a curve on a radius of 20,000 feet delivers the line upon a bearing, a few degrees to the right of that on which it had been previously passing; on this bearing it proceeds direct to the Jumna. The town of Rawun lies opposite to the 165th mile at a short distance to the left. The canal passes Rawun on a moderately cultivated, although a very dry country (the depth of wells being 79 feet), free from drainage, until it reaches the 168th mile at the village of Bhambi; here the extreme southern limit of a very extensive hollow, upon which the villages of Mooya and Sirinuggur are situated, and which is connected with the Noon, is touched upon without any interruption to its drainage. At the 170th mile, a hollow of considerable extent is crossed at what appears to be the watershed or summit level of two lines of drainage running in opposite directions, one to the Jumna under Moosannuggur, the other to the Noon. No impediment appears to exist at this point, and it will act as the escape head for the locks which lie below it. Onwards to the 172nd mile, the line of canal proceeds uninterruptedly over an undulating and barren surface; at this point, however, it reaches the crest of the high land that overlooks the Jumna River; here the lower levels will be gained by a series of locks, which will deliver the canal into the main river at the 175th mile.

The land lying between the Noon and the Seyngoor, and through which the canal passes, after it leaves the 145th mile at Tugaeen, may be on an average 10 miles in width, its course (after the passage of the heads of the Noon, near Ukburpoor) being equidistant between the two rivers.

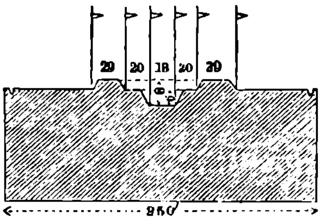
The slope of the surface of the country from the 120th mile to the crest of the high land overlooking the Jumna, or to the 172nd mile, is equal to 50·68 feet, or on an average of 0·97 foot per mile. From the 172nd mile to the surface of the water in the Jumna River (on the 3rd January, 1854), the fall is equal to 98·08 feet.

The relative position of the beds of the rivers, as deduced from Mr. Dodsworth's cross sections, is shown in the annexed table (p. 373); the plus and minus quantities showing the elevation or depression in feet from the bed of the Rinde River.

The section of the canal channel at the 141st to the 150th mile, or that portion on which the Sithmurra escape is situated, is,—

Diagram 55.

Section from 141st to 150th mile.



The distribution of spare earth being arranged in the manner before specified.

The average depth of excavation throughout this line of the canal is—

At the	125th mile	
„	130th „	6·00 feet.
„	135th „	
„	140th „	
„	145th „	7·50 „
„	150th „	
„	155th „	
„	160th „	9·68 „
„	165th „	
„	170th „	8·25 „
„	173rd „	12·00 „

The soil is of a similar quality to that which has been met with throughout the Etawah and Cawnpoor districts: it appears to be well adapted for a canal channel, although in the region of oosur and kunkur gravel, the substrata melt away as it were, leaving the sides perpendicular; in

Distance in Miles from Nanoon on the Rinde River.	Seyngoor River.	Town of Oorya.	Village of Indrook.	Noon River.	Town of Ukburpoor.	Village of Tilounchi.	Town of Moosanuggur.	Town of Gujnare.	Town of Ghatumpoor.	Town of Kora Juhanabad.	High land overlooking the Jumna River.	Jumna River.	Wells. Maximum.	Wells. Minimum.
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
125	−16·41	+32·28	...	...	...	...	...	...	...	...	+20·65	...	80·41	34·66
130	−11·52	...	...	...	...	...	...	...	...	...	+26·56	...	74·16	44·16
135	−17·77	...	...	...	...	...	...	...	...	...	+27·30	...	102·16	45·00
140 High land .	+33·93	...	+33·93	...	...	...	...	...	...	...	+35·79	...	92·25	56·75
145 " .	+32·69	...	...	+40·27	+45·65	...	...	...	...	...	+46·08	...	96·83	46·25
150 " .	+31·41	...	...	+22·71	...	+32·20	+35·23	...	...	...	+25·23	−67·87	94·46	46·00
155	...	...	...	+19·88	...	...	+31·47	+28·9	...	...	+23·90	...	87·00	30·25
160	...	...	...	+23·10	...	...	...	...	...	...	+31·95	...	81·33	54·00
165	...	...	...	...	...	...	...	...	+45·56	...	+39·40	...	81·08	45·83
170	...	...	...	+11·57	...	...	...	...	...	...	+43·21	...	87·41	54·83
175	...	...	...	−21·05	...	...	...	...	...	+30·07	+30·61	...	85·91	55·08
180	...	...	...	−23·30	...	...	...	...	...	...	+ 1·08	...	77·58	52·25
185	...	...	...	...	...	...	...	...	...	...	...	−60·10	72·66	58·83

other respects the soil is good, and being little absorbent, will be a good medium for economizing the distribution of water.

The depth of wells is on a maximum 102·16 feet, and on a minimum 30·25 feet, the measurements being taken from the surface of the earth to that of the water.

Continuing from the bridge which is situated between the 118th and 119th miles near the village of Luknanpoor, we have the following series of works :—

1st. Bridge at Nogaon, 52 feet waterway in two arches, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

2nd. Bridge at Bunheya, 52 feet waterway in two arches, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

3rd. Bridge at Jhinjee, 33 feet waterway in one arch, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 1st class choki attached.

4th. Bridge at Joreea, 33 feet waterway in one arch, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

5th. Bridge at Sithmurra, 33 feet waterway in one arch, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached, connected with an escape.

6th. Bridge at Jhundermow, 33 feet waterway in one arch, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

7th. Bridge at Roora, 33 feet waterway in one arch, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 1st class choki attached.

8th. Bridge at Tugaeen, 30 feet waterway in one arch, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

9th. Bridge at Nurhea, 30 feet waterway in one arch,

18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

10th. Bridge at Ukburpoor, 30 feet waterway in one arch, 25 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

11th. Falls and works at Nubbipoor, similar to those in the main, but having only one chamber of 30 feet waterway, roadway of bridge 25 feet broad, with 1st class choki situated in the island in the usual position.

12th. Bridge at Koorari, 30 feet waterway in one arch, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

13th. Bridge at Jaffirabad, 26 feet waterway in one arch, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

14th. Bridge at Rhutgaon, 26 feet waterway in one arch, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

15th. Bridge at Rawun, 26 feet waterway in one arch, 18 feet roadway, with ghats, rajbuha and inlet heads, and a 1st class choki attached.

16th. Bridge at Bhambi, 26 feet waterway in one arch, 20 feet roadway, with ghats, rajbuha and inlet heads, and a 2nd class choki attached.

17th. Escape and under drain at the 170th mile, similar to that at Dubowli.

18th. Bridge at a point below the escape, one arch of 20 feet span with an arrangement for regulating, similar to that at Dubowli.

19th. Locks and works appertaining to the Jumna terminus (*vide* Plate XLVI. of the Atlas).

At this point we have reached the Jumna and the terminal works of the Etawah line; having explained in detail the different works, and having passed in review the peculiarities of surface, and the intricacies of drainage, through which the line of canal had to pass in its progress from Nanoon.

As remarked in the summary on the sister line to Cawnpoor, I may observe, that I have preferred throughout the whole of the works connected with these terminal lines to retain the precise figures of diagram 17, figure 2, leaving corrections on actual measurements resulting from work executed to be made afterwards; the differences can comparatively be small, whereas an alteration to the figures of the table on which the capacities of channel and value of discharge for irrigation were calculated, would lead to unnecessary and useless trouble.

In referring to the diagram above alluded to, it will be found that the supply for the head of the Etawah terminal line, which is estimated at 180 miles in length, is equal to 1,640 cubic feet per second; the expenditure of this supply being calculated as follows:—

Miles.		Cubic Feet per Mile.		
180	×	8	=	1,440 cubic feet per second for the use of irrigation, as per rules laid down in table.
				200 cubic feet per second, retained as a reserve supply for navigation.

When drawing a comparison between the values of the Cawnpoor and Etawah lines as means for irrigation, I shall enter more fully into the causes which have led me to design both the channels and works of the former on a somewhat larger scale than those of the latter; it will be sufficient to observe here, that the supply which enters the Etawah line at Nanoon, will in its passage forwards be liable to considerable diminution, especially at the early part of its course, from the draw off of water which will be required for the country lying on the right bank of the Seyngoor, on which the towns of Ferozabad, Etawah, and Ooriya are situated. This supply will act in feeding the "Hatrass line of irrigation," under which name the Bolundshuhur and Koel branches, after their confluence at the point C (diagram 58) near the town of Hatrass, proceed onwards, for the use of the country lying between the Seyngoor and the Jumna rivers.

The Cawnpoor terminal line, looking at it in a navigable point of view, was considered to be of more importance than that running to the Jumna, and in making the channel wider the convenience of boats and navigation in general was consulted.

In the progress of detailing the different works, I have given diagrams showing the transverse sections of the line at different parts of its course; the value of discharge at the points where these sections occur is shown in the following table; the width of rectangular section, I may observe, having as a general rule been reduced by one foot at the end of every three miles:—

—	Value of R.	Value of $\frac{1}{S}$.	Sectional Area in sq. feet.	V in feet.	Discharge.	
					Theoretical.	Required.
1st mile .	63·85	$\frac{1}{4224}$	516	3·109	1,604·2	1,640
30th " .	62·81	$\frac{1}{4224}$	450	3·083	1,387·2	1,400
65th " .	60·87	$\frac{1}{5280}$	360	2·677	963·7	1,120
100th " .	58·14	$\frac{1}{5280}$	276	2·616	722·0	840
141st to 150th	49·41	$\frac{1}{5280}$	144	2·409	346·9	512

The variations of the slope of the bed are similar to those in the Cawnpoor line, although the disposition of that slope is somewhat different. From the head at Nanoon the slope of 15 inches is carried on to the 54th mile, where a reduction of the slope from 15 to 12 inches takes place; in advance of the 54th mile, the slope of the bed is uniformly 12 inches, until it approaches the Jumna, and comes within the influence of the Khadir lands connected with that river.

The difficulties which were met with in the manufacture of bricks on the Cawnpoor line have been equally felt on the Etawah one. The first 65 miles of the course of these two branches run parallel and with a separation of only 5½ miles of country between them; on this line, therefore, their field of operations was very nearly the same, and the difficulties in obtaining fuel were greatly enhanced by the villages being common to both; the same inconvenience occurred in the kunkur quarries, which had a double demand upon them by a draught for two different boards of works. As a general rule, however, material, both brick and kunkur, has been procured on this line with less difficulty than it was on the other; but, nevertheless, we have here also been driven to the greatest economy in the use of bricks, and to the adoption, as far as was possible, of block kunkur, not only in the bridges, but in the choki buildings attached to them. This latter material has on the Etawah line of works been met with of a very superior quality, fully equal, if not superior, to that which is procured from the Bahosi quarries in the Furrukabad district; that taken from the quarries of Hussayn, and which has been largely used in the choki and bridge at Jao, is so compact, as to be wanting in one of the most marked characteristics of kunkur, viz., its honeycombed texture: many of the blocks which have been used in the Pilkutra Bridge, and which were extracted from the deserted ruins of Hindoo buildings in the neighbourhood, have on them sculpture in deep relief, carved on a surface as compact as that of the Portland and Bath oolite. The material is no doubt excellent, but, as I have noted elsewhere, great discrimination is required in its use; it is essential that the outer surfaces, which are invariably of a soft and very inferior texture when taken out of the quarries, should be carefully removed; and that in laying the blocks in the building, the horizontality of the natural laminæ should be preserved, or more properly speaking, that the weight or thrust should be brought to bear on their flat and not on their end surfaces.

The design of the bridges is in every way similar to that of the Cawnpoor line, the waterway being adapted to the position in which the bridge is situated; side arches, in prolongation of the towing-paths, keep up the line of communication on the berm level, and the plan and arrangement for rajbuha heads, inlets, ghats, and chokies, correspond in every way with those I have before described.

The same remark applies equally to the escapes, which are built on the same plan, and connected in the same way with the ghats and bridge works in their neighbourhood. The rule in all cases has been to avoid as much as possible the separation of the works, and especially that of the heads for irrigation, inlet, or escape, from the immediate control and supervision of a choki post. It will be observed, that throughout the whole of this project, the rajbuha heads and inlets, by being designed as a component part of a bridge, become accessible from both sides of the canal; the escape heads, being placed in connection with the revetments attached to the rajbuha heads, lie under similar advantages; and the establishment of a choki post, by the construction of a building sufficient for the accommodation of the necessary guard, in the immediate vicinity, forming a part, in fact, of the works, places the whole machine, viz., of irrigation, inlet, and escape, under the immediate supervision and easy control of the canal establishment.

The heads of irrigation are situated at nearly every bridge, their dimensions being, with modifications depending on local causes, the same as those on the Cawnpoor line. From the head at Nanoon to the 30th mile, or to the bridge at Guhrana, the width of waterway is 10 feet, with its sill raised 24 inches above the canal bed. From the 30th to the 90th mile, or to the Budamyee Bridge, the sill is raised only 16 inches above the canal bed, whilst the width of waterway is reduced to 6 feet. From the 90th to the 150th mile the waterway is retained on the width of 6 feet, with its sill raised 8 inches above the bed of the canal. From the 150th mile to the terminus, the heads are continued on the 6 feet width, but their sills are laid on the level of the bed of the channel.

The outlets or escapes have been fixed as nearly as possible about 40 miles apart, and at similar distances to those on the Cawnpoor branch; their sites are at Gihror, Mulhosi, and Sithmurra: the escape, which is connected with the terminal works, being considered as a portion of the works attached to the lockage, and not coming under the classification of a separate building.

The views which I have entertained with regard to the postponement of the works on the Futtigurh, Bolundshuhur, and Koel branches, and to which I have drawn attention in a former chapter, have inclined me to place the terminal works of the Etawah line in abeyance; at least, to postpone their execution until the supply of water at the extremities of these long lines is more accurately understood and determined; this postponement may, in fact, resolve itself simply into a prosecution of the works when the progress of operations arrive at that particular point, or to a delay of two or three years; but with the example before us of the terminal works on the Cawnpoor line, which are now under completion, we shall be better able to form an opinion as to the immediate necessity of forming a connecting link for navigable purposes with the Jumna, by seeing how far the canal supply, which for the first few years will be comparatively small, will act in maintaining a head-water on the lockage at extreme points; the delay, at any rate, in completing the terminal works on the Etawah line will be beneficial, in enabling us to act on most valuable experience gained, without in any way interrupting the main object of supplying irrigation to the country. The delay, moreover, will give us the means of collecting material in sufficient quantities to provide for an uninterrupted completion of the works, instead of carrying them on by the hand-to-mouth process that has characterized the progress of the Cawnpoor terminal works, which we had an object in finishing off at once.

I have proposed, therefore, that for the present the works on the Etawah line should terminate at the bridge and escape at Sithmurra, or at the 141½ mile of its course. The works at Sithmurra are of considerable extent and importance; they will form a 1st class choki post, and the residence there of the head-quarters of the division will enable the executive engineer to collect material, and to make arrangements for ultimately completing the works which are situated below it; rajbuha heads, with their waterways of six feet in width, and with their sills on a level with the canal bed, will be attached to the bridge at this point; that one on the left will pass off the water, for the temporary supply of the country, between the Rinde and the Noon; whilst that on the right will afford the means of irrigation to the country lying on the west of the town of Ukburpoor. I use the expression "temporary," because, on the completion of the canal channel below the Sithmurra Bridge, the rajbuha heads, which are situated below that and Ukburpoor, will add their quota to the line of rajbuha which passes on to Ghatumpoor and Kora Juhanabad.

On the subject of irrigation generally, I may observe here, as I have done elsewhere, that the lines of rajbuha will not be limited to the country between the Rinde and Seyngoor; they will be projected boldly across their boundary rivers, wherever such may be considered expedient; the capacity of the channel of the Etawah branch has, as I have before remarked, been expressly designed, with a view of its supply being considerably reduced on the first 100 miles of its course; the rajbuha heads, on the right, being converted into feeders for the Hatrass line of irrigation.

The design of the channel, with its berm, or towing-path, its embankments, its milestones, plantations (both of fruit and forest trees), and the single line of mangoe trees for affording shade to the roadway, is precisely the same on the Etawah as it is on the Cawnpoor line. The milestones are numbered in a consecutive series from the Nanoon head to the Jumna terminus, and the plinth of each milestone is a bench-mark, or fixed point of level, the figures of which are engraved upon the stone. The roadway is formed on the left bank of the canal, similar to that on the main and Cawnpoor lines, and its design, both in width and slope outwards, is exactly the same.

The accommodation for the establishment, and for maintaining a line of choki posts, is precisely similar to that before described; and great care has been taken here, as on the Cawnpoor line, where the country is subjected to inundation, arising from the slopes being insufficient to effect rapid drainage, to raise the buildings high above the country, and to remove them as much as possible from the inconvenience and evil of dampness. To each of the 1st class chokies, buildings which are situated about 12 miles apart, a mangoe graft plantation is to be attached on the same scale as has been projected elsewhere.

I have, at the early part of this chapter, explained that the whole of the country which comes under the influence of the Etawah terminal line was subjected to a rigorous examination, borne out by numerous cross and longitudinal sections by Mr. Dodsworth, the surveyor attached to the works. After testing Mr. Dodsworth's survey, and proving most satisfactorily how correctly the work had been done, Lieutenant Whiting, of the Bengal Engineers, assisted by Lieutenant Johnstone, of the same corps, commenced the works in the cold season of 1850–51. Since that period they have in active progress; Lieutenant Johnstone having been succeeded in 1852 by Lieutenant Brownlow, of the Engineers; Lieutenant Angelo, of the 16th N. I., and Lieutenant Span, of the 62nd N. I., additional assistants, having been attached since the months of November, 1852, and July, 1853, respectively. The state of the works in the beginning of 1854 was very far advanced: 60 miles had been completed, including both earth and masonry work; 50 miles were in active progress; and I have no doubt that if my friend Lieutenant Whiting's services are continued (which I hope they will be) until the whole is completed, the admirable system of supervision, which has enabled him to make such good progress hitherto, will secure its deserving recompense, in a consummation of the desired object, in a period of two or three years.

BYTUK ROAD, NEAR MYAPOOR, LOOKING TOWARDS HURDWAR.

Chapter III.

DETERMINATION OF THE ALIGNEMENT AND WORKS ON THE BRANCHES.

In the preceding chapter, I have endeavoured to describe in its fullest detail that portion of the Ganges Canal works consisting of the main trunk and the two terminal lines into which it is separated at the Nanoon Fork. The detail has necessarily been great, although not more so, I hope, than the circumstances of the case have called for; it has been founded on works actually completed, or at the time of my writing in a forward state of progress; and the surveys and levels on that particular part of the country over which the works are carried, have been so elaborately executed, that the detail has not been interrupted by any points of obscurity, or by any want of information tending to embarrass a narrative, which has had for its object the accurate delineation of the surface of the country, and a precise statement of the works as actually completed, or in progress of completion. These remarks apply specifically to the main line of the canal from the head to the Nanoon regulators, and from thence to the Ganges and Jumna rivers, on the two terminal lines, into which the main stream is divided.

The advantages above noted do not offer themselves in the subordinate lines of canal which I am now about to describe, upon which the same time and labour in investigation have not up to the present period been expended. The preliminary surveys, although sufficient in themselves for establishing points, and for marking the general direction upon which the alignements may be carried, do not enable us to describe with accuracy the courses upon which drainage, in all its intricacies of detail, tends to influence the practical carrying out of field operations; nor do they enable us to determine with accuracy the position of works, or the number of lines of cross communication which the wants of the country may demand. On such foundations, we must be satisfied with a general programme, exhibiting in as much detail as possible the objects for which the branches are intended, and the best available method of obtaining those objects as derived from the data which are in our possession. The length of channel, the general slope of the country, and the head supply of water being given, the capacities both for excavation and bridge waterways are easily determined. We are, therefore, restricted to these particular points. I shall, therefore, on the plan which I have previously laid down for my guidance, enter into a description of the subordinate works above referred to; these consist of—

I.—The Futtigurh Branch.
II.—The Bolundshuhur Branch.
III.—The Koel Branch.

I.—*The Futtigurh Branch.*

This is a channel intended for the irrigation of the country lying between the East Kalli Nuddi and the Ganges River: its point of departure is situated at the 50th mile of the main canal, near the village of Jaoli, in the Mozuffurnuggur district. The head works are designed with regulators, both across the main canal itself and the branch; a 1st class choki has been built in conjunction with these works, and the station is one of the main posts on the canal.

The theoretical volume for the Futtigurh branch is 1,240 cubic feet per second; on an estimated length of 160 miles of this length, the five miles at the head coming under the influence of the irrigation from the main canal have, in the effective distribution of the above supply, been deducted; the full theoretical volume being calculated for the irrigation of the remaining 155 miles, at the rate of eight cubic feet per second per mile.

It is proposed that the Futtigurh branch on its reaching the 160th mile shall be continued onwards to the town of Futtigurh as a navigable channel, so as to connect that place with the main canal, and thereby to give it the advantages of water carriage. Whether it may be necessary hereafter to build a series of terminal locks into the Ganges in the same way as has been done at Cawnpoor, may be at present doubtful; but, at any rate, as these are works demanding a large outlay of money, they may well be postponed until a future occasion.

The preparatory surveys required for the Futtigurh branch are in a more advanced state than those of the other subordinate lines. The whole country from the main trunk of the canal at Jaoli to the junction of the East Kalli Nuddi with the Ganges, has been surveyed and levelled by Mr. Dodsworth, the series of levels consisting of a centrical or longitudinal line, keeping as closely as possible upon the watershed, with transverse cross sections from river to river at a distance of five miles apart. (*Vide* Plate No. VI. of the Atlas.) Mr. Read, the executive officer of the second division of the works, has on Mr. Dodsworth's map as a groundwork taken a proof line along the watershed, thereby testing the levels originally taken. Mr. Read has at every mile on the leading 155 miles established a masonry bench-mark, and to ensure the preservation of these fixed points, which indicate not only the true levels, but the direction upon which the excavation is to be carried, he has raised over them pyramidal mounds of earth 8 feet in height, to the repair and maintenance of which his attention has been directed.

Mr. Read reports, "that levels have been taken at every 400 feet apart, closed upon the masonry bench-mark above mentioned and terminating at the 155th mile below the head works. From comparison with the plans of cross sections and levels executed by Mr. Dodsworth, this line of levels shows that it has been taken along the high ridge of the country through which it runs, and is in every way favourable for canal purposes. Beyond the point above alluded to (viz., that at the 155th mile), the levels and line have still to be adjusted to allow of water communication with Futtigurh, either by a still channel or otherwise, as the nature of the ground and levels will admit of."

Mr. Read adds, "that bricks have been made in sufficient quantities for the masonry works on the first 20 miles of the branch, and for the next 20 miles I have ascertained that an ample supply of native bricks are procurable from different ruins in the vicinity; beyond this no arrangement for material has been made, but that at this point or near it commences a series of block kunkur quarries admirably adapted to building purposes; the localities of these quarries have been carefully noted in the field book, therefore the necessity for making bricks below this point (except for the purposes of arching) will almost be dispensed with. Earth lime will have to be used for the first 40 miles of the works, and a large supply of marl for the manufacture of this material has been collected on the main line, which can be carted to the branch in sufficient quantities for each work; beyond this point (viz. that at the 40th mile from the head) kunkur lime will be used, which is procurable in any quantity along the line."

Although, therefore, for reasons which have been before explained, work has not been commenced upon on the Futtigurh line of irrigation, all preparatory arrangements have been made with exception of the examination in detail of the surface drainage, and the final inspection of the line by the director of the works, previously to the commencement of excavation.

Mr. Read's profile of the country, to which he alludes in the above extracts from his report, will be found on the sheets of Mr. Dodsworth's levels (*vide* Plate VI. of the Atlas); on this profile I have projected a channel with an uniform slope of 1·25 foot per mile, which leaves no less than 80 feet of superfluous descent; I have disposed of this in ten masonry falls of 8 feet each, so that the amount of drop may be in uniformity with that on the main trunk. The position of these falls is as follows:—

——	Number of Bays of 20 feet width each.	Depth on Sill.	Discharge.	
			Theoretical.	Required.
		Feet.	Feet.	Feet.
1st or 11th mile.	3	3	1,058·76	1,192
2nd or 18th ,,	3	3	1,058·76	1,136
3rd or 25th ,,	3	3	1,058·76	1,080
4th or 32nd ,,	3	3	1,058·76	1,024
5th or 37th ,,	3	3	1,058·76	984
6th or 55th ,,	3	3	1,058·76	840
7th or 62nd ,,	3	3	1,058·76	784
8th or 79th ,,	2	3	705·84	648
9th or 88th ,,	2	3	705·84	576
10th or 119th ,,	2	3	705·84	328

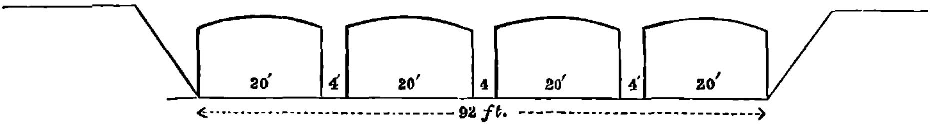
The branch head at Jaoli has four waterways or bays of 20 feet in width each, each bay being fitted with gates, for the regulation of the supply. For the design of this work, Plate No. XXXIII. of the Atlas, which includes the whole of the works, both of the main canal and the branches at this particular point, must be consulted.

The capacity of the excavated channel is shown by the following table, the head supply being as before noted 1,240 cubic feet per second, the slope of the bed 1·25 feet per mile, and the supply being supposed to diminish as it advances in its course at the rate of 8 cubic feet per running mile of channel.

Depth of Water calculated at 6 feet.			Value of R.	Value of $\frac{1}{b}$.	Sectional area in square feet.	V in feet per Second.	Discharge. Theoretical.	Discharge. Required.
Supply at the head . .			..	..	..	..	..	1,240
1.	70′	10th mile.	62·91	$\frac{1}{4224}$	456	3·086	1407·2	1,200
2.	65′	20th ,,	62·36	$\frac{1}{4224}$	426	3·073	1309·1	1,120
3.	60′	30th ,,	61·74	$\frac{1}{4224}$	396	3·057	1210·5	1,040
4.	55′	40th ,,	61·02	$\frac{1}{4224}$	366	3·039	1112·2	960
5.	50′	50th ,,	60·21	$\frac{1}{4224}$	336	3·018	1014·0	880
6.	40′	70th ,,	58·14	$\frac{1}{4224}$	276	2·965	818·4	720
7.	35′	90th ,,	56·81	$\frac{1}{4224}$	246	2·939	723·0	560
8.	30′	110th ,,	55·18	$\frac{1}{4224}$	216	2·890	624·2	400
9.	25′	130th ,,	53·17	$\frac{1}{4224}$	186	2·833	526·9	240
10.	20′	150th ,,	50·62	$\frac{1}{4224}$	156	2·764	431·2	80
11.	15′	160th or 170th	47·29	$\frac{1}{4224}$	126	2·670	336·4	—

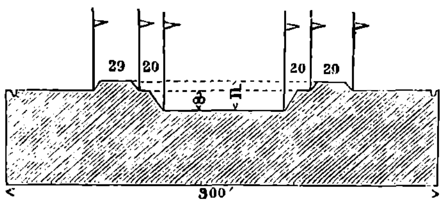
At the head, which, including piers, has a section as follows :—

Diagram 56.



the width of excavation is 92 feet; the channel in advance is 70 feet wide up to the 10th mile, as shown in the first section in the above table. The general section of the canal with its embankments is as follows :—

Diagram 57.



the width of embankments, as above shown, being considered a minimum one. From the 70th mile the vertical dimensions, which up to that point have been 8 and 11, will be reduced to 6 and 8 feet, or, in other words, the berm and embankments will be 6 and 8 feet respectively from the canal bed.

The width of land between the canal boundaries will be as follows :—

From the head	to the		10th mile,		300 feet.	
,,	10th	,,	70th	,,	250	,,
,,	70th	,,	160th	,,	200	,,

Up to the 70th mile, the diminution continues at the rate of 6 inches per mile, or 5 feet in every 10 miles.

From the 70th mile onwards, the diminution is at the rate of only 3 inches per mile, or 5 feet in every 20 miles of length of channel.

The dimensions of the sections above given are so arranged that in advance of the 70th mile the depth of water in the canal, which up to this point has been 6 feet, will gradually decrease, for instance :

—	Discharge.	
	Theoretical.	Required.
On the 6th section a depth of 5 ft. = a discharge of	619·875	720
7th ,, 5 ft. ,,	545·600	560
8th ,, 4 ft. ,,	334·560	400
9th ,, 3 ft. ,,	178·500	240

Beyond this the channel is excavated with regard to the emergent demands upon it in non-irrigating seasons, during the period of floods, and for the purposes of navigation onwards.

From the head to the 62nd mile, in which the volume of water passing down the canal will vary from 1,240 to 784, I would maintain the falls on one plan of opening, viz., three bays of 20 feet each; the value with reference to discharge is shown in the table above given: in advance of the 62nd mile, or on the three falls that are required below it, the waterways might be reduced to two bays of 20 feet each. The calculations on this point give a depth of 3 feet only upon the sills of the overfalls, which is equal to the average of the work that the falls on the Eastern Jumna Canal have to undergo.

For the purposes of navigation each of these ten falls will require a lock channel and all its appendages, the design of which would be similar to that put in practice on the main canal.

Keeping to the plan of navigation which would ultimately be adopted, I would in the bridges maintain the flank passage for towing-path communication, and even at the expense of additional length of wing, place them at a distance well removed from the inner side of the abutment.* On the main line of canal these passages

* In determining the position of the towing-path passages, the rule (although deviated from in some cases) has been to place it on

have in many cases been placed too close to the waterways, a circumstance which, whatever may be the improvement to the elevation of the bridges, is undoubtedly of no advantage to the communication along the towing-path, whilst any unnecessary approximation to the impost blocks of the abutment arch exposes the work unnecessarily to the consequences arising from careless and defective building.

I would in the waterways of the bridges confine them to bays of 25, 20, and 15 feet each; and supposing that lines of cross-communication are required at every three miles, the works adapted to this purpose would be as follow:—

Miles.	—	Water-way of Bridge.	Width of excavation as per Table above.
3	Bridge of 3 Bays of 25 feet each .	75	70·00
6	" " " .	75	70·00
9	" " " .	75	70·00
11	Falls	...	69·50
12	Bridge of 3 Bays of 25 feet each .	75	69·00
15	" " " .	75	67·50
18	Falls	...	66·00
21	Bridge of 3 Bays of 20 feet each .	60	64·50
24	" " " .	60	63·00
25	Falls	...	62·50
27	Bridge of 3 Bays of 20 feet each .	60	61·50
30	" " " .	60	60·00
32	Falls	...	59·00
33	Bridge of 3 Bays of 20 feet each .	60	58·50
36	" " " .	60	57·00
37	Falls	...	56·50
39	Bridge of 3 Bays of 20 feet each .	60	55·50
42	" 2 Bays of 25 feet each .	50	54·00

the outside and close to the intersection of the tangents of the extrados of the main arch and the flooring of the passage (vide fig. 2, diagram 117, part iii. chap. iii.)

I would extend this dimension, giving an additional 2 feet to the width of masonry between the main waterway and the inner side of the passage.

Miles.	——	Water-way of Bridge.	Width of excavation as per Table above.
45	Bridge of 2 Bays of 25 feet each .	50	52·50
48	" " " .	50	51·00
51	" " " .	50	49·50
54	" " " .	50	48·00
55	Falls	...	47·50
57	Bridge of 2 Bays of 25 feet each .	50	46·50
60	" " " .	50	45·00
62	Falls	...	44·00
63	Bridge of 2 Bays of 25 feet each .	50	43·50
66	" " " .	50	42·00
69	" " " .	50	40·50
72	" " 20 feet each .	40	39·50
75	" " " .	40	38·75
78	" " " .	40	38·00
79	Falls	...	37·75
81	Bridge of 2 Bays of 20 feet each .	40	37·25
84	" " " .	40	36·50
87	" " " .	40	35·75
88	Falls	...	35·50
90	Bridge of 2 Bays of 20 feet each .	40	35·00
93	" " " .	40	34·25
96	" " " .	40	33·50
99	" " " .	40	32·75
102	" " " .	40	32·00
105	" " " .	40	31·25
108	" " " .	40	30·50
111	Bridge of 2 Bays of 15 feet each .	30	29·75
114	" " " .	30	29·00
117	" " " .	30	28·25
119	Falls	...	27·75
120	Bridge of 2 Bays of 15 feet each .	30	27·50
123	" " " .	30	26·75
126	" " " .	30	26·00
129	" " " .	30	25·25
132	" " " .	30	24·50
135	Bridges of 1 Bay of 25 feet span .	25	23·75
138	" " " .	25	23·00
141	" " " .	25	22·25
144	" " " .	25	21·50
147	" " " .	25	20·75
150	" " " .	25	20·00
153	Bridges of 1 Bay of 20 feet span .	20	19·25
156	" " " .	20	18·50
159	" " " .	20	17·75

The above would give, independently of ten falls,—

5	bridges of	3	arches	25	feet each.
7	„	3	„	20	„
10	„	2	„	25	„
13	„	2	„	20	„
8	„	2	„	15	„
6	„	1	„	25	„
3	„	1	„	20	„

The number of bridges of cross communication in a total length of 160 miles would thus be 62, of which 52 would be plain bridges, and 10 bridges with falls attached.

The details of dimensions of width of roadways would be the same here as elsewhere, viz.:—

High military roads	. . . .	25 feet.
Road fund „	. . . .	20 „
Village „	. . . .	18 „

I consider the design for the rajbuha heads as adopted on the main canal, applicable in every way to the branches; those at the heads of the masonry falls being similarly situated with regard to the navigable canal and the locks; those at the bridges being carried obliquely through the bridge ramps with attached ghats and inlets. As a rule, I should say, that for a distance of six miles on the down-stream side of a masonry fall, and its attendant heads for irrigation, the bridges ought to be plain and without rajbuha heads; at such points, however, I would construct well inlets, with channels laid out on the same design as that where rajbuhas are used, in which case the wells at the ramp angles, which during flood season would act as inlets, would at other periods provide access to the canal water for the purposes of irrigation.

All works attendant on the embankments, and provision for the accommodation of the establishment, I would design uniformly with the main canal.

The details given for the roadway, milestones, and plantations ought to be the same, and the method pointed out for their maintenance need not, I imagine, be departed from. A 1st class choki at every 12 or 15 miles, with 2nd class chokies at every bridge to which rajbuha heads are attached, would be sufficient for the accommodation of the establishment.

Escapes ought to be established at a distance of 40 miles apart, the sluices being of the same dimensions as those elsewhere adopted; the width of collected waterway of each escape ought to be rather in excess than otherwise of the canal channel at the point where the building is erected. At the extreme end of the irrigating line, or at the 160th mile, a work of this sort is proposed for the purpose of passing off the tail water. Eventually when the branch is carried forward to Futtigurh for navigation, this escape will become an useful regulator of the supply; it ought, I think, to be made a capacious one, with five sluices of 6 feet each in width.

The want of detailed surveys of the superficial lines of drainage and hollows, which intersect the surface of the country over which the line of canal runs, will prevent my entering into a description of the subordinate cuts which will be required for relieving the canal, and the country from intercepted drainage. The rule, however, which I have before adverted to, as that which has been our guide in the main canal works, is, I believe, to be recommended, viz. to draw away from the canal alignement all intercepted water, and to carry it by artificial cuts into the natural lines of drainage lying on the right and left.

The following tables will show the surface levels of the country at each five miles in length of the course of the canal as taken from Mr. Dodsworth's series of sections; the maximum and minimum depth of wells, *i. e.*, the distance between the surface of the water, and that of the earth lying in the neighbourhood of each cross section, is also exhibited :—

Number of miles from head.	Levels showing depression of country. Left or Ganges.	Centre or Canal line.	Right or East Kalli Nuddi.	Wells. Maximum.	Minimum.	—	Width of cross section or distance between East Kalli Nuddi and Ganges.
							Miles.
5	170 7·4	162 4·4	...	57 9·0	30 9·8		
10	167 6·0	171 9·1	177 4·8	51 5·0	22 0·0		12
15	189 0·0	182 5·8	194 7·7	48 9·0	22 6·0		12
20	204 6·9	198 0·0	212 2·6	48 9·0	18 3·5	On top of bank of Ganges.	16
25	228 7·3	207 3·3	220 7·6	47 11·5	23 11·0		14
30	228 3·6	225 2·2	232 7·9	35 11·0	25 7·3		13
35	240 5·3	230 0·5	244 5·0	38 11·0	12 2·6		17
40	250 0·5	236 9·4	255 0·1	38 10·0	22 4·0		15
45	298 5·7	251 3·2	260 11·8	32 6·0	22 2·0	On Ganges River	15
50	259 5·1	256 5·8	281 3·9	45 0·0	23 2·0	On top of bank.	16
55	265 10·2	263 11·1	294 5·6	31 8·0	16 5·0		19
60	309 0·3	276 3·1	308 8·0	32 8·0	19 0·0	On Ganges River—Bolundshuhur, on the East Kalli Nuddi.	27
65	314 10·4	286 8·2	318 3·6	39 2·0	27 9·6		28
70	324 9·5	295 0·0	325 11·6	42 7·0	23 0·0	On Ganges River.	27
75	332 11·9	302 11·8	332 0·1	27 2·0	23 1·7		22
80	348 8·8	314 5·6	337 7·6	40 1·5	17 11·0	On Ganges River—Anoopshuhur, on the Ganges.	20
85	354 5·3	324 4·5	345 9·3	25 9·0	23 1·0		15
90	362 3·2	331 9·1	350 5·4	36 1·0	18 0·0	On Ganges River.	14
95	371 11·1	340 7·5	365 10·9	26 6·0	12 5·0		20
100	374 11·9	349 11·3	376 0·4	32 0·0	13 4·0		19
105	381 5·0	367 11·3	384 7·5	29 5·0	23 10·0		17
110	392 3·1	364 10·6	393 9·5	23 6·0	11 10·0		16
115	395 0·7	370 3·8	400 6·9	30 1·0	19 8·0		16
120	403 3·1	378 8·8	408 3·0	27 3·0	9 2·0		10
125	413 1·2	381 6·8	416 5·2	27 3·0	7 11·0		10
130	425 10·7	393 6·0	424 11·3	16 9·5	8 5·0	Old Branch of Ganges.	11
135	434 3·1	400 6·9	425 4·8	28 5·0	11 4·0		14
140	441 1·9	406 0·4	437 0·3	32 5·0	8 0·0		15
145	448 8·5	411 4·5	444 3·7	20 10·0	10 4·0		11
150	462 0·9	417 0·5	450 11·2	20 9·0	8 7·0		21
155	466 0·9	423 0·8	458 4·3	39 9·0	10 4·0		22
160	475 3·4	435 6·5	465 11·6	39 9·0	10 4·0		21
165	479 3·1	437 11·4	474 2·6	19 7·0	7 5·0		21
170	485 11·1	444 8·9	477 6·5	35 3·0	9 8·0	On Ganges River	23
175	495 11·1	450 9·9	485 7·8	37 2·0	9 2·0		23
180	502 3·7	461 9·0	493 9·6	46 5·0	25 4·0		20
185	508 6·7	464 3·4	500 8·9	34 8·0	22 5·0	Branch of Ganges, Furrukabad near the Ganges.	19
190	513 2·8	473 11·1	504 4·9	40 0·0	12 1·0	Ganges River, Futtigurh.	14
195	519 3·7	479 4·7	516 1·0	39 1·0	14 8·0	Ganges River, Kumalgunj.	7

Mr. Read's line of levels upon which the bench-marks have been built, terminates at the 150th mile, or at a point where the surface of the country is 427·20 feet below the zero of the above table: at the 160th mile, or at that point where the canal channel for irrigating purposes terminates, the surface of the country will, I imagine, from the above table of Mr. Dodsworth's, be 435·54.

From the above terminal point to the town of Furrukabad, the distance may be estimated at 21 miles, and the level figure at that place is 476·63 feet. In 21 miles, therefore, we have (to complete our channel as a navigable line) to overcome a descent of 41·19, or nearly 2 feet per mile. Allowing ·437 foot, or 5¼ inches nearly, per mile, we should require four locks each with a drop of 8 feet, to connect the 160th mile of the Futtigurh branch with the town of Furrukabad, and four locks more of the same dimensions to connect it with the Ganges River.

I consider, that the whole question of navigation, as it affects the branch which we are now describing, is one that may well be left until its value as an irrigating channel has been sufficiently proved. In carrying on the works, therefore, I should refrain in the first instance from undertaking either the locks and lock channels round the falls, or the excavated channel and works for navigation beyond the 160th mile. I should confine the works for the present entirely to irrigating purposes, as per estimate of 1850; the escape which I have proposed at the 160th mile has, in fact, this object in view, and the design laid down for the canal channel with its towing-path, and the towing-path arches on the bridge flanks will, by the mere addition of the works, the construction of which I would now postpone, render the branch a line for navigation.

The general slopes of the country from the main canal at Jaoli to the 195th mile, together with those of the Ganges and East Kalli Nuddi rivers (the drainage boundaries of the strip of land which the Futtigurh branch is intended to irrigate), will be seen clearly enough from the above table, as well as by a reference to Mr. Dodsworth's maps, Plate No. VI. of the Atlas. A few words on the direction of the branch, as proposed by Mr. Read, will complete all that I have to say on the works connected with this subject.

Mr. Read's line, on leaving the head at Jaoli, in the Mozuffurnuggur district, proceeds on a direct course to the east of the village of Mowanna; the bearing is a few degrees to the east of south, and the distance 23 miles; at the 12th mile from the head, it enters the district of Meerut. On leaving Mowanna, the direction runs for a distance of 23 miles almost due south to the village of Dutteeanna, leaving the town of Pureetchutgurh on the west; the village of Dutteeanna is within a mile of the west of the line.

On the whole of the above course, it keeps well clear of the heads of the East Kalli Nuddi, which commence at the village of Untwarra, north of the town of Khutowli.

From the village of Dutteeanna, the line has an inclination of about 20 degrees to the east, bearing in some measure upon the direction of the Ganges, so as to clear the heads of an extensive line of drainage, which under the name of the Choiya, commences almost on the right bank of the Ganges River, and flows into the East Kalli Nuddi, on the boundary of the Budaon and Alligurh districts. To avoid as much as possible the ramification of nullas connected with the Choiya, and to escape interference with the hollows with which it is connected, Mr. Read's line, in passing between Mullukpoor and the Ganges at Anoopshuhur, keeps as close as possible to the latter, and for about 24 miles, in which distance both

Anoopshuhur and Ramghat are passed, the canal is separated from the high bank of the Ganges by a distance varying from two to three miles. As the line proceeds onwards from Ramghat, it obtains a considerable departure from the Ganges, arising in a great measure from a bend in the course of the river, and reaches a point about three miles west of the town of Deyori in the Budaon district. The total distance from Dutteeanna to Deyori is 78 miles or thereabouts, the early 4 of which are in the Meerut, 50 in the Bolundshuhur, 21 in the Alligurh, and 3 in the Budaon districts. That portion of the line which lies in the Bolundshuhur and Alligurh districts, and which evidently comes in contact with the Choiya drainage, requires to be more carefully examined and reported upon than it has been; the line taken up by Mr. Read is, I have no doubt, the true one, but we have as yet no accurate and precise map of the detail of the cross drainage, which we ought to have before our works are commenced upon. I would recommend that the Choiya Nulla be surveyed from its junction with the East Kalli Nuddi, upwards; and that all the lines of hollows into which it ramifies (in other words, that the whole of its catchment basin) should be carefully placed upon paper, in the same way as has been done on the Cawnpoor terminal line on its approach to the Ganges.

On leaving Deyori, Mr. Read's line continues for 31 miles on a bearing inclining to the east, leaving the town of Puttialla about three miles on the left and terminating at the village of Bunar. I am not aware of any remarkable nullas or lines of drainage which would interfere with this part of the course of the canal; Puttialla itself lies within a short distance of the old branch of the Ganges, parallel to and within about 4½ miles of which the canal would run. It is possible that the escape which is proposed to be made at the 160th mile, or at the termination of that portion of the branch which is intended for irrigation, may be conveniently turned into one of the ravines connected with the Ganges River. Of the 31 miles above referred to, the three early ones are in the Budaon, 15 in the Mynpoori, and 13 in the Futtigurh districts.

The Futtigurh branch, therefore, to which this section is devoted, passes through the districts of Mozuffurnuggur, Meerut, Bolundshuhur, Alligurh, Budaon, Mynpoori, and terminates in the Futtigurh district, to each of which, within the limits bounded by the Ganges and East Kalli Nuddi, it will afford the means of irrigation; the 7th column of the table of levels which is above given, exhibits the width of the country between the limits above mentioned; the figures are dependent on Mr. Dodsworth's cross lines of section, which are not always at right angles to the course of the rivers, and may, therefore, be occasionally in excess; they will, however, be sufficient to show the average width of the strip of land which comes under the influence of irrigation.

II. & III.—*The Bolundshuhur and Koel Branches, forming the Head of the Hatrass Line of Irrigation.*

These branches are so intimately connected with each other, that although they leave the main line of the canal at points separated by a distance of 42 miles, the one in the Bolundshuhur, and the other in the Koel or Alligurh district, their projection, as the heads of a series of uninterrupted irrigation, which extends as far as the junction of the Seyngoor with the Jumna, places them under one head, as portions of one great work.

With the exception of lines of cross levels taken over the country, the surveys of both the Bolundshuhur and Koel branches are (1854) incomplete. At the present time, the data upon which my remarks are founded are a series of cross sections taken by Mr. Volk between Bolundshuhur and Alligurh; the sections extend from the East Kalli Nuddi (across the country over which the branches will be carried) to a distance of about 12 miles to the right of the Kuroon River; they are carried in parallel lines at a distance of five miles apart. Mr. Volk has also provided me with a longitudinal line of levels, taken on the proposed course of the Bolundshuhur branch, for a distance of 46 miles; this longitudinal line terminates at the village of Rajpoor, from whence he has carried branch lines, one to the Putwai Nulla, which lies on the right, and the other to the Kuroon River, situated on the left of the line.

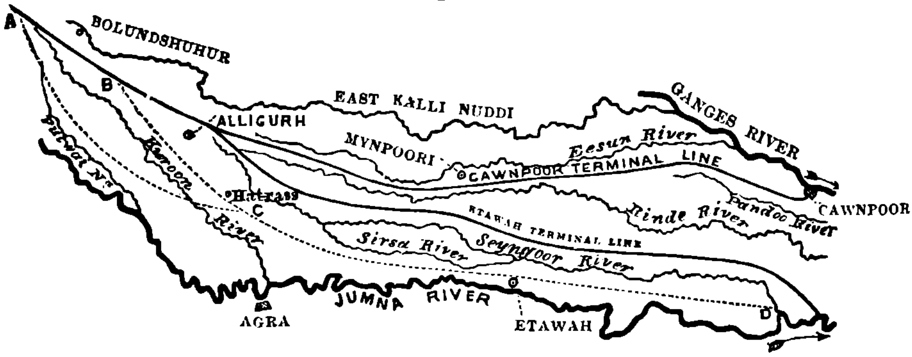
As far as Mr. Volk's survey extends, the profile is satisfactory; but as it consists of mere lines without reconnoissance, or examination of the details of cross drainage, I have postponed further progress in laying out the works, until the topographical features of the country through which the line of levels has been carried, are more accurately known.

In advance of Mr. Volk's cross sections, which terminate at the town of Sasni, Mr. Dodsworth's series commences on a line taken from a masonry bench mark, or fixed point established on a tank near Koel, due south to the town of Hatrass. From thence the whole country lying between the Seyngoor and the Jumna rivers has been covered by a reticulation of levels, consisting of a longitudinal line running as closely as possible on the watershed, intersected at every five miles by a cross section between the two rivers.

As far, therefore, as a general examination of the country by cross levels, unaccompanied by the details of subordinate drainage, is concerned, there are data sufficient to enable me to arrive at tolerably accurate conclusions as to the general bearing on which the lines of canal will be carried. The detail of works, the precise position of the masonry descents for overcoming the superfluous fall in the country, and the actual line upon which the works will be projected, can only be determined after the country has been surveyed in greater detail.

The plan of irrigation contemplated in the above series, of which the Bolundshuhur and Koel branches are the ostensible heads, is shown by the dotted lines in the following diagram :—

Diagram 58.



Where A C and B C represent the Bolundshuhur and Koel branches, which, uniting at the point C in one channel, proceed onwards between the Seyngoor and the Jumna rivers to D.

The design on which the original estimates were framed was merely one assigning to each branch a defined length of channel, regulated by the amount of supply considered sufficient for irrigating the tract of land coming under its influence. The detail of the works, and the direction upon which the branches were to run, were left for future consideration, after the country had been properly examined.

The length of canal which was embraced in the estimates was 70 miles for each branch, with a head supply to each of 520 cubic feet per second; the total amount of the estimates for each branch was (2,10,000 rupees) two lakhs and ten thousand rupees; giving an aggregate of four lakhs and twenty thousand rupees for both works.

The extent, therefore, to which the Government works will be carried is equal to 140 miles; they will terminate at the point C, or at the junction of the two branches. In advance of the point C, a line of rajbuha, which is chargeable to the Tukkavi account, will proceed onwards between the Seyngoor and Jumna, terminating in the bed of the former river at D. This rajbuha will pick up the tail water of the Bolundshuhur and Koel branches after they have formed their junction at the point C, and would be supplied on the first 100 miles of the course of the Etawah terminal line by feeders from that line carried across the Seyngoor River.

The system of irrigation, above described, makes a provision, it will be observed, for the whole of the country lying between the main canal and the Jumna River; and there is not a section or spit of land throughout this tract that will not be accessible by watercourses. As far as I can judge by the relative position of points of level, as gained from Mr. Volk's and Mr. Dodsworth's surveys, the area of surface open to Tor irrigation, or to that where the aid of machinery is not required, will be unusually extensive.

The length of the works, into a description of which I am about to enter, is as follows: using the round numbers of measurement from a map, which, although not precisely correct, will be sufficiently so for my purpose.

A C, Bolundshuhur branch .	90	miles in length.
B C, Koel branch . . .	50	,, ,,
C D, Main rajbuha . . .	160	,, ,,

For the supply of these lines, 1,040 cubic feet per second have been given, by estimate, to the 140 miles included in the Bolundshuhur and Koel branches; and for the remaining portion, which is considered under the head of a rajbuha, an indefinite supply will be provided by feeders taken from the Etawah terminal line, for which provision has been made in the estimate for that particular work.

It appears, from the reduction of Mr. Volk's and Mr. Dodsworth's levels, that assuming as the fixed point C, or bench mark established by the latter gentleman at the village of Pykwarra, situated three miles to the south-east of the town of Hatrass, we have the following level points, using the figures of the original surveys:—

A . . .	225·69	feet.
B . . .	979·56	„
C . . .	348·51	„

The total declivity, therefore, on the 90 miles, included in the Bolundshuhur branch, is equal to 122·82 feet, or on an average, 1·364 foot per mile.

On the Koel branch, which in the above diagram is represented as 50 miles in length, we have a declivity of 68·95 feet, or an average of 1·379 foot per mile.

The slope of bed, which is proposed to be given to the above branches, is equal to 1·25 foot per mile. We have, therefore, in the case of the Bolundshuhur branch, a superfluous or disposable amount of fall equal to 10·32 feet; and in the Koel line, 6·45 feet; the whole of which must be provided for by masonry descents.

I have, in the description of the country over which the main line of canal passes on its approach to the Alligurh from the Bolundshuhur district, drawn attention to the sudden fall that occurs in the surface at that point. This sudden fall in the levels is, on the main canal, met by two masonry descents of five feet each, which have been built at the villages of Pulra and Simra. The line of the Bolundshuhur branch, the head of which is situated near the village of Duhurra, at a point 39 miles above the head of the Pulra or upper falls, comes in contact, it will be observed, with this sudden change of level; the superfluous slope, which is figured as 10·32, approximating as closely as possible to that which occurred on the main line. As an exhibition of this slope, in as much detail as Mr. Volk's cross sections will enable me to give it, and using the figures and measurements of his surveys, the following appear to be the results :—

	Fall.	Rise.
From the head at Duhurra,	Feet.	Feet.
or from the 1st to the 5th mile . .	6·01	
5 ,, 9½ ,, . .	14·14	
9½ ,, 13½ ,, . .	..	4·97
13½ ,, 17 ,, . .	4·23	
17 ,, 22½ ,, . .	4·48	
22½ ,, 27 ,, . .	18·18	
27 ,, 30 ,, . .	3·40	
30 ,, 35½ ,, . .	10·44	
35½ ,, 43 ,, . .	7·54	
43 ,, 48½ ,, . .	9·75	
48½ ,, 53 ,, . .	6·46	
53 ,, 58½ ,, . .	4·97	
58½ ,, 62½ ,, . .	9·68	
62½ ,, 69 ,, . .	10·15	
69 ,, 75 ,, . .	6·21	
Total fall	115·64	
Deduct rise . . .	4·97	
Total fall in surface of country on 75 miles	110·67	

The sudden declivity occurs between the 20th and 25th miles.

From the terminal point of the above series which is noted in the map as situated near the village of Soneyee, the fall to Mr. Dodsworth's bench mark at Pykwarra appears to be 12·15 feet; the superfluous fall, therefore, lies between the head and the village of Soneyee.

The head of the Koel branch is situated three miles below the Pulra falls; a portion, therefore, of the superfluous slope which has been noted as attending upon the line B C has been disposed of in the main canal, before the Koel branch leaves it. The superfluous slope before noted may consequently be reduced from 6·45 to 1·45, and the only question that then remains is, whether there is any necessity for going to the expense of masonry falls to meet such a small excess of slope, which, spread uniformly over the whole length of fifty miles, would merely increase the average from 1·25 to $(\overline{1{\cdot}25+029})$ 1·279 foot per mile. It is proposed, however, to carry this excess of slope on the prolongation of the Koel branch from the point C to the 80th mile at Ferozabad; now, as the Bolundshuhur branch meets that of Koel at the point C on a reduced slope, the regimen of the beds after the confluence of the two branches would be, to a certain extent, disarranged. The total amount of excess of fall in 80 miles is $(80 \times {\cdot}029')$ 2·32 feet. It is questionable whether, with the given depth of section as shown in diagram 59, it may be worth while to dispose of this superfluous slope by masonry works. I am rather inclined, looking at the subject in an economical point of view, to leave nature to make her own adjustments.

Pursuing the course adopted in the case of the Bolundshuhur branch in giving the detail of levels as derived from Mr. Volk's cross sections, the following is the result on as much of the Koel line as has yet been surveyed.

	Fall.
From the head at Gungowli,	Feet.
or from the 1st to the $6\frac{1}{2}$ mile . .	6·66
$6\frac{1}{2}$,, $12\frac{1}{2}$,, . .	10·40
$12\frac{1}{2}$,, $18\frac{3}{4}$,, . .	10·50
$18\frac{3}{4}$,, $22\frac{1}{2}$,, . .	0·54
$22\frac{1}{2}$,, 29 ,, . .	7·61
29 ,, 34 ,, . .	18·73
Total fall in surface of country on 34 miles	54·44

From the terminal point of the above series, which lies three miles south-west of the town of Sasni, to Mr. Dodsworth's bench mark at Pykwarra, the total fall is 14·61 feet, the distance being 16 miles; here also the excess of slope falls within the country between the main canal and Sasni.

I may observe with reference to the above points of level which are taken on an assumed line traced upon Mr. Volk's map of his survey, that the figures above shew the necessity of further examination, of the country, before the line of operations is actually determined on; for instance, attention is naturally drawn to the profile of the country on the Koel line, as shown by the table between the $6\frac{1}{2}$ and the $22\frac{3}{4}$ mile, in which the hollows attached to the Seyngoor and Kuroon drainage and the steppe in the surface of the country, depending on the proximity to the Seyngoor, lead to an irregularity in the disposition of the levels. This, without an accurate reconnoitering survey, in which the different lines of hollow are traced up to their sources, is fatal to arriving at satisfactory conclusions as to the true line upon which the branch ought to be carried. There is some obscurity therefore on this point, which must be cleared up by careful investigation: judging, however, from the cross sections, as shown on Mr. Volk's plan, the assumed line appears to be more adapted to the purpose than that bearing on the higher levels near the town of Koel, in which the exceeding flatness of the country would lead to a depth of excavation, involving an expense, greater in all probability than that required for the artificial disposal of the drainage elsewhere.

I have before remarked, that it is essentially necessary to have the lines of drainage accurately mapped before the direction of the Bolundshuhur or Koel branches is determined on.

There is a great advantage in assimilating the proportions of works, especially those to which wood and ironwork are appended. For this reason, I would divide the fall that occurs in the Bolundshuhur branch into two descents of 5 feet each, by doing which, the woodwork which is applicable to the falls on the main trunk would be equally appropriate to those on the branch; by following this rule also, an uniform measurement for sluice-shutters, sleepers, or lock-gates, would exist throughout the whole of the division.

With the above preliminary observations, and the results of the level points as explained in the foregoing paragraphs, we possess data for the two branches, which resolve themselves into the following, viz.:—

I. The Bolundshuhur branch with a head supply equal to 520 cubic feet per second, with a slope of 1·25 foot per mile, and two masonry descents of 5 feet each, for overcoming the superfluous fall in the country; the length of this branch being 90 miles.

II. The Koel branch with a head supply equal to 520 cubic feet per second, with a slope of 1·279 foot per mile, and with a length of 50 miles.

In considering these two lines as parts of one system of irrigation, I shall adapt their supply to the lengths of their courses; throwing out the first five miles as coming under the influence of the main channel, and allowing 8 cubic feet per mile as the supply required for the irrigation of the country through which it passes. Although, therefore, the waterway of the heads is on one dimension, and although in the calculations for capacity of channel I shall abide by the originally estimated discharge, I shall consider that each branch is capable of carrying an additional volume, and that the irrigation will not be interrupted by the occasional closing of one or the other heads, placing them under the same conditions as exist on all lines which are dependent upon two or more heads for their supply.

Depth of Section calculated as 5 feet.		Value of R.	Value of $\frac{1}{S}$.	Sectional area in square feet.	V in feet per second.	Discharge.	
						Theoretical.	Required.
50′	At the 1st mile	51·00	$\frac{1}{4224}$	275	2·783	765	680
45′	10 „	50·70	...	250	2·783	695	640
40′	20 „	49·87	...	225	2·755	619	560
35′	30 „	48·80	...	200	2·728	545	480
30′	40 „	47·50	...	175	2·684	469	400
25′	50 „	45·90	...	150	2·641	396	320
20′	60 „	43·90	...	125	2·582	322	240
15′	70 „	41·10	...	100	2·491	249	160
10′	80 „	37·20	...	75	2·328	174	80

Agreeably to the terms above mentioned, the actual supplies for the country lying on the Bolundshuhur branch will equal

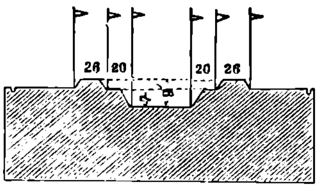
$\overline{90-5}\times 8$, or 680 cubic feet per second, whereas that on the Koel line will be

$\overline{50-5}\times 8$, or 360 cubic feet per second. The waterway of the heads, both at Duhurra and Gungowli, is equal to 50 feet in width, and is therefore adapted to the discharge of the same body of water; the slopes of the branches being considered similar.

For the excavated channel, therefore, of the Bolundshuhur branch we obtain by the formula which has been used throughout the project for the Ganges Canal works, the preceding table of dimensions.

The general section of the channel is represented by the following diagram, the width of rectangle varying agreeably to the above table, and the width of embankments depending on the quantity of earth which is derived from the excavation. The section is in fact a minimum one with reference to width of embankments, and to the height from the canal bed to the embankment tops.

Diagram 59.



The slopes of the canal channel are 1 to 1, and those of the embankments $1\frac{1}{2}$ to 1. The berms to be carried on one uniform height of 7 feet from the bed of the canal, or, if this should involve an extraordinary expense, the system of gradual inclination on long lines, so as to make the higher and lower levels meet by an imperceptible change, can be adopted.

In the above table it has been thought sufficient to give the transverse section at every ten miles in length of the course of the channel; in carrying on the excavation, however, the width of rectangle ought to be reduced to an extent of 6 inches at the end of each mile, a proportion that will in practical operation be found convenient.

In viewing the Koel branch as the second head for the supply of an extended line of irrigation, and as one liable to be charged with a volume of water equal to that in the Bolundshuhur branch; the capacities of both the waterway at their heads and of their excavated channels having been designed on precisely the same dimensions; the detail given in the above table for the Bolundshuhur branch is, in fact, that which is proposed for the Koel one, and although there is a slight excess of bed slope in the latter (the causes of which have been before explained), it has not been thought of sufficient moment to render alteration necessary.

In adopting the plan, therefore, of assimilating the Koel branch works to those of the Bolundshuhur, the latter it will be observed will meet and form a junction with the Koel line at the 50th mile of its course, or at a point where the excavated channel is 25 feet in width. From this or the starting point of the Hatrass line of irrigation, the dimensions will be reduced on the same scale as that shown in the table. At the 80th mile, near the town of Ferozabad, the minimum width of 10 feet will be reached, and on these dimensions it is proposed to carry the line onwards for a distance of 85 miles to Oorya. From Oorya to the Seyngoor, which is 35 miles, the above dimension might be gradually decreased to 3 feet in width.

The town of Ferozabad, which lies on the 80th mile of the direct course from the Koel branch head, is situated at a distance of about 17 miles due south from the Etawah branch, in the vicinity of the town of Moostafabad. The Etawah branch has at this point passed the 45th mile of its course, and is separated from Ferozabad by the Seyngoor and the Sirsa rivers; the latter, as I have before explained, being a divided stream of the Seyngoor itself, which leaves that river near the north boundary of the Muttra and Agra districts at a point about 12 miles north-west of Ferozabad.

The Bolundshuhur and Koel branches, therefore, after their junction at the point C, near the town of Hatrass, proceed onwards for a distance of 30 miles, with a capacity of channel equal to that of the Bolundshuhur branch in the last 30 miles of its course. Between Hatrass and Ferozabad, the line runs parallel to and at about 17 miles distant from the Etawah branch, the Seyngoor and its drainage passing equidistantly between them. On these 30 miles it is proposed to establish three feeders from the Etawah branch, or three lines of rajbuha, the water of which will cross the Seyngoor on sheet-iron channels. The width of the rajbuhas, and of these channels, need not exceed 10 feet; but it is essential that, in crossing the shallow depression and hollows of which the Seyngoor in this part of its course consists, as little interference as possible should be given to the free and unimpeded escape of the drainage of the country; flat tubes, laid upon masonry piers, appear to be the most appropriate method for obtaining a maximum waterway; and their efficiency has been proved on the works for irrigation connected with the Jumna.

I have limited the feeders which lie above the 30th mile of the Etawah branch to three, considering that the supply derived from 30 feet width of waterway will be ample; but the excavated channel of the Etawah branch is calculated for the wants of six feeders to the Hatrass line of irrigation on the first 100 miles of its course; so that, considering that these feeders act as the supplies for irrigation to the country through which they pass, it appears to be a matter of indifference in how far they are multiplied, as long as the expense, attendant on their passage of the Seyngoor, is economically considered.

	Fall.	Rise.
	Feet.	Feet.
From the 1st to the $4\frac{3}{4}$ mile . .	3·00	
$4\frac{3}{4}$ „ $9\frac{3}{4}$ „ . .	1·97	
$9\frac{3}{4}$ „ $15\frac{1}{4}$ „ . .	7·68	
$15\frac{1}{4}$ „ 20 „ . .	5·49	
20 „ $25\frac{1}{2}$ „ . .	3·75	
$25\frac{1}{2}$ „ $32\frac{1}{4}$ „ . .	11·00	
$32\frac{1}{4}$ „ $38\frac{1}{4}$ „ . .	3·60	
$38\frac{1}{4}$ „ $43\frac{1}{4}$ „ . .	6·36	
$43\frac{1}{4}$ „ $48\frac{3}{4}$ „ . .	...	0·44
$48\frac{3}{4}$ „ $54\frac{1}{4}$ „ . .	11·11	
$54\frac{1}{4}$ „ $59\frac{3}{4}$ „ . .	6·12	
$59\frac{3}{4}$ „ 65 „ . .	2·44	
65 „ 70 „ . .	4·08	
70 „ $75\frac{1}{2}$ „ . .	7·20	
$75\frac{1}{2}$ „ $80\frac{3}{4}$ „ . .	10·09	
$80\frac{3}{4}$ „ $87\frac{1}{4}$ „ . .	2·99	
$87\frac{1}{4}$ „ $92\frac{3}{4}$ „ . .	5·44	
$92\frac{3}{4}$ „ 98 „ . .	4·40	
98 „ $103\frac{1}{4}$ „ . .	3·33	
$103\frac{1}{4}$ „ 110 „ . .	6·90	
110 „ $114\frac{3}{4}$ „ . .	3·57	
$114\frac{3}{4}$ „ $119\frac{1}{4}$ „ . .	7·10	
$119\frac{1}{4}$ „ $125\frac{3}{4}$ „ . .	5·56	
$125\frac{3}{4}$ „ $130\frac{3}{4}$ „ . .	4·65	
$130\frac{3}{4}$ „ $136\frac{3}{4}$ „ . .	3·44	
$136\frac{3}{4}$ „ 143 „ . .	8·34	
143 „ $148\frac{1}{2}$ „ . .	9·27	
$148\frac{1}{2}$ „ 154 „ . .	2·93	
Totals . .	151·81	0·44
Deduct rise . .	0·44	
Total fall in surface of country from the junction of the Bolundshuhur and Koel branches at C to the junction of the Seyngoor with the Jumna . . .	151·37	

The position of the Seyngoor River, however, naturally leads to these considerations, and it becomes an object to restrict the number of aqueducts within moderate, although efficient limits. With this view, a feeder might be established at every 10 miles, or at every third bridge of the course of the Etawah branch. It is needless, however, to speculate on points which experience will soon simplify; it is sufficient for our purpose that the relative position of the two lines provides ample means for their accommodating themselves to each other.

From the junction at the point C, down to which the bed slopes have been determined on levels taken by Mr. Volk, connected with Mr. Dodsworth's bench mark at C; the following table will explain the slopes of the country from the point where the Bolundshuhur and Koel branches unite to the Seyngoor River at the point D, assuming the point of junction, near Hatrass, as the 1st mile.

In examining the above table (p. 413), we find that—

On the first 20 miles, the total amount of fall is		. .	18·14
,, next 50th	,,	,, . .	48·02
,, ,, 40th	,,	,, . .	40·35
,, remaining 44	,,	,, . .	44·86

The average fall, therefore, on the whole line, as shown by points in Mr. Dodsworth's levels, does not give 12 inches per mile, which is somewhat less than the parallel line of the Etawah branch.

From the last station noted as the 154th mile, which is situated close to the ravines on the right of the Seyngoor, the Etawah branch, at a point near Sirinuggur, is 12½ miles distant. The station point at Sirinuggur is 15·58 feet below that of the 154th mile; these stations, however, are separated by the Seyngoor River, which runs through a deep channel, bounded on both sides by a labyrinth of huge ravines, whereby more than half of the width of country that separates the two points is occupied; the region is an intractable one, uncultivated and uninhabited. The town of Moosanuggur lies at the distance of 7½ miles south-east of the station at the 154th mile.

As far as the data with which we have been provided enables us to form an opinion, we shall be able to obtain slopes, for the beds of these lines of irrigation, quite sufficient for every purpose. Those of the Bolundshuhur and Koel branches, up to the junction, being 1·25 and 1·279 respectively; and that from the junction being 12 inches throughout its whole course. The supply, both from the main canal and from the Etawah terminal line, will be adequate to maintain a sufficient volume of water in the 10 feet channel, which runs from Ferozabad to Oorya; and with proper regulation at the heads, and with adequate means of escape, there appears to me to be no reason why this, although a very extended line, may not prove to be a very efficient one.

With reference to the escapes and works which have been designed for these branches, I would refer to sheet XLVII. of the Atlas, which contains general designs for all the different species of works that may be required on the subordinate lines, whether of branch or of rajbuha.

Before closing my remarks on the above line of irrigation, which I have designated "the Hatrass," from the town of that name, which lies at the point where the two main branches from the Bolundshuhur and Koel heads form a junction, it is necessary to advert to the means of escape that must be provided, not only to relieve the works from flood-water during the rainy months, but to provide for exigencies of superabundant supply, which, from the circumstances of the two branches terminating in a canal of comparatively speaking smaller dimensions, will, in all probability, be frequently necessary.

Both the Kuroon and Seyngoor rivers, as far south as the region of Hatrass, are by no means capable of acting as the receivers of waste water; their beds are depressed below the level of the country to a very moderate extent, and their capacities of channel are small. The Seyngoor River lies between the Etawah terminal and the Hatrass line, and will be crossed by numerous aqueducts, which would interfere, more or less, with the channel, under a supply in excess of that of the natural drainage of the country.

The Kuroon River will be crossed, in the neighbourhood of Hatrass, by an aqueduct for the uses of the Bolundshuhur branch; it would, therefore, be unwise to load the channel of this river, at any point on the upstream side of the aqueduct, with additional water.

Above Hatrass, therefore, or above the junction of the two branches, both the Kuroon and Seyngoor have been considered unavailable as lines for escape; and consequently, the Koel branch, from its head to its junction, has no escape whatever, further than that which may be provided by the rajbuhas, or lines of irrigation on its right and left.

The Bolundshuhur branch, which may be considered the leading one as connected with the Hatrass irrigation at a point about 10 miles from its head at Duhurra, crosses some low land lying under and to the north of the village of Kot. This low land, which lies to the westward of the town of Jarcha, is the head of a line of nulla, which, under the name of the Putwai, enters the khadir of the Jumna, and joins that river to the south of the jheel and town of Nooh. The total length of the Putwai Nulla, from its sources to the Jumna, is about 52 miles. Mr. Volk observes, that "from the jheel, near Kot, to the village of Runhera, or in a distance of about 35 miles, no regular river bed is formed, and cultivation is carried on in the slight depressions, occupied by water at the time of very heavy rain. Close above the village of Runhera, the Putwai Nulla is joined by another line of drainage, collected in the extensive dâk jungle, lying between Dunkour and Ruboopoora. After the junction of these two lines a regular nulla is formed, which increases in width until it joins the Jumna, several miles below the Nooh Jheel, in the Muttra district."

It will be understood, from the above description of the Putwai Nulla, which runs parallel to and on the right of the branch, that, as far south as the village of Runhera, it offers no facilities for escape; at the village of Rajpoor, however, and at a point situated at the 46th mile of the line laid out by Mr. Volk, a series of levels carried to the Putwai Nulla, under the village of Barote, shows a depression of 30·9 feet in a distance of seven miles; the actual section of the nulla, at this point, being 15 feet wide and 2½ feet deep. Here, therefore, a leading head for escape might be established; and I would, as the section of the branch at this point will be about 27½ feet wide, independent of slopes, give a waterway to the escape equal to 30 feet, or five sluices of 6 feet each. At the point where the branch crosses the Kuroon River, a similar escape would render the Bolundshuhur line complete, and enable the supply, which is received from Duhurra, to be held in perfect command. In addition to the two escapes above mentioned, which would be specifically for the relief of the Bolundshuhur branch, an escape, with a waterway of 30 feet, with five sluices of 6 feet each, ought to be placed in the neighbourhood of the town of Suhpoo, or at some point immediately below the junction of the two branches; the escape channel would be carried into the Kuroon River, and it would act during the dry weather as a regulator, under the contingency of accidental over-supplies of water coming down the two branches; during the rains, it would, in all probability, afford the most serviceable relief, at a point where such relief is most particularly needed.

It is needless to attempt, under the imperfect knowledge of the detail of the country which I possess, to fix upon precise spots for escapes from the junction to the terminus at the Seyngoor River; the line, however, runs parallel, and in many cases close to the ravines which skirt the Jumna, all of which are available as receptacles for escape water. Again, as the Seyngoor River advances in its course, its channel becomes more capacious, and from the 60th mile, or from the neighbourhood of Ghiror, it is applicable at any point for receiving any supply of water that might be thrown into it: I would, however, in fixing upon sites for escapes, consider that a distance of 40 miles is sufficient between each, and that the waterway should be divided into sluices of 6 feet each in width, and be rather in excess than otherwise to the width of the channel at the point where the escape is situated. Where the fall between the bed of the canal and the bed of the nulla or river into which the escape runs is very great, it is at all times advisable to protect the channel from retrogression of levels, either by permanent masonry works, or by the application of any species of heavy material that may be at hand. The evil of retrogression of level upon the canal channel is one of such magnitude, that I would prefer, as a general rule, selecting points for escape at some distance from the ravines and khadirs of the large rivers, or, in fact, were such possible, having nothing to say to them at all; this, however, is unavoidable in many cases; it has been so in our escapes to the West Kalli Nuddi, on which expensive masonry works will be ultimately required to prevent the levels from retrograding upon the main canal; and on the line now under review, it will be equally unavoidable, as the only available receptacle for escape water are the ravines of the Jumna Khadir and of the Seyngoor.

In conclusion, I may observe, that in the design for these, as well as in that for the works on the main canal, the demands for navigation, as well as for irrigation, have been consulted. The falls or masonry descents will be passed by a navigable channel fitted with locks on the same plan as those on the main trunk line; the bridges, towing-paths, and the detail of the masonry works generally, will be adapted to navigation, so that rafts or boats may reach every point to which the main lines extend. It may possibly be a matter worthy of consideration hereafter, whether by combining an escape with a navigable channel, taken from the Bolundshuhur branch near Belaspoor to the Jumna River, two good objects may not be attained—1st, the means of providing relief during floods; and 2ndly, the means of connecting the main canal with the Jumna by a navigable line at a point just below that where the Hindun River joins it. This line might perhaps be more favourable for navigation than that which I have suggested as leaving the main canal near Moradnuggur, and joining the Hindun near the Ghazioodeennuggur Bridge. In the former case the connection with the Jumna would be on its whole course by a well-regulated line of canal; in the latter, the greater portion would be occupied by the tortuous course of the Hindun River. Mr. Volk's levels from the surface of the country at Belaspoor to a nulla lying in the khadir near the main river show that on a line of eight miles the fall is equal to 47 feet. Belaspoor is a jaghire belonging to the late Colonel Skinner, whose sons now hold it in hereditary right from their distinguished father.

Before closing this chapter, I may draw attention to the comparatively imperfect data upon which the original estimates for the branches had necessarily to be formed.

This will be gathered from the opening paragraphs when explaining that even at the closing of my reports in 1853–54, I have been unable to lay down the same definite views as to detail that accompanies my description of the main and terminal lines. Since the period when the estimates were drawn up, much information has been obtained, not only of the topographical features and contour, but of the demands and resources of the country, through which the branches take their course. This information in all its successive developments has at every step given increased confidence to the views which I had formed as to the value of these subordinate works; whatever the increase of expense may be therefore (and in that of the Futtigurh branch, if my views are carried out, they will be heavy), this increase will be met by a proportionate return to the outlay expended, and by increased benefit and accommodation to the trade and agriculture of the country.

VIEW OF THE KUNKHUL BRIDGE, GANGES CANAL WORKS.

CHAPTER IV.

DESCRIPTION OF THE SYSTEM OF DISTRIBUTION BY RAJBUHAS, OR MAIN LINES OF WATERCOURSE.

THE term "rajbuha" is the only one which has been left to us by our native predecessors as distinctly attached to irrigation. On the Delhi and Hansi canals, or those which are now designated the "Western Jumna Canals," the country was marked by extensive lines of mound or embankment, the origin of which was hardly understood at the period when, with a view to the restoration of the canals, which had for nearly a century been deserted, the half-obliterated canal channels were examined by the British surveyors. A cut or watercourse for the purpose of irrigation naturally implies a hollow or an excavated channel, and it was difficult, in the existence of these long lines of elevated mound, to recognize in them the remains of ancient lines for irrigation; such, however, they undoubtedly were, and the peculiarity of form merely depended on the weathering of the collections of sand and silt deposits with which they had been encumbered. The constant necessity for the removal of deposits was in all probability as great a source of expense and inconvenience to cultivators in those times as it has been to us. The lines of mound above alluded to have at this period their representatives on both sides of the Jumna, where the desertion of recent watercourses after a few years' occupation leaves a trace similar in every respect to that of the ancient rajbuha.

It was the non-existence of these old traces of water-courses on the country through which the Eastern Jumna Canal takes its course, that led to the supposition that this canal in its ancient state had either not been used at all, or had only been partially applied to the uses of irrigation; they were numerous and appeared as remarkable features on the western side of the Jumna, whereas on the eastern side they were unknown; the inference, therefore, that the engineering difficulties which had interfered with the maintenance of a continued supply* in this canal had led to its failure in the original conception, was borne out in a measure by the absence of all traces of ancient watercourse.

As the traditions of the inhabitants of the Delhi and adjoining districts, handed down from father to son, had invariably represented these old mounds as the remains of rajbuhas, this name was assumed by us, although perhaps with a more specific application.

To illustrate the relation of the rajbuha to the canal itself, in the system of irrigation adopted in the North-West Provinces of India, in a manner which will be familiar to most readers, the details of the method of

* There are traditions of serious damage having been caused to the towns of Behut and Saharunpoor by the opening of this canal by Zabitha Khan, and it is possible that both in this case as in that of the original project, the difficulties of maintaining a passage over so many mountain torrents led to the works being abandoned. It is, however, perfectly clear that no great quantity of water could ever have been allowed to run for any lengthened period of time: the excessive slope of the country between the Nogong and the Muskurra rivers would have led to a retrogression of levels fatal to the works. No masonry works of any description were discovered, and although traces of excavation were found in the Meerut district, it may be fairly doubted whether the canal ever reached so distant a point.—(Page 1, Memorandum on East Jumna Canal.)

supplying the population of towns and cities in Europe with water may be referred to. In the latter, the water is collected in the reservoir, from whence it is carried to the outskirts of the town in the "mains" or great supply pipes; from these it is led through the different streets in the "distributary pipes," and the wants of individual houses are met by a system of "service pipes."

Now, in our irrigation system, the trunk and terminal lines, with the great branches, play the part of the reservoir; the rajbuhas hold to these the relation of "distributary pipes," and the village watercourses represent the "service pipes" in the disposal of the supply in detail. The rajbuha is, therefore, the connecting link between the supply and the service channels, and it is from it alone that the process of distribution is carried on; the success of this distribution depends upon the judicious lining out and adjustment of their heads and channels, with reference not only to the command of water as derived from their sources, but to that over the country which they are intended to irrigate. The rajbuhas, again, are private property, executed at the cost of the irrigators, and, although their execution, their superintendence, and their maintenance in a state of repair, are the specific duties of the Government establishments, these duties have been imposed at the desire of the community, Government having no claim of any description upon the works.

From what has been said before of the general design of the works on the Ganges Canal, and the position that they hold with reference to the slopes of the country, it will be understood that this position is uniformly on the summit levels, or on the watershed of the different sections or spits of land into which the Doab is divided by the different rivers which constitute its natural drainage. Taking, therefore, the main trunk from Hurdwar to the point of separation into its two terminal lines at Nanoon, and considering the position of these two lines, as well as that of the subordinate ones which (under the designation of the Futtigurh, the Bolundshuhur, and Koel branches) have been constructed as sources of main supply, we have as a leading feature in the proposed system of irrigation, an extended series of reservoirs, adapted to the purposes of providing water by the agency of as many rajbuhas as the exigencies of the land requiring irrigation may call for.

With a provision of reservoirs, as above explained, the method of distributing water, simple as it may appear in a general way, has demanded much consideration. The mere lining out of the rajbuhas is, in consequence of the interposition of rivers, and their proximity to the main lines of canal in cases where the watershed impinges upon them, a question not altogether free from perplexity; but this is of minor consideration, when placed in juxtaposition with that of the best method of distributing the water to the irrigators, of equalizing this distribution, and of determining a measure by which the quantity of water, and consequently the value of the water supplied, can be adjusted.

This adjustment is by no means difficult where, as in the canals in Upper Italy, the height of water in the reservoir or in the main canal remains constant, or nearly so; where the water is free from impurities, and where the slopes of the country are considerable: with such propitious elements, the Italian engineers have established, after eight centuries of practice in irrigation, a measure or module, which enables them, by the application of a very simple and, at the same time, a very ingenious watercourse head, to supply water by measurement, or by a certain amount of discharge, the unit of which has been determined. Both in Lombardy and

Piedmont, however, the value of this unit varies with the locality of the irrigation; up to the present period there is no fixed standard, nor are the details of the different parts of the structure, which has, after so long a period, been accepted as the most perfect, similar in different districts. The module, in fact, is still capable of improvement. Practically speaking, the machine in use appeared to me to be roughly built, and the parts not put well together; my impression was that, were the supply heads in general similar to those which came under my inspection, their value, as measures for water, each of which represents a fixed value in money, had been overestimated. It appeared to me, also, that the object of protecting the interests of the buyer and seller (supposing that the principle on which the machine is designed is perfect) could only be obtained by a more carefully-built structure, and by the provision of more careful superintendence than appeared to be given to it.

On the canals of irrigation, in the North-West Provinces of India, the elements, which I have before referred to as so favourable to the success of the Italian engineers, are altogether wanting. On the Jumna Canals, for instance, the absence of uniformity in the surface level of the main canal or reservoir is remarkable; the water is loaded with impurities, in the shape of sand and silt; and the slopes of the country, although rapid in the northern districts, are in the southern, and in those where the greatest extent of irrigation exists, comparatively small.

This is not the place to enter into a description of the Italian module; although, to show its difficulty of application on canals labouring under the impediments above described, it is necessary to point out that the efficiency and, in fact, the whole use of the machine, as applied to the purposes for which it was invented, depend entirely on a free and uninterrupted flow of water away from it; obstructions dependent on want of slope at the tail, or on deposits of sand, would be fatal to the uses of the machine, so that, laying aside the want of similarity between the Jumna and the Italian canals in other respects, the impurities which exist at the present time, and which have existed, though in a greater degree, during the early periods after the Eastern and Western Jumna Canals were opened, are not only a great bar, but almost a prohibition, to the establishment of apparatus for regulating the discharge from the watercourse heads. I may remark, here, however, that in the valley of Deyra the canals, small as they are, are free from all the evils to which those on the Jumna are liable. They possess all the elements requisite for the application of measuring apparatus, and from the shortness of their courses, the water runs on depths more uniform than it does on the longer lines of the canals attached to the Jumna.

Up to the present period, the method of distributing water from the canals in the North-West Provinces has been partly by village watercourses taken directly from the main line or its branches, and partly from rajbuhas; the former and the most objectionable method has almost entirely given way to the rajbuha system on the Eastern Jumna Canal, which has been carried out to the utmost extent possible, and with extraordinary advantages to the cultivators; on the canals west of the Jumna, where the slopes are not so favourable to the connected series forming a rajbuha system, main lines have as frequently as possible been substituted for the village watercourses, but the extension of these main lines does not make rapid progress, one great cause of which is the frightful depositions of sand and silt, which cannot be got rid of, until the slopes of the main canal, which in parts are those of a natural river, are modified.

Neither in the case of the rajbuha or village watercourse head, is there any further arrangement for regulating the supply than the intervention of planks or shutters for opening and closing them; in many cases where the village watercourse head is taken direct from the main canal, the depression of a foot in the high-water mark leaves the head high and dry, and universally the sand deposits, which, although common to all, are more certain at the heads of those lines through which there is no constant circulation of fluid, render clearances at very short periods constantly necessary. Up to the present time, in fact, the method of distributing water from the canals in these provinces has, with the exception to the system of rajbuhas established on the Eastern Jumna Canal, owed as little to science as possible; it commenced in the year 1819, when the first canal was opened, and has continued up to the year 1853, much in the same fashion.

Irregularity in the means of distributing water naturally leads to imperfections in the way of levying payment for land irrigated; the system under the above described distribution has been:—

1st. By measurement of area of surface of land irrigated, without reference to the amount of water taken, but *with* reference to the species of crop, and to the means by which the water was obtained, whether by a free flow on the surface, or by the medium of machinery.

2ndly. By annual contracts for machinery, or the payment of a fixed annual price for permission to establish a Persian wheel (*ruhut*), lever and bucket (*dhinkli*), or any of the machines in use for raising water.

3rdly. By *area* of opening of outlet; in contract determined by the parties concerned.

4thly. By actual contract for a period of years by which a landholder agrees to pay a fixed price for a water-course head with a given area of opening.

The first and second methods are those most commonly in use on the canals throughout these provinces; they are in fact the methods by which the greatest portion of the irrigation is effected. The imperfections of the first are conclusive: they embrace, amongst other minor evils, those of want of economy in the expenditure of water and the introductions of expensive establishments, for the periodical measurement of land irrigated; they lead to unnecessary interference on the part of the canal establishment with the domestic details of villages; and from the circumstance of the irregular rotation of crops, they lead to fictitious returns in so far that crops for which water rent is due have frequently been removed, and the ground has been re-sown, long before the measuring parties are able to measure it: the whole system is bad, as one of unnecessary interference and uncalled-for meddling in detail; but bad as it is, it has been much easier to recognize its imperfections, than to remedy them.

The second method is a great step towards improvement; here the irrigator is restricted in the use of the water, by the trouble and expense of raising it; the water, therefore, is economized, and the annual payment of a fixed sum relieves both the givers and receivers from any further connection.

The third method is an improvement on the first on the same principle as that above described; but with a varying surface of head water in the canal, it is quite impossible as well as utterly hopeless with a mere plank or shutter to determine any given quantity of discharge; the consequences have been, therefore, that the receiver has in nine cases out of ten obtained more water than was bargained for, and the results have been so unsatisfactory, even when the utmost has been done to secure the water from misappropriation, that the plan described here is not of frequent recurrence; the method, however, is so far good, that the transaction is one of contract, without any interference in minor details.

The fourth method, is, *par excellence*, founded on the true system by which water ought to be supplied to the cultivators: it involves a mere contract transaction between the parties, on the signing and sealing of which the price of the water is secured to the revenue, and the value of the water is, without any interference on the part of the canal establishment, secured to the contractor.

Much as the value of this contract system has been recognized, it has been found impossible, as a general rule, to carry it into effect; the cause of this impossibility arises in a great measure from the habits and disposition of the people: there is an uncertainty as to the area of ground that will be irrigated from an opening of a given size; a doubt as to the proportions of water required for crops of different descriptions, and the habitual dread that the cultivator has of being imposed upon by not receiving the supply that he calculated on getting, leads him, in all probability, to prefer paying for that which he sees actually measured, to that which in his idea has the appearance of uncertainty.

This system has, however, been carried out to a considerable extent on the canals west of the Jumna, where contracts have been entered into for periods of 20 years; these contracts, however, do not unfortunately correspond with the revenue assessments, and they were made at a period when the canal supply was very much less than it has been for the last few years; the consequence has been that, although in some cases the contractors have from a variety of causes been allowed to give up their contracts, those who have kept them are benefiting in a very great degree. The position of the outlet on which the contract was made, remained fixed, whilst the value of the additional head pressure, gained by the increase of supply in the canal, has fallen to the share of the contractor.

It was the beginning of an improved system, and as such deserves every commendation ; and the utmost that can be said against it, is that it has given to the fortunate holders of the contracts extraordinary benefits, which in all probability they never contemplated; whilst at the same time it has undoubtedly led to the extension of cultivation, and to the breaking up of new ground, both of which will ultimately lead to an increase of land and canal revenue.

Practically speaking, however, the necessity of non-interference with the heads of these contract water-courses, all of which are situated on the main line, has prevented the extension of the rajbuha system, and has in some cases interfered with the improvements which have been in progress on the main line of the canal. I have no doubt that it is from these causes partly, that the system of giving contracts for long periods has not been continued, and that the termination of those now existing is so anxiously looked forward to, by the canal executives. Nobody, however, doubts that the principles on which the giving of these contracts originated were good, and that the same security to non-interference, which was so desirable in the land measurements, was equally so in those for irrigation : in fact, had the contracts, when made, depended on a fixed discharge, instead of on a fixed area of opening, the desideratum which had been so long coveted would have been obtained, and we should at that early period of the history of these canals have been furnished with a modulus, on which the distribution of the water might have been adjusted.

It is to this adjustment, to this determination of an unit by which water can be equally distributed, and of the invention of a machine by which such units can be discharged in a given time, that we have to look to a fair and economical expenditure of the canal supply: whether the Milanese module (*magistrale*) or any other machine is introduced, the results will be equally satisfactory, if we can obtain even a moderately close approximation to the quantity of water which is required for the irrigation of given areas, or which is adapted to the wants of individual estates. To know, in fact, the true value of the property that we hold for distribution, and the extent to which that property can be made the most beneficial to the community, are the great desiderata to which all our views ought to be directed.

It was with a view to a full acquirement of knowledge on this point, as well as on the legislative enactments connected with the irrigation in Lombardy and Piedmont, I should say rather of that of Northern Italy generally, that Captain Baird Smith of the Bengal Engineers, who, for many years, had devoted his time to the study of canals for irrigation in these provinces, was deputed by the Court of Directors of the East India Company to proceed to Lombardy and Piedmont, and to report upon the canals of those and the neighbouring States.

The results of Captain Baird Smith's visit to Italy have been now for some time before the public, in a work which is full of the most detailed information, and which abounds in suggestive remarks, connected with the methods adopted in the irrigation and its management in these provinces, as compared with that on the longer established canals in Italy. The work itself is in fact the text-book by which our operations must necessarily be guided, and it will, under its author's auspices, lead to a complete reorganization of our system.

The known imperfections, however, of the methods adopted on the canals in these provinces for regulating the supply of water as delivered to the cultivators, the fact that Captain Baird Smith's deputation to Northern Italy would throw upon this subject all the light that could possibly be expected, and the certainty that the valuable experience he had obtained would lead to his becoming my successor, have induced me to adopt the simplest possible designs for the heads of rajbuhas, or for the heads of the works from which the water for irrigation will be supplied to the country. With the exception of fixing their positions (a matter that is immediately connected with the lining out of the channels, and comes within the province of the civil engineer), the heads of all works of this sort have been built in the form of open-arched channels, of sufficient capacity to admit of the application of any species of apparatus that may hereafter be determined on. As the capacity of these channels is in all cases either 10 or 6 feet in width with a height in proportion, there will be ample room for the purpose. I have, it may be stated, adopted a size of channel, capable of admitting any form of module or machine; my aim having been to give full scope for reduction of area of opening, but to avoid the evils of alteration and reconstruction of the original work, which a channel built on too confined a scale would have undoubtedly led to.

The above, although but a brief outline of the existing arrangements, is sufficient for the purpose of the present chapter; it will enable the reader to form an opinion on the progress that has been made, and on that which the extension of works for irrigation is tending to make in these provinces; it will, moreover, act as introductory to the views by which I have been guided in my scheme for laying out the irrigation on the Ganges Canal works; and of my desire to confine myself entirely to that object, leaving the occupation of determining a module of supply, and of providing a code for the management and protection of the irrigation to my successor.*

The above prefatory remarks introduce me at once to the rajbuhas as designed for the Ganges Canal works; the relative stations that they hold between the main canal and the village water-courses having been before explained.

It will be necessary for the purpose of simplifying the description of the rajbuhas to divide the canal works into sections, as both the design for the heads, and that for the channels vary somewhat, according to locality. There are a few leading rules, however, that have been attended to, and may be noticed before proceeding further. I here allude to the general design, the modifications of which will be explained in the sectional detail.

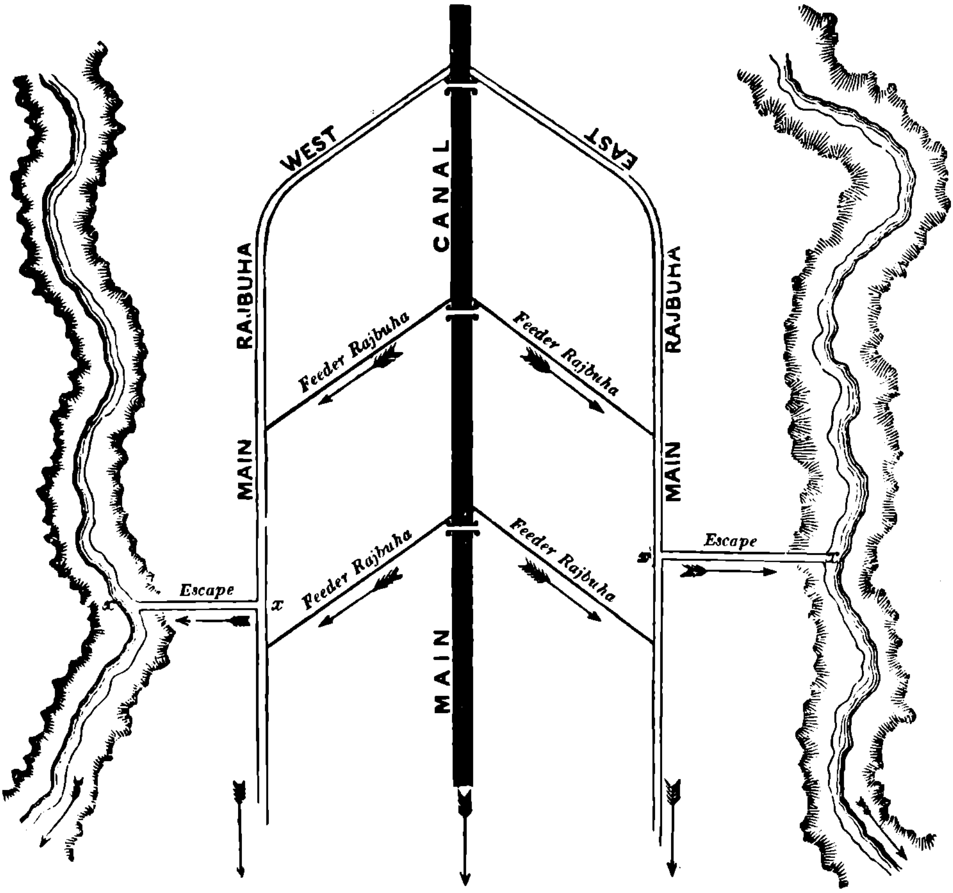
1st. Rajbuha heads as a general rule have been constructed at all the bridges, both on the right and left of the canal, excepting in those districts where the declivity of slope is in excess; in that case the rajbuha heads are limited to the upper levels, and to the vicinity of the masonry falls and locks.

2nd. The heads are attached to the bridges or works near which they are situated, and in the immediate vicinity of choki posts, so that they may be under the most perfect supervision.

* On my departure from Roorkee, in April, 1854, I left Captain A. G. Goodwyn, of the Bengal Engineers, the Executive Engineer of the north division of the Ganges Canal works, engaged in experiments on discharges with reference to a plan for a module, which he had designed. The apparatus by which he proposed to secure uniformity of discharge was simple, viz., the action of a cone in a circular orifice, the action being regulated by a float appended to the cone by a lever. Captain Goodwyn had the full use of the workshops, and my authority for expending money to any reasonable amount in completing his experiments. Some time before I left Roorkee, Captain Goodwyn had succeeded in obtaining discharges in fair time very accurately; and unless the machinery with which the regulator must necessarily be encumbered is of too delicate or complicated a nature, I look with sanguine hopes to a successful termination of his labours.

3rd. The width of these heads is on the whole of the main line, and as far down the terminal lines as the 30th mile, equal to 10 feet; below that they are 6 feet in width.

Diagram 60.



4th. The height of their sills or floorings from the bed of the canal, is in the main canal and to the 30th mile of the terminal lines equal to 24 inches; from thence they gradually decrease in height until they approach the terminal regions, at which the sills of the rajbuha heads and the bed of the canal are on one level.

5th. All these rajbuha heads are designed as mere open channels, with grooves in front and rear for the application of shutters or sleeper planks. No further design has been attempted for the regulation of discharge beyond that of the grooves for the application of the above-mentioned woodwork, and the supply of planks sufficient for the purpose of retaining the water on the opening of the canal.

6th. The rajbuha channels are divided into main lines and feeders. The first or main lines run parallel to the canal on both its right and left sides, extending from the Assoffnuggur Falls, or from the commencement of the high land of the country on the whole length of the canal and its branches: these parallel lines on their passage downwards are met by feeders from the different rajbuha heads in the neighbourhood, as shown in diagram 60.

7th. The main lines of rajbuha as running parallel and approximating to the natural lines of country drainage are connected with them by escapes, vide *x x* in diagram. These might be multiplied to any reasonable extent, so as to give the most efficient means for riddance from superfluous water.

8th. It is supposed that during floods when the main canal and its branches are overcharged, the opening out of the rajbuha heads, and the consequent distribution of the surplus water over such extended surfaces, as the above system of reticulated rajbuha channel ensures, would tend greatly to the security of the works, by a relief of the escapes proper, from dangerous and collected drainage. That, obtained by the medium of the rajbuhas, would be divided amongst numerous channels, and would finally obtain relief through numerous rajbuha escapes; it would in fact enable us to destroy the enemy in detail instead of allowing him to collect in dangerous masses.

9th. By the rule above laid down, the whole system of main canal branches, rajbuhas and their feeders, become part and parcel of one great machine; the rajbuha heads being the safety valves, and the rajbuha escapes being the waste pipes. If properly managed, and if the sluice heads attached to the canal are properly adjusted, it is supposed that the scheme above propounded would lead to the maintenance of such an equilibrium in the height of the water's surface, that no apprehension might be entertained of the main canal or reservoir channels being dangerously overloaded.

In the general design for the Ganges Canal, and in the calculations on the supply of water required for irrigation, the leading 27½ miles, or that part including the khadir, and extending on the high land beyond it, as far as the village of Nusseerpoor, are "considered as removed from the influence of irrigation from their passing through khadir land in the early part of their course, and deep digging immediately above Nusseerpoor." This, although true to a great extent under the remodelled works, has been somewhat modified by the construction of the falls at Assoffnuggur from the head of which the leading main lines of rajbuha are taken, and by the establishment of heads for irrigation for the high lands of the khadir. In the former case, however, the Assoffnuggur heads have merely led to a redistribution of the supply originally devoted to the line of canal situated between the 27½ and the 110th mile; and in the latter, the proximity of the heads for irrigation to the Ganges River, will enable us, if necessary, to draw away an extra quantity of water for their especial purpose. The alterations, therefore, although it may be necessary to allude to them, do not in any way interfere with the original project for supply.

The country with which the rajbuhas are connected may be classed under three denominations:—

I. The Ganges khadir, where from the natural moisture arising from its proximity to the mountains, the demand for irrigation is at a minimum.

II. The lands between Roorkee and the terminus of the main trunk at Nanoon, on the greater part of which, owing to excessive slope of country, the rajbuha heads are restricted to the heads of the falls.

III. From the branches where rajbuha heads are the usual appendage to every bridge.

I. I have restricted the heads for supplying irrigation on this tract to the Kunkhul outlet or escape, and to the Bahadoorabad mills: the former is placed in such a position in proximity to the branch of the Ganges, that it may be used either for escape, irrigation, or for mills, without any fear of its being injured by either. The latter is connected with the mill reservoir, of which work it forms a component part. Whilst the Kunkhul head will supply water for the villages of Kutarpoor, Chandpoor, &c., and to the eastern portion of the Puttri lands lying on the banks of the Ganges; that at Bahadoorabad will complete the irrigation of the western tracts of the Puttri forests. From these two heads, in fact, any quantity of water may be taken, and at the same time an equivalent is obtainable from the Ganges River, should the irrigation of the Puttri and the neighbouring lands call for an extraordinary supply. Although I have restricted the heads to these two points, there is every facility for providing the most efficient means for irrigation on the whole tract lying from Bahadoorabad to the Puttri River; and the establishment of one or two rajbuha heads on the left embankment of the navigable cut would do everything that could possibly be required; beyond this, and in the vicinity of the great works at Dhunouri and Roorkee in connection with the Rutmoo and the Solani Rivers, irrigation is hardly required. In the immediate neighbourhood of the Rutmoo, spring water is near the surface, and on the Peerun Kulleeur ridge, the depth of canal channel is opposed to its use for irrigation. At the down-stream extremity of the Solani aqueduct, however, the inlet drains, which are connected with the cattle ghats, are designed in a way that will render them available for the irrigation of the gardens and land both at and in the neighbourhood of Roorkee; they are, in fact, in design similar in every respect to the inlet that has been universally adopted on the Ganges Canal works; viz., a masonry channel opening into the canal, with its head in the form of a circular well or cylinder, in which the water stands to a height equal to that of the canal high-water mark.

II. The rajbuhas on this section are, as far as the 105th mile, or to the Dasna Falls, entirely limited to the heads of the falls, or to leading positions on the canal before it changes its level. From the Dasna Falls to the works at Nanoon, or to the 180th mile, this limitation ceases; and although in the immediate vicinity of the falls at Simra and Pulra, it partially exists, heads for rajbuhas have been constructed with few exceptions in connection with every bridge.

At the Assoffnuggur and Dasna Falls, or at the head and tail of a long line of rapid descent in the country, which is overcome by masonry falls, the sills or floorings of the rajbuha heads have been laid down on a level even with the canal bed, or to speak precisely, 3 inches higher, an elevation which has depended on the arrangement for the sluice shutters; the escape of water, therefore, at the head of the irrigation at Assoffnuggur, and for the head supply of the main rajbuhas, east and west, will be free and unimpeded; it will be in direct proportion to the depth of water on the main canal. A similar remark applies to that at the Dasna Falls, which may be considered as the head and the commanding supply of a line of country comparatively flat which lies beyond it. In both the above cases, however, I have, by keeping the floorings of the heads as nearly as possible on a level with the canal bed, given the means of supply to the utmost extent that the canal will admit of.

In every other case, both at the heads situated at the falls between the extreme points above mentioned, and at those below Dasna, the sills of the rajbuha heads are placed above the canal bed, so as to prevent the channel from being drained to its uttermost dregs, and to secure a supply, to a certain extent, to the canal works below them.

In making a commencement (May 1853) to the rajbuha excavation on this section, the rules which were drawn up for the guidance of the executive officers, and which I shall enter in this place, will give a very fair idea of the details of both the lining out and construction of the works. The rules in question were issued on the 29th of November 1852 to Mr. Read, and to Mr. Volk, the former having the executive charge of the works down to the 110th mile, the latter holding that from the 110th, or from the Bolundshuhur branch head, to the Nanoon regulators.

"I. The principles on which rajbuhas are constructed and laid out need not be explained here; it will be sufficient to state that the object of such works is to effect irrigation at the cheapest cost, by laying out lines for irrigation on true and correct levels, and by reducing their slopes of bed to a minimum sufficient to keep up a scour, and at the same time to maintain a good head supply for irrigation.

"II. The method of accounts and of obtaining ground for the purpose of these rajbuhas, are as follow:—

"1st. The cost of a rajbuha to be estimated, and on that estimate assignments to be granted. Accounts to be kept separate under the head of 'Tukkavi advances.'

"2nd. The land which will be occupied by these rajbuhas is to be obtained in the usual form, and on the usual scale of remission.

"3rd. The amount of remission to be annually debited to the zumeendars, in the above account of 'Tukkavi advances' until the rajbuhas are accepted by the zumeendars as lines of irrigation.

"4th. On the rajbuhas being accepted as lines for irrigation, the remission is to cease,* and the advances including the outlay for remission formerly made, are to be repaid by the zumeendars in kists, at periods which may ultimately be fixed, and which would depend on the time when the works north of Roorkee can be depended on for a regular supply of water.

"5th. That water should not be given to the lands of any village, until the zumeendars have given a written agreement to accede to the above terms.

"The whole of the cost, including payment for ground-rent, which will be periodically remitted to the collector on his demand, will be charged on the debtor side of an account, which will be opened in a separate book; an abstract of this account with (after the first account has been rendered) arrears brought forward, so that the Director of the Works may be kept fully

* This will be a question for after consideration; it would be better that the remission should be charged, as before, to the debtor side of the rajbuha account, by which arrangement the holder of the land over which the rajbuha runs, and which is necessarily kept out of cultivation, would receive his fair and full remission for the land so occupied; whilst the amount of remission would be levied from the irrigators generally:—It is evident that the irrigators in general, and not the individuals whose land is occupied by the works of the rajbuha ought to pay the remission: this, in fact, is a legitimate portion of the annual expenses of outlay and repairs.

acquainted with the expenditure, is to be submitted quarterly in the form accompanying—

Dr. Assoffnugger main Rajbuha. (East.) Cr.

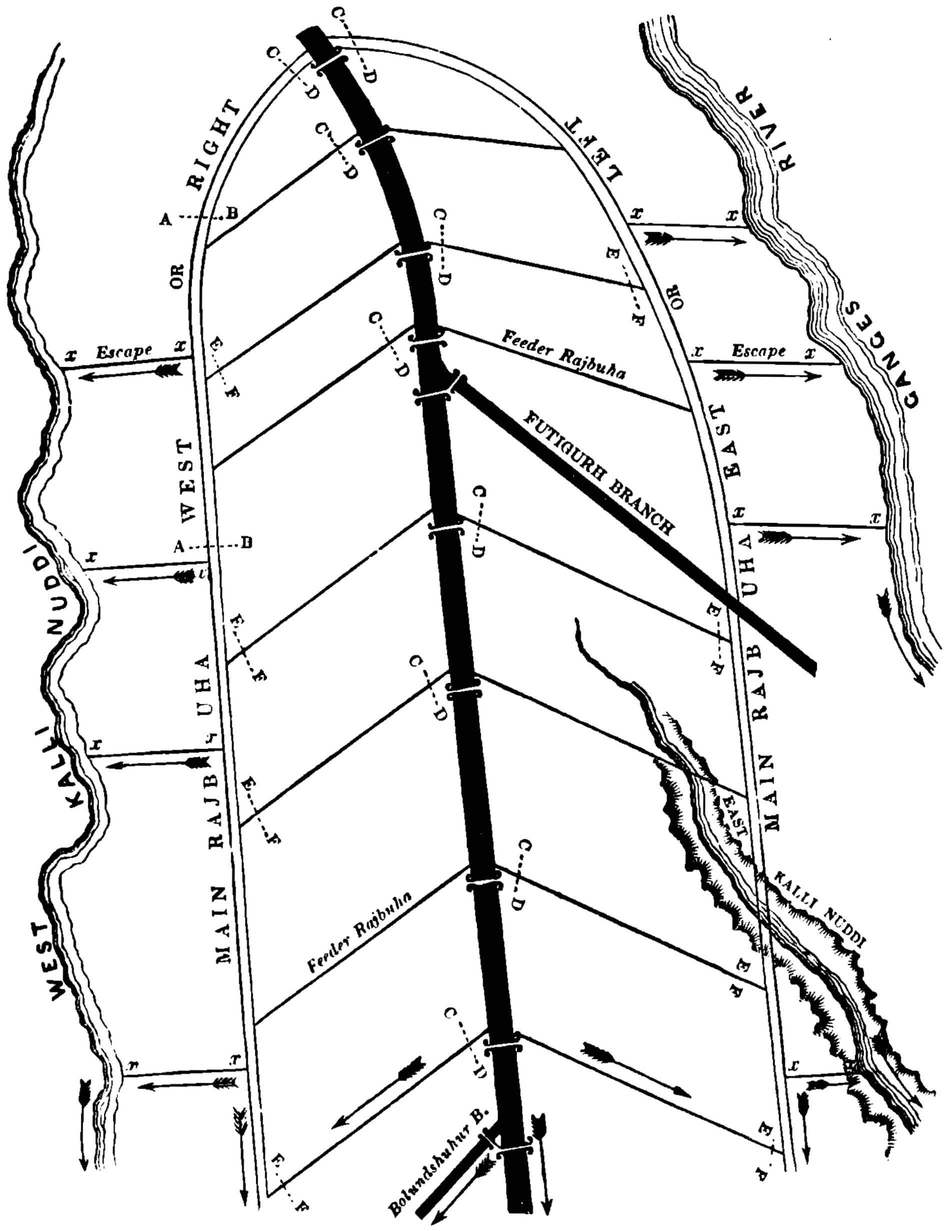
		Total Co.'s Rs.						Total Co.'s Rs.			

"III. The following sketch explains in skeleton the general design of rajbuhas in Mr. Read's division, the main arteries (shown by double lines) being kept supplied by feeders (shown by single lines) from the rajbuha heads, which are situated above the falls and locks.

"A bridge will be required at the Futtigurh branch, combining a passage or aqueduct for the rajbuha; the rajbuha will also cross the valley of the East Kalli Nuddi by an aqueduct connected with a raised embankment; the designs for these works cannot be determined on, until the direction of the rajbuha is accurately laid down.

"IV. The east and west main lines or arteries must run on the ridge between the main canal and the valley that bounds the irrigation on the right or left, or in other words, on a line from which the water may flow towards the sides with the greatest facility. Executive officers will observe that these lines will not be mathematically centrical, but that their directions will depend upon the profile of the country. Great care, observation, and judgment will be required in determining the course of

Diagram 61.



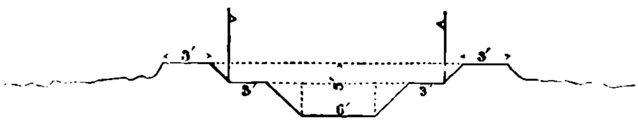
these main lines, as well as in calculating the slope of bed; as a general rule, I should make the line from the Assoffnuggur rajbuha head, as far as the first masonry descent, with a slope equal to that of the canal, viz., $1\frac{1}{4}$ foot per mile, so that a good and rapid run might be given to the water on its first admission into the rajbuha: from the lower level of the first masonry descent above mentioned, I would make the slope of bed either 9″ or 12 inches per mile, the superfluous slope being overcome by masonry descents. I would also make all the feeders with a slope of $1\frac{1}{4}$ foot per mile, and I would endeavour so to arrange the direction of the feeders, that they should enter the main rajbuha by a masonry descent or overfall, with a drop of from 1 to 3 feet.

"V. Before commencing excavations executive officers will send their protracted lines of levels to the directors' office for approval; with their own projects for the slopes of the bed marked upon them.

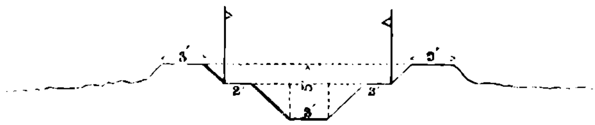
"VI. The dimensions of the main rajbuha and feeder channel will be as follow; those which are given to be considered as minimum ones:—

Diagram 62.

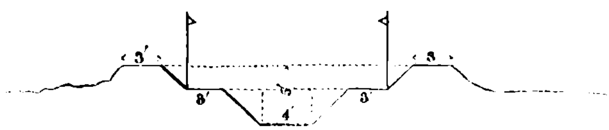
Section on C D, or at the heads of Rajbuhas and Feeders.



Section on E F, or at the tails of Feeders on their entrance into Rajbuha.



Section on A B, or on Main Line below 1st Masonry descent.



"Slopes of excavation equal to depth; slopes of banks $1\frac{1}{2}$ to 1. These lines should be carried out at right angles to the main canal* for a distance of a furlong at least; and in laying out the levels, and in fixing the pins for excavation, I would recommend furlong distances, or even portions of miles, each portion being excavated in one horizontal level, commencing from the sill or level of the upper flooring of the rajbuha head.

"VII. The banks, berms, and slopes, will be made regularly and neatly, as is done on the main channel.

"VIII. The bank on the sunny or eastern side will be considered the line of 'gusht' (patrol) or road-bank.

"IX. The channel, berms, and road-bank will be kept clear from grass and jungle *always*.

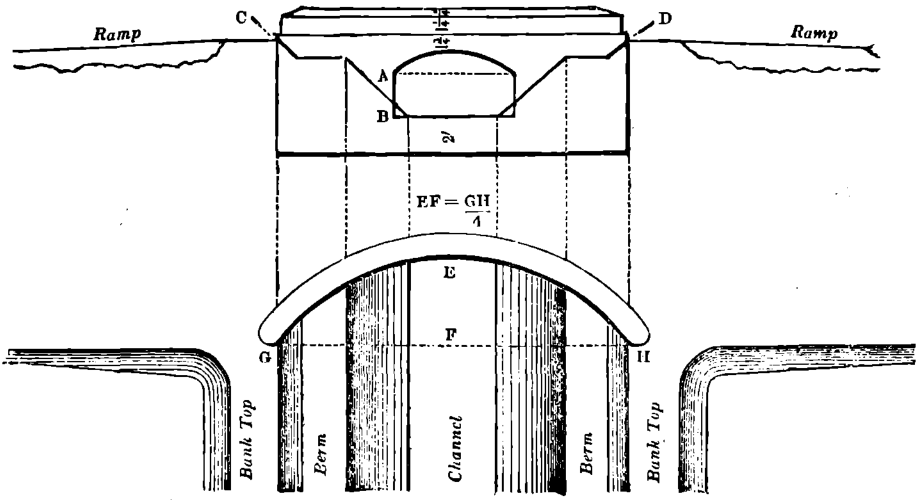
"X. The best depth 'in soil' for rajbuha excavation is considered to be 3 feet, by which depth, surface irrigation, and the repairs of the channel appear to be most easily managed. Varieties in depth of excavation, however, cannot be avoided; although in laying out the slope of bed, and in determining the position of masonry descents, executive officers must be guided by the above approved depth, and by the well-understood inconvenience of shallow excavation and the consequent necessity under such circumstances of 'bank raising.'

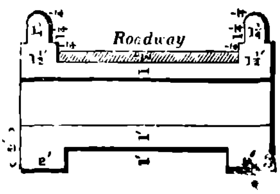
"An inspection of the Eastern Jumna Canal rajbuhas, by executive officers, would show the advantages and disadvantages of different depths of excavation.

"XI. No 'kucha' or earthen sloped cattle ghats are to be permitted in either the rajbuhas or feeders. Wherever lines of crossing are required, the cross-communication will be effected by a masonry bridge, the plan and design of which will be of the simplest description, as shown in the following diagram:—

* In cases when rajbuha heads are situated at bridges, and where the masonry channel lies obliquely to the line of embankment, the rajbuha excavation will be carried on in prolongation of the bearing at which the axis of the masonry channel is situated.

Diagram 63.





Height of Abutment, or from A to B, will depend upon depth of excavated channel.

The plinth C D is always 3 inches above the top of the bank.

"XII. The width of bridge waterway is always to be 24 inches greater than that of the nulla or rectangular section of the canal at the point where the bridge is built; *i.e.* on the main line of rajbuha when the width of nulla is 4 feet, the width of bridge waterway will be 6 feet. The flooring of the waterway must be carefully laid on the true level of the bed. It is better to lay this flooring too low than too high: the former leads to no great difficulty, but the latter is a positive evil.

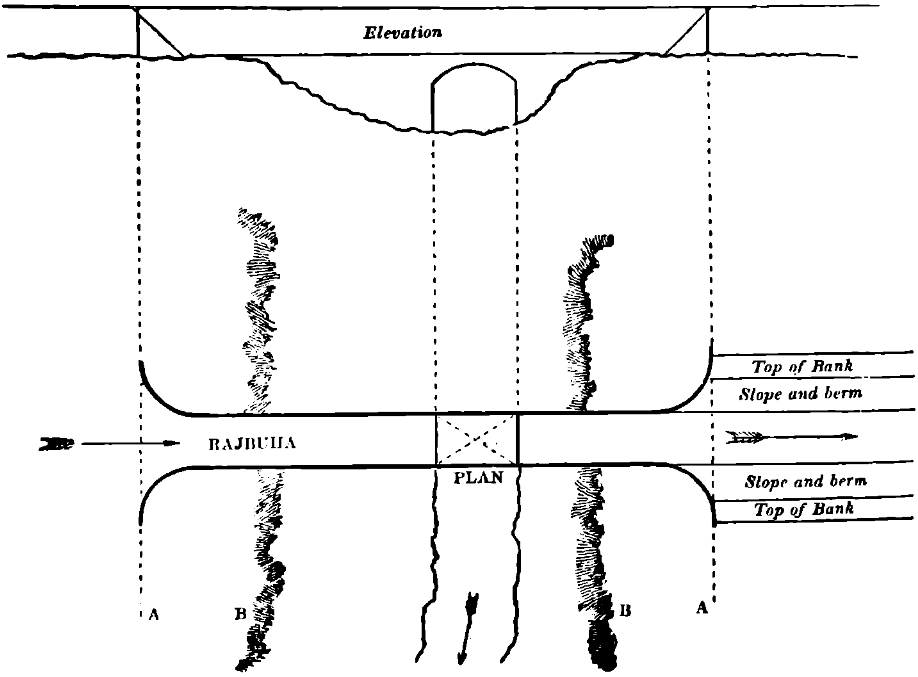
"XIII. The width of roadway of village bridges is to be 12 feet between the plinths; ditto of town roads or roads near towns, 15 feet; ditto of district roads, 20 feet; ditto of high military roads, 25 feet.

"XIV. The width of aqueduct channels is always to be 12 inches greater than the nulla of the excavation at the point where it is built.

"XV. When a line of rajbuha or feeder has to cross a hollow or low tract of land, great care must be taken in making the wings of the masonry channels for the passage of the canal water sufficiently long, so that they may be well imbedded in the embankments, and that they may rest well in soil.

"Thus :—

Diagram 64.



"It is not easy to fix the dimensions or distance from A to B; but the engineer employed on the work must be guided by his own judgment. I may mention that in every case where the above rule has not been attended to, disappointment has taken place, in either the water escaping at the point of junction between the earth and masonry, and in such cases by a failure in the masonry; or in great trouble being given afterwards in protecting the entrance and exit in and from the masonry channel.

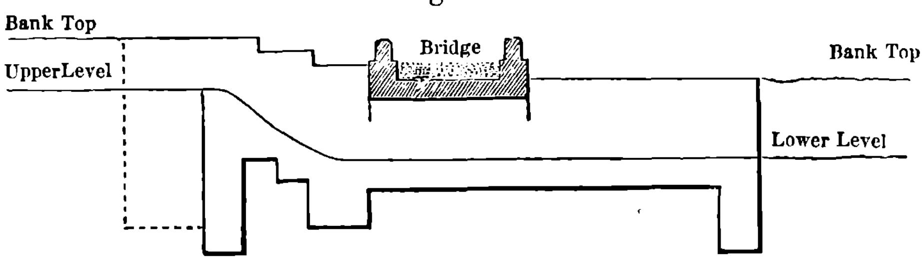
"XVI. When the line of road crosses the rajbuha or feeders obliquely, the arches of the bridges may be built skew fashion.

"XVII. The arrangements for delivering water for irrigation to the cultivators, by channels through the rajbuha banks, will be left for after consideration.

"XVIII. The descents in masonry will be of the plainest construction in ogee, similar to the design on the main canal. Plain flank walls with curved terminations, well fitted into the sides both on the up-and-down-stream extremities.

"Where cross-communication takes place at a descent, it is better to keep the road on the lower level, by throwing the arch over the lower instead of the upper revetment wall.

Diagram 65.



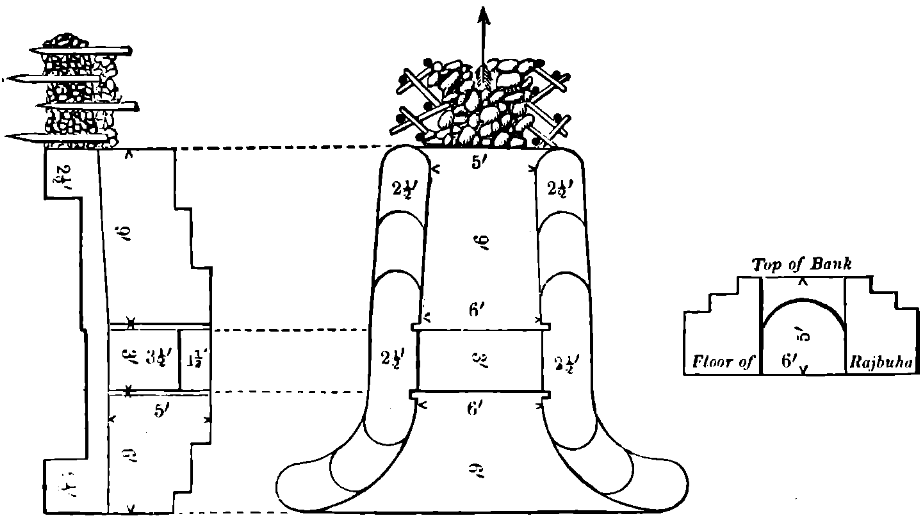
Grooves for planks are on no account to be admitted in the design of these falls, working plans of which will be provided hereafter.

"XIX. Escapes into the side rivers must be designed at numerous points on the main line of rajbuha (vide *x x*, diagram 61); these points should be as near as possible below the junction of a feeder. The width of escape to be 6 feet, with a well-protected tail, as represented in diagram 66.

"XX. In crossing deep hollows where it is necessary to construct an aqueduct for the passage of the rajbuha, it is always desirable to establish an escape *above*, or on the up-stream side of the aqueduct. This escape ought to be built at a point selected for its convenience, and for its offering easy means of delivering the escape water into the low levels with as little wear and tear as possible.

"XXI. The use of the escapes referred to in paragraph 20, ought to be reserved for occasions when the protection of the aqueduct is needed; for this reason, that the situation of these works will be generally a dangerous one, from their proximity to the high embankments.

Diagram 66.



"The escapes described in paragraph 19, are especially designed for relieving the rajbuhas, the main canal, and the country, from excess of water during the rainy months.

"XXII. The method of crossing the branches and escapes connected with the main canal, by combining an aqueduct for the passage of the rajbuha water, with a bridge, will be described, and a design furnished, when the profile of the rajbuhas, as connected with the above lines, is submitted.

"The main line of rajbuha ought, for the sake of economy, to be directed upon the probable site of a bridge on the branch or escape."

The above, in describing the detail of operations required in the making of rajbuhas, will point out the method in which the works are to be executed. It has been before explained, that the whole of these works are the private property of parties unconnected with the government; that instead of making money advances to the irrigators for the purpose of digging watercourses, the failure of which had in the early history of the canals been complete, the government takes the initiative, and has the watercourses, under the name of "rajbuhas," executed for them: the government, in fact, makes the advances in "rajbuhas" instead of in "money." Should the economical and simple designs which are explained in so much detail in the above-quoted memorandum, be viewed with an eye to criticism, or should the minuteness of detail into which I have thought it necessary to enter be considered superfluous, it must be recollected that the circumstances under which the works have been undertaken, and the interests of the irrigators who ultimately have to pay for them, call for the strictest economy in money expenditure.

It would be needless, laying aside the impossibility of doing so, to enter here into the minor details of the irrigation, or of the precise direction of the rajbuhas and their feeders, all of which will depend on the results of surveys, which up to the period that I am now writing (1853–54) have only just been begun. The general outline sufficiently explains the object of the undertaking, and the principles upon which they have been founded.

In looking at that portion of the canal extending from the head of the irrigation at Assoffnuggur to the 110th mile, or to the head of the Bolundshuhur branch, and in estimating the value of a supply, the whole of which is obtained from the heads of falls situated at a considerable distance from each other, I may observe that, independently of the arrangements made at the Assoffnuggur and Dasna rajbuha heads, by which the supply will be greatly facilitated, the position of the heads universally is favourable to obtaining water from the canal channel; those on the right being situated immediately above the bridge of boats, which stretches across the main canal at and below the navigable cut-head; those on the left being connected with the upper revetment of the lock and waste chamber, by the opening and shutting of which their supply will be regulated.

The theoretical supply for each of these heads is equal (as I have explained elsewhere) to $41\frac{1}{4}$ cubic feet per second, or to the irrigation of $(218 \times 41\frac{1}{4})$ 8,992·5 acres; and it will be delivered under such peculiar advantages of slope of country, that those portions of the Mozuffurnuggur and Meerut districts which come under its influence are most favourably situated for irrigation.

The upper, and, in fact, the greater portion of the Mozuffurnuggur district, which will be thus benefited by the Ganges Canal, consists of a light soil, frequently accompanied by *bhoor* or sand-hills, and in the immediate vicinity of the main line in its passage by Togulpoor, Dimat, Chitowra, &c., irrigation from wells is scarce, and very extensive tracts of land are occupied entirely by khureef or rain-weather crops. Canal irrigation will here create an entire revolution in the agriculture of the country, and, as has universally been observed, wherever canals have been carried, a complete change in the level of the spring-water. The cause of this alteration in spring-water level arises, I imagine, from the direct connection of the canal channel with the wells themselves by the substrata of sand or soil of a pervious nature. That we have come in contact with these sandy substrata, and, therefore, with those links by which the wells and canal are connected, sufficient evidence has been provided in the increase of estimates caused by the sandy beds in which the canal channel has been excavated. The strata of sand, judging from the wells and from the outcrop, as exhibited in the scarped faces of the high bank overhanging the Ganges River, underlie the superficial mould throughout the whole of this part of the country; and it is possible that the same cause that influences the spring-water in wells may act in the introduction of springs on the high bank of the Khadir. The nearest approach of the canal channel to this bank is 1¼ mile. In many cases, however, rajbuha lines will run close upon it. We may, therefore, expect leakage, although to an extent which will not, I imagine, be injurious.

In laying out the rajbuhas on this tract of country, the most interesting features appear to be the passage of the West Kalli Nuddi for the purpose of irrigating the country lying on the right of the latter river; and the introduction of irrigation on the section of land lying between the Choiya and the East Kalli Nuddi, especially upon that part of it in the proximity of Haupper, and the government stud-lands.

In both these cases, a leading line might turn the heads of drainage, and be afterwards maintained in supply by feeders carried across the intersecting river by aqueduct. For instance, the head of the Seela Nulla, which lies on the west of Roorkee, might be turned, and irrigation be provided for all the land lying between it and the West Kalli Nuddi; in its passage onwards, the rajbuha would cross the latter river by aqueduct, and in its prolongation down the country lying on the right of the West Kalli, would be met by a feeder carried across the valley near Mozuffurnuggur. This feeder would, on its way, provide irrigation to the country through which it runs, in addition to the supply that it would give to the West Kalli Nuddi rajbuha. It is doubtful whether, for the purposes of aqueduct, the existing bridges on the West Kalli Nuddi might in any way be applicable in using the space under the roadway or their cutwaters as the supports of a water channel; their roadways are in all probability situated on a lower level than that which would be required for the bed of the rajbuha, although even in this case the syphon plan of channel is an available expedient.

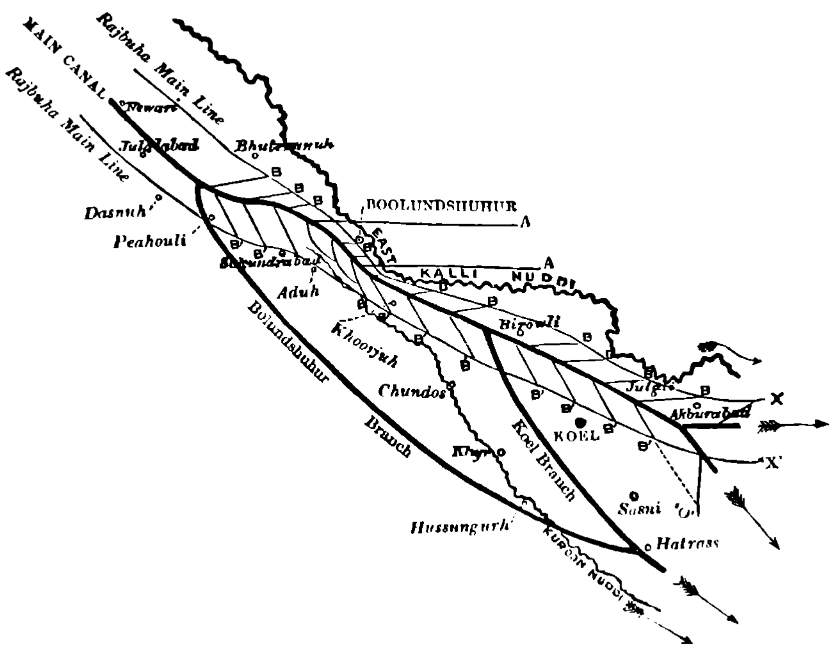
Again, in the case of the Haupper stud-lands, which lie at the junction of the Choiya with the East Kalli Nuddi, as well as for the irrigation of the land lying between these two rivers,—a rajbuha from the Bhola feeder would turn the heads of the Choiya, and might, in prolongation, be not only extended to Haupper, but it might be continued onwards and across the Choiya at some convenient point on its approach to the East Kalli Nuddi. Its tail-water might by these means be brought in circulation through the rajbuhas below. Feeders from the rajbuhas which are situated between the Bhola and Dasna falls might, by being carried across the valley of the Choiya, maintain the Haupper line in an ample state of supply.

On the whole tract of the country, therefore, lying above the 110th mile, or above the Bolundshuhur branch, there appears to be the most perfect means for supplying irrigation.

From the 110th to the 180th mile, or to the Nanoon regulators, facilities for supplying water from the main canal or reservoir are given at almost every bridge—at every one, in fact, where such is necessary. At the crest of the high land overlooking the flats lying at the heads of the Seyngoor, Rinde, and Eesun rivers, the rajbuha heads situated on the upper levels of the Pulra and Simra falls (the general design of which is similar to those at the falls before described) give a command of water for irrigation sufficient to maintain the main rajbuha lines below them in full supply. I do not in this place advert to the Bolundshuhur and Koel branches, which are specifically attached to the Hatrass irrigation, under which they will be described hereafter.

Between the points above described, the main line of canal runs with the East Kalli Nuddi on its left, and the Kuroon and the Bolundshuhur and Koel branch irrigation on its right;—the East Kalli Nuddi being at one point within $1\frac{1}{4}$ mile of the canal channel. The East Kalli Nuddi, on all this line, passes through a wide tract of khadir land, depressed more or less below the surface of the country upon which the canal runs, and sufficiently so at all points to give the fullest facilities for enabling the engineer to pass it by aqueducts. The works for this purpose would consist of raised earthen channels, with masonry at their points of immediate contact with the river. The rajbuha works on the Eastern Jumna Canal

Diagram 67.



offer so many examples of apparent difficulties of this sort having been overcome without the slightest trouble, and at a comparatively very small expense, that I should not hesitate in treating the East Kalli Nuddi and its inauspicious-looking khadir with the utmost indifference. Rajbuhas, therefore, I should say, would be carried from the main line of canal boldly across the valley for the irrigation of the country on its left bank. I would especially select the neighbourhood of *Mamun*, where the proximity of the canal and the khadir is at a minimum, for the site of one of the leading aqueducts over the valley. The rajbuha heads above this point would act as feeders to supply this aqueduct; the width of its channel might be 10 feet. The design for the distribution of the rajbuha lines on this tract may be best described by the preceding diagram.

The above sketch is supposititious altogether, but it shows that at those points where the canal and East Kalli Nuddi come in the closest proximity, I would propose aqueduct lines for passing the river; these in the above diagram are marked A A, and their number might be extended to any required amount adapted to the supply of water that is available. The country, it will be recollected, claims a theoretical right of irrigation on a belt of five miles from the canal boundaries. A consideration of this circumstance will lead to the calculation of how much water ought to cross the East Kalli Nuddi, so as to irrigate the lands which come within this belt; and consequently what extent of aqueduct is sufficient for the purpose. The feeders are shown by the line B B. The consecutive line marked B B B is in prolongation of the main rajbuha on the left, which I have before described as commencing at the head of the Assoffnuggur falls. The above merely presents a general view of the lining out of the rajbuhas on the left of the canal, but it may be worked out into a well-combined and comprehensive series of channels the waters of which are in free circulation.

On the right of the canal, and keeping in mind that the Bolundshuhur and Koel branches act as irrigating lines for the country lying parallel to the Kuroon, and that, agreeably to the project, the theoretical area to be irrigated by the main line is limited to a belt five miles in width, the line B′B′B′, which is a continuation of the main rajbuha west from Assoffnuggur, after crossing the Bolundshuhur branch, either by an under tunnel, or by an aqueduct (which might be built in connection with the Chourah bridge, or with that which is situated about three miles from the head of the branch), would proceed onwards, keeping within the legitimate five miles, and in a direction parallel to the main canal. In the same way that the Bolundshuhur branch was passed, that of Koel would be passed also, and this great western line of rajbuha would ultimately either cross the Etawah terminal line, and maintain its prolongation downwards, as shown in the diagram at ‘X,’ or it would fall into the leading rajbuha attached to the Etawah terminal line, with which it would form a junction, as represented in the diagram at ‘O.’ To this main line the rajbuhas at the different bridges would act as feeders, and the whole of the irrigating lines on this tract of the canal would be placed in one great connected series, through which the water would flow, with an uninterrupted circulation.

From both the main lines which I have described, and represented in the diagram as B B B on the left, and B′ B′ B′ on the right of the canal, escapes (the former into the East Kalli Nuddi, and the latter into the Kuroon) ought to be established at every available point. These escapes might with advantage be situated at every six miles on the course of the main rajbuhas, and this distance perhaps could not well be exceeded.

The above gives a general idea of my views of the distribution of the rajbuhas on the main canal: we now come to that on the terminal lines, which brings us to the third section of this paper, in which the irrigation is derived from rajbuha heads at the different bridges, unaided by the intervention of masonry descents, or of rapid slope in the surface of the country.

III. In the former section we obtained a great command over the country by the extraordinary slope which it naturally possesses. This enabled us to restrict the rajbuha heads to those points which were best adapted for giving command, whilst at the same time it gave an impetus to the circulation, by enabling us to maintain a head and constant supply under very peculiar advantages.

In the Cawnpoor and Etawah irrigation these advantages are wanting; but we, nevertheless, from continuing the rajbuhas in an unbroken line from the Pulra and Simra falls downwards, derive the full benefit of the command which their elevated position enables them to give.

The rajbuha heads, on the Cawnpoor terminal, are situated at every bridge, or at a distance of about three miles apart; their dimensions, on the first 30 miles of its course, are similar to those of the main line—that is to say, their width of channel is 10 feet, and the height of their floorings above the canal bed is 24 inches.

From the 30th to the 90th mile the width of channel is reduced to 6 feet, and the sill or flooring is 16 inches above the canal bed.

From the 90th to the 150th mile, the width of channel is 6 feet, and the sill is 8 inches above the canal bed.

From the 150th mile to the terminus, the channel is 6 feet wide, and the sill and canal bed are on one level; with the exception of the head of the Pandoo and Ganges irrigation, to which I shall advert hereafter, the above dimensions hold good throughout the whole course of the terminal line.

The slope of the country, from Nanoon to the immediate neighbourhood of Cawnpoor, varies from 15 to 12 inches per mile, the greater portion being on the minimum slope. To gain, therefore, the requisite advantages from rajbuha irrigation, it will be necessary to reduce the slopes of the rajbuha channels to a minimum, which I should fix at 6 inches per mile. This, in the first 70 miles of the branch, would on each mile give the rajbuha channel a command over that of the reservoir from which it was supplied, of 9 inches. Supposing, therefore, that the average level of the canal or reservoir bed was 7 feet below the surface of the country, the rajbuha channel must lie 9⅓ miles in length before its bed would strike out upon the surface of the country. From the 70th mile downwards, where, from the surface slope being only 12 inches per mile, we could only give 6 inches of command on each mile in length of the rajbuha, fourteen (14) miles in length would be necessary to obtain the result above described. With a depth of water in the rajbuha equal to 3 feet, which we may fairly take as an average, the above length will be reduced, in the first case, to 5⅓, and in the latter, to 8 miles; which we may consider as the points at which tor or surface irrigation would be available, with slopes of 15 and 12 inches per mile. At the Kylunpoor Bridge, however, the fall of 2 feet will give increased command to the rajbuhas lying above it. In this case, the distance at which tor-water will be delivered becomes reduced from 5⅓ to 2⅔ miles. Advantages of an equally favourable nature will exist at the 91st mile, from whence tor-water will be delivered at a distance of 5⅓ instead of 8 miles. It will be very evident, therefore, that if a proper use is made of the main lines of rajbuha which come from the higher levels of the upper country, and if these main lines are kept well supplied from the feeders which have been so liberally scattered over the whole length of the canal, irrigation will be obtained with facility on the whole surface of the land which comes under their influence.

Commencing, therefore, with the left of the Cawnpoor terminal, in explanation of the general views that I entertain of the distribution of the channels: in prolongation of B B B, and from its termination X, in the above diagram, I would carry the main or eastern Assoffnuggur rajbuha (as it may be still called) straight forward, keeping it altogether to the left, and free from the heads of the Rinde and the Eesun rivers. The former, I have before explained, lie to the north of Nanoon and Akrabad; the latter are situated in the neighbourhood of Sikundra Rao. This main line would proceed onwards, keeping to the most approved or summit levels of the strip of land lying between the Eesun and the East Kalli Nuddi. I apprehend that the course would be in approximation to the latter; that it would pass to the north of the towns of Eyta, Kooraoli, Bhongaon, Bewur, Chubramow, and onwards, keeping to the south of the ruins of Kunoge. It would terminate in the low ground of either the Ganges, or of the Eesun, in its proximity to it.

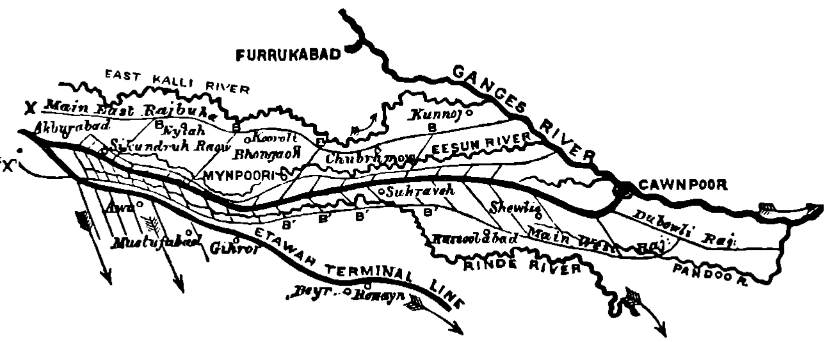
I should treat the Eesun in the same way as I did the East Kalli Nuddi, as described in Section II., and as figured in diagram 67. Feeders from the main rajbuha would be carried boldly across the valley, under precisely the same rules as those laid down for the irrigation above the Nanoon regulators, restricting the points of aqueduct to those where the line of canal and the valley of the river are in the closest contiguity, and retaining the rajbuhas at the intermediate points as feeders for the aqueduct lines.

The rajbuha from the Ootha Bridge, or that which is situated at the 130th mile, would probably be the last in connection with the main rajbuha, or that running between the East Kalli Nuddi and the Eesun. The Ootha feeder would, in all probability, cross the Eesun by aqueduct, and act as the last of a series in which the east Assoffnuggur rajbuha is the prominent feature.

Below the Ootha Bridge the rajbuha heads would provide irrigation for the tract between the Noon and the Eesun; those situated at the Munowa and Kukwan Bridges acting as the heads of supply for a main channel that would turn the low ground, constituting the heads of the Noon, and in which that river takes its rise; those lying below Kukwan acting on the usual plan as feeders, by crossing the Noon by aqueduct.

A general sketch of the irrigation on this part of the Cawnpoor terminal line is shown in the following diagram:—

Diagram 68.



On the right of the Cawnpoor terminal, the irrigation and the detail of the rajbuhas are, for the first 65 miles, somewhat more complicated; they are entirely regulated by the Etawah terminal, which is, as I have elsewhere described, in close connection with the Hatrass irrigation, to which the first 65 miles of its course are especially devoted.

The capacity of the channel of the Etawah terminal line has been designed with reference to the irrigation tending to the Jumna side of the Doab; to which, immediately after its departure from the head at Nanoon, it will be expected to throw off large supplies. The greater part of the land lying between the Cawnpoor and Etawah terminals, from their separation to a point 65 miles below, will be irrigated entirely from the former. The width of country that separates these two lines does not exceed in average 5½ miles, and it contains, on its whole length, the Rinde River. This river will have to be crossed on the same plan as proposed for the East Kalli Nuddi and the Eesun, and should the west Assoffnuggur rajbuha be prolonged and carried over the Etawah terminal, instead of being dropped into one of its rajbuhas, this main line would continue on the right of the Rinde, would sweep through the sections of land formed by the Ahneea and Phoora rivers, would cross these two rivers on their approach in one channel to the Rinde, and would ultimately proceed onwards, as the main line of rajbuha towards the eastern portion of the Ghatumpoor purgunna.

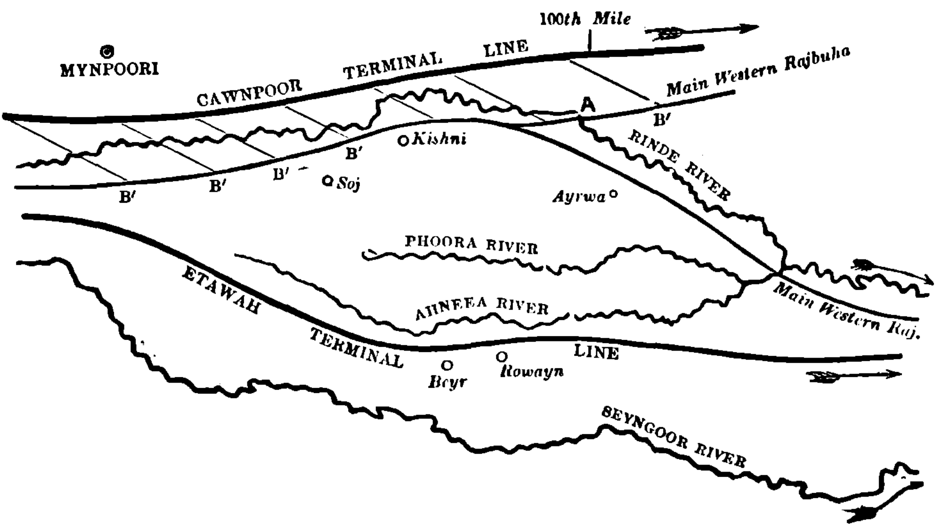
It will be understood, however, that, on the first 65 miles, the Cawnpoor terminal will supply irrigation for all the tract lying between the two terminal lines; and that the rajbuha heads, on its right bank, will act as feeders to the great western Assoffnuggur line, which will run on the right of the Rinde.

In advance of the 65th mile, the Cawnpoor terminal continues its course in close approximation to the Rinde, coming nearly in contact with it at the 85th mile, at a point opposite the town of Kishni, and continues even as far as the 100th mile in such close contiguity, that the rajbuhas on the right will naturally cross the Rinde, and act as feeders to the great line of rajbuha which I have above described as sweeping through the country near the Ahneea River.

From the starting point at Nanoon, therefore, as far down its course as the 100th mile, the rajbuha heads, on the right of the Cawnpoor terminal, will act as feeders to the main rajbuha, which runs on the opposite side of the Rinde; the detail of aqueduct arrangements being regulated on the principles before suggested.

It is desirable, for the purpose of retaining the command of water that the great western Assoffnuggur rajbuha holds at this point, to carry it forward, and take it across the Rinde by an aqueduct, as shown in the following diagram at A. A branch line of equal capacity of channel, however, would be continued onwards, on the right of and in parallelism to the Rinde, leaving the

Diagram 69.



town of Ayrwa on the right, and (as described before) crossing the Phoora and Ahneea immediately above their junction with the Rinde. This branch is the main line for the ultimate irrigation of the eastern portion of the Ghatumpoor purgunna.

From the aqueduct at A the main rajbuha would be carried round the heads of the Pandoo, and keeping on the right of that river it would pass the town of Shewli. From thence leaving Suchindi on its right, it would cross the Pandoo River by aqueduct, and would ultimately form a junction with the Dubowli rajbuha; a main line which, passing through the country between the Pandoo and Ganges, terminates the Cawnpoor irrigation.

The direction with reference to the towns of Shewli and Suchindi, will require to be fixed by careful and accurate survey. Both my own and Mr. Dodsworth's maps of the country lying on the right of the Pandoo will afford good groundwork for determining the best direction for the rajbuhas. The country, however, is much cut up by drainage, the whole tending towards the Rinde. The line will, I imagine, cross the Pandoo in the vicinity of the village of Newri, or not very far from it. The Pandoo is a river that carries a good deal of water during floods, and it would be advisable to select a point for the aqueduct crossing where the section is capacious, and in designing the building to make it as free from obstruction as possible. For this purpose (as well, I may say, as for the same purpose in all cases connected with these rivers) I would use a sheet-iron channel resting on masonry piers in preference to arches, which, with their spandrils, occupy so much space and offer so much obstruction to the waterway.

The detail of feeders from the Cawnpoor terminal, for maintaining the supply in a state of efficiency, would be similar to that before described; the Pandoo River would be crossed at convenient points by aqueducts, and the channels from the intermediate rajbuha heads would act as feeders to the aqueduct lines.

The heads of the rajbuhas on the right of the Cawnpoor terminal end at the Dubowli regulator. Here there is a bridge with a drop-gate, fixed just below a rajbuha head. This head acts as the supply for a main line extending down the section of land enclosed between the Pandoo and the Ganges up to their junction. The waterway is 10 feet, with its sill on a level with the bed of the canal. The disposition of the works at this point is planned with reference to maintaining a constant supply for navigation to the heads of the Cawnpoor lockage, and at the same time to afford provision for all the spare water to pass off to the irrigation of the lands on the above-mentioned tracts. The closing of the gate or shutter in cases of drought, and in emergencies when water is not required at the works in Cawnpoor, admits of the whole of the tail-water being passed off for irrigation on the Dubowli rajbuha. This line, after leaving the Dubowli regulator, would be carried on the summit levels of the country lying between the Pandoo and the Ganges; it would in its course be joined by the great western Assoffnuggur rajbuha, which has been above described, and its tail-water would ultimately be conducted into the Pandoo, on the boundary of the Cawnpoor and Futtipoor districts.

I may observe that with reference to the sanatory laws laid down for the prevention of irrigation in the vicinity of towns, the rajbuha heads on the left of the Cawnpoor terminal, end at the Muswanpoor Bridge, or at a point situated three miles from the head of the Cawnpoor works at the village of Dubowli.

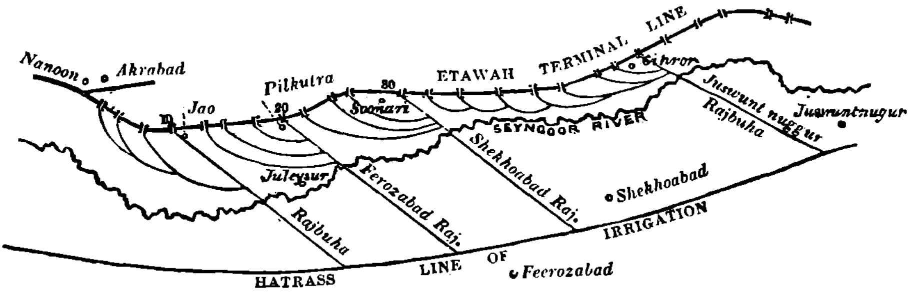
From the above description, it will be seen that the main rajbuhas on the right and left, which leave the canal at the head of the Assoffnuggur falls, continue in uninterrupted lines the whole way down the country, maintaining their course parallel to the main canals or reservoirs of supply: on the left, to the separation of the main trunk at Nanoon, at which point the line takes a departure to the left, keeping to the vicinity of the East Kalli Nuddi, and terminating in the ravines and low land connected with the Ganges and Eesun: on the right, maintaining an equally parallel course on a much greater extent, even to the neighbourhood of Cawnpoor, at which point it forms a junction with the Dubowli rajbuha, and passes off in connection with that line into the Pandoo.

The detail of rajbuha heads, their position relatively to bridges, their dimensions, and the general arrangements connected with discharge, are, on the Etawah, precisely the same as on the Cawnpoor terminal line.

I have, in the former chapter, as well as in that under the head of the Bolundshuhur and Koel branches, drawn attention to some of the leading points connected with the distribution of the water from the Etawah terminal, and in the detail of the works. I have in a general way pointed out the method that could be adopted for maintaining a sufficient supply for lands lying at a distance from the main canal. It will be sufficient, therefore, in this place, whilst recapitulating the different details, to bring the whole under review as one comprehensive scheme of irrigation.

From what was said before, it will be understood that on the leading 65 miles of the course of the Etawah terminal, the supply for irrigation will be almost entirely drawn from the rajbuha heads on its right bank. This supply, which is intended to be free and continuous, is, in fact, the source upon which the Hatrass line of irrigation will depend for its existence. On the principles above described, the Seyngoor will be crossed by aqueducts, and these aqueduct lines (which I propose to make 10 feet in width) will be kept in supply by the intermediate rajbuhas, which will meet the aqueduct line on the canal side of the Seyngoor valley. I have supposed that four aqueducts, with a waterway of 40 feet in width, in the aggregate, would be sufficient for the Hatrass irrigation on the first 65 miles of the course of the Etawah terminal. The position of the four aqueducts, with their feeders, may be shown in a diagram, the four main lines being designated by the leading towns or places upon which or from which they are directed.

Diagram 70.



The mere numerical extent to which these aqueduct lines are carried is, however, a question of economy, either in the expenditure of money on the works themselves, or on that of water; the detail, therefore, must necessarily be left to the future. The capacity of the Etawah terminal, however, has been determined on the large and efficient supply which must necessarily be extracted for the purpose of the Hatrass irrigation; and I consider that as far as the 100th mile of the course of the terminal line, it is available in the fullest possible way for affording supplies to as many aqueduct lines as can conveniently and economically be pushed over the Seyngoor valley.

The Western Assoffnuggur rajbuha, which crosses the Etawah terminal, and proceeds forwards on the right bank of the Rinde, is on the first 65 miles of its course supplied almost entirely from the Cawnpoor terminal; it will be connected with that of the Etawah, by numerous feeders from the rajbuha heads lying on the left of that line, but the supply to be obtained from this source is looked upon as one of emergency rather than one of necessity.

At the 65th mile, the Assoffnuggur rajbuha, which, it will be understood, is still the main line for irrigation, instead of proceeding parallel with the Etawah terminal, retains its parallelism with the Rinde, piercing the lands intercepted by the Phoora and Ahneea Rivers. As has been before explained, this Western Assoffnuggur rajbuha crosses the Rinde by an aqueduct near the town of Ayrwa, having previously thrown off a branch which continues its parallelism to the Rinde, regaining its position relative to the Etawah terminal by crossing the above two rivers at a point below their junction.

To the above rajbuha, the Etawah branch will, from the Gihror to the Gangsi Bridges, provide a full supply from each of the intermediate rajbuha heads. A further supply will be delivered by aqueduct from the heads between the Gangsi and the Uchuldi Bridges across the Ahneea, to the strip of land lying between that river and the Phoora. The main rajbuha will be kept well supplied with water from the Cawnpoor terminal line (as described in a former paragraph) by aqueduct lines carried across the Rinde in the neighbourhood of Kishni, Sukrava, &c.

Confining my description to the irrigation lying on left of the Etawah terminal, the main rajbuha, after passing the Ahneea River, proceeds onwards between that line and the Rinde, receiving on its course a supply from the different rajbuha heads, until it has passed the Sithmurra escape. At this point, instead of proceeding onwards parallel to the canal, it pursues the course of the Rinde in the same way that it did on the former occasion, keeping on the summit level of the tract of land lying between the Noon and the Rinde. From the different rajbuha heads situated above the town of Ukburpoor, this main line of rajbuha and its different branches will receive their supplies. This main line will provide irrigation for all the eastern portion of the Ghatumpoor purgunna, and it will be aided in this by cuts for irrigation taken from the different rajbuha heads lying between Ukburpoor and the canal terminus.

By the above arrangement, the Assoffnuggur west rajbuha, or rather that branch from it which commences from the town of Ayrwa, will terminate, after having run continuously for a distance of 330 miles, in the ravines of either the Rinde or the Jumna, in the neighbourhood of Jar.

Looking to the right of the Etawah terminal, it has been shown that the first 65 miles of its irrigation will be almost entirely devoted to the Hatrass line of irrigation, and that even as far as the 100th mile, or up to the Mulhosi escape, the above line will be supplied by feeders taken from the terminal by aqueduct across the Seyngoor. This system, however, which leads to the necessity of such a large quantity of water being taken for the irrigation of the country lying on the right bank of the Seyngoor, makes provision also for the lands which lie intermediate, all of which have the means of irrigation provided by the main aqueduct line as well as by its feeders. To the extent, therefore, of the supply of water, the whole tract of country lying on the right of the Etawah terminal from the 1st to the 100th mile of its course will be irrigated.

In advance of the 100th mile, keeping in view the advantages of securing a thorough circulation of fluid, and the consequent necessity of maintaining a main rajbuha, or as we may term it, a catch channel for the spare water of the different feeders, I would adopt the last, or the Oorya aqueduct line, as the source of a connected series of rajbuhas which should extend from that point to the terminus at the Jumna.

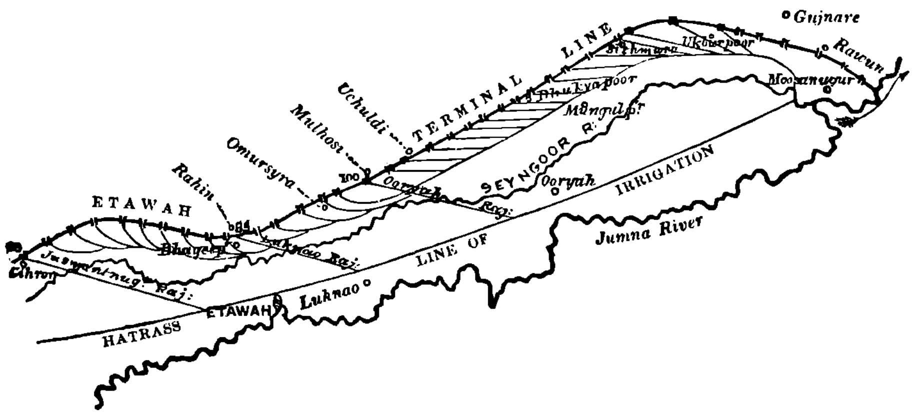
I imagine that this last line will leave the Etawah terminal at the Mulhosi Bridge, and that it will join the Hatrass line of irrigation near the town of Oorya, having, previously to its reaching the aqueduct by which it will cross the Seyngoor, provided the means of irrigation to the land in the neighbourhood of the town of Puhpoond. The total length of this (as it may be called, the terminating, or Oorya) aqueduct will be about 27 miles; in its course it will receive supplies from the different rajbuha feeders lying between it and the aqueduct line that joined the Hatrass branch at the town of Luknao. The capacity of these aqueduct channels ought to be at least 10 feet in width from the junction of the feeders; and I would not in any case make the masonry or iron passages over the Seyngoor River less in width than 10 feet.

From this Oorya rajbuha a main cut would be led off at a point about three miles from its departure from the terminal; it should run parallel to the canal at a similar distance, receiving in its passage a supply from each of the rajbuha heads of the different bridges. This main cut would probably rejoin the terminal at a point below the town of Ukburpoor, or it might terminate in the same way as the main rajbuha on the left, by falling into the ravines of the Seyngoor in the neighbourhood of the village of Jinsen, or in those still farther on, near the town of Moosanuggur.

The lining out of rajbuhas on the plan that I have represented, necessitates the crossing by aqueduct of every tributary, to which the main rajbuhas run at right angles, but this crossing by aqueduct is by no means a very expensive, or a very difficult operation, and its advantages are so great in enabling us to provide a main line well supplied by feeders in a position capable of pouring water into every corner of the land, that I don't object even to a moderate excess of outlay on aqueducts, if the advantages above described are well secured.

The rajbuha irrigation from the Bolundshuhur and Koel branches will be conducted on the same principles as those above described, viz. by parallel lines of main rajbuha supplied by feeders from the different heads; these, however, will cease in the first case on the right bank of the Kuroon, and before the branch reaches that river; and in the latter at the junction of the two branches. In advance of this junction, the Hatrass line will deliver its water for irrigation immediately from the main channel, which is supplied, as above described, by feeders from the Etawah terminal. The description, however, will be more distinct by the following diagram, which represents an outline of the system of proposed irrigation from the Juswuntnuggur rajbuha at the 65th mile to the extreme end at Ukburpoor and Moosanuggur.

Diagram 71.

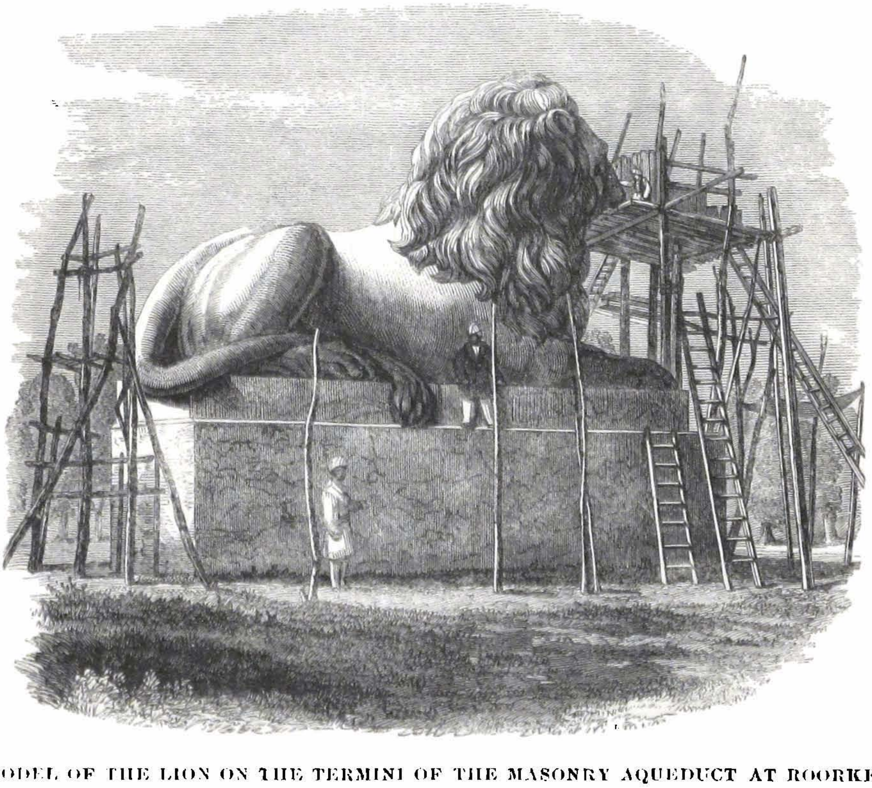


The Futtigurh branch, which leaves the main canal at the 50th mile of its course, and runs on the water-shed or summit level of the section of the country bordered by the East Kalli Nuddi and the Ganges, will embrace an equally comprehensive system of irrigation, carried out on the same plan as has been described before. This branch is proposed to terminate at the 160th mile of its course as an irrigating medium; the channel in prolongation being specifically designed for boats, rafts, &c., and for the purpose of connecting Futtigurh with the main trunk by water carriage.

From the departure of this branch, therefore, from the main canal at Jaoli, or, rather I should say, from the head of the falls which are situated below it, main lines of rajbuha would be carried on the right and left parallel to the course of the branch, receiving their supply from each rajbuha head in succession. The main lines would terminate in the navigable channel, at some convenient point below the 160th mile. The system of rajbuhas and feeders, with a complete circulation of the current would be maintained on the Futtigurh branch, as it has been proposed to be done on the whole of the canal series.

Some apology is necessary for the length to which this chapter on rajbuhas has been extended; it has not arisen from any intention of laying down definite rules; nor presumption that any experience I may possess may warrant even an attempt at fixing the position of lines, or determining the distribution of water. These must necessarily depend, not only on the result of carefully acquired field observations, but on the wants of the country, and on the natural qualifications of land for receiving irrigation. My reason for entering into so much detail is, the recognized fact, that a plan once laid down offers a base upon which something may be constructed; if the plan shows nothing but the ignorance of the designer, it has the merit of pointing out the evils to be guarded against; if generally or only moderately applicable to the purpose, it relieves others from preliminary and rudimentary trouble, and enables the mind to be employed on improving that of which the original is the mere groundwork.

In the present case, the interference of rivers, and the peculiarly narrow sections of country through which the main canals take their course, render the distribution of the rajbuhas a somewhat complicated question; it is one that has given me much thought, and the conclusions at which I have arrived are the results of mature and deliberate consideration. The general principles are derived from those which originated on the Eastern Jumna Canal, and which have been attended with the greatest success, not only in economizing the supply, and in facilitating the distribution of water to the cultivators, but in protecting the interests of both the government and those who are dependent upon the canals for irrigation. The details will offer a skeleton for operations and a groundwork for bringing to completion that which I have only within the last year begun; and I shall have explained myself very imperfectly if these details are viewed in any other light than the merest possible outlines on which one general and comprehensive series of watercourses (embracing throughout a free and uninterrupted circulation of current) has been contemplated.



MODEL OF THE LION ON THE TERMINI OF THE MASONRY AQUEDUCT AT ROORKEE

(Designed and constructed by Lieutenant George Price, 1st Fusiliers).

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