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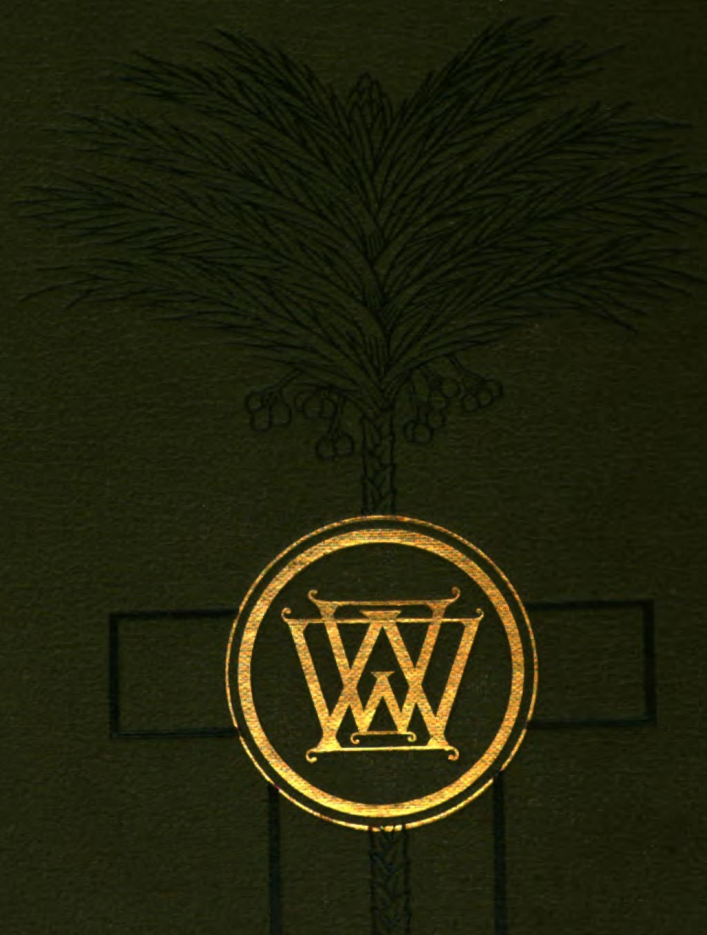
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THE IRRIGATION OF MESOPOTAMIA



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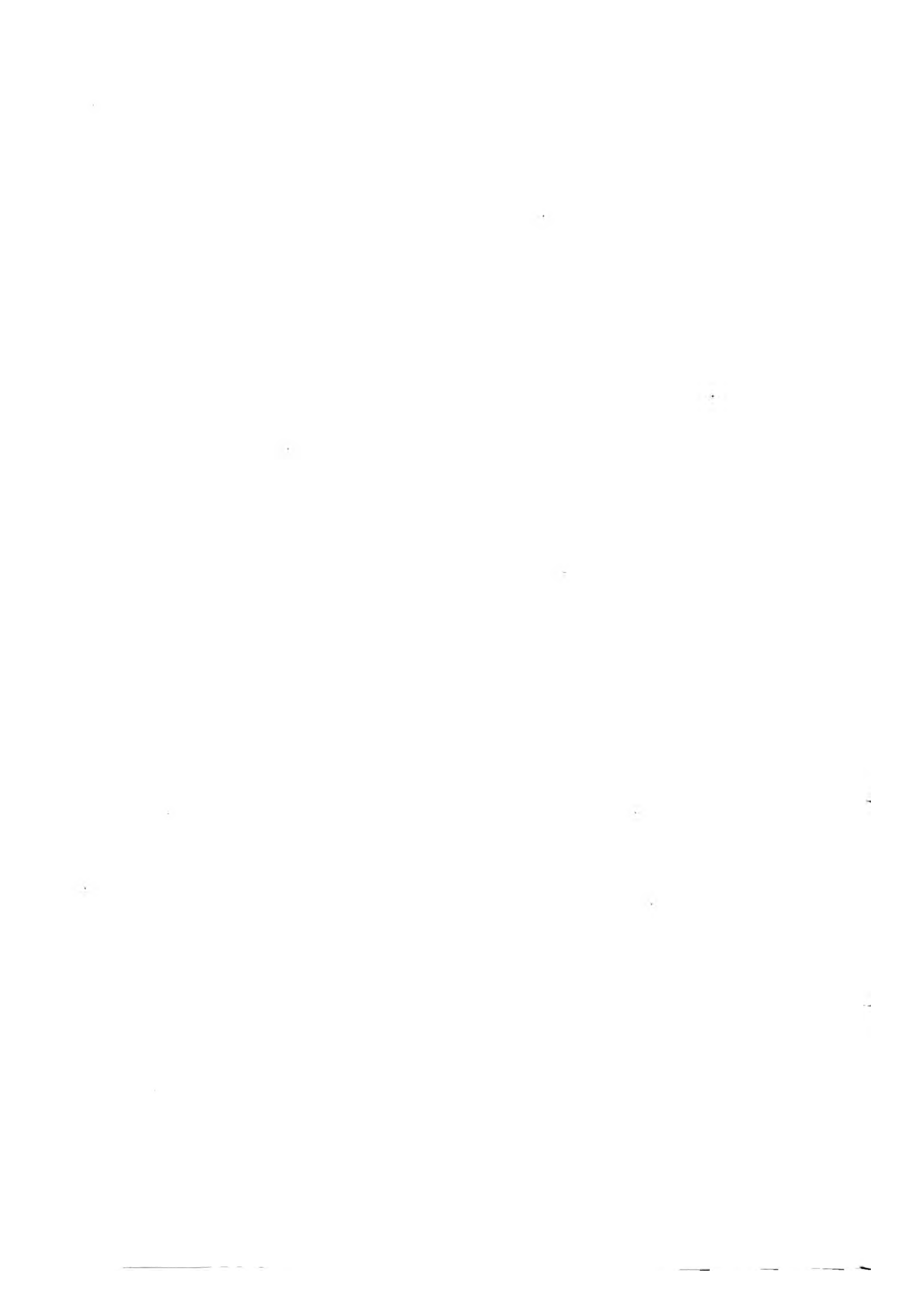
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THE IRRIGATION OF MESOPOTAMIA

20/- NET

PLATES IN PORTFOLIO

THE
IRRIGATION OF MESOPOTAMIA



THE
IRRIGATION OF MESOPOTAMIA

BY
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WITH 46 PLATES IN PORTFOLIO



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1911



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REPORT

ON THE

IRRIGATION OF MESOPOTAMIA

1. **Introduction.**—"We have done with the romance of the Revolution, we must now commence its history. We must have eyes only for what is real and practicable....." With such words Napoleon met his first Council of State, and, struck by their wisdom, I have put them in the forefront of my work. With me, too, the romance of this ancient country has passed away and I confine myself to projects which are real and practicable.

No irrigation engineer who has travelled through Mesopotamia can have failed to have been struck by the great difference between the delta of the Nile and the joint deltas of the Euphrates and Tigris. The Nile is in flood from August to October, and the turbid waters can be retained on the land in the historical basins of Egypt and discharged back into the falling river in November. This permits of the winter cultivation, without further irrigation, of rich fields of wheat, barley, beans and clover.

Such a system of irrigation is impossible in Mesopotamia. The rivers are in flood in March, April and May, while the floods are followed by the burning and rainless months of June, July and August, in which irrigation must be practised if any crop is to be brought to maturity. So that while Egypt was for thousands of years the home of basin irrigation, Mesopotamia was the home of perennial irrigation.

According to Herodotus the whole country was studded with "a vast number of great cities" and grain commonly returned two hundredfold to the sower. Cultivation depended on irrigation which was supplied by a large number of canals. Pliny and Berosus are eloquent on the subject of the agricultural wealth of the country. And Ammianus

Marcellinus states that from the point reached by Julian's army to the shores of the Persian Gulf was one continuous forest of verdure.

To-day the traveller contemplates a different landscape.

Beginning at Beled, the Delta first consists of bare plains of clay with the silt banks of countless canals, showing what a desperate fight the wretched agriculturists made for existence when the dams were carried away and the level of the water fell. We have then alternate stretches of level country covered with a thorny leguminous plant which dies down in winter, and the same bare plains which we met in the north. Near the rivers are jungles of liquorice plant and the same leguminous thorn. On the rivers themselves, but especially on the Euphrates, wherever there is a foreshore, there is a luxuriant growth of poplars and sometimes of willows. On the Upper Euphrates, and as one approaches Babylon, we have great stretches of salted land interspersed with bare plains and low sand-drifts. All this land is capable of easy levelling and reclamation. The presence of 15 % lime in the soil renders reclamation very easy compared with similar work in the dense clays of Egypt. One is never far away from the giant banks of old canals and the ruins of ancient towns. As one goes south the salted land increases in area, and then the marshes begin with their stretches of rice.

Though there are date groves and stretches of cultivation along the river banks in places, and along a small number of canals, it is only when one approaches the low-lying marshes traversed by the Euphrates and the Shaat el Arab that one sees extensive date groves and gardens mingled with wheat and clover, and a look of prosperity which brings back the memory of ancient days. And it is worthy of remark that the earliest settlers clustered round just those very reaches of the river where cultivation is fully developed to-day. The locality has shifted nearer the sea, but the conditions of irrigation are the same. Suk el Sheyook to-day must be very like what Erech, Niffur, Lagash and Ur of the Chaldees were in ancient days.

2. Nomenclature.—The Mesopotamia treated in this report is the true delta of the rivers Euphrates and Tigris, and comprises the country traversed by the two rivers and their branches southwards of Hitt, on the Euphrates, and Samarra, on the Tigris. From Hitt to the south of Mosaib and Samawa, the Euphrates divides into two

branches; the right hand one is the Hindia branch and the left hand one is the Hilla or ancient Babylon branch. From Samawa to Garmat Ali, near Basra, is the Euphrates again. The junction of the Tigris and Euphrates used to be at Gurna; it is to-day at Garmat Ali, but there is a navigable backwater at Gurna, and the river from Gurna to the sea is known as the Shaat el Arab.

From Samarra to Gurna, past Bagdad and Amara, is the Tigris. The Hai canal leaves the Tigris at Koot and flows into the Euphrates near Nasria.

The Adhaim river is a tributary of the Tigris and joins the latter to the north of Bagdad. The Dyala is another tributary of the Tigris and joins the latter downstream of Bagdad.

3. The Delta an arid region.—The Tigris-Euphrates Delta may be classed as an arid region of some 5,000,000 hectares. A part of this area is the delta of the Dyala. This latter is well irrigated by the Khalis, Khorassan and Beled Ruz canals and needs only good regulating heads, bridges and drains to be an area of first class irrigated land. Another area of well irrigated land is the lower Euphrates from Nasria to Suk el Sheyook, and the Shaat el Arab along nearly its whole length. The swamps traversed by the Hindia branch of the Euphrates and the branches of the Tigris below Amara contain large areas of rice. A fair amount of irrigation is performed by "Chareds" worked by mules and oxen along the whole length of the Euphrates, and in scattered places on the Tigris. All these areas together form but a small fraction of the delta which is in need of irrigation on broad lines, ~~if anything is ever to be made of it~~

Correction.

Page 6, line 2 from foot :—*Instead of* "From Hitt to the south of Mosaib and Samawa, the Euphrates divides into two branches," *read* "From Hitt to the south of Mosaib is the Euphrates. Between the south of Mosaib and Samawa the Euphrates divides into two branches;"

4. **Discharges of the rivers.**—Our work in the country has not been of sufficient duration to enable us to make absolutely reliable discharge tables for the two rivers, but we have taken many discharges which are given in Appendix P, and from these I have calculated the following table:—

Discharge table of the Tigris at Bagdad and the Euphrates at Hitt.

THE TIGRIS AT BAGDAD.			THE EUPHRATES AT HITT.		
R. L.	Discharges cubic metres per second.		R. L.	Discharges cubic metres per second.	
	ordinary.	in quick rises.		ordinary.	in quick rises.
28·0	250				
·5	300				
29·0	400		51·0	270	
·5	540		·5	340	
30·0	680	900	52·0	500	
·5	850	1,200	·5	730	
31·0	1,040	1,500	53·0	1,000	
·5	1,240	1,880	·5	1,330	1,970
32·0	1,470	2,340	54·0	1,670	2,400
·5	1,730	2,950	·5	2,015	2,900
33·0	2,040	3,450	55·0	2,370	3,470
·5	2,560	4,080	·5	2,770	3,740
34·0	3,240	4,780	56·0	3,200	3,930
·5	4,050	5,350	·5	— 4,000 —	
35·0	— 5,500 —				

The R.L. of the zero of the gauge at the British Residency at Bagdad is 28·06; this gauge has been read since 1906.

Drawings Nos. 62, 63, and 64 give the gauge diagrams for the Tigris at Bagdad, the Euphrates at Hitt, and again the Euphrates at the Hindia Barrage.

The discharge of the Tigris as it enters its delta at Beled, south of Samarra, is considerably in excess of that at Bagdad. When the river reaches a certain point, it bursts its banks north of Bagdad and overflows the country. The river has been below the average for both the seasons that we have observed it, and we have had no opportunity

of finding out what the actual discharge of the Tigris is in high floods as it enters its delta. From the discharge tables given above and the gauge diagrams I calculate the volume carried by the two rivers as follows :—

Mean daily discharge in cubic metres per second.

	TIGRIS AT BAGDAD.	EUPHRATES.	TOTAL.
January	450	500	950
February	1,400	1,000	2,400
March	1,750	1,250	3,000
April	3,000	2,750	5,750
May	2,750	2,500	5,250
June	1,750	1,750	3,500
July	1,000	1,000	2,000
August	500	550	1,050
September	400	450	850
October	300	400	700
November	400	500	900
December	450	500	950
Year	1,180	1,095	2,275

With the aid of the gauge diagrams for Bagdad, which have been read for five years, we have made allowances for the fact that on the Euphrates, the only two years for which we have gauges, the river in flood has been below its average.

5. Area capable of being irrigated.—Assuming that the duty of water in Mesopotamia would be the same as that of the hottest and driest parts of the Nile Valley near Luxor, we may say that one cubic metre per second of water will, in winter, irrigate 3,000 hectares, and in summer 400 hectares of rice, or 1,250 hectares of dry crops, such as millets, sesame, etc. Using the discharge tables of the two rivers given above, we may say that the water supply will permit of 3,000,000 hectares of winter crops, while the summer discharge will permit of 400,000 hectares of rice or 1,250,000 hectares of millet, sesame, cotton, etc.

During the winter months, as a general rule, the rainfall is a not inconsiderable factor in the success of the crops ; and over large areas

of Mesopotamia barley is sown and matured in sole dependance on the winter rainfall, which is considerable enough to allow of the deserts of the country being classed, not as absolute deserts like those of Egypt, but as steppes capable of sustaining millions of sheep. In years of exceptional drought, however, the parts of the delta liable to inundation in flood are the great stand by of the pastoral wealth of the country.

6. Whole Delta incapable of being irrigated simultaneously.—It will be evident from the preceding paragraph that the whole of the area of 5,000,000 hectares in the Delta is not capable of being irrigated at the same time ; and in a comprehensive scheme for the whole Delta the first point is to decide where the available water can be utilized to the best advantage. For it must be borne in mind that never in the history of Mesopotamia has the whole of the country been under irrigation at one and the same time. The centre of cultivation was at first in the lower reaches of the two rivers between Niffur and Ur of the Chaldees. Then it travelled to the tract between Sippara and Babylon. In Persian times the centre was Ctesephon ; while Basra, Wasit and Kufa, in the lower part of the Delta, were the first capitals of the Arabs, though Bagdad became the centre in the times of the Khalifs.

To meet the requirements of irrigation the Tigris and Euphrates are happily placed in respect of their relative levels. The water of the Euphrates can be made to irrigate the whole area capable of irrigation between Feluja and Koot, and also all the lands on both the Hilla and Hindia branches along their entire lengths. The Tigris, on the other hand, is capable of irrigating the lands north of Bagdad, which the Euphrates cannot reach, and also the whole of the lands along the course of the Hai or ancient Tigris from Koot to Nasria, as well as all the lands along its present course past Amara.

We have, indeed, a wide field from which to choose.

7. Selection of tracts for irrigation.—There are certain tracts situated within the Delta itself capable of storing the excess waters of the months of April and May and aiding the river in July, August and September. For example, the Akkar Kuf reservoir is capable of maturing 100,000 hectares of rice, the Habbania 100,000, and the Euphrates Valley above the Sakhlawia 20,000.

Since rice is the most valuable crop in the country after the date crop it would be unwise to select for irrigation any tract which could be utilized eventually for storing water for the maturing of this crop. Such areas are naturally left out of all schemes for development.

All the Mesopotamian rivers are liable to very heavy and sudden floods capable of inundating the country, and all irrigation schemes must take count of this factor and provide against it. The natural way is to follow the practice of the ancient Egyptian and Babylonian engineers, and to confine our attention to one bank of each river and insure that bank against inundation. The floods will be allowed to waste their energies on the other bank. As years go on and the escapes for the rivers are improved and the banks solidified, it will be possible to begin work on the other bank of each river, but not to-day.

Keeping these considerations before me, I have chosen those areas for irrigation which can be most profitably provided with water, and at the same time insured against inundation. In their order of importance the tracts may be thus classified :—

A. The country lying between Feluja and Bagdad on the north and Babylon and Baghaila on the south.

B. The Hai branch of the Tigris.

C. The country between Basra and Zobeir.

D. The Hindia branch of the Euphrates.

E. The country between Beled and Bagdad on the right bank of the Tigris.

F. The Nahrwan canal.

We have had no opportunity of examining the lands irrigable by the Adhaim river.

To meet the requirements of these tracts the different projects may be thus placed in their order of importance :—

- (1) Provision for the excessive floods on the Euphrates—Paragraph 9.
- (2) Provision for the excessive floods on the Tigris—Paragraph 10.
- (3) The Feluja Barrage with the left Euphrates and right Tigris canals and their branches—Paragraphs 11, 12, 13.
- (4) Provision for drainage, forests, and escapes — Paragraphs 14 and 15.
- (5) The conservation of the navigation of the Tigris until railway communication is provided—Paragraph 16.

- (6) The Koot Barrage on the Tigris and the Hai branch—Paragraph 17.
- (7) The Basra project—Paragraph 18.
- (8) The Hindia Barrage and subsidiary works—Paragraphs 8 and 19.
- (9) The Beled Barrage and subsidiary works—Paragraph 20.
- (10) The Nahrwan canal project—Paragraph 21.

8. **Hindia Barrage.**—If one had an absolutely free hand to deal with the country, the order in which the works should be carried out would be simplicity itself. Matters, however, have been gravely complicated by the conditions of the Hilla or ancient Babylon branch of the Euphrates.

Some forty years ago Midhat Pasha closed the head of the Sakhlawia branch of the Euphrates without making any provision for the heavy discharge of some 750 cubic metres per second which for 500 years had escaped down its channel. This large volume of water, added to the discharge of the Euphrates, played havoc with the country downstream of Feluja. But this was only a fraction of the damage it did. The high-lying Hilla branch was quite incapable of carrying this extra supply which found its way into the low-lying Hindia branch, swept away the temporary earthen dams across its channel, scoured out its bed, and permanently lowered the level of water at the bifurcation. The Hilla branch began immediately to silt up. About 25 years ago the Government began to combat this state of affairs by constructing the Hindia Barrage, a structure of loose rubble cemented for about one metre in thickness along its crest, and provided with an opening twenty metres wide in the middle of the river. The work was designed and constructed by M. Schoenderfer, and was eminently suited for its purpose.

As the silting up of the Hilla branch steadily advanced, and less water went down its channel and more down the Hindia branch, the Barrage needed serious modifications to suit the new conditions; but the work was practically left to itself, and, in spite of all the efforts of Mr. Mougel, the engineer in charge, with the limited and spasmodic sums of money at his disposal, it was being gradually swept away, when the Government undertook its repair in 1909 under the direction of Mr. Cugnin. In the flood of that year the Hilla branch was discharging 300 cubic metres per second, as against 2,500 cubic

metres per second going down the Hindia branch. Last year the discharge of the Hilla branch, which 40 years ago had been 2,000 cubic metres per second, fell to 150 cubic metres.

To remedy this state of affairs I proposed the construction, upstream of the present work, of a new barrage provided with 36 regulated openings of 5 metres each and the thorough repairs of the existing work. Mr. Cugnin began by constructing two flank walls, each 100 metres long, downstream of the existing barrage. This greatly diminished the action of the water. He then partially closed the central opening which had become 30 metres wide and some 8 metres deep. At the same time he lowered the crest. If then the new barrage had been hurried to completion, I believe we could have gained all our ends. Not having the new barrage, we were compelled to keep on raising the crest of the existing barrage to save the Hilla branch from extermination. It has been remarked that this barrage consists of loose rubble, and, in spite of all our additional works, the barrage was breached midway between the middle and the flank towards the end of the year. During 1910 the barrage works were under the charge of Mr. J. H. Medlicott, who repaired this breach after the floods and closed it sufficiently to give us a head of two metres, which was what we needed for the Hilla branch. It seems as if another breach would occur in 1911, to the right of the central opening. If this right hand breach does occur and the barrage is not swept away by the flood, it will be possible, after the flood, to partially close the breach and to tie the three openings by a crest wall along the unbroken parts of the barrage. Such repairs will, I think, enable the work to hold its own until the new barrage is completed. In case the existing Barrage is swept away, the subsidiary Barrage shown on Plate 81 should be constructed at the same time as the new Barrage.

It will certainly not be without interest to state here, that the first public work Alexander the Great undertook in Babylonia was the construction of a new head on solid ground for the Hindia branch or the Pallacopas. Its head had hitherto been in sandy soil, and as the branch had to be opened annually in flood to escape the excess waters of the Euphrates, and then closed after the flood to keep the Babylon channel full of water, the annual closure had been a work of extraordinary difficulty entailing the presence of 10,000 men. Next to building a masonry barrage, this was the wisest thing to have been

- (6) The Koot Barrage on the Tigris and the Hai branch—Paragraph 17.
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done. I may further say that till to-day the Hindia branch at its head traverses some of the hardest soil of the Delta, and it is possibly owing to the wisdom of Alexander's choice that the barrage holds its own in the way it does.

The works proposed for the Hindia Barrage with their estimated costs, including contingencies, may be classed as follows :—

(1) The addition of a lock 50 metres by 8 metres and 7 openings of 3 metres each on the right flank of the existing Hindia Barrage, L.T. 45,300.

(2) A new barrage about 800 metres upstream of the present one, with a lock 50 metres by 8 metres and 36 openings of 5 metres each, L.T. 153,300.

(3) The diversion of the Euphrates through the new barrage, L.T. 49,610.

(4) Dam across the Euphrates, L.T. 5,000.

(5) Diversion of the Hilla branch, earthwork, L.T. 5,500.

(6) Masonry head for the Hilla branch, L.T. 13,330.

(7) Silt clearance of the Hilla branch, L.T. 58,000.

(8) Addition to the existing Hindia Barrage, earthwork, L.T. 4,700.

The total cost of these works will amount to L.T. 334,740.

With respect to the Hilla branch, I should like to remark, that never again should the Arabs be allowed to undertake its silt clearance in the manner they have been permitted to do this year. In spite of protests on our part, they were allowed to dig a trench 10 metres wide and 1 metre deep down its middle and to throw the spoil inside the flood channel itself. This spoil should of course have been thrown clear of the flood channel. Its existence in its present position will add greatly to the silt deposits during the coming flood.

Drawings Nos. 17 to 24, 44 to 47 and 81 refer to these works, and, as many comments are made on the plans themselves, they need not be repeated here.

Drawings Nos. 22 and 49 show the changes that I have been compelled to introduce in the treatment of the Hilla branch. The silting up of this branch has been so persistent that it is no longer possible to have a canal 60 metres wide inside its bed. The thing for us to do now is to dig a channel as nearly straight as we can, joining the different reaches up to Hilla, as shown on drawing No. 49. In this way we secure a slope of water surface of $\frac{1}{8,000}$ and of bed of $\frac{1}{10,000}$, and

at the 40th kilometre of the new section the canal will flow within the existing bed of the Hilla branch. The cost of this excavations has been included in the estimates of the Hindia Barrage.

9. Provision for the excessive floods on the Euphrates.—It was stated in the preceding paragraph that the Sakhlawia branch of the Euphrates was closed forty years ago. Though the closing of this branch meant the ruin of the Hilla branch of the Euphrates, the benefit to Bagdad West and to the country traversed by the Tigris, which used formerly to be flooded by the Sakhlawia, has been great, and it would no longer be possible to open the Sakhlawia without damaging Bagdad West and the lands on the Tigris. Some escape has to be found for the excess waters of the Euphrates, and not only for those which used to flow down the Sakhlawia, but also for the high floods of the river itself. Fortunately for the country such an escape can be constructed at a reasonable cost.

The Euphrates from Hitt to Ramadi is confined within its valley. Near Ramadi is the first point at which the water of the Euphrates, after entering its delta at Hitt, can leave the valley. To the south and south-east of Ramadi are three openings in the desert through which the waters of the river in flood can escape into the Habbania lake. Between the Habbania lake and the wide and deep depression on its south, lies a neck of land which will have to be cut through to allow of an effective escape from the Euphrates.

The Habbania depression covers an area of 146 square kilometres at R.L. 46·00. The lowest part of the southern depression is lake Abu Dibis with its water level at R.L. 19·00 metres. This depression has a thick belt of Euphrates shells at R.L. 25·00 metres showing that in ancient times it was filled with escape water from the Euphrates. At this level it has an area of 1,200 square kilometres. These two depressions, between them, will provide a thoroughly efficient escape for the excessive floods of the Euphrates and enable the whole Euphrates Valley to be cultivated without fear of inundation.

The Abu Dibis depression will, in the future, be possibly a reservoir of great value. The contents of the depression below R.L. 26·00 may be taken as over 4 milliards of cubic metres, with an annual evaporation of 3 milliards. As we are not concerned to-day with the storage of

water I have confined myself to the escaping of the excess waters of the Euphrates.

The waters which find their way into the Abu Dibis depression will obliterate the present scrubby cultivation carried on by the Aneza Arabs near Rezaza, north of Abu Dibis, but they will allow of summer crops on its shores, pastures for sheep, and reeds and brushwood for sale in Kerbela. These products will be a hundredfold more valuable than anything the Arabs produce to-day on lands which have only been cultivated for some 30 or 40 years, and which have been almost entirely converted into a salt plain. The only crop that could save them from destruction is rice, which they cannot cultivate, as the water from the rice fields would drown out the fields themselves which lie at the very bottom of the depression.

The works proposed with their estimated cost, including contingencies, may be classed as follows :—

(1) Regulating head for the Habbania escape, near Ramadi, with 25 openings of 3 metres each, L.T. 57,700.

(2) Excavation of the escape in the Euphrates Valley, L.T. 40,200.

(3) Excavation of the escape in the desert, L.T. 297,600.

The total cost of the estimates amounts to L.T. 395,500.

Two inspection-houses have been built, one at Ramadi and the other south of Habbania lake. The excavation in the Euphrates Valley will be easily accomplished with the aid of the Dillems in the neighbourhood, but the excavation of the gypsum rock in the desert will not be accomplished without the aid of excavators and lines of tramways. To make the work a real success, the Euphrates breach of 1909–1910 should be kept open, the whole valley of the Habbania submerged, and a good supply of drinking water insured at the south end of the Habbania lake.

Drawings Nos. 25 to 27 refer to the Habbania escape works.

10. Provision for the excessive floods on the Tigris.—We have already made provision for protecting the tracts to be irrigated from the excessive floods of the Euphrates; and there remains the provision needed for the floods of the Tigris. The Tigris at Mansuria, above Bagdad, carries a discharge which in very high floods is out of all proportions to what the river can discharge at Bagdad itself. In the hopes of finding an escape from the Tigris into the deep depression

on its right bank, west of Samarra, we carried our levels and surveys to the Hamrin hills, beyond Takrit, but no site for an escape could be found which did not entail the raising of the water surface of the river in flood by 6 metres. Such a work would of necessity be very costly, and I have consequently not included an escape from the Tigris in the estimates of works. Plate 80, however, gives a preliminary project for a barrage on the Tigris which would raise the flood surface by 6 metres and permit of the construction of the escape. The day both the Tigris and Euphrates are provided with good working escapes the delta will be free of all risks; and I have no doubt that once the Euphrates escape has been constructed and the real reclamation of the Delta begun, a demand will be made for an escape from the Tigris. At this stage of the works, however, the Tigris escape is unfortunately too costly to be undertaken.

In ancient times the right bank of the river above Bagdad was protected by massive dykes and canal banks and prevented from drowning out the rich gardens and orchards which clustered round Bagdad West, while Bagdad East was a strong fortress surrounded by a massive earthen wall. Between this fortification and the higher land to the east lay, and lies to-day a wide depression down which all the excess waters found their way to join the river below Bagdad. I propose to imitate the ancient works and provide a strong embankment along the right bank of the river from Mansuria to Kazimain. The depression on the left bank of the Tigris, between Bagdad East and the highland beyond, will be utilized as in the past for the excessive floods of the Tigris. H.E. Nazim Pasha, Vali of Bagdad, has constructed an earthen bank across this depression, but has informed me officially that it will be removed the day the irrigation works are begun.

To prevent the waters of the flood stagnating as in the past in the depression east of Bagdad, I propose a regulator in the bank south of Bagdad and an escape into the Tigris. These will ensure the waters of the depression flowing off as the river falls.

On the right bank of the Tigris I also propose a regulator like that for the right Tigris canal at the point where the Sakhlawia crosses the Akkar-Kuf dam. This will act as an escape when needed. It will be necessary to keep the right Tigris canal west of the Sakhlawia. This will have no effect on the estimates of the right Tigris canal.

The proposed works will consist of :—

- (1) A dyke along the right bank of the river, L.T. 47,580.
- (2) Pipe crossings for irrigation, L.T. 5,490.
- (3) Spurs at salient points on the Tigris, L.T. 8,000.
- (4) Regulator at the Sakhlawia crossing of the Akkar-Kuf dam, L.T. 5,130.
- (5) Dyke at Bagdad, from Moadam to Gararah, L.T. 9,360.
- (6) Regulator and escape into the Tigris across the Bagdad bank, L.T. 5,040.

The cost of these works will be L.T. 80,600, which, with $33\frac{1}{3}\%$ for contingencies, or L.T. 26,870, will bring the grand total to L.T. 107,470.

Below Bagdad the Dyala enters the Tigris on its left bank.

In ancient days the country between the Tigris and the Euphrates, downstream of Bagdad, was protected by the massive banks of canals leading from the Euphrates and running parallel to the Tigris. This protection was very effective. It allowed the floods to flow over the lands on the left bank of the river which acted as an escape. The principal canal whose banks acted as a dyke was the Nahr Melcha. This canal has, on a length of 2 kilometres at the Ctesiphon bend, been eaten away by the Tigris, while the river has made a long loop and advanced some 5 kilometres into the country. The extreme end of the loop is known as the Harrea reach of the Tigris, and over it the river in high floods spills and escapes its excess waters.

If any serious reclamation of the country is to be taken in hand this breach must be closed, as the flood waters pour into the only depression down which has to be taken the main drainage line of the Delta.

I have no doubt the same problem faced the ancient Babylonian engineers, and after taking two years to find a solution, I have come to the same conclusion as they did. I have rejected, as they did, the easy solution of leaving the breach as it is, accepting it as the natural escape of the river, and sacrificing the drainage of the country as well as the cultivation of over 100,000 hectares of easily-drained and easily-irrigable land of excellent quality. The details of the manner in which I propose to deal with the question are given in paragraph 12, which is concerned with the right Tigris canal and its branches.

The description of the Tigris downstream of Koot is given in paragraph 16, where the methods are described on which it is proposed to regulate the river.

The drawings which refer to this paragraph are Nos. 2, 4, 5, 8, 43 and 80.

11. The proposed Feluja Barrage on the Euphrates.—This will be the most effective irrigation work in the country. The barrage will be constructed on the Euphrates, south of Feluja, at the head of the present Abu Goraib canal. It will ensure perennial flush irrigation to the tract of country lying between Feluja and Mosaib on the Euphrates and between Bagdad and Koot on the Tigris. Of this tract, Ibn Serapion, writing in the time of Haroon el Rashid, when the canals were far inferior to what they were in the old Babylonian and Sassanian days, says:—"This country is irrigated by four canals, taking off from the Euphrates and tailing into the Tigris. The Euphrates feeds a canal called the Nahr Issa (the modern Abu Goraib); this canal irrigates the villages and domains on both its banks. The canals of the City of Peace (Bagdad) are fed by this canal. The Euphrates feeds also a canal called the Nahr Sirsa (the modern Radwania), this is a great canal whose waters irrigate the country by means of chareds and levers. A bridge of boats crosses the canal along whose banks stretch villages and domains. The Nahr Malik (the ancient Nahr Melcha) also takes off from the Euphrates. Numerous villages and fertile domains stretch along both its banks. A bridge of boats thrown across the canal serves many fields and villages. The Nahr el Malik itself feeds numerous canals. From the Euphrates takes off also a canal called the Nahr Kutha, which feeds numerous canals and numerous villages. It is crossed by a bridge of boats. At its tail it flows into the Tigris, ten leagues south of Madain (Selucia)." *

In ancient days, owing to the absence of barrages on the main Euphrates, it was exceedingly difficult to keep up perennial irrigation on the canals. With canals, however, supplied by important feeders taken from the upstream side of the barrage, and capable of maintaining flood levels throughout the year, irrigation will be carried on under very favourable conditions.

As soon as the Feluja Barrage and the left Euphrates canal are completed, it will not be necessary to wait for the excavation of all the ancient canals which will depend on this feeder, but by putting it in communication with the modern Abu Goraib, Radwania, Mahmudia and Latifia canals, it will be possible to provide perennial irrigation

* Translated by Mr. Guy le Strange, I.C.S.

to an extensive tract of rich land which will attract settlers from every part of Turkey in Asia.

The barrage will be constructed in the dry on the outcrop of the desert at the head of the Abu Goraib canal. Like the new Hindia Barrage, it will be provided with a lock 50 metres by 8 metres and will have 40 openings of 5 metres each. I do not consider it safe to build any barrage or regulating work on the light sand of the Euphrates and Tigris bed.

The works proposed consist of :—

(1) The Feluja Barrage, with 40 openings of 5 metres and a lock 50 metres by 8 metres, L.T. 107,300.

(2) The diversion of the Euphrates through the desert outcrop, L.T. 154,560.

(3) A bank across the Euphrates, L.T. 5,000.

The cost of the works amounts to L.T. 266,860, and, if a sum of L.T. 88,950, representing $33\frac{1}{3}\%$ for contingencies, be added, the total cost amounts to L.T. 355,810.

The drawings which refer to this paragraph are Nos. 29 and 48.

It will be seen from the drawings that I have chosen the Egyptian system of barrage for all the works in Mesopotamia. I have done this for three special reasons :—

(1) Such a barrage will be capable of being fully opened in flood and not causing any rise of the river in a country where any rise would be disastrous.

(2) The Tigris and Euphrates floods are not gradual, but consist of a series of rapid rises and falls. Now at the crest of the rise the quantity of deposit carried by the river is extraordinarily great. During a rapid rise in winter the matter carried in suspension may amount to 750 parts in 100,000, or five times the maximum of the Nile. Four days afterwards the quantity may fall to 140 parts in 100,000. Now there can be no doubt that the complete obliteration of the ancient canals was due to these heavy deposits. All the canals took off the Euphrates without weirs; and while they were veritable rivers themselves they preserved their sections (for depth gives velocity as readily as slope does), but when in troublous times they began to be neglected and silt their beds, they became like the small canals of to-day, incapable of taking the reasonable waters of the falling floods or the clear waters of the low supplies, and had to content themselves with the muddy

waters of the crests of the rises of the river, which gradually choked them up and ended by absolutely obliterating them. One has only to see the Hilla branch to understand how fast this obliteration can proceed. To obviate these disadvantages it will be essential for all canals to take off from above Egyptian barrages. When a rising flood surcharged with suspended matter is coming down, the barrage will be fully opened and the canal head closed. In this way the canals will be free of the heavily charged waters of the rivers; and to enable their regulating heads to keep out the floods I have designed them with very massive foundations.

(3) It is a well known fact that the mass of the heavy sediment carried by a river is to be found where the velocity of the river is greatest, and that the slack water is comparatively free of this deposit. I have already stated that during the times of very heavy deposit the canal heads will be closed, but there will be a considerable amount of sediment when the floods have fallen and the canals are open. An Egyptian barrage will allow us to close the openings near the canal head and so force the heavy current to the other side of the river. By judiciously placing spurs upstream of the canals and taking the canals themselves backwards, as will be clearly seen on drawings Nos. 48 and 71, it will be possible to make doubly sure of letting a minimum of deposit enter the canals when they are open.

If the works answer the purpose for which they are designed we may contemplate the introduction of irrigation into the Delta of the Euphrates and Tigris without the anxieties which beset the ancients according to their own historians.

12. Irrigation systems depending on the proposed Feluja Barrage.
The right Tigris canal.—From upstream of the barrage will take off two systems of canals. The first will be the right Tigris system, which will be fed by the Sakhlawia canal. This canal will discharge into the Akkar-Kuf depression and be there maintained at a level of R.L. 33·50 by a massive embankment stretching from the west of Kazimain to the desert north of the police station on the Bagdad-Feluja road. The right Tigris canal will start from the embankment, and with its branches will irrigate the country down to Koot along the right bank of the Tigris. The total area commanded will be 270,000 hectares. The clear water from the lake will provide irrigation during

the times of low supply in the Tigris, while the muddy flood waters of the Tigris will be taken very freely across the canal by means of iron pipes of the "Acme" class. In ancient times the dyke along the right bank of the Tigris was a work of the first importance. By using the left bank of the canal as a dyke, the same security will be given to the country as was given by the Nahr Melcha canal bank in ancient times.

The proposed works will consist of :—

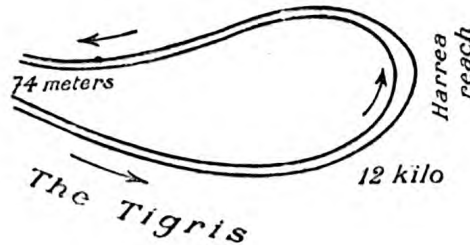
- (1) Two regulators at the head of the Sakhlawia, L.T. 50,183.
- (2) Excavation of a new head for the Sakhlawia, L.T. 29,130.
- (3) Akkar-Kuf embankment, L.T. 31,770.
- (4) Regulating head for the Tigris canal, L.T. 5,130.
- (5) Excavation of the right Tigris canal and its branches up to kilometre 69, L.T. 242,990.
- (6) Excavation of the right Tigris canal and its branches below kilometre 69, L.T. 179,060.
- (7) Masonry works, L.T. 22,885.
- (8) Pipe crossings for flood irrigation, L.T. 90,500.
- (9) Irrigation culverts or pipes, L.T. 38,910.
- (10) Spurs at salient points on the river Tigris, L.T. 18,000.

The total of these works amounts to L.T. 708,558, which, with an additional $33\frac{1}{3}\%$ for contingencies, or L.T. 236,182, amounts to a grand total of L.T. 944,740.

These works should, I think, be carried out in the following manner:— The two head regulators of the Sakhlawia branch and the Akkar-Kuf bank should be carried out as designed, as well as the masonry works and the pipe crossings on the Tigris. The right Tigris canal should at first be dug on half its width, but to its full depth up to kilometre 69. The spoil should be principally used to make a massive embankment along its left bank to protect the country from the Tigris. The width of this bank would be everywhere at least 10 metres and its height 1 metre above maximum flood. It is for this purpose that I have taken the alignment through high land. It would have been easy to take it through lower lands and considerably reduce the estimates, but in a country liable to floods such as Noah experienced, I can recommend no economy when we are facing the question of inundation.

Where the right Tigris canal will cross the Tigris at the Ctesiphon

bend there is only a width of 74 metres to be cut through, for the river to decrease its length by 13 kilometres and gain a head of 1 metre.



At this point I propose to make a cutting and use spurs to induce the river to silt up the bend and so render the embankment across it more economical. All the flood water which at present escapes along the Harrea reach will be retained in the river the day the right Tigris canal is carried across the bend. It will not be convenient to immediately allow all this water to travel down the whole length of the Tigris, so I propose to construct the right Tigris canal only as far as its 69th kilometre and there stop it for some years. The discharge of the canal will be carried on by the proposed lower Nahr Melcha canal for 90 kilometres. This canal will follow the alignment of the old Babylonian canal and protect the country to be irrigated by the Euphrates from the Tigris floods which will be kept on the left of the canal as they were in old days. As the country becomes developed it will be possible to continue the right Tigris canal for another 70 kilometres, and so on until Koot is reached. This must have been the way the country was developed in old times.

Adopting the programme proposed for this canal the estimated cost works out as follows :—

- (1, 2, 3, 4) as before, L.T. 116,213.
- (5) Half the right Tigris canal to kilometre 69, the lower Nahr Melcha Canal, Harrea canal and escape, L.T. 144,240.
- (6) Masonry works as above, L.T. 13,608.
- (7) Pipe crossings, L.T. 29,050.
- (8) Irrigation outlets, L.T. 20,910.
- (9) Spurs on the Tigris, L.T. 7,000.

The cost of those works amounts to L.T. 331,021, which, with an addition of L.T. 110,339, or $33\frac{1}{3}\%$ for contingencies, brings the total to L.T. 441,360.

13. The left Euphrates canal.—The second system of canals taking off from the Feluja Barrage will be the left Euphrates canal system. The feeder will follow the left bank of the Euphrates from the Abu Goraib head to the Iskendaria canal head. The area commanded will be 270,000 hectares. This feeder will provide water in times of low supply to the Abu Goraib, Radwania, Nahr Melcha, Mahmudia, Latifia, Kutha, Babylon and Iskendaria canals. During the floods, the same canals will be fed directly from the Euphrates and taken under the left Euphrates canal by means of iron pipes of the “Acme” type. Pipe crossings will also be provided for flood irrigation as on the Tigris. In this way the main canal will be kept from silting up and the country will not be deprived of the muddy flood waters so necessary for agriculture.

Of the canals of this system the Abu Goraib will irrigate the lands of western Bagdad as in the days of the Khalifs, the Nahr Melcha will irrigate the country up to Selucia, while the Kutha and Babylon canals will bring us back to the old Babylonian times.

The proposed works consist of :—

- (1) A regulator at the head of the left Euphrates canal, L.T. 7,719.
- (2) Excavation of the left Euphrates canal, L.T. 183,500.
- (3) Masonry heads for the Abu Goraib canal and others on the Euphrates and on the main canal, L.T. 27,588.
- (4) Pipe crossings for flood irrigation, L.T. 26,380.
- (5) Excavation of the Abu Goraib and other canals, L.T. 118,725.
- (6) Masonry works on the canals, L.T. 26,339.
- (7) Irrigation culverts, L.T. 51,000.
- (8) Spurs at salient points on the Euphrates, L.T. 6,000.

The cost of the work amounts to L.T. 447,251, to which, when we add the contingencies at $33\frac{1}{3}\%$, or L.T. 149,079, the total cost amounts to L.T. 596,330.

The drawings which refer to these works are Nos. 2, 3, 4, 4A, 10, 32, 33, 34, 40 and 43.

The alignment of the canals down the lines of the existing ancient water courses or veritable abandoned rivers will be a work needing considerable skill. The water courses themselves are well above the level of the country and the ground falls away fairly abruptly from them. By aligning the canals along the slopes at the most suitable levels, economies will be made which will more than cover the expense

of cutting frequently across the high-lying centre ridges. In the estimates free provision has been made for banks as well as cuttings, but the canals should, if possible, be kept in cutting as they easily command the country a few hundred metres away.

It will not be necessary to dig the canals to their full depth to begin with. Half the section will suffice on any canal for many years to come. The masonry and iron works, however, should be all made to their full section.

Longitudinal sections Nos. 10 and 17 give full information of banks in section. Ample provision is allowed everywhere. Drawing No. 60 gives sections of some of the ancient canals. It will be seen how readily they lend themselves to alignment at any required level.

An examination of drawing No. 40 will show how massive are the foundations which have been provided to allow of the main canal head being closed in full flood whenever the water is heavily charged with sediment.

14. Drainage. Forests.—No sooner had Alexander fixed the site of the head of the Pallacopus than he turned to the drainage of the country. Here was the true irrigation engineer.

No irrigation canals in Mesopotamia will be a success without efficient drainage cuts as there is an appreciable quantity of salt in both rivers. One has only to inspect the irrigated tracts of the lower reaches of the Khalis canal to see the damage which can be done by irrigation without drainage.

The main drainage line between the Tigris and the Euphrates will follow the natural depression between the two rivers from lake Akkar-Kuf southwards. This drain will be given a width of 20 metres from head to tail, so that it may discharge 50 cubic metres per second after the flood, and help to mature the valuable rice crop. Its large section will also enable it to act as a carrying channel for the escapes from the two main canals. To enable this drain to perform this function successfully it will be provided with three regulators of which the third will be built near kilometre 133, at the crossing of the ancient Nil canal embankment. There it will be possible, if it is considered necessary, to form a lake like that at Akkar-Kuf and store water for use further down. The drains from No. 1 to No. 6 will tail into the Akkar-Kuf drain, and their longitudinal and cross sections have been accordingly

designed. Drains Nos. 7 and 8 will tail into the low lands south of Baghaila, near the end of the Akkar-Kuf drain. Drain No. 9 will serve the country between the Hindia and Hilla branches of the Euphrates; while drain No. 10 will flow between the Nahrwan and the Tigris. The longitudinal sections of the drains are given in drawings No. 12, and their position in drawings Nos. 4 and 4A.

As a general rule the slope of water surface is good, and the only country whose drainage is difficult is that to the west of the Kutha canal. The drainage of this tract must always have been bad, but once drain No. 5 has been made there will be an outlet into the Akkar-kuf drain.

Where the canals cross the drains the cost of the syphons has been credited to the canals.

The cost of the drains may be thus subdivided :—

Excavation of the Akkar-Kuf drain	L.T.	130,104
Excavation of minor drains	„	58,716
	L.T.	<u>188,820</u>

The masonry and iron works will cost as follows :—

Head regulator Akkar-Kuf drain	L.T.	2,941
3 road-bridges at 804	„	2,412
2 other regulators at 2,029	„	4,058
Road pipes, 60 at 160	„	9,600
	L.T.	<u>19,011</u>
Earthwork	L.T.	188,820
Masonry works	„	19,011
		<u>207,831</u>
Total	L.T.	207,831
Contingencies at $33\frac{1}{3}\%$	„	69,279
Grand total	L.T.	<u>277,110</u>

Of these estimates the only uncertain item is the tail of drain No. 10 where the survey party levelling down the Nahrwan canal forgot to take a cross section of the canal showing ground levels.

Mesopotamia must at one time have been covered with dense forests, since even to-day, in spite of the Arabs and their flocks of goats and sheep, one meets in the deserts some fine specimens of the Nebek, or wild plum tree. The trees which flourish best are poplars and willows near the river's edge, and elsewhere mulberries, dates and Nebeks,

Once irrigation works have been taken in hand there will be many localities where plantations could be begun on a large scale. Especially will this be the case in the depressions to the east of Bagdad, along the edges of the Akkar-Kuf lake, and down the lines of the drainage cuts and escapes. All that will be needed will be protection with wire-fencing and watering for a couple of years, and after that the trees will look after themselves.

For the works connected with plantations I have entered L.T. 10,000 in the estimates. In a country where fuel is so scarce and valuable, these plantations will soon be a source of considerable revenue.

15. Escapes.—Every canal system needs its escapes, and it is for one of these reasons that the main Akkar-Kuf escape has been made 20 metres wide from head to tail so that it might be capacious along its entire length. From the left Euphrates canal two canals tail into the Akkar-Kuf drain, the Radwania and the Latifia. These canals are provided with head and tail regulators, so that they may be used for irrigation and as escapes. Both the canals have rapid slopes of between $\frac{1}{2,500}$ and $\frac{1}{5,000}$ and will be effective. From the right Tigris canal there is one escape into the Akkar-Kuf drain, the Harrea canal. The slope here is of $\frac{1}{8,000}$. From the 53rd kilometre of the Nahr Melcha canal will be a second escape into the Akkar-Kuf drain. Here the canal and drain are within 3 kilometres of each other and the escape will be very effective. As the cost of the earthwork of the escapes and their masonry works have already been included in the estimates of the canals no further sums are needed for these works.

16. The navigation on the Tigris.—The river Tigris, on a length of 805 kilometres between Bagdad and Basra, is the only means of communication worth the name between the capital of Mesopotamia and the outer world. If this navigable channel were interrupted, Bagdad would be completely isolated, and looking at the state of the river as it is to-day, this is not a remote possibility.

Between Bagdad and Koot the distance by water is 345 kilometres, though the distance by land, neglecting the sinuosities of the river, is only 165 kilometres. Bagdad stands at 35 metres above sea level, while the level of Koot is 17·5 metres. In this reach of the river, navigation at low water is impeded owing to the existence of shoals,

but is practically uninterrupted. The width of the river may be taken at 350 metres, with a depth of 8 metres in flood, diminishing to $1\frac{1}{2}$ metres in low supply. The fall of the river surface is 1 in 20,000. The discharge in flood may be taken as 5,500 cubic metres per second, and in low supply as 300 cubic metres; while the velocity in flood is 6 kilometres per hour, and in low supply 2 kilometres. In this length of 345 kilometres no works are necessary. At Koot, the Hai branch, itself the ancient Tigris, leaves the right bank of the river, discharging up to 1,000 cubic metres per second in high flood and dry in low supply.

Between Koot and Amara the distance by river is 245 kilometres, as against a direct land-route of 190 kilometres. The fall in the level of the land is 9 metres, Koot being 17·5 and Amara 8·5 metres above mean sea level. In this reach navigation is easy all the year round. The width of the river may be taken as 300 metres with a depth of 8 metres in flood, and diminishing to 2 metres in low supply. The fall of the water surface is 1 metre in 35,000. The discharge in flood may be taken as 4,500 cubic metres per second at the beginning of the reach, and in low supply as 300 cubic metres along the entire length. The velocity in flood is 6 kilometres per hour, and in low supply 2 kilometres.

In this reach the first of the branches which deprive the Tigris of water in low supply is met with on the right bank above Amara. This branch, known as the Bitera, discharges about 1,000 cubic metres per second in flood, diminishing to about 100 cubic metres in low supply. But it seems as though the water which enters the river by infiltration between Bagdad and Amara during the time of low supply makes good the loss of the water taken by the Bitera, for the low supply downstream of the Bitera seems to be the same as at Bagdad. In addition to the Hai and Bitera numerous small branches and overflows take off the waters of the flood, so that the Tigris above Amara, at the tail of the reach, may be considered as discharging 2,500 cubic metres per second in high flood.

Between Amara and Gurna the distance by river is 140 kilometres, as against 105 by the direct land-route. The fall in the level of the country is 5·5 metres, Amara being 8·5 metres and Gurna 3 metres above mean sea level. In this reach the Tigris experiences many

vicissitudes, and it is here that all the difficulties of navigation are to be found.

At Amara, on the left bank of the river, the Chala branch leaves the Tigris, with its bed about 2 metres lower than that of the Tigris itself, and discharges 1,000 cubic metres per second in flood and 150 in extreme low supply. The extreme high flood discharges of the Tigris, therefore, below Amara, may be taken as 1,250 cubic metres per second, and the low supply discharge as 150 cubic metres. The width of the river averages 180 metres, with a depth of 4 metres in flood, diminishing to 2 metres in low supply.

A short distance downstream of Amara, on the right bank, the Majar Kabir leaves the Tigris. This branch discharges about 600 cubic metres per second in high flood and 50 in low supply. Immediately below it, on the left bank, the Machera branch takes off, discharging about 300 cubic metres per second in high flood and 30 in low supply. Both these branches have their beds lower than that of the Tigris and, with the Chala, they constitute a distinct menace to the existence of the Tigris as a river. In the reach below Kila Saleh, after all these branches and overflows have left the river, the Tigris itself is about 60 metres wide, with a depth of 4 metres in high flood, and $1\frac{1}{2}$ metres in low supply. In this whole reach navigation is extremely difficult at low water. Steamers have to be handled with considerable skill, and are delayed again and again. In some years the large steamers have had to suspend their running, the mails being conveyed in launches. This state of the river continues to near Ezra's tomb. There the waters which have left the river by various branches enter it again through the swamps, and the river gradually swells its volume, so that at Gurna it is some 180 metres wide, with a depth of 6 metres, the water being nearly free of deposit and of a dark transparent colour and marshy odour. The effect of the contrary current due to the tide from the Persian Gulf is felt up to Gurna, though the tide helps to swell the river to near Ezra's tomb.

Between Gurna and Basra, on a length of 75 kilometres, the river is from 250 to 550 metres wide with a depth of 8 to 14 metres. In ancient days Gurna was the point of junction of the Euphrates and Tigris, but it is no longer so. Indeed, a little Tigris water may occasionally travel up to the Euphrates, but no Euphrates water reaches Gurna.

A little below Gurna, on the left bank, the Shaat el Suaib, which brings in the water of the Kerkha and the marshes joins the river. A short distance above Basra, on the right bank, the Euphrates flows into the Tigris at Garmat Ali. Where the two rivers meet, the Tigris may be taken as 380 metres wide and 10 metres deep. The water of the Euphrates at this point has no deposit and presents an opaque and wholesome look in marked contrast to the dark marshy water of the Tigris. Immediately below the junction the river increases to a width of 550 metres with a depth of 14 metres.

Basra is 2·5 metres above mean sea level, and the extreme difference between high and low flood, as affected by the tide and by the discharge of the river itself, is about 3 metres, extreme high water being about 2·5 metres above mean sea level and low water—0·5. At the head of Khor Abdullah, about 25 kilometres south of Basra, the difference between high and low water of the Persian Gulf tide on the 11th and 12th January, 1909, was found by Messrs. Watts and Moore to be 1·854 above and 1·854 below zero, making a difference of 3·7 metres.

From Basra to Fao is 100 kilometres, and this length of this river is navigable by Ocean-going steamers. On the left bank at Mahommerah, about 35 kilometres below Basra, the Shaat el Arab is joined by the Karun river some 400 metres wide and 11 metres deep, and discharging from 4,000 cubic metres per second in flood to 150 cubic metres in low supply. The Karun is a river essentially different to either the Euphrates or the Tigris. It traverses no marshes, but comes down straight from the Persian hills, carrying in flood the same deposit it carries at Ahwaz, and the addition of its rich and plentiful supply is one of the principal factors in considering the Shaat el Arab or Basra river.

From the above it will be seen that there are four branches of the Tigris which endanger the navigation of the river. The first is the Bitera, above Amara. Here I consider the danger as not very serious as the velocity in low supply is insignificant. But the three remaining branches, the Chala, the Majar Kabir and the Machera are a serious menace to the existence of the river; and works for the proper regulation of all of them should be taken in hand if any serious effort is to be made to keep communication open between Bagdad and Basra.

The principles which underlie the designing of works such as these are well-known by hydraulic engineers, and I have designed these

works in accordance with them. Three main points are essential: firstly, to allow that portion of the high flood to freely escape which the river itself could in no wise carry; secondly, to prevent the water at low supply from so escaping that the main river itself run dry, and thirdly, to provide a fixed crest so that no regulation be required. The first of these three essentials, viz., the necessary waterway in flood, might be formed by building the barrage at an angle to the current of the stream, but I have thought it preferable to obtain it by lengthening the barrage and building at right angles. The second point is gained by keeping the level of the crest of the weir a little below extreme low water. The crest has been designed always at 50 centimetres below low water. The third point is gained by designing the barrage as a solid weir. The works may, therefore, be described as solid substantial waste weirs with crests 50 centimetres below low water level and lengths such that the areas between the crests and high flood level are exactly those of the branches themselves in high flood to-day.

The works proposed are :—

- (1) Regulating head for the Chala branch, L.T. 18,731.
- (2) Regulating head for the Majar Kebir, L.T. 11,471.
- (3) Regulating head for the Machera, L.T. 6,083.

The cost of these works amounts to L.T. 36,285, to which, if L.T. 12,095, representing contingencies at $33\frac{1}{3}\%$ be added, the grand total becomes L.T. 48,380.

17. The proposed Koot Barrage.—For thousands of years the Hai branch which leaves the Tigris at Koot was the main stream of the river and continued to be such during the times of the Khalifs. Ibn Serapion, writing in the time of Haroon el Raschid, thus described this reach of the river:—“Now from the Tigris at various points below the city of Wasit are taken many canals which either flow into the swamps or else flow into one another. Of these we have already mentioned the finest and largest. The Nahr Ban passes by villages and domains and flows into the swamps. The Nahr Kuraysh flows by villages and domains and falls into the swamps. The As Sib canal flows through villages and domains and from it many minor canals are derived. The Barduda is a fine canal and flows out

into the swamps. Such, therefore, are the canals which are taken from the Tigris, and we have so detailed them that thou shouldst understand the matter." To-day the Hai branch is about 100 metres wide and some 4.50 metres deep in high flood. It is proposed to construct a barrage across the Tigris at Koot and give perennial irrigation to the Hai branch.

The tract commanded by the Hai covers some 750,000 hectares of land, of which one-third, or 250,000 hectares, should be developed. The Hai has an excellent channel for some 200 kilometres, and is at our disposal once the barrage is built on the Tigris.

As at Feluja, I propose building the barrage in the dry and diverting the Tigris. Fixing the site of the barrage at Koot has entailed a considerable amount of surveying, levelling and boring. The most economical site was found unsuitable for the foundations of such a work, but the borings along the alignment east of the village and marked on the plan "Possible site for the Barrage," disclosed excellent clay. Though on the plan and in the estimates, the symmetrical alignment west of Koot has been designated "Proposed Barrage site," I accept the site east of the village as well suited for such a work. There is an estimated economy of L.T. 175,770. The higher figures have, however, been allowed to stand in the final estimates as the engineers could not bore along the very edge of the river owing to the matted roots of a tamarisk grove, and there might be sand there to a great depth. The presence of sand would necessitate moving the centre line of the barrage a few metres further from the river which would add appreciably to the cost of the diversion.

A regulator and a diversion flowing backwards have been provided for the Hai canal head. The diversion will not be needed if the site east of Koot is adopted. The regulator has been given very massive foundations.

Through antiquity and through the times of the Khalifs the giant canals from the Euphrates tailed either into the Hai branch or were diverted southwards a little to its west. These canals have ceased to exist for hundreds of years, while the levels of the Hai have been steadily rising with the result that there is a mild depression to the west of the Hai branch down which run the overflows of the Tigris floods. Now all the drains and escapes proposed by us tail into the depression, and

I propose a bank with a deep trench on either side from the 4th kilometre of the Hai branch right up to the walls of Erech. This bank will insure against inundation the lands to be irrigated by the Hai, while the trenches on either side will act as drains. I may note, in passing, that such a bank would answer admirably for a railway connecting the Tigris and the Euphrates.

We have longitudinal and cross sections of the first 100 kilometres of the Hai branch, but, as the authorities did not allow us to go further, we have taken the alignment of the remainder of the branch from the existing maps. I inspected the last 10 kilometres from Nasria, and have before me the report which Herr Tholens, a German engineer who has just traversed the Hai from end to end, has kindly placed at my disposal. Opposite Tel Lo the branch has a width of over 100 metres and a depth of 5 metres. At Shattrah the bed width is between 30 and 50 metres and the depth 3 metres. Between Shattrah and Nasria the subsoil water is from 4 to 5 metres below the surface, and there is a fair amount of irrigation from "Chareds" in the bed of the river and from channels fed by the Husseinieh swamps. The whole country could be readily irrigated by the Hai if supplied with perennial water.

As we were not able to survey and level the country in detail I have taken the estimates of the left Euphrates canal system to guide me in framing the cost of the works.

These estimates are liberal ones :—

(1) Koot barrage and lock	L. T.	257,171
(2) Diversion of the Tigris	,,	342,623
(3) Diversion of the Hai	,,	47,040
(4) Regulating head for the Hai	,,	24,670
(5) Main drains and bank	,,	108,000
(6) Irrigation canals excavation	,,	118,700
(7) Drains	,,	58,700
(8) Masonry works	,,	26,339
(9) Irrigation outlets	,,	51,000
Total	L. T.	1,034,243
Contingencies, 33 $\frac{1}{3}$ %	,,	344,747
Grand total	L. T.	<u>1,378,990</u>

If the Koot barrage is built to the east of Koot village the estimates stand as follows :—

(1) Koot Barrage and lock	L.T.	257,171
(2) Diversion of the Tigris	,,	247,832
(3) Diversion of the Hai	,,	10,000
(4) Regulating head of the Hai	,,	24,670
(5) Main drains and bank	,,	108,000
(6) Irrigation canals and excavation	,,	118,700
(7) Drains	,,	58,700
(8) Masonry works	,,	26,339
(9) Irrigation outlets	,,	51,000
Total	L.T.	902,412
Contingencies, 33 $\frac{1}{3}$ %	,,	300,808
Grand total	L.T.	1,203,220

Drawings Nos. 2, 8, 13, 30, 65 and 66 refer to these works.

18. Irrigation works at Basra.—An examination of the plan of the Tigris will disclose the fact that between Gurna and Garmat Ali, near Basra, a sheet of open water stretches from the Shaat el Arab to the desert on the south. This shallow lake, covering some 270,000 hectares of land, has its bed about one metre above mean sea level and is in communication with the Shaat el Arab by one small opening at Shafai, which will eventually be closed, and one very large opening at Garmat Ali, near Basra. Through the middle of this stretch of water the Euphrates is at present cutting its course to join the Tigris at Garmat Ali. Immediately downstream of the open water past Basra, Zobair, the heads of the Khor Abdallah and up to Fao stretches a belt of comparatively high-lying land about 1·50 metres above mean sea level and over 200,000 hectares in extent. As the Tigris and Euphrates traversing their swamps can never have brought down this deposit, the comparatively high land has evidently been formed by the Karun river. In ancient days, when the joint waters of the Euphrates and Tigris entered the Persian Gulf by the western head of the Khor Abdallah and the Karun by the eastern head, the muddy waters of the Karun swept over these lands and laid down this deposit. The Karun, unlike the Euphrates and Tigris, traverses no swamps, but comes straight down from the Persian hills at a high velocity and carries its

muddy water into the sea, and is capable to-day as it was in the past of forming such a delta.

The lands under water and the comparatively high-lying land between Basra and the Persian Gulf are both extraordinarily level.

We have therefore to deal with a level plain inundated in flood and a large stretch of level land permanently under shallow water. The land itself is exceedingly rich, and the strip stretching west of a line joining Basra to Zobair, some 16 kilometres in length by 12 in width, though under water to-day, was, in the time of the early Khalifs, covered with date groves, gardens and orchards, and considered at that time as one of the four earthly paradises. How they reclaimed this land is easy to understand from the description of the Arab historians. The Tigris joined the Euphrates higher up its course, probably at Gurna, and the land flooded to-day was then a marsh. A channel was dug along the edge of the desert from the Euphrates to opposite Zobair, which was then known as Basra. This canal took a right angular bend at Zobair and made straight for the Shaat el Arab, down the line of the present Ashar creek, to the modern Basra, which was then known as Ubulla (Apollyon). This rectangular canal, which was known as the "Faid" (or flood canal) of Basra, provided the irrigation waters for these lands, and the appearance of the country was undoubtedly very like what we see on a small scale round Suk el Sheyook on the Euphrates to-day.

In projecting works for the reclamation of the swamped lands of the Euphrates and Tigris Delta, my first idea was to drain the swamps by means of a canal connecting the permanent open water west of Garmat Ali with the Khor Abdullah, and having near its tail a powerful self-acting regulator, which, taking advantage of the three-metre tide, would allow the waters to flow out and prevent the ingress of the sea. Some 800,000 hectares of land could be thus drained, but the effects would be disastrous. We should convert 800,000 hectares of swamps worth something even to-day, into a desert, and the Shaat el Arab deprived of this reserve of fresh water would find itself for many months of the year full of sea water to the great detriment and perhaps destruction of many of the 10,000,000 date trees with which the tract is credited.

After two years' study of these questions, with plans, levels and discharges of the rivers before me, I consider the conservation and

regulation of these swamps as of the utmost importance to the country, and the works I now propose are founded on this basis.

The first work we need is a barrage to control the outlet at Garmat Ali, and to enable us to design it we require the discharge. I now demand some attention, for we are going to deal with big figures. The following table gives the mean daily discharge of the Tigris and Euphrates throughout the year in cubic metres per second.

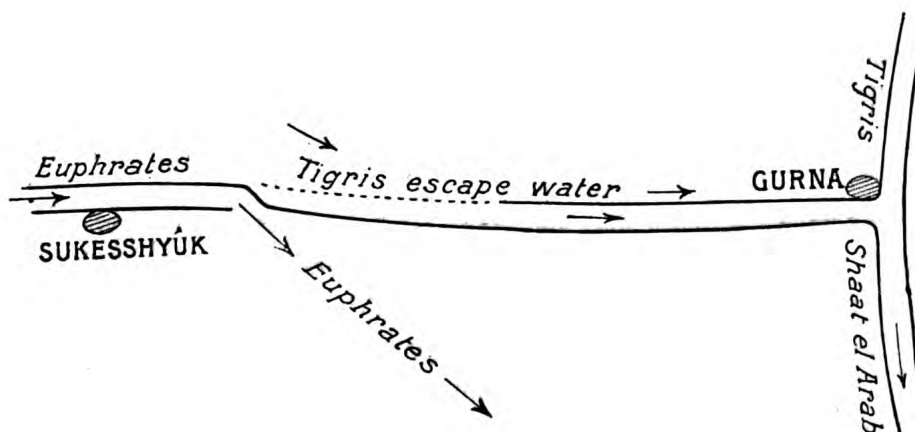
	TIGRIS AT BAGDAD.	EUPHRATES.	TOTAL.
January	450	500	950
February	1,400	1,000	2,400
March... ..	1,750	1,250	3,000
April	3,000	2,750	5,750
May	2,750	2,500	5,250
June	1,750	1,750	3,500
July	1,000	1,000	2,000
August	500	550	1,050
September	400	450	850
October	300	400	700
November	400	550	900
December	450	500	950
Year	1,180	1,095	2,275

In extraordinary floods the Euphrates discharge may rise to 4,000 cubic metres per second and the Tigris to 7,000 for short periods of time. Of this water only some 300 cubic metres per second remains in the Tigris at the Devil's Elbow, while the Euphrates has no bed at all for 110 kilometres. The whole of the water of the two rivers spreads in flood over the country, and I calculate that 2,820,000 hectares are under one metre of water or more, with a daily evaporation in summer of 4,100 cubic metres per second. A discharge of 8,200 cubic metres per second would take 40 days to raise the level of the water by one metre, neglecting evaporation. Including evaporation, and remembering that the area is inundated gradually, the discharge of 8,200 cubic metres per second would take 60 days. The swamped area in rising one centimetre absorbs 3,300 cubic metres per second and evaporates 4,100, or disposes of 7,400 cubic metres per second. As one-third of

the waters of the Tigris escape on the left bank, we have to deal with two-thirds of the discharge of the Tigris and the whole of the Euphrates. We thus find that owing to the enormous evaporation off the flooded land and its storage capacity in front of a regulator, that a barrage at Garmat Ali would have to deal with no more than the ordinary flood discharge of the Euphrates. I have so designed the barrage; but, to allow for contingencies, an escape has been provided into the low-lying Khor Abdallah, over a width of 4 kilometres and a depth of water of 1 metre.

So far we have dealt with the flood, we now come to the time of low supply. As the discharge of the two rivers falls from over 5,000 cubic metres per second in April and May to 3,500 in June, 2,000 in July and 1,050 in August, the swamped area decreases steadily, and finally in September we have to do with the marshes covering an area of 830,000 hectares and evaporating 1,000 cubic metres per second, while the rivers are discharging only 850 cubic metres per second. Under the joint losses from the escapes of water into the Persian Gulf and the heavy evaporation, the level of water continues to fall until we come to December, when the evaporation has decreased to 300 cubic metres per second, while the discharge of the rivers has risen to 950 cubic metres per second. As our object in the time of low supply is to raise the level of the water on the upstream side of the barrage, we cannot do so when we have to deal with a reservoir so large that it evaporates 1,000 cubic metres per second, while it is only receiving 850 cubic metres. Our object is to decrease, if possible, the reservoir above the barrage, and this we can do. Some thirty years ago the Euphrates joined the Tigris at Gurna, and the channel of the Euphrates not only carried its own discharge, but also that which escaped from the Tigris. Overburdened with this water the river burst its right bank and covered the lands behind it, and opened a deep channel for itself into the Shaat el Arab at Garmat Ali. The action of the waves has worn down the banks of the Euphrates, but it can be seen in many places, and here and there are still existing the villages and palm trees which once lined its whole course. I propose to let the whole of the Euphrates find its way to Garmat Ali, but with the aid of dredges to again make up the right bank of the Euphrates, join it to the left bank of the Euphrates at its upstream end, and so insure a passage for the escape waters of the Tigris down the old channel of the Euphrates to Gurna.

In this way we shall reduce the area of the reservoir above Garinat Ali Barrage from 830,000 hectares to 270,000 hectares and the evaporation in summer from 1,000 cubic metres per second to 320 cubic metres



per second. By adding to the discharge of the Euphrates that obtained from the numerous reservoirs on the river upstream of Nasria which will be conserved for this purpose, we shall have control over our water.

The figures we have been dealing with are very large compared with the discharges which will be withdrawn for the river by the proposed irrigation systems, but to complete the study I here give them.

The Feluja-Hindia Barrage system will withdraw, in the time of low supply, from the Euphrates 150 cubic metres per second for irrigation, and 50 cubic metres per second to be evaporated off lake Akkar-Kuf, or 200 cubic metres per second in all from the Euphrates. In time of low supply the Koot system will take 70 cubic metres per second, and the Beled system 50 cubic metres, or 120 cubic metres per second in all from the Tigris. The discharge withdrawn from both rivers will be 320 cubic metres per second.

Having found work for our reservoir and put it in a position to raise the water surface on its upstream side to R.L. 2·00 or even R.L. 2·50, I now turn to the canals.

The day a barrage is constructed across the Garinat Ali channel we shall be where the Emir Hajjaj was in the early days of the Khalifat, when by his energy and skill he converted 20,000 hectares of this land into a veritable agricultural paradise. By constructing a canal 50 metres wide and 3·5 metres deep parallel to the course of the Shaat el

Arab, and providing escapes for the drainage of the country into the lower head of the Khor Abdallah, we shall be able to cover the plain between the canal and the river with irrigants fed from both ends. The existing irrigants of the Basra date groves are to-day fed from one end only, and that on the river, and the difficulty of extending irrigation is due to this fact. The palms receive their water from the rising tide, and cultivation extends only as far as the water can travel. I have often followed the water of an irrigant or creek and seen it reach the last clumps of miserable half-starved date trees, deprived of their water by the outgoing tide just as they were going to receive it. Canals fed from both ends will remedy this evil. It might indeed be practically remedied to-day by self-acting shutters on the creeks which would permit the water to enter and prevent egress at will, but such regulators would be very costly works and useless in the hands of most of the present landowners.

The high-lying land near Basra capable of being irrigated is 200,000 hectares in extent, but we shall confine our attention to the strip of 90,000 hectares near the river. The projected works will cost as follows :—

(1) Basra Barrage	L.T. 131,960
(2) Repairing bank of old Euphrates	„ 78,000
(3) Earthwork in canals	„ 531,250
(4) Earthwork in drains	„ 7,650

Giving a total of L.T. 748,860, to which, when we add $33\frac{1}{3}\%$ for contingencies, or L.T. 249,620, we have a grand total of L.T. 998,480.

To begin with I should recommend the construction of the Basra Barrage, the repairs of the old Euphrates bank, and the construction of the canals shown on Drawing No. 76. These works will amount to L.T. 526,820. The area capable of reclamation will be 35,000 hectares.

I cannot leave the tract which is permanently under the opaque, healthy-looking water of the Euphrates, without recalling the fact that it was in such places that all the early settlements began :

“ The river had widened into a sea,

“ At that time Eridu was created ; E-Sagila was built ; E-Sagila in the midst of the fresh water deep, where the god of the glorious abode dwells.”

By the construction of earthen banks in the shallow lake traversed by the river, areas were reclaimed and cultivation began. Irrigation was

easy with fresh water all round at a level higher than the land. Suk el Sheyook is much like this to-day. Once security is established in these wild regions I anticipate a great increase of such reclaimed land.

Judging from reclamation works carried out in other countries I should estimate the cost of the reclamation works carried out in compartments of 5,000 hectares as follows:—

Fully equipped bank, per hectare	L.T. 4·0
Drainage cuts, per hectare.. .. .	„ 0·5
Masonry works and structures, per hectare	„ 1·0
Pumping plant erected at site, per hectare	„ 3·0
Total per hectare	<u>L.T. 8·5</u>

The maintenance charges would be L.T. 0·60 per hectare. There are some 100,000 hectares which could thus be reclaimed at an expenditure of L.T. 850,000. If reclaimed, they would be worth L.T. 100 per hectare at a moderate calculation I think. Such reclamation would need neither barrages nor public works of any kind.

Drawings Nos. 74, 76, 77, and 78 refer to these works.

19. Subsidiary works on the Hindia branch.—In addition to the irrigation works on the Euphrates already given there are two canals which should be constructed along the left and right banks of the Hindia branch from upstream of the barrage to beyond Tuarij. These canals will insure perennial irrigation to the country down to Kufa and feed all the canals which take off from the right and left banks of the Hindia branch.

The proposed works will consist of:—

- | | |
|---|-------------|
| (1) Excavation of two canals | L.T. 15,325 |
| (2) Masonry works on the two canals | „ 10,152 |

The cost of the works amounts to	<u>L.T. 25,477</u>
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which, increased by L.T. 8,493, representing contingencies at 33 $\frac{1}{3}$ %, brings the total sum to L.T. 33,970.

The area commanded will be 80,000 hectares.

Downstream of Tuarij, at the bifurcation of the Shamia and Kufa branches, barrages will be needed in future, but the Hindia branch itself is undergoing such great changes that the time is not yet ripe for undertaking them.

At Shamia a connecting canal joining the Hindia and Hilla branches at Diwaniâ is being undertaken by the Arabs, and if successful, will be a valuable asset to the country.

In the rice tracts below Tuarij no works have been allowed for. The river and its branches are undergoing great changes, freely irrigating the low lands in flood and covering them with a rich deposit which enriches the rice fields. The perpetual change seems admirably suited to the Arab character, and as I had no opportunity of thoroughly understanding the Arab methods of culture, I can recommend no improvements. The day will come, however, when engineers will have time to master this irrigation and introduce superior methods of rice cultivation borrowed from other countries.

Drawings Nos. 2 and 10 refer to these works.

20. The Beled Barrage and the irrigation of the Country between Beled and Bagdad.—The Tigris enters its delta at Beled, south of Samarra, where were situated the famous weirs of antiquity, which, judging from the bed level of the El Gaim head of the Nahrwan, must have held up the water of the Tigris to a height of 10 metres. In this reach of the Tigris, under the surface alluvium, lies a 10-metre belt of very compact conglomerate which again overlies a stratum of clay. This belt of conglomerate dips to the south-east and disappears under the bed of the river east of Beled. Formerly the Tigris rolled its waters above this hard conglomerate and entered the Delta at a high level. The undermining of the conglomerate began in historic times, and the serious consequences to the country moved some giant of antiquity to construct an earthen dam across the channel and turn the waters over the compact conglomerate on the right bank of the river. In this new channel the river flowed for many years and indeed through historic times.

The dam is locally known as Nimrod's dam to-day. From upstream of this work were taken the second and third heads of the great Nahrwan, on the left bank, and the Dijail on the right. In the troublous days which followed the devastations of Halaku and Timur, everything in the country went to ruin, and either the earthen dam was swept away by the floods of the Tigris, or the undermining of the rock on the Tigris diversion reached the dam and annihilated it.

The terminal line of the conglomerate, as it was gradually undermined, must have presented the appearance of a cataract 10 metres high,

and it was this which Tavenier saw in his travels. As the cutting back of the rock went on steadily, instead of imitating the great men of antiquity, the feeble Arab rulers led off canals from higher and higher up the river like the Iskaki canal, and allowed the river to be completely ruined. At Ashik, north of Samarra, was an excellent site for diverting the river, as there had been one at Nimrod's dam. A dam of modest dimensions would have sufficed if built on the surface of the conglomerate. We show on drawing No. 70 the massive class of work which is needed to-day.

The area between Beled and Bagdad capable of being reclaimed consists of 170,000 hectares of land, and there are three ways open to us for irrigating it, and we have prepared all three projects :—

1. The most economical is the low level Beled Barrage given in drawing No. 41. This work would, however, entail heavy maintenance charges for years and could not hold up the level of the river to R.L. 54·5, which is essential for complete command of the country.

The cost of the work amounts to L.T. 233,091.

2. At Ashik, north of Samarra, at the spot already mentioned, we have designed a dam across the Tigris and a diversion for the river shown in drawing No. 70. By diverting the Tigris over the compact conglomerate which, once formed its bed, we could command the country, while a side canal would lead back to the Tigris all the water needed for the tract we wish to reclaim. A second earthen dam of very ordinary proportions thrown across the river at the site of the proposed Beled Barrage (and shown on drawing No. 70) would enable us to hold up the water to R.L. 60·00, and command the whole desert between the Tigris and the Euphrates, as well as the delta of the Tigris. The cost of these works is estimated at L.T. 601,430.

3. The third project is the one I have finally approved of and is given on drawing No. 71. Here we have a barrage similar to the one at Koot with a subsidiary barrage downstream of it, on the same lines as the work constructed by Sir Hanbury Brown on the Nile near Cairo. This work will hold up the water to R.L. 54·50 and provide amply for all our needs. The estimated cost is L.T. 619,668.

I could have added a lock as at Koot, but I did not care to face the heavy expenditure, considering that the Bagdad railway will soon be running parallel to the Tigris, and that the rafts which float down the river will be as easily broken up at Beled as at Bagdad.

With the water level raised permanently to R.L. 54·5 we can reconstruct the ancient Izkaki and Dijail canals and also a new canal which we have named the Kazimain. This last canal will follow the Tigris from Mansuria to Kazimain, and, with its banks, protect the country from inundation.

The estimated cost of the work is as follows :—

(1) Beled main barrage	.. .. .	L.T.	225,503
(2) Beled subsidiary barrage	.. .. .	„	110,315
(3) Diversion of the Tigris	.. .. .	„	278,850
(4) Damming the Tigris	.. .. .	„	5,000
(5) Regulator for Dijail canal	.. .. .	„	9,225
(6) Masonry works..	.. .. .	„	13,720
(7) Pipe crossings for the Tigris flood	.. .. .	„	18,100
(8) Irrigation pipes	.. .. .	„	24,000
(9) Canal earthwork	.. .. .	„	114,950
(10) Drains	.. .. .	„	32,250
Total			 L.T. 831,913
which, with contingencies at 33½ % or			„ 277,307
gives a grand total of			 L.T. 1,109,220

Drawings Nos. 2, 8, 41, 70 and 71 refer to these works.

21. The Nahrwan Canal.—The Dyala river leaves the Hamrin hills and hurries over shingle deposits for some 20 kilometres. There many canals are led off both banks, of which the principal are the Khalis and its branches on the right bank, and Beled Ruz and Khorassan on the left. The country is well irrigated and prosperous, while Bakuba, at the tail of the Korassan canal is a veritable garden. Good masonry regulators at the heads to properly distribute the supply, and regulators for the escapes back into the Dyala are much needed. Under a perfect system of irrigation many of the tracts between the canals would be provided with drains, while all the canals should have iron pipe culverts to regulate the amount of water going down the numerous private water courses. All these works should be executed, but they are outside the projects which I have in hand. We surveyed and levelled all the canals and the country traversed by them in the hope of gaining an idea of their irrigation duty, but the escapes back into the river or into the desert

were so numerous and so capacious that we have not been able to gain any information.

Cyrus the Great diverted so considerable a portion of the waters of the Dyala into the many canals excavated by his army that his engineers were able to dam what remained of the river at Sifwa and turn it down the lower Nahrwan canal. In addition to the waters of the Dyala, this canal was supplied by feeders from the Tigris with their heads above Nimrod's dam near Beled. This magnificent canal irrigated the lands on the left hand of the Tigris right up to Koot. The destruction of Nimrod's dam deprived the Nahrwan of its supplies from the Tigris, while the dwindling away of the canals constructed by Cyrus so increased the discharge which remained in the Dyala that the Beldai dam at Sifwa was swept away and the Nahrwan was altogether deprived of water. All this must have happened six or seven hundred years ago. The lands irrigable by the Nahrwan are some of the richest in Mesopotamia and the restoration of this canal has engaged our most serious attention.

The old Nahrwan canal in its upper reaches can only be reconstructed at a very heavy cost. The Tigris in changing its course has gone far to the east and cut up the country into such extraordinarily deep and wide ravines that no canal could be possibly constructed across them which would be remunerative enough under present conditions. It is possible, looking many years ahead, that the value of land on the Nahrwan might be sufficiently high to open up this question of feeding the Nahrwan from the Tigris as in ancient days; but it is waste of time to think of such a project to-day.

There are three methods by which the waters of the Dyala could be led into the Nahrwan :—

(1) The construction of a masonry barrage at Sifwa and the excavation of the lower Nahrwan canal. Drawings Nos. 9 and 92 explain the works which would have to be executed. Their estimates amount to L.T. 203,190, thus made up :—

(1) Barrage on Dyala	.. .. .	L.T.	79,220
(2) Diversion of Dyala	.. .. .	„	42,870
(3) Excavation of lower Nahrwan	.. .. .	„	74,320
(4) Nahrwan head	.. .. .	„	6,780
Total	.. .. .	L.T.	<u>203,190</u>

The barrage would be strained very severely to maintain the level of the water needed for the canal.

(2) The construction of the upper Nahrwan canal from the Hamrin hills to the 12th kilometre of the lower Nahrwan canal at a high level. These works are shown on drawings Nos. 5 and 9 and are estimated at L.T. 153,220, thus made up :—

(1) A. Excavation of upper and lower Nahrwan canals	L.T. 143,220
(2) A. Canal head	„ 10,000
Total	<u>L.T. 153,220</u>

Of these projects the second is undoubtedly the better. It might be found more economical to leave the alignment of the canal traced on the map at kilometre 40 and follow the trace of the ancient Nahrwan east of the Dyala, but I doubt it. There remains the third.

(3) It would be possible to divert the Dyala river from the point where it leaves the Hamrin hills and make it follow an alignment east of the Beled Ruz canal. It seems as if in old days the Dyala had a tendency to move in this direction as there is a massive masonry wall along the left bank of the Dyala from the point that it leaves the Hamrin hills, which is shown on drawing No. 16. The Dyala river, thus diverted, would travel down the Mardj depression and finally join the Tigris to the east of Koot. This diversion would free the Tigris, near Bagdad, of the heavy floods which the Dyala brings down, and constitute an escape of immense value. If the alignment east of the Beled Ruz canal were not the best, it might be possible to divert the river west of the Beled Ruz canal. Making rough sections of the country with the aid of levels down the Beled Ruz canal to its tail, I estimate the cost of such a diversion at L.T. 492,700. We have not been able to take all the levels we needed for a complete project owing to the early floods which have interfered with our work. If this project were carried out, the Dyala would thus again be in a position to be utilized as it was in Cyrus' time, and an earthen dam across the river at Sifwa would suffice for diverting the water down the lower Nahrwan canal.

If the Dyala diversion were carried out the execution of the Nahrwan project would entail very little expenditure and be a sound work on financial grounds, in spite of the fact that the waters of the Dyala in times of low supply, are already utilized by the existing canals, and

the Nahrwan could only receive its supplies from November to July. The Nahrwan soil is very rich, and 200,000 hectares capable of producing an annual crop of wheat would be no mean asset to Mesopotamia.

As the diversion of the Dyala will assuredly be carried out one day in the interests of the whole country, I thus estimate the cost of the resuscitation of the Nahrwan canal :—

(1) Dyala diversion	L.T. 479,400
(2) Dam across Dyala	„ 13,300
(3) Earthwork	„ 111,760
(4) Minor canals earthwork	„ 25,500
(5) Irrigation outlets	„ 30,000
(6) Masonry works	„ 14,680
(7) Masonry head for an escape into Dyala	„ 8,780
Total	L.T. 681,420
33 $\frac{1}{3}$ % for contingencies	„ 227,140
Grand total	L.T. 908,560

Drawings Nos. 2, 5, 9, 15, 16, 42 and 54 refer to these works.

22. Financial aspect.—In estimating the value of the land in the Delta I shall follow a single rule for all the projects. Of the area commanded by a canal, it will be assumed that half the area is irrigated in winter and a third in summer. Of the area irrigated in winter it will be further assumed that half is grown with wheat ; while of the area irrigated in summer half is sown with cotton or the best paying crop. No account will be taken of the palm trees which will attain a development beyond all calculation. (The day dates gain a popularity in China, Mesopotamia will have quite a special value). In calculating the winter rents of the area commanded, the value of the wheat crop will be taken ; and in calculating the summer rents, the value of the cotton crop. A hectare of wheat may be taken as yielding 2 tons of wheat at L.T. 6 per ton, or L.T. 12. A hectare of cotton may be taken as yielding 10 cwt. at L.T. 2·5 per cwt., or L.T. 25. A hectare of land commanded by a canal will, therefore, be credited with a rent of one-fourth of L.T. 12, or L.T. 3, per annum for winter irrigation, and of one-sixth of L.T. 25, or L.T. 4, per annum for summer irrigation. Perennially irrigated land will, therefore, be credited with a rent of L.T. 7 per annum per hectare commanded.

A tithe is 10 per cent. of the whole produce, or 20 per cent. of the half produce we have been considering. In other words, the tithes will amount to 0·60 per annum per hectare commanded in winter, and L.T. 1·4 per annum per hectare perennially commanded.

Deducting the tithes from the rent, the net rents become L.T. 2·4 and L.T. 5·6 for winter and perennially irrigated lands respectively.

The cost of maintenance of the works will be heavy. I shall assume L.T. 0·30 per hectare commanded per annum.

If we take land in the country as worth 14 years purchase we may consider each hectare of land commanded in winter as worth L.T. 33, i.e. $(14 \times (3 - 0·6))$, and each hectare commanded perennially as worth L.T. 78, i.e. $(14 \times (7 - 1·4))$.

With respect to the estimated cost of the projects, one-third, or $33\frac{1}{3}\%$, has already been added to the cost obtained from quantities and rates, for contingencies, establishment, tools and plant and accommodation. The total sum thus obtained has been called the estimated cost of the works. Now to allow for interest on the money spent during the execution of these works and their subsequent development, I consider it a safe rule to double the estimated cost of the works to obtain the *true cost* of the irrigation works. This will be done for each project.

Having obtained the true cost of the irrigation works, there remains the cost of the agricultural operations or works. Of the agricultural works, the water courses and drainage channels will be very economical, as the country is covered with the remains of the ancient canals from which the ground slopes away abruptly on both sides. Ploughing and levelling will also be exceedingly easy in a land already once under cultivation and consisting of a light loam. The clearance of weeds will be costly. All works which are ordinarily made of masonry will be made here of pipes of the “Acme” class, insuring both economy and expedition. Taking all these factors into consideration and comparing them with those in other countries, I estimate that the water-courses and drainage channels will cost L.T. 2 per hectare; and the levelling and clearing L.T. 8, including establishment, accommodation and all contingent charges. The total will amount to L.T. 10 per hectare.

With the aid of the preceding paragraphs we can now form a fair idea of the financial aspect of the different projects and the order in which they should be executed. At the very outset, I put away all short cuts at the reclamation of the country by isolated works which

would eventually stand in the way of the development of the whole Delta. We might, for example, make a dyke from near Akkar-Kuf to the south of the iron bridge near Bagdad and economise on the works needed for the Feluja project, but at the cost of the permanent abandonment of the whole area west and north-west of Bagdad. Bagdad would for ever be situated in the middle of a desert. The projects I propose are, I believe, sound ; and, far from standing in each other's way, will help each other.

The first works to be undertaken will be those for the reclamation of the 550,000 hectares between *Bagdad on the Tigris* and *Kufa on the Euphrates*.

The works themselves may be thus classed :—

(1) Euphrates protection works	L.T. 395,500
(2) Tigris protection works	„ 107,470
(3) Feluja Barrage	„ 355,810
(4) Left Euphrates canals	„ 596,330
(5) Right Tigris canal to kilometre 69	„ 441,360
(6) Drainage cuts	„ 277,110
(7) Hindia Barrage	„ 334,740
(8) Hindia subsidiary works	„ 33,970
Total	<u>L.T. 2,542,290</u>

The actual cost of the irrigation works will be	L.T. 5,084,580
The agricultural works will cost	„ 5,500,000
The net rents per annum	„ 3,080,000
The tithes per annum	„ 770,000
The maintenance charges per annum	„ 165,000
And the value of the land	<u>„ 42,900,000</u>

The next tract to be undertaken will be the 250,000 hectares irrigated by the *Hai canal* from above the Koot Barrage. The works are estimated to cost L.T. 1,378,990.

The actual cost of the irrigation works will be	L.T. 2,757,980
The agricultural works will cost	„ 2,500,000
The net rents per annum	„ 1,400,000
The tithes per annum	„ 350,000
The maintenance charges per annum	„ 75,000
And the value of the land will be	<u>„ 19,500,000</u>

At the same time as the Hai there should be undertaken the *Basra* reclamation works of 90,000 hectares.

The works are estimated to cost	L.T.	998,490
The actual cost of the irrigation works will be ..	„	1,996,980
The agricultural works will cost	„	900,000
The net rents per annum	„	504,000
The tithes per annum	„	126,000
The maintenance charges per annum	„	27,000
And the value of the land will be	„	<u>7,020,000</u>

I here call attention to page 40 of paragraph 18 where the reclamation in blocks of 5,000 hectares of 50,000 hectares in the *overflow of the Euphrates* is recommended at an expenditure on irrigation works of L.T. 425,000. The agricultural expenditure would amount to L.T. 250,000, and the maintenance charges to L.T. 30,000 per annum.

The land would be worth	L.T.	<u>3,900,000</u>
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The tract irrigated from above the *Beled Barrage* is estimated to cost L.T. 1,109,220, and covers 170,000 hectares.

The actual cost of the irrigation works will be ..	L.T.	2,118,240
The agricultural works will cost	„	1,700,000
The net rents per annum	„	952,000
The tithes per annum	„	238,000
The maintenance charges per annum	„	51,000
And the value of the land will be	„	<u>13,260,000</u>

It will be remembered that we have so far only considered the estimates of the first 69 kilometres of the *Right Tigris canal*. When the canal is completed to its *tail* there will be a further estimated expenditure of L.T. 503,308, while the area commanded will be 100,000 hectares.

The actual cost of the irrigation works will be ..	L.T.	1,006,760
The agricultural works will be	„	1,000,000
The net rents per annum	„	560,000
The tithes per annum	„	140,000
The maintenance charges per annum	„	30,000
And the value of the land will be	„	<u>7,800,000</u>

The *Nahrwan* tract has an area of 200,000 hectares to be irrigated only in winter. The estimated cost of the works is L.T. 908,560.

The actual cost of the irrigation works will be	L.T. 1,817,120
The agricultural works will cost	„ 2,000,000
The net rents per annum	„ 480,000
The tithes per annum	„ 120,000
The maintenance charges per annum	„ 60,000
And the value of the land will be	„ 6,600,000

To insure the navigation of the Tigris we have estimated for an expenditure of L.T. 48,350 south of Amara. These works will create a maintenance charge of L.T. 5,000 per annum.

The table at the end of this paragraph tabulates all the figures we have been considering, and its results may be thus summed up :—

The total cost of the irrigation works will be	L.T. 15,255,020
The total cost of the agricultural works will be	13,850,00
Grand total ..	<u>L.T. 29,105,020</u>
The net rents (after deducting tithes) will be	
25 per cent. on the grand total or	L.T. 7,256,000
The tithes will amount to	„ 1,814,000
From which have to be deducted the maintenance charges of	„ 443,000
Leaving a balance of	<u>L.T. 1,371,000</u>

which represents 9 per cent. on the cost of the irrigation works.

Much of the success of the works will depend on the expedition with which they are carried out, and the sooner they are completed the sooner will they be remunerative, and reduce the interest charges. It is on this account, therefore, that I think it will be a real economy to employ metal pipes of the “ Acme ” class wherever possible in place of masonry works ; Portland cement on a large scale for the masonry works ; and every kind of steam excavator for the earthwork. Indeed, to these three essentially modern productions will be due in great part the resurrection of this ancient country.

That the works will be exceedingly remunerative I have no doubt whatever. All that is needed is the goodwill of the Ottoman Government ; and I close the report with a direct appeal to the new spirit which animates the Turkish Empire. The last voyage I made before

coming to this country was up the Nile, from Khartoum to the great equatorial lakes. In this most desperate and forbidding region, described by travellers as "a damp hell," I was filled with pride to think that I belonged to a race whose sons, even in this inhospitable waste of waters, were struggling in the face of a thousand discouragements, to introduce new forest trees and new agricultural products and ameliorate in some degree the conditions of life of the naked and miserable inhabitants. How should I have felt if, in traversing the deserts and swamps which to-day represent what was before the Arab conquest the richest and most famous tract of the world, I had thought that I was a scion of a race in whose hands God had placed, for hundreds of years, the destinies of this great country, and that my countrymen could give no better account of their stewardship than the exhibition of two mighty rivers flowing between deserts to waste themselves in the sea for nine months in the year, and desolating everything in their way during the remaining three. No effort that Turkey can make can be too great to roll away the reproach of these parched and weary lands, whose cry ascends to heaven.

W. WILLCOCKS.

Bagdad, 26 March, 1911.

Table of Financial Results.

(1) Name of system.	(2) Cost of irrigation works.	(3) Cost of agricultural works.	(4) Total cost of irrigation and agricultural works.	(5) Area commanded.	(6) Net* rents per annum.	(7) Percentage of column 6 on column 4.	(8) Tithes per annum.	(9) Maintenance per annum.	(10) Tithes less maintenance per annum.	(11) Percentage of column 10 on column 8.	(12) Value of land (14 years purchase).
	L.T.	L.T.	L.T.	Hectares	L.T.		L.T.	L.T.	L.T.		L.T.
Feluja-Hindia ...	5,084,580	5,500,000	10,584,580	550,000	3,080,000	30.0	770,000	165,000	605,000	11.9	42,900,000
Hai	2,757,980	2,500,000	5,257,980	250,000	1,400,000	26.7	350,000	75,000	275,000	10.0	19,500,000
Basra	1,996,960	900,000	2,896,960	90,000	504,000	17.4	126,000	27,000	99,000	5.0	7,020,000
Euphrates overflow.	425,000	250,000	675,000	50,000	280,000	41.4	70,000	30,000	40,000	9.4	3,900,000
Beled	2,118,240	1,700,000	3,818,240	170,000	952,000	24.9	238,000	51,000	187,000	8.8	13,260,000
Nahrwan	1,817,120	2,000,000	3,817,120	200,000	480,000	12.5	120,000	60,000	60,000	3.3	6,600,000
East Tigris Tail...	1,006,760	1,000,000	2,006,760	100,000	560,000	28.0	140,000	30,000	110,000	10.9	7,800,000
Navigation... ..	48,380	—	48,380	—	—	—	—	5,000	—	—	—
TOTAL OR MEAN...	15,255,020	13,850,000	29,105,020	1,410,000	7,256,000	24.9	1,814,000	443,000	1,371,000	9.0	100,980,000

* Net rents are the rents with the tithes deducted from them.

The Nahrwan project includes the diversion of the Dyna which would be a great gain to the country generally.

The profit on the undertaking is calculated by the percentage of net rents on the total cost of the irrigation and agricultural works, and is 24.9 %.

The profit to the Government is calculated by the percentage of tithes minus maintenance on the cost of the irrigation works and is 9.0 %.

In addition to the direct gain on the irrigation works expenditure the Government will profit by increased import duties and all other sources of revenue which accompany increased wealth among the people.

APPENDICES.

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APPENDIX A.

Staff of Mesopotamian Irrigation Survey.

Mr. B. T. WATTS, *Director.*

Messrs. F. E. APTED, *Surveyor.*

Y. ASHKAR, „

M. BADIE, „

N. BAUER, *Head draughtsman.*

Y. ELNECAVÉ, *Surveyor.*

S. ESMAT, „

I. HAMDY, „

M. IBRAHIM (Bey) „

R. MICHAEL, *2nd draughtsman.*

E. C. F. MOORE, *Surveyor.*

I. NÉGUIB, „

A. RUSHDY, „

S. SIMO, „

E. M. TABOR, „

H. E. WEBER, „

J. O'F. WILLCOCKS (Revd.), *Surveyor.*

P. G. LOCH, *English secretary.*

G. LEGRAND, *French* „

Y. OUFİ, *Accountant.*

T. ABDULKERİM, *Clerk.*

APPENDIX B.

Survey.

The following report on the methods employed to obtain the maps and levels of the country was written for me by Mr. B. T. Watts, who directed the work.

In deciding upon the method in which the surveys and levels should be carried out the following facts had to be taken in count :—

- (1) There were no levels at all of the country ;
- (2) Except Collingwood and Selby's survey of part of the Delta and the "Comet" plan of the Tigris there were no reliable maps of the country ;
- (3) The area of the land capable of being irrigated, from which the most suitable tracts were to be selected, was very extensive ;
- (4) The work had to be done as quickly as possible.

Taking the above facts into consideration it was decided that triangulation was superfluous, and that plane table traverses with the aid of the tacheometer and magnetic needle would suffice. We should thus not have perfect maps of Mesopotamia, but a good workable idea of the nature of the country sufficient to allow projects for the irrigation of the country to be prepared.

There were four survey parties, each of which consisted of one surveyor and two levellers. The levellers worked side by side using 14-inch levels (Cook's and Son) fitted with stadia hairs and compass.

Good results were obtained by plotting (Chamber's traverse tables) each day's level traverse from the level compass readings, and then transferring it to the map, the surveyor and levellers starting and finishing on the same points; by this method it was found possible to cover a much larger area, as the plane table did not necessarily follow the same line as the levels ; the difference between the two lines generally worked out at about 1 in 200.

The first work undertaken was to connect Bagdad with the sea by a line of levels, and the mean sea level found on two consecutive days at the Khor Abdallah was taken as the zero for all future levelling.

The length of sights taken when fixing the preliminary bench marks varied between 100 and 200 metres according to the time of day.

The numerous checks on these bench marks, except in a few isolated cases, have been well within the limits of levelling for irrigation purposes.

The scale of all field maps was $\frac{1}{30000}$, this being found to give a good idea of the country traversed.

Traverses were run down the two rivers (Tigris and Euphrates) and down the centre of the country, and were tied up by numerous cross traverses between the two rivers. These lines have formed the bases for compiling the $\frac{1}{30000}$ scale map.

The error in length of the different traverses generally worked out at about 1 in 300.

Subsoil water was recorded wherever it was found.

The sections and discharges of the rivers were found to be a work of some difficulty, as proper boats could only be obtained at Bagdad, and "gooffas," circular coracles, peculiar to Mesopotamia, could only be obtained in a very few places outside of the towns, and then, from their peculiar shape and method of propulsion, made the work a slow and tedious affair.

The discharges were taken with surface floats over some fixed distance, the positions of these floats or of the boat when taking the soundings, etc., were read off by the tacheometer from a staff held in the boat or "gooffa." Harlacher's method for calculating discharges was invariably employed.

Though the authorities rendered us every aid in their power and supplied police to accompany every party there were difficulties peculiar to the country, among which may be mentioned (1) the absence of water in the interior; (2) the large marshes which form close up to the river in flood time greatly impeding the movements of the baggage animals; and (3) the intertribal troubles which in a few places prevented the work from being carried out.

With respect to the difficulties encountered owing to the absence of water; it may be stated that Egyptian army fantasses, or metal water cans, were found invaluable.

APPENDIX C.

The Agricultural possibilities of Mesopotamia.

The following report has been written for me by Mr. G. P. Foaden, late of the Khedivial Agricultural Society.

A brief examination of the climatic conditions of Mesopotamia leads one to the conclusion that with a kind soil and an efficient system of irrigation, practically all those crops which flourish under a sub-tropical sun might be successfully grown. During the winter, or cold weather season, extending from November to May, the ordinary cereal crops of wheat and barley which grow under such wide ranges of climate, should succeed admirably; in fact they are at present extensively cultivated, as also is rice. The conditions also seem quite suitable for numerous pulse crops (so well-known in India and other eastern countries and of which there are such numerous kinds); beans exist at present and do quite well. Maize and millet should also find a place in the rotation and grow well; in fact there seems no reason why practically all crops which rejoice under a strong sun should not be raised, and of other crops which should succeed, we may mention sesame and earth nuts. Forage crops should show rapid growth during the winter, though during the summer it is practically certain that the same difficulty would be experienced as is felt in Egypt in this respect, unless an abundant supply of water is available. The strong sun and dry atmosphere would probably render the successful growth of really nutritive forage crops very difficult during this period. With plenty of water, lucerne might be grown; in fact it forms at the present time a considerable part of the forage in Basra. The crop does well in Egypt, but the great objection to it is that it requires much water at a period when every drop is needed for cotton and other summer crops. Should lucerne succeed generally, not only would the soil itself be improved, but all difficulty as to summer forage would be removed. Under irrigation, green maize, sorgho, and a host of other crops could be grown to provide food during the hot months, but preference would naturally be given to one of a leguminous nature. Winter forage would present no difficulty. Whether berseem would succeed or not is very problematical. Experiments which promise well are being conducted in some of the southern states of America with this crop, and it is very likely that eventually its growth will not be confined to Egypt, as it is practically at present. As a soil renovator this crop would prove more valuable should local conditions prove suitable to it. To find a leguminous forage crop which will grow with success must be almost the first step towards the successful cultivation of these soils. The existence of such a crop has largely contributed to the fertility of Egyptian soils, just as the want of an extensive growth of a plant of this nature has, on the other hand, been a great want in the cotton-growing states of America. Successive

forage crops and a plentiful supply of water go together. With the latter provided in Mesopotamia, there can be no doubt but that the former would be easily secured.

The question of the possibilities of fruit-growing is a somewhat difficult one. Melons would certainly do well in the summer. Oranges of good quality are found at present. Grapes would probably succeed to a certain point. Date trees are found in profusion, though the fruit is not of a very good quality. By the introduction of the best kinds from Algiers and Egypt no doubt this could be remedied.

At the present time, when so much attention is being given to the question of cotton-cultivation, it will be advisable to examine in a little detail the climatic conditions under which this crop is grown and to deduce whether, in a general manner, they are likely to be fulfilled in the valleys of the Tigris and Euphrates. A glance at the map will show that the soils fall within what we may call the "cotton belt," and a closer examination of the climatic conditions will indicate that, as far as the temperature is concerned, the region possesses the conditions necessary for the production of cotton. In examining the possibilities of the growth of cotton, we have first to consider the duration of the season, which must be sufficiently long for the crop to mature. From six to seven months at least of favourable growing weather are required for its development. The temperature must be high, and the daily range somewhat uniform, during the period of active growth. It should gradually increase from the time of sowing until the period of maximum growth is attained, after which a fall is by no means disadvantageous, as it induces the plant to ripen, and checks the tendency to increased vegetation. That these conditions exist will be seen from the following table which indicates the mean daily temperature at Bagdad. For the purposes of comparison, similar observations taken at Cairo are given, as well as those of the southernmost portion of the cotton-growing belt of America.

	BAGDAD.	ASWAN, 1902.	CAIRO.	Southernmost section american cotton- growing states.
	°	°	°	°
January... ..	9·5	14·8	12·2	—
February	12·7	20·1	13·2	—
March	16·3	22·0	16·9	—
April	21·9	26·6	21·1	21·0
May	26·9	32·6	25·5	24·0
June	32·2	32·4	28·3	28·0
July	34·5	32·5	29·2	29·0
August	34·8	32·5	28·8	28·5
September	31·2	31·6	26·2	25·5
October	25·1	28·6	22·7	21·0
November	16·9	20·8	18·9	16·0
December	11·9	14·3	14·6	—
THE WHOLE YEAR...	22·8	25·7	21·5	—

From the prevailing conditions it will be seen that March is the most suitable month in which planting should take place, and that for the first three months of the growing period, the temperatures at Bagdad and Cairo are practically similar. A comparison of the figures with those of the southern section of the cotton belt in the United States, indicates that the temperatures are slightly higher than those prevailing in the region. This is a considerable advantage when we bear in mind that the American crop is often retarded by too low temperatures during the early period of growth. During the months of June, July, August and September, the temperatures at Bagdad are higher than those at Cairo, the result of which would be to considerably hasten the maturity of the crop. It was thought at one time that good cotton could not be successfully grown in the southernmost district of Upper Egypt, where the temperatures are considerably higher than those in the Delta, but recent experiments have tended not only to disprove this theory, but also indicate that a heavy yield may be obtained owing to a greater percentage of the bolls coming to maturity. In the Delta a very considerable percentage of the bolls never open owing to the falling temperature and the consequent fogs in late summer. Where these conditions do not prevail to such an extent a much greater proportion of the bolls open. The climatic conditions of Mesopotamia, as instanced by the records of Bagdad, would appear to indicate that the crop would come to speedy maturity, and that there would be ample time for the great majority of the bolls to develop, especially if water be judiciously withheld at the proper moment. It is worthy of mention that in the southern provinces of Upper Egypt, where the temperatures are highest, the damage resulting from insect and fungoid pests is considerably less than in the Delta.

From the point of view of quality, it is well-known that the finest cottons are grown in those districts where the temperatures do not run so high, and where humidity is greater, but recent experiments have shown that good cotton can be grown where the temperatures are considerably higher than have been generally regarded as favourable to the plant, and when the atmosphere is also dry. There is every reason to believe that by a system of selection, varieties eminently suitable to such districts could be secured which would produce high yields of excellent quality. The idea which was at one time prevalent to a great extent, that Egyptian cottons could not be cultivated with any great measure of success in other countries, has in the light of recent experience been dispelled, and in many widely differing regions, it has during the past two or three years been grown with success. We see no reason why, therefore, from this point of view also, Egyptian cotton should not be produced in Mesopotamia. The variety grown in Upper Egypt (Ashmouni), would be the most suitable to introduce from this standpoint, though it must be borne in mind that it is not increasing in favour in the commercial world. The minimum temperature recorded during the months which cotton would occupy the ground, indicate that they are high, and that no arrestation of growth, or set backs, need be feared in this respect. They are higher than both Egyptian figures and those of the American cotton-growing states. This is a matter of the greater importance and cannot be over-estimated.

From the point of view of climate, therefore, as measured by temperature, Mesopotamia seems to possess the necessary conditions for successful cotton-raising; a high temperature and a sufficiently long growing period, with no suddenly-occurring variations.

The next most important consideration is that of the amount and distribution of rainfall. It is at once clear that the crop would depend entirely on irrigation. During the first two months of March and April the normal rainfall is about 60 millimetres, corresponding to less than one watering, such as is usually given to cotton in Egypt. During the remainder of the growing-period, practically no rain falls. The whole of the supply of water therefore must be artificially supplied, as in Egypt. Provided this is done, conditions seem eminently favourable, though it must be observed that the relations of climate to crop production are so complex that it is impossible to give any exact or adequate interpretation of meteorological data, and to show their full importance to the production of any crop. Average monthly temperatures, for example; may show favourable conditions, but one or two days of extremely unfavourable weather may injure the crop to such an extent that no subsequent favourable conditions can fully remedy. This is not shown, however, in monthly means. From a general point of view the conditions in Mesopotamia are such that the probabilities of this occurring seem reduced to a minimum.

The question of the supply of a sufficient amount of labour faces the cotton grower in almost every country, and is one to which attention should be directed.

From an examination of the samples of soils sent it is evident that they are free-working, and of the nature of calcareous loams. Though it is difficult to express an opinion from the data available, it does not seem that they would be particularly suitable for sugar cane. Rich porous clays, and alluvial soils in low lands through which rivers run, are the most suitable for cane cultivation, as well as loams formed by the decomposition of volcanic rocks. It is true that canes will grow on almost any soil; the wide diversity of soils on which the crop is actually grown being proof of this. When large profits were made by planters, the nature of the soil was not of such amount, but at the present time of low prices, the crop can only be profitably raised on those essentially suited to it. The nature of the soils of Mesopotamia does not at first sight seem suitable, but it may be remarked that in Barbados, where the soil is particularly adapted to it, lime exists in considerable quantity, the island being of coral formation. It will be noticed subsequently how rich the soils under consideration are in this ingredient. In parts of Antigua again some of the rich cane lands have been formed by the decomposition of a kind of limestone. It seems, however, that under present conditions the soils of Mesopotamia would be more likely to grow cotton with success than canes, though as far as climate is concerned nothing would prevent the successful growth of sugar. Though the temperature sometimes falls one or two degrees below zero in January, it is extremely probable that the canes could be cut by that time. This is the main point to which attention may be directed from a climatic point of view. It is worthy of mention that the growth of canes

involves a greater expenditure of capital than that of cotton, for which but little is required. A ginning installation with presses is much less costly than a sugar factory.

Cotton delights in deep loams, well drained soils of a somewhat light nature, such as those found in Mesopotamia. The latter will not be retentive of water, but on the contrary will need, under the conditions of climate prevailing, a very plentiful supply.

Looking at the soils from a chemical point of view, we may first deal with three typical soils of the Tigris which gave the following results on analysis. The samples were taken to a depth of 10 inches :—

Typical Tigris soils.

Moisture... ..	3·04	1·54	4·29
Loss on ignition	5·54	4·12	6·99
Insoluble silica and sand	49·22	46·88	47·26
Lime	11·20	18·25	12·65
Potash	0·58	0·59	0·62
Phosphoric acid	0·21	0·25	0·25
Nitrogen	0·117	0·122	0·122
Total soluble salts	Traces	Traces	Traces
Sodium chloride	Traces	Traces	Traces

The percentage of lime present is very striking and exceptional. It is much greater than is found in Egyptian soils, where it averages from 2 to 4% (5% being exceptional), and much more so than Indian and American cotton-growing soils. It is difficult to foresee the effect of its presence on the cotton plant, but instances are not wanting where cotton is grown on soils containing an even greater amount than in the soils under consideration. In Alabama, some of the soils on which the crop is grown contain 29% ; in Arkansas, the black calcareous prairies often contain 28%, and in Mississippi, some of the the prairie soils contain 22%. These quantities are greater than those indicated in the above analysis, which average 14·03 %.

Of the valuable ingredients, nitrogen, phosphoric acid and potash, the soils show full percentages; of the former the average is similar to that found, generally speaking, in Egyptian soils, though the “ condition ” in which it exists is a most important factor. The normal percentage of nitrogen in good soils is stated to be about 1 %, whereas in the soils under consideration the average is 0·12%. For soils not under cultivation or vegetation the amount present is high. Whether soils containing so much nitrogen as indicated would be benefited by nitrogenous manures depends largely on the condition in which it is present, and would be a matter for experiment. The nitrogen probably exists in forms which are not readily available. It is satisfactory, however, to note that the percentage present reaches the generally accepted limit.

Phosphoric acid is present to the extent of 0.2 %. This amount is quite normal. When the percentage is below 0.1 % manure containing this ingredient may generally be employed with advantage, but in this case again, as with nitrogen, much depends on the forms of combination in which it is present. In England 0.12 to 0.13 % of phosphoric acid is considered an average, and 0.16 to 0.17 % is above it. The percentage present in these soils is quite equal, generally speaking, to Indian figures, and though it is often exceeded in Egypt, many good soils of the Nile Valley do not surpass it.

Potash is also present in considerable quantities, in fact, in more than average amount. Soils containing 0.25 % are generally considered to fail to respond to potash manuring, an amount which is surpassed in the soils under consideration, where the average is approximately 0.6 %. Good black cotton soils in India contain about 0.25 to 0.3 %, and many of the best cotton producing soils of the United States fall below this amount.

Summarizing, we may say that as far as the valuable constituents, nitrogen, phosphoric acid, and potash are concerned, these samples of good Tigris soils may be regarded in a very favourable light.

Two samples of "fair" Euphrates soils were analysed with the following results:—

	No. 10.	No. 4.
Moisture	6.53	3.79
Loss on ignition	2.60	2.44
Insoluble silica and sand...	47.71	49.92
Lime	12.60	13.72
Potash... ..	0.48	0.54
Phosphoric acid... ..	0.25	0.19
Nitrogen	0.092	0.078
Total soluble salts	Traces	Traces
Sodium chloride	Traces	Traces

These are lower in nitrogen than those of the Tigris, averaging 0.085 %, as compared with 0.12 %. Soils of the nature of No. 4 would certainly require nitrogenous manuring, while No. 10 would also probably show considerable benefit thereby. In phosphoric acid they both reach the limit, the average being 22 %. They are both well provided with potash, the average being 0.51 %. It is only in nitrogen that they are low. Though the term "low" is employed, it is only so in a comparative sense. Many soils in Egypt do not exceed 0.09 %, but it is most probable that the nitrogen is in a much more available form. An average of 0.085 % is not low for soils which have not been cultivated for ages, and which do not naturally support vegetation.

The result of the analysis of nine other samples of soils from the valleys of the Tigris and Euphrates are practically similar to those already given. The nitrogen averages 0.103 per cent., the lowest limit being 0.067 and the highest 0.132. With the exception of the former all the samples reach 0.09 %.

The average content of phosphoric acid and potash is 0.198 and 0.60 respectively.

Considerable areas of salt land exist on the Tigris and Euphrates, corresponding to the salt lands of Egypt in the northern part of the Delta. Samples of these gave on analysis the following results :—

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
	%	%	%	%	%
Total soluble salts...	2.12	6.40	6.84	3.80	7.28
Common salt... ..	1.48	5.41	4.90	1.72	4.88
Sodium sulphate ...	0.64	0.47	1.64	1.92	2.06

The average percentage of total soluble salts in these samples is 5.28 %. The bulk of it consists of common salt (sodium chloride) and sodium sulphate. It is needless to remark that the percentage of salts present is such as to preclude vegetative existence. The texture and physical nature of the soils are such that levelling preparatory to reclaiming would be easy, and with a sufficient supply of water the salts would be easily removed. Lands in Egypt, containing as much as 10 % of injurious salts, have been successfully reclaimed and have grown cotton after three years. The Egyptian soils are generally heavy in nature, and certainly more difficult to wash than would be the soils of Mesopotamia.

Further samples were analysed with, as would be expected, varying results. The percentage of salts fell to as low as 0.41 %. In some cases the bulk of the salts consisted of sodium chloride, in others of sodium sulphate. It is satisfactory to note that in no case was the much more injurious carbonate present.

The samples of waters from the Euphrates and Tigris were examined and the suspended matter determined.

The ordinary water supply of the Euphrates contained 28.4 parts of suspended matter per 100,000.

Two samples of water from the Tigris were examined. The first sample, taken 4 days later than that taken from the crest of the rising flood, contained 191 parts of suspended matter per 100,000 ; while the sample taken on the crest of the rising flood contained 755 parts of suspended matter per 100,000. The Nile at the same time of flood contains about 170 parts of suspended matter per 100,000.

	Euphrates.	Tigris, 4 days later.	Tigris on crest of rising flood.
Suspended matter... ..	28.4	191.3	755.0
" mineral	22.8	171.9	658.0
Total dissolved salts	44.5	33.0	34.5
Chlorine equivalent to common salt...	6.4	0.7	1.8

All three samples gave a reaction for potash in the dissolved salts, the bulk of the latter consisting of carbonates of lime and magnesia.

The suspended matter in the Tigris sample, from the crest of the rising flood, contained 0.19 % of phosphoric acid.

APPENDIX D.

The Meteorology of Mesopotamia.

This description of the meteorology of Mesopotamia was kindly written for me in 1903 by the late Sir John Elliot, K.C.I.E., Director-General of the Meteorological Department of India. I give the greater part of the report as written by Sir John, but in metrical measures. I may note that figures for Cairo, Alexandria, Aswan and Khartoum have been added by myself.

The following account of the meteorology of the eastern portion of the river valley of the Euphrates and Tigris (roughly the province of Irak-Arabi) is based on observations recorded at Bagdad at the British Residency. The observatory is in latitude $33\frac{1}{2}^{\circ}$ N. and longitude $44\frac{1}{2}^{\circ}$ E., and at an elevation of 35 metres above mean sea level. It is the same as Peshawar (elevation 338 meters), and $5\frac{1}{2}^{\circ}$ further north than Jacobabad (elevation 57 metres). Bagdad is about 560 kilometres in a direct line from the mouth of the river.

The tabulated data at once suggest that the year may be divided into two seasons. The first season includes the period from November to April in which rain is of occasional occurrence. The mean maximum temperature is below 32° , the mean temperature is below 24° , and the air moderately damp (the mean 8 a.m. humidity ranging between 59 and 81). This may perhaps be termed the winter or cool weather half year. The remaining six months, from May to October, have a mean maximum temperature exceeding 32° , a mean daily temperature exceeding 24° , low humidity (ranging at 8 a.m. between a mean of 52° in May and 39° in June and July), and an almost complete absence of rain. This season may be termed the summer or dry season half year. The following discuss briefly the meteorological conditions as given by each of the elements of observation.

Pressure is high in December, when it averages 768. It decreases very slightly in January and February, and thence falls rapidly until July, when it averages 753 millimetres. It increases slightly in August and then rapidly until December. The maximum and minimum epochs are in the same months as in Northern India, viz., December and July. The amplitude of the annual variation is 16 millimetres, slightly larger than at Peshawar (15), Lahore (14), and slightly less than Jacobabad (16.5). In the cool or winter season Bagdad (as representative of east Mesopotamia) is near the axis of the anticyclone or high pressure belt which stretches from Central Asia to the Mediterranean; and along the axis of which, pressure increases in December, January and February, from about 762 millimetres, in the west Mediterranean to 763 in a central area near lake Baikal. It is on the other hand during the hot dry season within the continental low pressure area of southern

TABLE I.

The following gives a summary of the observations which have been taken at Bagdad, at 8 a.m., from 1891 to 1902 (8 a.m. data).

NORMAL VALUES.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	YEAR.
Mean monthly air pressure reduced to sea level and constant gravity	767	767	764	762	759	755	752	753	758	763	766	768	761
Mean monthly maximum temperature	15.4	18.9	22.7	28.7	33.8	39.9	42.6	43.1	39.8	33.1	23.2	17.2	29.9
Mean monthly minimum temperature	5.7	6.3	9.9	14.7	19.9	24.5	26.3	26.4	22.6	17.1	10.6	6.6	15.7
Mean monthly temperature (mean of maximum + minimum) ...	9.5	12.7	16.3	21.7	26.9	32.2	34.5	34.8	31.2	25.1	16.9	11.9	22.8
Mean hourly air movements in kilometres	5.2	7.0	8.2	6.9	6.4	7.8	7.4	6.3	3.8	4.5	3.7	5.2	6.1
Mean wind direction	N 20° W	N 9° E	N 14° W	N 6° W	N 3° W	N 11° W	N 16° W	N 10° W	N 14° W	N 7° W	N 7° W	N 9° W	N 10° W
Mean absolute humidity in millimetres	5.9	6.9	8.7	10.2	12.5	12.4	13.3	13.7	11.0	9.9	7.8	6.8	9.9
Mean relative humidity	80	73	71	59	52	39	39	40	42	55	70	81	58
Mean cloud amount	2.7	2.7	2.6	1.9	1.4	0.2	0	0.3	0.4	1.2	2.0	1.8	1.4
Number of rainy days	2.7	2.5	4.0	2.3	0.6	0.2	0	0.1	0.0	0.4	1.9	4.0	18.7
Rainfall in millimetres	29	46	38	23	5	—	—	2	—	2	27	40	212

Asia, which is one of the most characteristic features of that region in the south-west monsoon period. The central area stretches from the north-east coast of Arabia (Oman) to the south-west Punjab, and is defined by the isobar of 748 millimetres in June or 747 millimetres in July and 749 in August, during which months it is practically unchanged in position. The basic gradients are hence throughout the whole year down the Euphrates Tigris-Valley and do not differ largely in their mean intensity month by month throughout the year.

The *temperature* conditions are very similar to those which obtain at Jacobabad and Peshawar in Upper India. In the cool season the maximum day temperature falls from a mean of 23°·2 in November, to 15°·4 in January, and then increases to 28°·7 in April. The corresponding lowest monthly day temperatures at Jacobabad are 23°·1 in January, and at Peshawar 17°·5 in the same month. The temperature is hence very considerably lower at Bagdad at the height of the cool season than in corresponding latitudes in Upper India. This is probably due to the extensive field of snow accumulation to the north-east of Kurdistan and Armenia. The minimum night temperature is lowest in January, when it averages 4°·2. In Upper India the night temperature is on the average lowest in December, when it averages 3°·9 at Peshawar, 4°·6 at Lahore, and 6°·3 at Jacobabad. The night temperature is hence lower at Bagdad than low level stations in corresponding latitudes in Upper India.

The difference is shown even more strongly by the comparison of the lowest temperatures recorded at these three places during the past ten years.

TABLE II.
Lowest temperature recorded during the year.

YEAR.	BAGDAD.	PESHAWAR.	JACOBABAD.	CAIRO.	KHARTUM.
	°	°	°	°	°
1893	— 1·1	— 0·1	+ 1·4	+ 2·0	—
1894	— 4·4	— 0·9	+ 0·3	+ 1·2	—
1895	— 1·1	— 0·1	— 0·3	0·0	—
1896	— 0·3	— 0·9	+ 0·6	+ 1·7	—
1897	— 4·6	+ 0·2	— 0·8	+ 1·3	—
1898	— 2·9	— 1·2	+ 0·8	— 0·7	—
1899	— 1·4	— 1·7	+ 0·0	+ 2·5	—
1900	+ 0·3	— 0·6	+ 1·1	+ 2·1	—
1901	— 0·6	+ 0·5	+ 1·1	+ 0·4	+ 11·0
1902	— 3·1	— 2·0	0·0	+ 3·0	+ 9·0

Note the lowest night temperature hitherto recorded was — 4°·6 in 1897, 2°·6 lower than the lowest recorded at Peshawar and 3°·8 lower than at Jacobabad.

The mean temperature falls from 16°·9 in November to 9°·5 in January, when it is lowest, and increases to 21°·7 in April. It is through the period about $\frac{1}{2}$ ° cooler than Peshawar and 5 $\frac{1}{2}$ ° cooler than Jacobabad. The temperature conditions are hence very similar to those which obtain in the north Punjab during this period.

The hot dry season lasts from May to October. The maximum day temperature increases rapidly in May and moderately in June, and is practically unchanged throughout July and August. It is absolutely highest in the latter month, two months later than the period of greatest day temperature in Upper India (June). The maximum day temperature averages 44°·8 at Jacobabad, and 41°·1 at Peshawar in June and falls to 39°·9 at Jacobabad and 37°·3 at Peshawar in August.

The hot weather is almost as severe at Bagdad (and in lower Mesopotamia) as in Upper Sind at Jacobabad, and is more intense than in the Punjab. It is also even more protracted than in the Punjab, as a mean day maximum temperature of 40°·6 probably obtains for about three months, viz., from about the middle of June to the middle of September.

The following table gives the highest temperatures which have been registered during the past ten years at Bagdad (with dates of occurrence) and the highest temperature at Peshawar and Jacobabad :—

TABLE III.
Highest maximum temperature recorded during the year.

YEAR.	BAGDAD.	Date of occurrence.	PESHAWAR.	JACOBABAD.	CAIRO.	KHARTOUM.
1893	46·1	20th August.	44·4	48·3	40·6	—
1894	45·5	4th Sept.	45·6	49·4	44·6	—
1895	45·1	13th August.	45·6	50·6	41·0	—
1896	45·5	21st ..	47·8	50·6	41·5	—
1897	46·1	2nd ..	47·5	52·2	43·2	—
1898	48·2	1st ..	45·8	50·6	42·7	—
1899	49·1	7th ..	46·4	50·6	40·2	—
1900	45·8	1st ..	48·1	51·4	41·5	—
1901	48·6	21 st & 22 nd Aug.	47·2	52·2	43·0	47·0
1902	48·7	24th August.	47·5	51·7	42·0	45·5

The maximum night temperature in this season ranges between a mean of 17°·1 in October and 26°·5 in August. It is 26°·4 in July.

The mean daily temperature (i.e., the mean of the maximum and minimum temperatures) increases from an average of 29°·4 in May to 34°·5 in July and 34°·8 in August, and falls to 25°·1 in October.

The following gives comparative data during this period for Bagdad, Jacobabad, Peshawar, Cairo, Aswan and Khartoum.

TABLE IV.
Mean daily temperature.

MONTH.	BAGDAD.	JACOBABAD.	PESHAWAR.	CAIRO.	ASWAN.	KHARTOUM.
	°	°	°	°	°	°
January ...	9.5	14.7	10.9	12.2	14.8	20.0
February ...	12.7	17.3	12.4	13.2	20.1	26.1
March ...	16.3	24.1	17.8	16.9	22.0	28.0
April ...	21.9	30.2	23.3	21.1	26.6	31.0
May ...	26.9	34.9	29.1	25.5	32.6	34.1
June ...	32.2	37.0	33.1	28.3	32.4	33.1
July ...	34.5	35.6	32.9	29.2	32.5	30.1
August ...	34.8	33.7	31.4	28.8	32.5	31.2
September ...	31.2	32.1	28.4	26.2	31.6	30.0
October ...	25.1	27.0	22.7	22.7	28.5	29.7
November ...	16.9	20.4	16.2	18.9	20.8	25.8
December ...	11.9	15.6	11.8	14.6	14.3	21.0
YEAR ...	22.8	26.9	22.5	21.5	25.7	28.3

The mean diurnal range of temperature is least in December, when it is only 10°·1. It increases steadily until September, when it is a maximum averaging 17°·3 for the month. The following gives comparative data for the same stations as the preceding table :—

TABLE V.
Diurnal range of temperature.

MONTH.	BAGDAD.	JACOBABAD.	PESHAWAR.
	°	°	°
January ...	11.7	16.8	13.3
February ...	12.6	16.3	13.1
March ...	12.8	17.5	13.4
April ...	14.0	18.6	14.5
May ...	13.9	18.6	15.9
June ...	15.4	15.7	15.9
July ...	16.3	13.1	13.1
August ...	16.6	12.4	11.9
September ...	17.3	15.3	14.4
October ...	16.0	20.1	17.3
November ...	12.6	20.0	17.8
December ...	10.7	18.2	15.8
Year... ..	14.2	16.9	14.7

Winds.—It has been stated above that the basic gradients in the Euphrates-Tigris Valley are steady from north to south during the year. The mean monthly wind observations are in accordance with this being from the north in all months with a slight westing, except in February when the mean wind direction is N. 9° E. A noteworthy feature of the air movement is its steadiness during the period May to September, when winds from other quarters than N. and N.W. are very rarely recorded.

Humidity.—The air is damper than might have been expected, but this is probably due to the position of the observatory close to the river. It contains least aqueous vapour (as measured by its pressure) in January. The aqueous vapour pressure in that month averages 5.9 millimetres, slightly higher than at Peshawar (5 millimetres) and Jacobabad (5.3 millimetres). It increases steadily with the increasing temperature and the consequent increasing evaporation from the neighbouring rivers until August, the hottest month when the aqueous vapour pressure is 13.7 millimetres. This is considerably less than the aqueous vapour pressure at Jacobabad, where it is 20.8 millimetres, and Peshawar where it is 19.8 millimetres.

Cloud amount.—The amount of cloud is small throughout the whole year at Bagdad. It is least in the dry or summer season when it barely averages 0.5 (an overcast sky being represented by 10). In the wet season it ranges between averages of 1.8 in December and 2.7 in January and February. The amount of cloud is somewhat less during this season than in Upper India, although it is probably mainly due to the same cause, viz., the formation or advance of shallow but intensive depressions or cold weather storms. These storms in the majority of cases form over the Persian area and give much cloud in Persia, Baluchistan, Afghanistan and Northern India. Bagdad is usually in the west quadrant of least cloud amount.

Rainfall.—The average annual rainfall is only 212 millimetres, of which 203 millimetres fall in the cool or winter season. The number of rainy days (on which the rainfall is at least $2\frac{1}{2}$ millimetres) is only 18.7. The rainfall is fairly equally spread over the cool season from November to March. The largest rainfall in one month occurred in February 1894, when a total of 201 millimetres was received. Of this amount 158 millimetres fell on one day, the largest rainfall in 24 hours recorded in Bagdad. The rainfall is hence entirely a winter rainfall, similar in character to that of Persia, Baluchistan and Afghanistan, but smaller in amount, apparently due to its low position.

The following gives comparative data for several stations :—

TABLE VI.

Normal rainfall in millimetres.

STATION.	January.	February.	March.	April.	May.	June.	July.	August.	Septem.	October.	Novem.	Decem.	YEAR.
Meshed ...	10	26	62	45	19	6	—	—	—	10	13	18	211
Teheran ...	33	21	71	30	8	1	10	1	3	2	24	35	241
Ispahan ...	7	4	25	10	3	—	1	—	—	5	23	14	93
Bushir ...	79	60	25	13	—	—	—	—	—	2	45	82	307
Jask ...	22	25	29	—	—	3	—	—	—	1	12	20	113
Muscat ...	33	20	26	—	—	9	1	—	—	—	15	7	112
Bagdad ...	29	46	38	23	5	—	—	2	—	2	27	40	212
Kabal ...	31	25	124	57	14	5	5	4	—	8	18	7	302
Kashgar ...	7	3	5	3	22	8	7	28	11	1	—	5	101
Jacobabad...	7	9	3	4	4	2	31	29	2	—	3	2	96
Hyderabad	6	6	4	1	4	10	69	61	10	—	3	1	175
Mooltan ...	11	11	10	2	8	16	61	51	8	—	2	5	185
D. I. Khan	11	20	23	17	9	13	60	41	7	1	4	5	216
Peshawar ...	41	31	52	44	19	7	42	60	13	2	12	8	332
Cairo	7	3	5	2	1	—	—	—	—	1	6	5	30
Alexandria	54	22	17	2	13	—	—	—	1	9	38	80	226

APPENDIX E.

Meteorological data 1904-1910.

The Meteorological Department of India has kindly supplied me with the following information for Bagdad. Bagdad is 35 metres above sea level and in N. latitude $33\frac{1}{2}^{\circ}$ and E. longitude $44\frac{1}{2}^{\circ}$. All observations for temperature are in Fahrenheit and for rainfall in inches.

The rainfall is given month by month for the 7 years. The daily temperature, wind and rainfall are given for 1909, a year of temperature above the average. The same information is given for the month of January 1911 which was quite exceptionally cold. We had four inches of snow on one occasion and two other light falls. One survey party was able to map and level a large area of low ground under water which was frozen hard.

Rainfall in inches.

MONTH.	1904	1905	1906	1907	1908	1909	1910
January ...	0·98	0 48	0·89	1·14	1·38	0·06	1·32
February ...	0·15	0·26	0·31	1·16	0·64	0·70	0·55
March ...	0·82	2·01	0 38	4·17	0·65	0·28	1·45
April ...	0·78	0·14	0·55	2·38	0·25	0·33	0·22
May ...	0·98	0·03	0·05	0·79	0·11	0·14	0·20
June ...	—	—	—	—	—	—	—
July ...	—	—	—	—	—	—	—
August ...	—	—	—	—	—	—	—
September...	—	0·02	—	—	—	—	—
October ...	0·05	—	—	0·26	—	0·25	—
November...	0·03	0·05	1·73	0·16	—	0·25	0·79
December...	1·17	0·23	0·74	0·17	0·48	0·77	0·99
TOTAL...	4·96	3·22	4·65	10·23	3·51	2·78	5·52

Meteorological readings, Bagdad Observatory.

JANUARY 1909.

DATE.	MAXIMUM.	MINIMUM.	WIND.	RAIN.
1	63	42	N N W	—
2	63·5	43·5	N	—
3	63·8	41	C	—
4	65	39·8	C	—
5	65·5	39·5	C	—
6	63	40·5	N N W	—
7	57·6	40·8	N N W	—
8	48	28·8	C	—
9	51·7	29·5	N W	—
10	53·5	30·8	N W	—
11	57·4	28	W N W	—
12	57·3	38·8	E S E	—
13	57·8	45	S	—
14	61·8	43·2	C	—
15	55·7	37	C	—
16	58	34	C	—
17	61	32·5	N W	—
18	57·7	33	C	—
19	59	37	C	—
20	61	34·5	C	—
21	61·8	41	C	—
22	63·8	42·6	N	—
23	63·6	41	N	—
24	62·8	41·5	C	—
25	63·4	41·5	C	—
26	64·6	44·5	C	—
27	59·8	45	S	—
28	60·8	44	W S W	—
29	62	41·6	C	—
30	65	42·7	C	0·02
31	60·8	42·5	S W	0·04
TOTAL				0·06

Meteorological readings, Bagdad Observatory.

FEBRUARY 1909.

DATE.	MAXIMUM.	MINIMUM.	WIND.	RAIN.
1	62	40·8	N	—
2	62·2	40	C	—
3	65	40·8	C	—
4	64·4	45·5	C	—
5	69·5	43·5	W S W	—
6	62·2	42	C	—
7	66	44·5	C	—
8	69·5	44·5	S S E	—
9	71·8	53·8	E S E	0·04
10	—	—	—	—
11	—	—	—	—
12	—	—	—	—
13	—	—	—	—
14	68·7	40·8	E	—
15	73·6	40·8	S	0·17
16	69	41·8	W N W	0·14
17	66·7	45	S E	—
18	72·5	45·8	C	—
19	72	53	S S E	0·12
20	64·8	42·5	W	0·23
21	—	—	—	—
22	—	—	—	—
23	—	—	—	—
24	—	—	—	—
25	66·2	46·5	N W	—
26	67	42	W N W	—
27	68·3	43·8	C	—
28	69·4	46·5	C	—
TOTAL				0·70

Meteorological readings, Bagdad Observatory.

MARCH 1909.

DATE.	MAXIMUM.	MINIMUM.	WIND.	RAIN.
1	68	48·3	N W	0·13
2	65	44·2	N W	—
3	65·5	41·8	W N W	—
4	66·3	43	S E	—
5	72·9	57·5	C	—
6	72	41·9	W N W	—
7	71·5	47·8	C	—
8	73·6	47·5	S E	—
9	75·8	49·7	E N E	—
10	80	53·8	E	—
11	81·5	57·5	S E	—
12	78·5	54·8	C	—
13	75·8	51·5	C	—
14	76	50·5	S E	—
15	81·7	53	E S E	—
16	86·8	63·8	S E	—
17	90·2	66·5	S S E	—
18	84	55·5	C	—
19	84·6	54·3	C	—
20	83·8	58	S E	—
21	70·8	60·8	C	0·15
22	77·8	52·5	N W	—
23	78	54·5	N	—
24	80·5	50	C	—
25	79	58·6	S S E	—
26	88·2	61·8	S S E	—
27	82·7	59·3	N	—
28	78·3	55·5	C	—
29	83·2	55·5	C	—
30	86·5	68·2	S S W	—
31	87·2	61·5	C	—
TOTAL				0·28

Meteorological readings, Bagdad Observatory.

APRIL 1909.

DATE	MAXIMUM.	MINIMUM.	WIND.	RAIN.
1	82.5	58	N N E	—
2	85.6	58	C	—
3	87.2	56.9	C	0.15
4	84.6	59.5	E N E	—
5	90	62.3	E N E	—
6	93.5	59.5	C	—
7	92	70.5	C	—
8	82.6	57	C	—
9	85	60.2	N N W	—
10	71.5	51.3	N W	—
11	67.4	53.2	W	—
12	72	58.8	S E	—
13	68	50.9	W	0.17
14	72.7	51.5	C	—
15	77.8	55.6	C	—
16	81.7	56.8	C	—
17	85	63.5	N W	—
18	78.2	58.5	C	0.01
19	81.4	57.8	C	—
20	87	62	C	—
21	87.2	65.7	C	—
22	86.2	61.5	W S W	—
23	83.5	59.3	W	—
24	85.6	59.9	W	—
25	89	62.8	C	—
26	87.2	61	C	—
27	87	54.5	N W	—
28	79.2	55.7	N N W	—
29	84	58.5	C	—
30	89.2	65.5	N E	—
TOTAL				0.33

Meteorological readings, Bagdad Observatory.

MAY 1909.

DATE.	MAXIMUM.	MINIMUM.	WIND.	RAIN.
1	90.8	62.2	C	—
2	94.5	60.8	C	—
3	95.4	63.5	E	—
4	96	66.8	C	—
5	94.6	68	C	—
6	97	66.8	C	—
7	99	68.9	C	—
8	100	67.7	C	—
9	98.7	70.8	N N E	—
10	102.2	71.3	C	—
11	100.5	74	N N W	—
12	97.6	70	N W	—
13	98.7	73.5	N	—
14	100.4	73.8	N W	—
15	100.8	70	N	—
16	104.6	69.5	W	—
17	103.2	73.5	N W	—
18	103.8	77	N W	—
19	105	72.8	C	—
20	105	75.2	C	—
21	106.8	80.5	N E	—
22	96.8	72.2	C	—
23	102	75.5	N W	—
24	102.2	77	C	—
25	92.6	72.8	C	0.11
26	102.6	73.8	W	0.03
27	102.2	75.3	C	—
28	102	72.8	N	—
29	106.7	73.0	N E	—
30	109	73	W N W	—
31	102	72.5	N W	—
TOTAL				0.14

Meteorological readings, Bagdad Observatory.

JUNE 1909.

DATE.	MAXIMUM.	MINIMUM.	WIND.	RAIN.
1	104·6	79·8	N N W	—
2	105·2	74·5	N W	—
3	98	72·8	N N W	—
4	106·2	71·3	N E	—
5	102·2	72·5	N W	—
6	93	70	N N E	—
7	95·8	72·9	C	—
8	96·9	74·5	N N W	—
9	100	78·2	N	—
10	104·2	74·9	N W	—
11	105	75·2	N N W	—
12	99·8	73·8	N W	—
13	96·7	72·3	N W	—
14	101	73·6	N	—
15	103	78·6	N N W	—
16	105·3	74·5	N N W	—
17	104	75	N W	—
18	102·6	74·8	N N W	—
19	105	78	N	—
20	107·5	74·9	N	—
21	103·2	75·3	N	—
22	102·3	73·3	N N W	—
23	105	78·6	N N W	—
24	105·6	75·5	N	—
25	105	74·6	N	—
26	106·8	77·3	N N W	—
27	106·8	76·4	N N W	—
28	107·3	76·9	N N W	—
29	108	76·8	N N W	—
30	105·6	76	C	—
TOTAL				—

Meteorological readings, Bagdad Observatory.

JULY 1909.

DATE.	MAXIMUM.	MINIMUM.	WIND.	RAIN.
1	106.4	76.8	N E	—
2	106.4	82	N W	—
3	106.6	80	N	—
4	106	78.8	N N W	—
5	109.4	78	N W	—
6	111.5	77.8	N W	—
7	114	85.3	N	—
8	112.2	80.8	N W	—
9	110.2	80.8	N N W	—
10	110.4	84.8	N	—
11	117	83.8	N N E	—
12	117	87.3	N N E	—
13	117.4	83.8	N W	—
14	117.8	89.2	N W	—
15	118	83.8	C	—
16	117	83.5	C	—
17	114	81.5	C	—
18	112.3	80.8	C	—
19	107.7	81.8	C	—
20	119.8	81	C	—
21	118.7	80.8	C	—
22	117.9	85.7	N W	—
23	113.5	77.6	W	—
24	109	78	C	—
25	108.7	82.3	N W	—
26	110	85.8	N W	—
27	114.6	83	N W	—
28	112	88.5	N W	—
29	113.4	82.2	N W	—
30	114.5	84.5	N W	—
31	117	84	C	—
TOTAL				—

Meteorological readings, Bagdad Observatory.

AUGUST 1909.

DATE.	MAXIMUM.	MINIMUM.	WIND.	RAIN.
1	118.5	80.8	E N E	—
2	112.8	80	C	—
3	116.8	82.6	N W	—
4	117.1	86.5	N W	—
5	111.8	86.8	N	—
6	111	81.5	N W	—
7	107	80.5	N N W	—
8	109.3	82.8	N W	—
9	111	79	C	—
10	110.7	81.5	C	—
11	107.2	99	N N W	—
12	111	80	N E	—
13	110.5	81	N W	—
14	106.8	75.5	N W	—
15	109.2	78.5	N W	—
16	109	79.8	N E	—
17	107.5	77.4	N W	—
18	106.4	79.8	C	—
19	107.7	80.5	W N W	—
20	111.6	76.5	N W	—
21	104.6	78	N W	—
22	102.6	73.8	W S W	—
23	103.8	73.9	N W	—
24	105	79	N W	—
25	105	75	W N W	—
26	107	78.8	N N W	—
27	107.8	71.5	C	—
28	107	76.5	N W	—
29	108	77.5	N	—
30	107.2	74	N W	—
31	104.5	78.8	N W	—
TOTAL				—

Meteorological readings, Bagdad Observatory.

SEPTEMBER 1909.

DATE.	MAXIMUM.	MINIMUM.	WIND.	RAIN.
1	108	76.5	N W	—
2	111.3	79.7	N W	—
3	110.3	79	W N W	—
4	108.8	74.5	C	—
5	107.6	74	C	—
6	108.5	75.4	N W	—
7	109.5	74.8	C	—
8	110.2	78.5	N N E	—
9	109.	75	N W	—
10	108.2	76.5	N W	—
11	104.3	72.8	C	—
12	105	69.8	C	—
13	102.8	71.5	W N W	—
14	96.7	69.5	N W	—
15	95.3	69.9	C	—
16	97.6	72.5	W N W	—
17	100	71.5	C	—
18	102	76.5	N E	—
19	100.3	75.5	C	—
20	98	69.8	N W	—
21	95.2	70.8	C	—
22	97.7	69.5	C	—
23	100.3	71	N W	—
24	99.6	69.5	W N W	—
25	97.4	70.5	N	—
26	100.6	69.8	C	—
27	102	71.8	N	—
28	96.6	70.5	N E	—
29	96.3	70.8	N	—
30	100.3	72.5	N E	—
TOTAL				—

Meteorological readings, Bagdad Observatory.

OCTOBER 1909.

DATE.	MAXIMUM.	MINIMUM.	WIND.	RAIN
1	101	70	N W	—
2	99.5	69.8	N W	—
3	96	70	C	—
4	96.8	70.5	N N W	—
5	93.8	70.6	C	—
6	95.8	66.7	S W	—
7	98	68.2	C	—
8	95.6	70	N E	—
9	95	69.8	N E	—
10	98	70.6	E N E	—
11	100	66.5	N W	—
12	91.8	65	C	—
13	93	65.8	C	—
14	93.8	68.7	N N W	—
15	93.2	65	C	—
16	98.7	65.3	E S E	—
17	100	61.9	C	—
18	97.2	67	N W	—
19	98.2	65	S W	—
20	84.7	67.5	N W	—
21	87.5	62	C	—
22	90	65.7	C	—
23	80	63.5	C	0.03
24	80	59.5	C	—
25	81	60	C	—
26	81.7	59.5	C	—
27	84.5	60	C	—
28	63	60.5	E	0.22
29	79.5	60	S S E	—
30	83.5	59	N N W	—
31	82.2	58	N	—
TOTAL				0.25

Meteorological readings, Bagdad Observatory.

NOVEMBER 1909.

DATE.	MAXIMUM.	MINIMUM.	WIND.	RAIN.
1	81·8	60	N W	—
2	80	55	N	—
3	80·2	57·9	N W	0·01
4	72·5	59·5	N	0·10
5	70	53·9	C	—
6	75	56·2	N W	—
7	75·8	58	W	—
8	78·1	62·5	S E	—
9	80	61·5	N N E	0·05
10	80	62·5	S S E	—
11	77·2	67·5	S E	0·06
12	73·7	61	N	—
13	75·8	51·2	C	—
14	74·6	56	S	—
15	68·1	50	N	0·03
16	72·8	51	N N W	—
17	74·8	47·9	W	—
18	71·5	47·9	C	—
19	73·9	52	N N W	—
20	74·2	—*	S	—
21	71·3	54	S S W	—
22	74·2	49	C	—
23	78·2	56·5	N	—
24	78·7	56	C	—
25	81	52	C	—
26	81	53	S	—
27	80·6	53·2	N	—
28	72	50·5	N	—
29	71·2	50·5	C	—
30	73	51	C	—
TOTAL				0·25

* Spirit column broken.

Meteorological readings, Bagdad Observatory.

DECEMBER 1909.

DATE.	MAXIMUM.	MINIMUM.	WIND.	RAIN.
1	78	49.8	C	—
2	78.3	52.9	E N E	—
3	78	47.6	E	—
4	75	57.8	E S E	—
5	74	57.5	S E	0.20
6	62.7	55.5	N W	—
7	67.5	47.9	C	—
8	68.7	48.4	N	—
9	68.8	44.8	N W	—
10	64	39.6	N W	—
11	64.8	41	W N W	—
12	62.7	38.5	C	—
13	62.4	37.5	W	—
14	61.6	44.9	C	—
15	61	44	C	—
16	51	46.2	N N E	0.04
17	62.7	45.8	C	—
18	68.2	48.4	S S E	—
19	68.8	48.4	C	0.41
20	65	45.8	C	—
21	63.8	44	N W	—
22	61	44.5	C	—
23	61	41.8	N W	—
24	60	36.5	C	—
25	58.2	31.5	W S W	—
26	56.4	—	C	—
27	60	36.5	C	—
28	65.8	49	C	—
29	66.8	45.7	S	—
30	66.3	47.8	S E	0.12
31	61.2	41.8	C	—
TOTAL				0.77

Meteorological readings, Bagdad Observatory.

JANUARY 1911.

DATE.	MAXIMUM.	MINIMUM.	WIND.	RAIN.
1	60·4	40·8	C	—
2	59·6	—	C	—
3	61·2	39·5	N	—
4	53·8	46	C	0·30
5	54·7	41	C	—
6	60	39·5	N W	—
7	59	34·5	C	—
8	57·7	33·8	C	—
9	56·8	33	N N E	—
10	57	29·5	N W	—
11	50·5	28·5	C	—
12	52·6	33·8	C	—
13	50·5	32	C	—
14	53	35·5	S S E	0·80
15	49	40	W N W	—
16	46·2	37·5	C	—
17	50·4	39·3	N W	0·16
18	46·3	26·8	W N W	—
19	41·8	28·3	C	—
20	44·3	27	S	—
21	39·7	32	N W	0·59
22	40·6	25	S	—
23	40·8	27·7	N E	—
24	42·4	27	N N W	0·14
25	40·8	26·6	C	—
26	44·5	29	C	—
27	47	32·5	N	—
28	41·2	31·5	C	—
29	42·7	27·5	N W	0·44
30	38	23·8	C	—
31	44·5	30·8	S S E	—
TOTAL				2·43

APPENDIX F.

Analyses of Soil and Water.

Report by MR. FRANK HUGHES, F.C.S., of the Khedivial Agricultural Society.

Thirty-seven samples of soil were sent for examination ; in all these the soluble salts have been determined, and in fourteen the lime, potash, phosphoric acid and nitrogen have also been estimated. The results are given in the annexed tables.

The general character of the soils from both the Tigris and Euphrates Valleys appears to be that of a light calcareous loam. They should prove very easy to work, and no difficulty ought to be found in washing out the soluble salts in those areas where reclamation is necessary; provided of course that a plentiful supply of water is available. The proportion of clay in most of the samples is small, so that drainage would be rapid.

As regards the chemical composition of these soils, it may be well to compare them with those of the Nile Valley. The chief point of difference is in the amount of lime, this in the soils from Mesopotamia averages about 12 % whereas in the Nile soils the quantity seldom reaches 5 %. The presence of this large amount of lime has a very considerable effect on the working properties of the soil, such soils always proving more friable and more easily worked than those containing but a small amount of lime. The power of the soil to retain moisture may in this way be somewhat diminished, but where water is abundant this is of little moment.

So far as the essentials of plant food are concerned these soils show an abundant supply. The nitrogen is about as high as in the average soils of Egypt and is certainly as high as one would expect in cultivated land. Probably much of the nitrogen is in a very unvariable form, but cultivation will remedy this, and even if it should be found that the nitrogen is not present in sufficient quantity to ensure a good cereal crop, the growth of pulse or leguminous fodder crops would probably soon remedy this defect. Potash is present in more than average amount, enough to meet the demands of any ordinary crop. Phosphoric acid is found also in sufficient quantity for the growth of all ordinary crops without the application of special manures. Possibly cotton might be benefited by the application of phosphate, but this can only be determined by experiment, as much depends on climatic conditions.

The samples examined consisted mainly of very fine sand with only a small proportion of clay. This should prove an advantage in those cases where salt is present and washing is necessary ; as the soils are readily permeable, an efficient drainage will be easy to obtain. The amount of salts in the uncultivated and at present barren soils is very variable. Fortunately there is no carbonate of

soda, so that reclamation will give little trouble, provided a sufficient supply of water is at hand. The salts consist of sodium chloride and sulphate in varying proportions with small quantities of the sulphates of lime and magnesia.

Three samples of river water were examined, one from the Euphrates and two from the Tigris. That taken from the Tigris in flood gave an extraordinary amount of suspended matter, as will be seen from the analyses. It may be of interest to note that Nile water in flood contains about 170 parts per 100,000 of suspended matter.

The difference between the total salts and the sodium chloride is mainly due to the presence of sodium sulphate, which in some cases was largely in excess. No carbonate of soda was found in any of the samples.

Sample No. 1. Top 25 centimetres, east of the Tigris, 20 kilometres south of Bagdad.

„ No. 2. Top 25 centimetres, east of the Tigris, 30 kilometres south of Bagdad.

„ No. 3. Top 25 centimetres, 40 kilometres south of Bagdad, between the rivers.

„ No. 4. Top 25 centimetres, 60 kilometres south of Bagdad between the rivers.

„ No. 5. Top 25 centimetres, 30 kilometres north of Bagdad, west of the Tigris.

„ No. 6. Top 25 centimetres, 50 kilometres north of Bagdad, west of the Tigris.

„ No. 7. Top 25 centimetres, 80 kilometres north of Bagdad, west of the Tigris.

„ No. 8. Top 25 centimetres, 80 kilometres north of Bagdad, east of the Tigris.

„ No. 9. Top 25 centimetres, of typical salted land near Mosaib.

„ No. 10. Euphrates deposit of January 1905 at Feluja.

„ No. 11. Tigris deposit of December 1904 at Ali Garbi.

„ No. 12. Top 25 centimetres of white salted plain between Basra and Zobeir.

„ No. 13. Top 25 centimetres of uncultivated land near Gurna.

„ No. 14. Top 25 centimetres of cultivated garden land in Basra.

„ No. 15. Top 25 centimetres of typical salted land near Babylon.

„ No. 16. Top 25 centimetres of bare plains north-east of Babylon.

„ No. 17. Top 25 centimetres of uncultivated lands north-east of Mosaib.

„ No. 18. Top 25 centimetres of lucerne fields 6 kilometres south of Basra on edge of salted plain.

Samples Nos. 19, 20, 21, 22. Top 25 centimetres of salted plain south of Basra.

„ Nos. 23-33. Typical cultivated lands 100 kilometres north and south of Bagdad.

River waters.

	PARTS PER 100,000		
	Euphrates.	Tigris (1).	Tigris (2).
Suspended matter : Total	28·4	191·3	755·0
Suspended matter : Mineral	22·8	171·9	658·0
Total dissolved solids	44·5	33·0	34·5
Chlorine equivalent to common salt ...	6·3	0·7	1·8

All three samples gave a reaction for potash in the dissolved solids, the bulk of the latter consisted, however, of the carbonates of lime and magnesia.

The suspended matter in Tigris (2) gave 0·19 % of phosphoric acid.

APPENDIX G.

Analysis of Materials.

AVAILABLE FOR THE PROPOSED WEIRS ON THE EUPHRATES AND THE TIGRIS.

By Mr. A. Lucas.

Limestone from Hit on the Euphrates.

The sample is limestone. As one of the pieces appeared to be somewhat different from the rest, this was analysed separately, the results, however, were practically identical.

The composition is as follows :—

Silica	1·02 %
Oxide of iron and alumina.. .. .	0·36
Lime	55·03
Carbon dioxide	43·14
	<u>100·06 %</u>

The various ingredients are probably combined as follows :—

Silica and insoluble matter.. .. .	1·02 %
Oxide of iron and alumina	0·36
Calcium carbonate	98·26
Magnesium carbonate.. .. .	1·06
	<u>100·70 %</u>

Euphrates sand from the north of Mosaib.

The sample is sand and is composed essentially of quartz and felspar, the former predominating ; it contains also a little biotite mica but practically no magnetite.

The sand is much finer than is ordinarily used for building purposes, the following results being obtained on testing :—

Residue on Sieve.

400 meshes per sq. inch.	900 meshes per sq. inch.	2,500 meshes per sq. inch.	10,000 meshes per sq. inch.	32,400 meshes per sq. inch.
2·8 %	3·2 %	6·7 %	70 %	99·1 %

(Sand for the works at Hindia is obtained from the desert. W.W.).

“ *Conglomerate* ” about 10 metres thick overlying clay along the *Tigris* bank from near *Beled* northwards.

The sample is a conglomerate. The cementing material between the pebbles is covered with what appears to be a lichen.

The cementing material is essentially carbonate of lime together with a little carbonate of magnesia, the silica present probably not being chemically combined. The composition is as follows :

Silica and insoluble matter..	38·69%
Oxide of iron and alumina ..	3·02
Lime ..	30·65
Magnesia ..	1·81
Loss on ignition being carbon dioxide and a little moisture	26·86
	<u>100·93%</u>

The mode in which the various ingredients are combined as is follows :—

Silica and insoluble matter..	38·59%
Oxide of iron and alumina ..	3·02
Calcium carbonate ..	54·73
Magnesium carbonate..	3·78
	<u>100·12%</u>

Clay underlying conglomerate at Samarra.

The sample is clay having the following composition :—

Silica ..	39·90%
Alumina with a little oxide of iron ..	20·07
Lime ..	16·75
Magnesia ..	trace.
Loss on ignition, being combined water with a little organic matter..	23·49
	<u>100·21%</u>

Limestone from Samarra on the Tigris.

The sample is essentially carbonate of lime having the following composition :—

Silica and insoluble matter..	2·70%
Oxide of iron and allumina..	1·27
Lime ..	52·87
Magnesia ..	1·01
Carbon dioxide ..	42·18
	<u>100·00%</u>

The various constituents are probably combined as follows :—

Silica and insoluble matter	2·70 %
Oxide of iron and alumina.. .. .	1·27
Calcium carbonate.	94·41
Magnesium carbonate.. .. .	2·11
	<u>100·49 %</u>

Burnt and slaked limestone from Samarra.

The sample is a slaked fat lime, that, having been exposed to the atmosphere, has absorbed a certain amount of carbon dioxide, and therefore contains a little carbonate of lime ; it has the following chemical composition :—

Silica and insoluble matter.. .. .	0·89 %
Oxide of iron and alumina.. .. .	2·71
Lime	65·28
Magnesia	3·54
Loss on ignition, being combined water and a little carbon dioxide	26·67
	<u>100·09 %</u>

Good holding mortar from the Ghaim concrete monument at the head of the Nahrwan Canal.

The sample is a mortar in which are embedded several small angular pieces of quartz and one large rounded stone. The mortar is partially covered on what has apparently been the outer side with a black substance, which on examination proves to be bituminous. Throughout the mass of the mortar there are seen to be distributed numerous small black particles. These particles consist of wood charcoal.

The mortar has the following composition :—

Sand and insoluble silicates	17·80 %
Soluble silica.. .. .	12·35
Oxide of iron and alumina.. .. .	7·62
Lime	27·75
Magnesia.	3·53
Sulphur trioxide	0·83
Loss on ignition, being carbon dioxide and a little organic matter.. .. .	29·54
	<u>99·22 %</u>

(This mortar was made with Samarra lime. W.W.).

APPENDIX H.

Labour, Materials and Transport.

The following has been written for me by Mr. E. M. Tabor, who has been in charge of the Hindia Barrage for 6 months.

Labour. Earthwork. The labourers employed on earthwork provide their own spades and carrying bags (hezzahs).

Sheikhs are employed who give a guarantee to the Government, that they are prepared to supply workmen and are responsible for their behaviour.

Labourers are employed in gangs of from 35 to 50, each gang being under a "serkal" or head ganger.

Each gang is given a plot to dig that will last them 8 to 10 days. The sheikhs who provide men are paid an allowance of L. T. 1 per month per 50 men.

In fixing the prices for earthwork, a price is fixed per cubic metre so as to allow an average labourer to earn 3 to 4 piastres per day if he works well.

In December, January, February and March, labour is very plentiful. In April and May many men are irrigating from the flood, reaping and strengthening banks, etc. In June, July and August, labour is very plentiful. In September, October and November, men are ploughing, sowing and attending to their land. For five months in the year labour in quantity is rather difficult to obtain, and for seven months it is very plentiful. We have a fixed gang of some 1,000 men, and when labour is plentiful can count on 3,000.

In digging the Hilla (at present in hand) with an average lead of about 40 metres, and average lift of $1\frac{1}{2}$ metres, we began by paying * $1\frac{1}{2}$ G.S.P. per cubic metre and thereby attracted a considerable amount of labour. We then reduced the price to $1\frac{3}{8}$ G.S.P., and again to $1\frac{1}{4}$ G.S.P., at which price we can now obtain as much labour as we require. For cutting the 1 : 1 slopes we are paying $1\frac{1}{2}$ G.S.P., and for digging a 10-metre channel 1 metre deep in the bed, and cutting 1 : 1 slopes for the same we are paying $1\frac{1}{2}$ G.S.P. per cubic metre; the average lead having increased to about 55 metres, and lift to about 3 metres. If the earth to be taken out is of a damp nature, the price must be immediately increased, but in the winter months it is impossible to get men to work in damp earth unless barrows or trucks are provided for transport.

Earthwork by donkey transport.—A very cheap and convenient method of doing earthwork with long leads. With a lead of about 200 metres and a lift of about 3 we can get earthwork done at $2\frac{1}{2}$ G.S.P. per cubic metre by donkeys. The men working with donkeys very rarely have a serkal who does not himself work, and

* One Turkish pound = 108 G.S.P., and one G.S.P. = two pence.

never have a guarantee from a sheikh. We can obtain about 200 donkeys and could no doubt obtain more if we slightly increased the price per cubic metre. Donkeys will also often carry damp earth, where labourers will not work in the cold months.

Earthwork by locomotive transport.—We pay $1\frac{1}{4}$ G.S.P. per cubic metre for filling the wagons and $\frac{3}{4}$ G.S.P. per cubic metre for tipping the earth, levelling the tipping platform and arranging the rails thereon, coupling up wagons, etc. One of our locomotives will draw about 150 wagons a day, a distance of about 900 metres, say one locomotive will dispose of 125 cubic metres per diem.

Locomotive expenses per diem :—

Driver and fireman	G.S.P.	14
Half wages of greaser and water carrier	„	2
Half wages of permanent way gang	„	10
Coal and wood	„	34
Oil and waste	„	6
Total		<u>G.S.P. 66</u>

Say $\frac{1}{2}$ G.S.P. per cubic metre.

Digging $1\frac{1}{4}$ G.S.P. per cubic metre.

Tipping, etc., $\frac{3}{4}$ G.S.P. per cubic metre.

Engine expenses as above $\frac{1}{2}$ G.S.P. per cubic metre.

Total per cubic metre say $2\frac{1}{2}$ G.S.P.

This does not include percentage on price of engines, wagons and rails, nor wear and tear.

Daily labour.—The price paid for ordinary daily labour is 3 G.S.P. per day, but for special work this is sometimes increased to $3\frac{1}{2}$ or even 4 G.S.P.

Piece work.—All work such as transporting materials, etc., that can be so given, is given by piece work to small contractors whom we have trained to their work. The pieces paid are reckoned on the number of the employed. These small contractors often employ women and children on their work.

Labour for building.—We have not done enough building to make the masons thoroughly understand a contract. We have built brick-kilns and houses at 7 to 9 G.S.P. per cubic metre (the mortar being of mud), including the transport of bricks about 30 metres, but in most of the buildings we have done, we have had an overseer always on the spot and have done the building by daily labour. Masons in this country are always used to work by daily labour, and they work hard throughout the day, especially if there is an overseer. We sometimes give piece work to a mason, say 2 cubic metres on a broad wall.

A mason earns from 5 to 9 G.S.P. a day, the price depending on the capability and the quickness of his work. The boys who carry mortar earn $1\frac{1}{2}$ G.S.P. per day, and labourers mixing mortar and carrying bricks 3 G.S.P. a day. It is

difficult to fix a price per cubic metre for labour in building as so much depends on the breadth of the wall and its height, etc., but simple building with lime mortar, when bricks are on the site, may be put at from 10 to 12 G.S.P. per cubic metre.

Carpenters.—The carpenters are paid a daily wage. Our head carpenter we pay L.T. 4½^{*} per month; other carpenters are paid from 6 to 10 G.S.P., per diem, according to their capabilities. They are very clever with their native tools, and under a good chief carpenter they seem always to put in a good day's work.

Blacksmiths.—When we require a blacksmith we pay him about 10 G.S.P. per day, and his striker 4 G.S.P.; they are not very clever but can do simple work.

Tinsmiths.—We can get a very clever tinsmith for L.T. 3 per month when necessary.

Transport of goods from Basra.—Goods are transported from Basra by native sailing craft and by barges towed by tugs. The best season for transport is during the flood, as at other times, when the river is low, it is difficult to pass a bar near Shenafia, and the river below Tuarij is apt to be low and difficult for navigation; nevertheless, native boats can make the passage throughout the year. When goods are brought up in barges they are transhipped at Shenafia into native boats, and it is therefore apparent that only such goods as can be handled fairly easily can be sent up by barge.

For transport by native craft, prices ranging from 5 Mejidies (*) (95 G.S.P.) per taghar of 1½ tons in May, to 7 Mejidies (133 G.S.P.) for the same weight in August, have been paid by Messrs. Gray Mackenzie, at Basra, who do our transport. The taghar mentioned is that of Basra which equals one ton and a half (the Bagdad taghar is equal to two tons). The above prices are for coal, cement or steel piling and railway material, etc. A barrel of cement weights 400 lbs. and a steel pile 623 lbs.

For transport of very heavy material such as lock gates, grooves, etc., Messrs. Gray Mackenzie have paid 10 Mejidies per 1½ tons in January and February. These prices do not include loading at Basra or unloading at the barrage. The largest native craft carry about 50 taghars, or 75 tons; but about 30 taghars, or 45 tons, is the most usual load. Out of the price paid to them the boat men pay the following taxes: A bridge tax of about 15 G.S.P. per boat is levied on all boats at Samawa, Shenafia and Shamia. An Amir El Bahr (Admiralty) tax is levied on all boats at Medina, Samawa, Shenafia and Shamia Nasria and Tuarij, amounting to about G.S.P. 8 (about 1½ at each place), and at Basra the "Amir El Bahr" tax of ½ G.S.P. (or 1d.) per ton is levied.

Beyond the above the boats have to pay 4 G.S.P. per night between Samawa and the Barrage, to local watchmen; also L.T. ½ between Suk El Sheyook and

* One Mejidie = 20 G.S.P. (and 5·4 make a Turkish pound).

Medina as blackmail to the Guebar tribe before they are allowed to pass through the lake there.

Transport from Hitt.—Transport by sailing craft of blocks of stone from Hitt, varies in cost from 45 to 50 G.S.P. per cubic metre including the stacking of the stone on the river bank.

Transport of lime costs about 24 G.S.P. per cubic metre. If lime and stone are transported in Shakhtors and Assabiehs (native flat-bottom boats) the transport expenses are from 5 to 10 G.S.P. lower per cubic metre but the stone is sometimes lost.

For unloading, weighing, and storing coal, we pay about 3 G.S.P. per ton. For unloading cement and transporting about 900 metres, with use of railway and wagons, and stacking, we pay about $\frac{1}{2}$ G.S.P. per barrel of 400 lbs. weight. For unloading piles and transporting about 800 metres, with use of trucks and railway and stacking, we pay $1\frac{1}{2}$ G.S.P. per pile, for steel piles, each pile weighing 632 lbs.

Broken Babylon bricks.—These can be obtained from the excavations at Babylon for about 16 G.S.P. per cubic metre. They are nice hard bricks, and are good for Homra when broken up. We can obtain broken bricks from other places, both up and down the river at about the same price; these bricks are usually not very hard, but good for breaking up into Homra.

Sand.—Sand is obtained from the desert at Abu Ghoraib at a price of 15 G.S.P. per cubic metre. It is of first rate quality.

Shingle.—We obtain this from Abu Ghoraib at 30 G.S.P. per cubic metre; this shingle is of a small size, but good for concrete. Larger shingle can be obtained from Hitt at 70 G.S.P. per cubic metre.

Stone.—Limestone is obtained from Hitt. This stone costs 15 G.S.P. per cubic metre for quarrying at Hitt and can be cut or quarried to any size required. Good hard stone can be procured, and its transport costs from 45 to 50 G.S.P. per cubic metre including stacking on the river bank at the Barrage. The number of boats that will do this stone transport is limited usually to about 15, but in the summer months the number is liable to increase.

Lime.—This is obtained from Hitt, where it is burnt with bitumen. It is brought down in country boats (sefinas) or shakhtors, and costs f.o.b. Hitt $68\frac{1}{2}$ G.S.P. per taghar of 2 tons, including all burning expenses. The average price for transport is $73\frac{1}{2}$ G.S.P. per taghar of 2 tons, making the total cost here, stacked, 142 G.S.P. per taghar.

Bitumen.—(Suitable for burning, and plastering flat roofs, etc.). Is transported from Hitt down the Euphrates in flat-bottomed boats (Shakhtors), and costs per taghar of 2 tons 160 G.S.P. delivered at the Barrage.

Cement.—“ Gillingham ” Portland cement, in barrels of 400 lbs. each, costs 66·45 G.S.P. c.i.f. Basra. Charges there amount to 4·87 G.S.P. per barrel, while freight up the Euphrates costs 12·98 G.S.P. this added to charge made for testing in England and unloading and storing at the Barrage brings the price per barrel up to 85·72 G.S.P. Some barrels are damaged in transport, and we issue it to the work a 90 G.S.P., per barrel.

Paraffin oil.—The cost of this oil (Standard Oil Co's. “ Tiger brand ”) is 35·14 G.S.P., per case of 2 tins containing each 4 gallons. The charges for unloading and storing, etc., amount to 0·85 G.S.P., thus the total cost, stored at the Barrage, is 36 G.S.P., per case of 8 gallons.

Lackawanna steel piles.— Each pile costs, c.i.f. Basra, 236·61 G.S.P.; the freight and charges at Basra, with cost of unloading, stacking, etc., at the Barrage, bring the cost up to 270 G.S.P. per pile, or £ 2·7·10 delivered to the store.

Including losses and contingencies, we estimate the actual cost of material at the Hindia Barrage as follows :—

Bricks, L.T. 1·10 per thousand.. ..	L.T. 0·44 per cubic metre
Stone	„ 0·70 „ „ „
Homra (Pozzolana)	„ 0·35 „ „ „
Sand	„ 0·15 „ „ „
Shingle	„ 0·30 „ „ „
Lime	„ 0·45 „ „ „
Cement, L.T. 0·90 per barrel	„ 7·20 „ „ „

Mortar, 1 lime and 2 homra	L.T. 0·50 per cubic metre
Mortar, 2 sand and 1 cement	„ 4·00 „ „ „
Mortar, 4 sand and 1 cement	„ 2·00 „ „ „
Mortar, 6 sand and 1 cement	„ 1·40 „ „ „

The cost of works we estimate as follows :—

Brick masonry in lime mortar.. .. .	L.T. 0·82 per cubic metre
Brick masonry in 2 to 1 cement	„ 1·70 „ „ „
Brick masonry in 4 to 1 cement.. .. .	„ 1·20 „ „ „
Concree lime mortar	„ 0·70 „ „ „
Concrete 4 to 1 cement.	„ 1·30 „ „ „
Concrete 6 to 1 cement.	„ 1·10 „ „ „
Pitching.. .. .	„ 0·80 „ „ „

By this calculation lime concrete is cheaper than pitching. The constituents of the lime mortar concrete are 15 shingle, 2 lime and 4 homra.

APPENDIX J.

Brick manufacture.

The following report on bricks has been written for me by Mr. J. W. T. Allen, the brick expert at the Hindia Barrage.

We began brick making in the first week in May and finished at the end of October. By the end of November all bricks had been cleared from the ground and were burning.

During this time 14,000,000 bricks were made. Of this number about 1,000,000 were unburnt.

Labour—There was a plentiful supply of labour the whole time. About one thousand work-people were employed each day, of which fifty per cent. were women and children.

The whole of the work was done by piece work.

The average earnings of a labourer were $3\frac{1}{2}$ to 4 G.S.P., (*) per day; of a woman $2\frac{1}{2}$ G.S.P.; and of a boy $1\frac{1}{2}$ to $2\frac{1}{2}$ G.S.P. per day.

A brick-moulder can earn 10–12 G.S.P. per day.

Supervision—There were two masons who superintended the building and setting of clamps and kilns. They received 8 G.S.P. per day. A foreman of the brick-moulders, whose duty it was to procure the moulders and look after them, received L.T. 3 per month. A clerk who entered the accounts of bricks, counted the workmen each day, and acted as interpreter, had a salary of L.T. $8\frac{1}{2}$ per month.

Kind of bricks.—Two kinds of bricks were made, viz., flat or water-made bricks and sand stocks or box-moulded bricks.

Flat bricks.—These bricks measure when burnt $19 \times 19 \times 6$ centimetres. They are the native bricks of the country, and are made by placing an open mould on the ground, smearing a piece of clay about the size of a brick with water, throwing it into the mould which is then removed and the brick left to dry. Owing to the clay being so soft and so much water used it is impossible to make a square solid brick.

Sand-stock bricks.—These bricks measure when burnt $25 \times 12 \times 7$ centimetres. They are european in shape, with a fray in the bottom to make a key for the mortar. They are made in a box mould. The clay is made into the shape of the brick before being put into the moulder, it is then rolled in sand and thrown

* Turkish pound = 108 G.S.P.

with force into the mould. The mould is bumped on the ground two or three times, which consolidates the clay and fills it out into the corners of the mould. The surplus clay is struck off with a wire, the brick turned out of the mould on to a pallet board and then set on its edge. The moulders receive 14 to 17 G.S.P. per thousand for flat bricks and 19 to 23 G.S.P. for sand-stocks. This price includes tempering clay, drying and stacking bricks. A moulder can make 800 bricks per day. The moulder sits on the ground at his work.

Drying.—No covering or sheds were used for the drying of the bricks. The flat bricks were lifted from the ground and stood on their side until dry, when they were carried into stacks ready for the kilns.

The sand-stock bricks are covered with sand directly they are made; when stiff enough to handle they are turned up on their ends and left until dry enough to be stacked. The moulders are only paid for whole bricks, and the broken bricks are usually stacked by themselves and put on the top of the kilns to be burnt for "homra" (Pozzlonana). A brick is dry and ready for the kiln in seven to ten days.

Setting.—The setting of the kilns and clamps was done by piece-work. A reliable man would be given a contract for a kiln at so much per thousand, usually 6 G.S.P. He would supply all labour, mostly women and children. These people carry the bricks from the stacks on a board which they carry on their backs. The boards are made like a letter L and cost about 5 G.S.P. to make. They carry from ten to fifteen bricks. The contractor supplies a mason to set the bricks and spread the coal.

Burning.—The clay was unfortunately salted, and in consequence did not take much firing. I found that the average consumption of coal per thousand for sand-stock bricks was 5 cwt. (250 kil.) and for flat bricks 9 cwt. (460 kil.). The flat bricks were mostly burnt hard into clinker for use on the old Barrage. Clamps that were burnt entirely into clinker consumed half a ton of coal per thousand or 3 cwt. (150 kil.) per cubic metre. The amount of coal that should be allowed to burn a cubic metre of clay into solid hard bricks is $2\frac{1}{2}$ cwt. (125 kil.).

We found this year that the last clamps we built were not so well burnt as they should have been, owing to the bricks not being dry and the rains making the ground damp. The heat of the clamps absorbs all the moisture which cools the bricks and prevents the coal from burning. In future no bricks should be burnt after the end of October.

We used three methods for burning the bricks, viz., the native wood kilns, Scotch kilns, and clamps.

Kilns.—The native wood kilns, of which six were burnt, are much the cheapest way of burning bricks. The fuel is the brushwood from the waste lands. It is collected and carried to the kilns by women, and I let the burning of these kilns to a contractor. He set the bricks in the kilns, burnt them, took them from the

kilns when burnt and stacked them, and purchased and supplied the brushwood necessary for burning. The contract price was fifty G.S.P per thousand inclusive for well burnt bricks; if there were bricks not sufficiently burnt he was paid less according to the value of the bricks.

This contract worked very well and we burnt about 1,000,000 bricks in this way.

The kilns are strongly built with burnt bricks and the walls are strengthened with hoop iron. They will last for a number of years. The six kilns hold altogether two hundred thousand bricks.

The three *Scotch kilns* are newly built and hold fifty thousand bricks each. They have twelve fire holes each side, all fitted with strong fire bars. These kilns are of the up draught type and the most simple of any kilns to burn. They can be burnt with wood or coal. We have only burnt coal in these here.

These kilns produce 90 per cent. by using 9 cwt. (450 kil.) coal per thousand.

Egyptian clamps.—Egyptian clamps are a temporary construction built of the bricks to be burnt. A clamp may be of any size, according to the number of bricks ready to be set. The construction is very simple. A number of fire holes are made according to the length and filled with large wood, this is covered with a layer of large coal, next is a course of unburnt bricks and then a layer of coal, and next a layer of bricks, and so on to a height of thirty-five courses. The top is then covered with a layer of dirt and the whole of the outsides plastered with mud. The fire holes are then lighted and allowed to burn for one day; in the same time the coal is well alight and the fire holes are then shut up and plastered and the clamp burns itself. A large clamp holding five hundred thousand bricks will take eight to ten weeks to burn and cool. Workmen shirked carrying enough coal, and in consequence parts of the clamps were soft. The overseers could not be relied to look after the work properly, and in future there should be a reliable foreman to superintend each three or four clamps.

We were unfortunate in not receiving in time the chimneys and dampers of Bull's continuous kilns to burn by this economical method.

Coal.—There were two sorts of coal supplied; the average cost per ton was 27s. 6d. at Basra. The freight from Basra to the Hindia bairage, including unloading, wharfage and expenses at Basra, was £ 1 per ton; total cost was £ 2: 7s. 6d. per ton, or L.T. 2.61. Allowing a margin, coal was charged to the work here a L.T. 2.75 per ton. The loss of weight from London to Hindia barrage was about 4 % which was added to the cost of the coal. The screened large coal cost 3s. per ton more than the other. If more coal is required, the type of kilns or method proposed for burning should be determined beforehand and suitable coal ordered accordingly. There would be an economy and at the same time work would be simplified and success ensured.

Cost of bricks.—The cost of the bricks has been compiled from the balance sheet. I worked the cost out on 75 % of the total burnt in the clamps and kilns.

This leaves 25 % of material which might be useful for homra or concrete. The cost of the flat bricks is higher than it would be for ordinary work as a number of kilns were burnt into solid clinker for the old Barrage and therefore consumed more coal.

The following table gives the cost of labour and prices of coal used :—

Price of work in producing one thousand bricks.

<i>Sand stocks.</i>		<i>Flat bricks.</i>	
	G S.P.		G.S.P.
Moulding	20	Moulding	15
Setting in kilns	6	Setting in kilns	7
Drawing from kilns... ..	6	Drawing from kilns... ..	7
Transport of coal	1	Transport of coal	1.5
Burning	1	Burning	1
Building kilns		Building kilns	
Fire-wood, moulds, manage- ment and sundry expenses }	3.4	Fire-wood, moulds, manage- ment and sundry expenses }	5.9
Labour	37.4		37.4
Coal (0.265 ton at G. S. P. 282.15)	74.77	Coal (0.481 ton at G. S. P. 282.15)	135.74
TOTAL COST ...	112.17	TOTAL COST ...	173.14

The bricks burnt in the brushwood kilns cost 70 G.S.P. per thousand burnt, thus made up :— the cost of moulding 20 G.S.P. and the contract price of 50 G.S.P. for setting drawing and supplying brushwood.

APPENDIX K.

Machinery.

The following report has been written by Mr. Wylie, the mechanical engineer at the Barrage.

There are two 20 HP. locomotives by Orenstein and Koppel, each hauling 16 wagons laden with $\frac{3}{4}$ of a cubic metre of earth per wagon. The distance from the excavation to the spoil bank is 900 metres. They have been steadily engaged at this work and have given every satisfaction. They are fitted for working with either oil or coal, but coal has proved far the more economical. To raise steam on one of the locomotives with oil costs 66 piasters and only 8·2 piasters with coal. They have been regularly worked with coal, the daily consumption being about 4·8 cwt. for both engines hauling on an average 300 wagons per day. The daily cost of working both is :—

4·8 cwt. coal..	..	..	..	..	..	..	..	..	..	67·0
Engine oil ..	..	..	..	..	..	..	..	..	..	9·5
Cylinder oil ..	..	..	..	..	..	..	..	..	..	2·2
Waste ..	..	..	..	..	..	..	..	..	..	1·375
Driver's wages ..	..	..	..	..	..	..	..	..	..	16·0
Fireman..	..	..	..	..	..	..	..	..	..	12·0
Platelayers ..	..	..	..	..	..	..	..	..	..	20·0
Water and coal porter..	..	..	..	..	..	..	..	..	..	4·0
										132·075

or 66 G.S.P. per locomotive per day.

There are five 16 break HP. portable oil engines by Hornsby which have been driving sets of 6-inch Gwynn's pumps, of which four are already installed. Both engines and pumps are sound and do their work thoroughly. At present with two pumps working the oil consumption is :—

4 gallons of oil ..	..	..	..	..	..	..	..	..	G.S.P.	18
Attendants ..	..	..	..	..	..	..	..	..	„	13
Engine oil ..	..	..	..	..	..	..	..	..	„	4
Waste ..	..	..	..	..	..	..	..	..	„	$\frac{1}{2}$
Guardians ..	..	..	..	..	..	..	..	..	„	4
										G.S.P. 39 $\frac{1}{2}$

There are six 6 break HP. portable Hornsby oil engines employed driving 6 mortar mills by Appleby. They have worked satisfactorily for the past three months.

In a working day of 10 hours 3 engines cost :—

12 gallons oil	G.S.P.	54
One attendant	„	5
Engine oil	„	7·8
Waste	„	1·5
	<u>G.S.P.</u>	<u>68</u>

or 23 G.S.P. per engine.

The 7½ break HP. portable Hornsby oil engine intended to drive a pugmill by Johnson and Sons has hitherto been employed to grind mortar. The cube concrete mixer from the Municipal Engineering Co., Chicago, capable of mixing charges of 17 cubic metres per time, has not yet been used.

The piling engine consisting of 1 hoisting engine by the Lambert's Hoisting Engine Co. (U. States America) with vertical tubular boiler and a 2-ton steam piling hammer by the Vulcan Co., of Chicago, and wooden leaders, has driven as yet only 160 Lackawanna 5 m. piles. The driving is too easy for such a hammer, and a common monkey piling engine now on its way here will be more suitable for the work we have to do.

The workshop tools are inadequate and we require :—

1 small vertical drilling machine driven by a 6 break HP.

1 second hand lathe to take work of 18" diameter.

1 circular saw to be worked by one of our 6 HP. oil engines.

As the spring water is very salted we need 4 sheet iron tanks of 160 gallons capacity to be erected at various points, and a small Duplex Worthington water pump piston 3 inches diameter and a small vertical boiler working at a pressure of say 60 pounds per square inch to be erected on the river bank.

Comparing coal and oil at the Hindia Barrage we may say that as a steam raiser coal is far preferable.

1 pound of oil evaporates 20 lbs. of water and one pound of coal evaporates 7 lbs. of water, and as the price of oil is 4½ times as dear as coal there is an economy in using coal.

The internal combustion oil engine, however, is more economical than a coal engine. One pound or pint of oil will do work equivalent to one HP. for one hour while steam engines require 6 tons of coal; and with the prices of coal and oil as we have them oil works out cheaper.

APPENDIX L.

Rates for earthwork for the Rohri Canal project in North India.

Calculated by Dr. SUMMERS, Chief Engineer.

It is assumed that it costs 0·67 gold piastre to dig one cubic metre and that 1 metre of lift equals 12 metres of lead.

Lead in metres.		Cost per cubic metre in gold piastres.
15	—	1·10
18	—	1·14
21	—	1·18
24	—	1·23
27	—	1·27
31	—	1·31
46	—	1·52
61	—	1·74
76	—	1·96
91	—	2·17
107	—	2·38
122	—	2·60
137	—	2·81
152	—	3·02

APPENDIX M.

List of plans.

No.	NAME.
1	Tigris-Euphrates Delta ١٥٥٥٥٥٥.
2	Irrigation works in upper half of Delta ٢٥٥٥٥٥٥.
3	Part of Delta south of Bagdad ٣٥٥٥٥٥٥.
4	" " north of Bagdad ٤٥٥٥٥٥٥.
4A	" " Hindia and Hilla branch ٥٥٥٥٥٥٥.
5	Plan of Dyala ٦٥٥٥٥٥٥.
6	Longitudinal section of the Tigris, Bagdad to the sea.
7	" " " Euphrates, Hitt to Shamia.
8	" " " Tigris above Bagdad.
9	" " " Dyala and Nahrwan.
10	" " " Left Euphrates canal system.
11	" " " Right Tigris canal system.
12	" " " Drains.
13	Cross section of the Tigris.
14	" " " Euphrates.
15	" " " Dyala, Nahrwan and Sakhlawia.
16	Proposed diversion of the Dyala river.
17	Plan of Euphrates at the Hindia Barrage ١٥٥٥٥٥٥.
18	Plan of existing Hindia Barrage 1909 ٢٥٥٥٥٥٥.
19	Proposed addition Hindia Barrage ٣٥٥٥٥٥٥.
20	Proposed new Hindia Barrage ٤٥٥٥٥٥٥.
21	Proposed Hilla branch head ٥٥٥٥٥٥٥.
22	Plan showing Hindia Barrage and subsidiary works ٦٥٥٥٥٥٥.
23	Plan showing proposed spurs above new Hindia Barrage.
24	Plan showing proposed temporary repairs to existing Hindia Barrage.
25	Plan of Euphrates, Hitt to Feluja, and proposed Habbania escape ٧٥٥٥٥٥٥.
25	Plan of proposed Habbania escape ٨٥٥٥٥٥٥.
26	Longitudinal section of proposed Habbania escape.
27	Proposed head regulator Habbania escape ٩٥٥٥٥٥٥.
28	" head regulator for Sakhlawia branch ١٠٥٥٥٥٥.
29	" Feluja Barrage on the Euphrates.
30	" Koot Barrage on the Tigris.
31	" Chala, Majar Kebir, and Machêra barrages.
32	" masonry works Left Euphrates canal system.

List of plans (continued).

No.	NAME.
33	Proposed typical head regulator for canals.
34	„ Kutha-Babylon canal bifurcation.
35	„ Akkar Kuf drain head.
36	„ Right Tigris canal head.
37	„ Syphon for Right Tigris canal under flood canal.
38	„ Ordinary road bridge Akkar Kuf drain.
39	„ „ regulator for „
40	„ left Euphrates canal head.
41	„ low level Beled Barrage on the Tigris.
42	„ Barrage on the Dyala river for the Nahrwan.
43	„ typical pipe syphons, culverts and bridges.
44	Longitudinal section of the Hilla branch 1909.
45	Cross section of the Hilla branch 1909.
46	Cross section of the Euphrates at the Hindia Barrage.
47	Plan of first 7 kilometres of the Hilla branch 1909.
48	Plan of the diversion of the Feluja Barrage 2000.
49	Plan of the Hilla branch to Diwania 2000.
50	Plan of the Hindia branch to Shamia 2000.
51	Earthwork cross section, new Hindia Barrage.
52	Possible railway lines in the Delta.
53	Regulating apparatus for needles.
54	Lower Nahr Melcha canal head.
55	Longitudinal section of the Sakhlawia branch.
56	Plan of proposed Bagdad navigation canal project 2000.
57	Section of proposed Bagdad navigation canal project.
58	Plan of masonry works on proposed Bagdad navigable canal.
59	Plan of tail lock on proposed Bagdad navigable canal.
60	Cross section of canals, ancient and modern.
61	Proposed Dijail canal head.
62	Gauge diagram of the Tigris at Bagdad.
63	„ „ „ Euphrates at Hitt.
64	„ „ „ „ Hindia Barrage.
65	Proposed Hai branch head.
66	Cross section of the Tigris at Koot.
67	Plan of the Sakhlawia branch 2000.
68	Plan of the Kania head of the Sakhlawia.
69	Discharge diagram of the Tigris and its branches.

List of plans (*continued*).

No.	NAME.
70	Proposed Ashik dam on the Tigris.
71	Proposed barrage and subsidiary barrage at Beled on the Tigris.
72	Longitudinal section of proposed canals, Beled project.
73	Proposed fall kilo. 69 Right Tigris canal.
74	Proposed Basra Barrage on the Euphrates (alternate).
75	Final plan of existing Hindia Barrage.
76	Basra reclamation project 300000.
77	" " " 200000.
78	Proposed Basra Barrage.
79	Feluja Barrage scale 20000.
80	Preliminary project Tigris diversion at Kadasia.
81	Proposed subsidiary barrage to new Hindia Barrage.

APPENDIX N.

Details of estimates of works.

Paragraph 8.—HINDIA BARRAGE WORKS.

(1) Addition to existing barrage:—

Earthwork	30,000 c.m.	@	L.T.	0.07 =	L.T.	2,100
Pitching	3,600 "	@	"	0.70 =	"	2,520
Concrete	2,300 "	@	"	2.20 =	"	5,060
Lime masonry	6,500 "	@	"	1.40 =	"	9,100
2-1 cement masonry...	400 "	@	"	7.50 =	"	1,000
4-1 " "	500 "	@	"	2.00 =	"	1,000
Metalling	15 "	@	"	0.50 =	"	75
Regulating gates	63 sq.m.	@	"	20.00 =	"	1,260
Lock gates	120 "	@	"	25.00 =	"	3,000
Draw bridge	...				"	300
Steel piling... ..	305 metres	@	L.T.	15.00 =	"	4,575
Pumping	...				"	4,000
Total ... L.T.						33,990
Contingencies @ 33½ % ... "						11,310
Grand Total ... L.T.						45,300

(2) New Hindia Barrage:—

Earthwork	68,000 c.m.	@	L.T.	0.07 =	L.T.	4,760
Pitching	16,500 "	@	"	0.70 =	"	11,550
Puddle	3,500 "	@	"	0.20 =	"	700
Concrete	7,000 "	@	"	2.20 =	"	15,400
Lime masonry	22,250 "	@	"	1.40 =	"	31,150
2-1 cement masonry...	2,100 "	@	"	2.50 =	"	5,250
4-1 " "	1,200 "	@	"	2.00 =	"	2,400
Metalling	300 "	@	"	0.50 =	"	150
Regulator gates...	900 sq.m.	@	"	16.00 =	"	14,400
Steel piling... ..	740 metres	@	"	15.00 =	"	11,100
Pumping	...				"	15,000
Lock gates	112 sq.m.	@	L.T.	25.00 =	"	2,800
Draw bridge	1	@	"	300.00 =	"	300
Total ... L.T.						114,960
Contingencies @ 33½ % ... "						38,340
Grand Total ... L.T.						153,300

(3) *Diversion of the Euphrates:—*

Earthwork	860,000 c.m.	@ L.T. 0·05 =	L.T. 43,000
Pitching	3,000 „	@ „ 0·70 =	„ 2,100
Total ...			<u>L.T. 45,100</u>
Contingencies @ 10 % ...			„ 4,510
Grand Total ...			<u><u>L.T. 49,610</u></u>

(4) *Dam across the Euphrates...* L.T. 5,000

(5) *Diversion of the Hilla branch:—*

Earthwork	190,000 c.m.	@ L.T. 0·02½ =	L.T. 5,000
Contingencies @ 10 % ...			„ 500
Total ...			<u><u>L.T. 5,500</u></u>

(6) *Masonry head for the Hilla branch:—*

Earthwork	7,370 c.m.	@ L.T. 0·05 =	L.T. 369
Pitching	6,950 „	@ „ 0·70 =	„ 4,865
Brick masonry	2,290 „	@ „ 1·40 =	„ 3,206
4-1 cement masonry ...	67 „	@ „ 2·00 =	„ 134
2-1 „ „	230 „	@ „ 2·50 =	„ 575
Regulating appliances ...	104 sq.m.	@ „ 16·00 =	„ 1,664
Puddle... ..	263 c.m.	@ „ 0·20 =	„ 53
Lift bridge	„	„	250
Pumping	„	„	1,000
Total ...			<u>L.T. 12,116</u>
Contingencies @ 10 % ...			„ 1,214
Grand Total ...			<u><u>L.T. 13,330</u></u>

(7) *Silt clearance of the Hilla branch:—*

Excavation	2,302,600 c.m.	@ L.T. 0·02 =	L.T. 46,052
Additional clearance ...	„	„	6,000
Total ...			<u>L.T. 52,052</u>
Contingencies ...			„ 5,948
Grand Total ...			<u><u>L.T. 58,000</u></u>

(8) *Addition to the existing Hindia Barrage:—*

Earthwork	140,000 c.m.	@ L.T. 0·03 ...	L.T. 4,200
Contingencies @ 10 % ...			„ 500
Total ...			<u><u>L.T. 4,700</u></u>

(1)	L.T. 45,300
(2)	„ 153,300
(3)	„ 49,610
(4)	„ 5,000
(5)	„ 5,500
(6)	„ 13,330
(7)	„ 58,000
(8)	„ 4,700
Total ...	<u><u>L.T. 334,740</u></u>

Paragraph 9.—PROVISION FOR THE EXCESSIVE FLOODS OF THE EUPHRATES.

(1) *Habbania Escape head :-*

Earthwork	41,500 c.m.	@	L.T. 0.07 =	L.T.	2,905
Pitching	6,000 "	@	" 0.70 =	"	4,260
Puddle... ..	1,300 "	@	" 0.20 =	"	260
Concrete	2,860 "	@	" 2.20 =	"	6,160
Lime masonry	7,700 "	@	" 1.40 =	"	10,780
4-1 cement masonry... ..	400 "	@	" 2.00 =	"	800
2-1 " "	900 "	@	" 2.50 =	"	2,250
Regulating appliances ...	375 sq.m.	@	" 20.00 =	"	7,500
Pumping				"	3,000
Metalling	200 c.m.	@	" 0.50 =	"	100
Steel piling... ..	350 lineal m.	@	" 15.00 =	"	5,250
Total ... L.T.					43,205
Contingencies @ 33 $\frac{1}{3}$ % ...					14,495
Total ... L.T.					<u>57,700</u>

(2) *Excavation in the Euphrates Valley :-*

Excavation... ..	1,464,000 c.m.	@	L.T. 0.02 $\frac{1}{2}$ =	L.T.	36,600
Contingencies @ 10% ...					3,600
Total ... L.T.					<u>40,200</u>

(3) *Desert excavation :-*

Desert excavation	2,232,000 c.m.	@	L.T. .10 =	L.T.	223,200
Contingencies @ 33 $\frac{1}{3}$ % ...					74,400
Total ... L.T.					<u>297,600</u>

(1)	L.T.	57,700
(2)	"	40,200
(3)	"	297,600
Total ... L.T.		<u>395,500</u>

Paragraph 10.—PROVISION FOR THE EXCESSIVE FLOODS OF THE TIGRIS.

(1) *Dyke along the right bank of the Tigris :-*

Earthwork... ..	3,172,000 c.m.	@	L.T. 0.01 $\frac{1}{2}$ =	L.T.	47,580
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(2) <i>Pipe crossings for irrigation (drawing 43). 122 @</i>	L.T.	45 =	L.T.	<u>5,490</u>
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(3) <i>Spurs at salient points on the Tigris ... 8 @</i>	L.T.	1,000 =	L.T.	<u>8,000</u>
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(4) <i>Regulator at the Sakhlawia crossing of the Akkar Kuf bank</i>					
(Drawing No. 36)				L.T.	<u>5,130</u>

(5) <i>Bagdad Dyke</i> :—			
Earthwork...	624,000 c.m.	@ L.T. 0.01½ =	L.T. 9,360
(6) <i>Regulator</i> (Drawing No. 35) L.T. 3,240			
Escape Earthwork ...	120,000 c.m.	@ L.T. 0.01½ =	„ 1,800
Total ...			L.T. 5,040
(1)	L.T.	47,580	
(2)	„	5,490	
(3)	„	8,000	
(4)	„	5,130	
(5)	„	9,360	
(6)	„	5,040	
Total ...			L.T. 80,600
Contingencies @ 33½ % ...			L.T. 26,870
Grand Total ...			L.T. 107,470

Paragraph 11.—FELUJA BARRAGE.

(1) <i>The Feluja Barrage</i> :—			
Earthwork...	66,000 c.m.	@ L.T. 0.10 =	L.T. 6,600
Pitching ...	18,100 „	@ „ 0.70 =	„ 12,670
Puddle ...	3,800 „	@ „ 0.20 =	„ 760
Concrete ...	7,400 „	@ „ 2.20 =	„ 16,280
Lime masonry ...	23,700 „	@ „ 1.40 =	„ 33,180
4-1 cement masonry...	1,300 „	@ „ 2.00 =	„ 2,600
2-1 „ „ ...	2,300 „	@ „ 2.50 =	„ 5,750
Metalling ...	320 „	@ „ 0.50 =	„ 160
Regulating appliances ...	1,000 sq.m.	@ „ 16.00 =	„ 16,000
Lock gates...	112 „	@ „ 25.00 =	„ 2,800
Drawbridge ...	...	...	„ 500
Pumping ...	...	...	„ 10,000
Total ...			L.T. 107,300
(2) <i>Diversion of the Euphrates</i> :—			
Earthwork...	1,545,600 c.m.	@ L.T. 0.10 =	L.T. 154,560
(3) <i>Bank across the Euphrates</i>			L.T. 5,000
(1)	L.T.	107,300	
(2)	„	154,560	
(3)	„	5,000	
Total ...			L.T. 266,860
Contingencies @ 33 ⅓ % ...			„ 88,950
Grand total ...			L.T. 355,810

Paragraph 12.—RIGHT TIGRIS CANAL SYSTEM.

(1) *Upper regulator on the Sakhlawia :—*

Earthwork	53,000 c.m.	@ L.T.	0·07 = L.T.	3,710
Pitching	4,600 "	@ "	0·70 = "	3,220
Puddle	800 "	@ "	0·20 = "	160
Concrete	1,900 "	@ "	2·20 = "	4,180
Lime masonry	6,120 "	@ "	1·40 = "	8,568
4-1 cement masonry...	220 "	@ "	2·00 = "	440
2-1 " "	550 "	@ "	2·50 = "	1,375
Metalling	120 "	@ "	0·50 = "	60
Regulating appliances ...	225 sq. m.	@ "	20·00 = "	4,500
Pumping	...	...	...	3,000
Steel piling	380 metres	@ "	20·00 = "	5,700
Total ...				<u>L.T. 34,913</u>

Lower regulator on the Sakhlawia :—

Rock excavation	3,100 c.m.	@ L.T.	0·10 = L.T.	310
Earth excavation	10,000 "	@ "	0·07 = "	700
Pitching	400 "	@ "	0·70 = "	280
Lime masonry	5,700 "	@ "	1·40 = "	7,980
2-1 cement masonry ...	220 "	@ "	2·00 = "	440
4-1 " "	600 "	@ "	2·50 = "	1,500
Regulating appliances ...	203 sq.m.	@ "	20·00 = "	4,060
Total ...				<u>L.T. 15,270</u>

Upper regulator	L.T.	34,913
Lower " "	"	15,270
Total...	<u>L.T.</u>	<u>50,183</u>

(2) *Excavation at new head of Sakhlawia :—*

Earthwork	971,000 c.m.	@ L.T.	0·03 = L.T.	29,130
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(3) *Akkar Kuf embankment :—*

Earthwork	454,000 c.m.	@ L.T.	0·03 = L.T.	13,620
Masonry... ..	12,100 "	@ "	1·50 = "	18,150
Total ...				<u>L.T. 31,770</u>

(4) *Regulating head for Tigris canal :—*

Earthwork	9,800 c.m.	@ L.T.	0·05 = L.T.	490
Pitching... ..	700 "	@ "	0·70 = "	490
Puddle	200 "	@ "	0·20 = "	40
Lime masonry	1,740 "	@ "	1·50 = "	2,610
Metalling	80 "	@ "	0·50 = "	40
Regulating appliances...	96 sq.m.	@ "	10·00 = "	960
Pumping	...	...	...	500
Total ...				<u>L.T. 5,130</u>

(5) *Excavation of the Right Tigris canal and its branches up to kilometre 69:—*

Right Tigris canal ...	7,900,000 c.m.	@ L.T. 0.02½ =	L.T. 197,500
Lower Melcha canal ...	2,251,000 „	@ „ 0.01¾ =	„ 39,390
Harrea canal... ..	347,800 „	@ „ 0.01½ =	„ 5,220
Escape kilometre 53 ...	58,600 „	@ „ 0.01½ =	„ 880
Total ...			<u>L.T. 242,990</u>

(6) *Excavation of Right Tigris canal and branches below kilometre 69:—*

Right Tigris canal ...	8,564,000 c.m.	@ L.T. 0.02 =	L.T. 171,290
Bagela canal... ..	517,600 „	@ „ 0.01½ =	„ 7,770
Total ...			<u>L.T. 179,060</u>

(7) *Masonry works:—*

First 69 kilometres:—

Aleppo road bridge (modified drawing No. 38)...	...	L.T.	1,600
Kerbela „ „ „ „ „ „ „ „	...	„	1,600
Pipe bridges on main canal 40 (drawing No. 43) @	L.T. 160 =	„	6,400
Lower Nahr Melcha head regulator (drawing No. 33) ...	„	1,500	
Harrea canal 2 regulators... ..	@ L.T. 1,000 =	„	2,000
Regulator escape kilometre 53 (Drawing No. 43) ...	„	508	
Total ...			<u>L.T. 13,608</u>

Below kilometre 69:—

Regulator at kilometre 69 (39)...	...	L.T.	2,029
Bridges on Right Tigris 10 ...	@ L.T. 450 =	„	4,500
Pipe bridges (drawing No. 43)...	10 @ „ 160 =	„	1,600
Bagela head regulator (53) ...	„	508	
Pipe bridges (drawing No. 43)...	4 @ L.T. 160 =	„	640
Total ...			<u>L.T. 9,277</u>

L.T. 13,608

„ 9,277

Grand Total = L.T. 22,885

(8) *Pipe crossings for flood irrigation:—*

First 69 kilometres (drawing No. 43).

60 of 3' diameter	@	L.T. 340 =	L.T. 20,400
10 of 4' "	@	" 445 =	" 4,450
7 of 5' "	@	" 600 =	" 4,200
Total ...			<u>L.T. 29,050</u>

Below 69 kilometers (drawing No. 43).

170 of 3' diameters	@	L.T. 250 =	L.T. 42,500
30 of 4' "	@	" 335 =	" 10,050
20 of 5' "	@	" 445 =	" 8,900
Total ...			<u>L.T. 61,450</u>

L.T. 29,050

„ 61,450

Grand Total ... L.T. 90,500

(9) *Irrigation outlets* (drawing No. 43):—

Above kilometre 69 :—

Right Tigris Canal	138	@	L.T. 55 =	L.T.	2,590
Harrea Canal	84	@	„ 30 =	„	2,520
Lower Melcha	36	@	„ 30 =	„	10,800
Total ...				<u>L.T.</u>	<u>20,910</u>

Below kilometre 69 :—

Right Tigris canal	288	@	L.T. 50 =	L.T.	14,400
Bagela canal	120	@	„ 30 =	„	3,600
Total ...				<u>L.T.</u>	<u>18,000</u>

L.T. 20,910

„ 18,000

Grand Total ... L.T. 38,910

(10) *Spurs on the Tigris* :—

Above kilometre 69 7

Below „ 69 11

18 @ L.T. 1,000 = L.T. 18,000

(1)	L.T.	50,183
(2)	„	29,130
(3)	„	31,770
(4)	„	5,130
(5)	„	242,990
(6)	„	179,060
(7)	„	22,885
(8)	„	90,500
(9)	„	38,910
(10)	„	18,000

Total ... L.T. 708,558

Contingencies 33 $\frac{1}{3}$ % ... „ 236,182

Grand Total ... L.T. 944,740

Paragraph 13.—LEFT EUPHRATES CANAL SYSTEM.

(1) *Regulator at head of Left Euphrates canal system* :—

Rock excavation	16,630	c.m.	@	L.T.	0·10 =	L.T.	1,663
Pitching... ..	675	„	@	„	0·70 =	„	472
Concrete... ..	561	„	@	„	2·20 =	„	1,232
Lime masonry	1,769	„	@	„	1·40 =	„	2,477
4-1 cement masonry	48	„	@	„	2·00 =	„	96
2-1 „ „	229	„	@	„	2·50 =	„	572
Metalling	45	„	@	„	0·50 =	„	23
Regulating appliances	74	sq.m.	@	„	16·00 =	„	1,184
Total ...						<u>L.T.</u>	<u>7,719</u>

(2) *Excavation of the Left Euphrates canal :—*

Earthwork	800,000 c.m.	@ L.T. 0.07	= L.T. 56,000
"	5,100,350 "	@ " 0.02½	= " 127,500
Total ...			<u>L.T. 183,500</u>

(3) *Masonry head for Abu Goraib canal and others on the Euphrates*
(drawing No. 32) :—

Abu Goraib canal head, Upper Melcha canal, Kutha canal :—

Regulator on river	L.T. 1,234
" on canal	" 1,256
Pipe siphon	" 2,910
3 @	<u>L.T. 5,400 = L.T. 16,200</u>

Radwania canal, Mahmudia canal, Iskandaria canal :—

Regulator on river	L.T. 927
" on canal	" 929
Pipe siphon	" 1,940
3 @	<u>L.T. 3,796 = L.T. 11,388</u>
Total ...	<u>L.T. 27,588</u>

(4) *Pipe crossings for flood irrigation* (drawing No. 43) :—

60 pipe crossings 3' diameter... ..	@ L.T. 310	= L.T. 18,600
10 " " 4' "	@ " 400	= " 4,000
7 " " 5' "	@ " 540	= " 3,780
Total ...		<u>L.T. 26,380</u>

(5) *Excavation of the Abu-Goraib and other canals :—*

Abu Goraib canal	1,561,750 c.m.
Left " "	142,200 "
Right " "	247,900 "
Radwania escape	447,500 "
Upper Melcha escape	1,328,600 "
Mahmudia " "	426,900 "
Kutha " "	2,223,000 "
Latifia " "	388,700 "
Babylon " "	558,600 "
	<u>7,325,150 c.m. @ L.T. 0.01½ = L.T. 109,875</u>

Additional for canals between Euphrates and Left Euphrates canal :—

Abu Goraib	90,000 c.m.
Radwania	100,000 "
Upper Melcha... ..	175,000 "
Mahmudia	75,000 "
Kutha	150,000 "
	<u>590,000 c.m. @ L.T. 0.01½ = L.T. 8,850</u>
Total... ..	<u>L.T. 118,725</u>

(6) *Masonry works on the canals :—*

Abu Goraib canal (drawing No. 43) :—

3 minor head regulators	@ L.T. 508 =	L.T. 1,524
2 siphons under Akkar Kuf drain	„	720
2 „ „ drain No. 1	„	500
20 road-bridge pipes	@ L.T. 160 =	L.T. 3,200
		<u>L.T. 5,944</u>

Radwania canal :—

1 regulator	@ L.T. 508 =	L.T. 508
1 tail regulator	@ „ 508 =	„ 508
6 road-bridge pipes	@ „ 160 =	„ 960
		<u>L.T. 1,976</u>

Upper Melcha canal :—

(drawing No. 43) Siphon under Akkar Kuf drain	=	L.T. 780
„ „ drain No. 6	=	„ 390
20 road-bridge pipes	@ L.T. 160 =	„ 3,200
		<u>L.T. 4,370</u>

Mahmudia canal :—

10 road bridge pipes	@ L.T. 160 =	L.T. 1,600
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Kutha and Babylon canals :—

1 minor regulator	L.T. 508	
Kutha bifurcation	„ 1,691	
4 siphons (43)	„ 1,210	
30 bridge pipes... @ L.T. 160... ..	„ 4,800	= L.T. 8,209

Iskandaria canal :—

4 road pipes	@ L.T. 160 =	L.T. 640
	Total ...	<u>L.T. 26,339</u>

(7) *Irrigation outlets (43) :—*

Left Euphrates	100 pipes @ L.T. 60 =	L.T. 6,000
Minor canals... ..	1,500 „ @ „ 30 =	„ 45,000
	Total ...	<u>L.T. 51,000</u>

(8) *Spurs on the Euphrates. 6 @ L.T. 1,000* = L.T. 6,000

(1)	L.T. 7,719	
(2)	„ 183,500	
(3)	„ 27,588	
(4)	„ 26,380	
(5)	„ 118,725	
(6)	„ 26,339	
(7)	„ 51,000	
(8)	„ 6,000	
Total ...	L.T. 447,251	
Contingencies 33 $\frac{1}{3}$ %...	„ 149,079	
Grand Total...	<u>L.T. 596,330</u>	

Paragraph 14.—DRAINAGE WORKS.

(1) *Earthwork :—*

Akkar Kuf drain	...	6,505,200 c.m.	@ L.T. 0.02 = L.T.	130,104
Other drains.				
No. 1	...	245,200 c.m.		
2	...	173,960 „		
3	...	99,500 „		
4	...	111,300 „		
5	...	901,400 „		
5 A	...	162,400 „		
5 B	...	139,840 „		
6	...	201,400 „		
7	...	551,650 „		
8	...	242,700 „		
9	...	102,200 „		
10	...	965,250 „		
add	...	17,600 „		
		3,914,400 c.m.	@ L.T. 0.1½ =	L.T. 58,716
			Total	188,820

(2) *Masonry works :—*

(35) Head regulator Akkar Kuf drain	...	...	L.T.	2,941
(38) 3 road-bridges	...	@ L.T. 804 =	„	2,412
(39) 2 regulators	...	@ „ 2,029 =	„	4,058
(43) 60 road pipes	...	@ „ 160 =	„	9,600
		Total	...	L.T. 19,011

(1)	...	L.T.	188,820
(2)	...	„	19,011
	Total	...	207,831
Contingencies 33½ %	„	69,279	
Grand Total	...	L.T.	277,110

Paragraph 16.— NAVIGATION OF THE TIGRIS.

(1) *Chala Barrage :—*

Earthwork	...	63,400 c.m.	@ L.T. 0.03 =	L.T. 1,902
Pitching	...	6,010 „	@ „ 0.70 =	„ 4,207
Lime masonry	...	3,530 „	@ „ 1.40 =	„ 4,942
Piles	...	84	@ „ 20.00 =	„ 1,680
Pumping	...	...	„	1,000
Earthen dam	...	...	„	5,000
			Total	L.T. 18,731

(2) *Majar Kebir Barrage* :—

Earthwork	39,000 c.m.	@ L.T.	0·03 = L.T.	1,170
Pitching	3,940 „	@ „	0·70 = „	2,758
Lime masonry	2,402 „	@ „	1·40 = „	3,363
Piles	34 metres	@ „	20·00 = „	680
Pumping	...	...	...	500
Earthen dam	...	...	...	3,000
Total ...				<u>L.T. 11,471</u>

(3) *Machera Barrage* :—

Earthwork	17,000 c.m.	@ L.T.	0·03 = L.T.	510
Pitching	2,000 „	@ „	0·70 = „	1,400
Lime masonry	1,445 „	@ „	1·40 = „	2,023
Piles	20 metres	@ „	20·00 = „	400
Pumping	...	...	...	250
Earthen dam	...	...	...	1,500
Total ...				<u>L.T. 6,083</u>

(1) L.T. 18,731

(2) „ 11,471

(3) „ 6,083

Total ... L.T. 36,285

Contingencies $33\frac{1}{3}\%$... „ 12,095

Grand Total ... L.T. 48,380

Paragraph 17.—HAI BRANCH IRRIGATION.

(1) *Koot Barrage* :—

Earthwork	118,000 c.m.	@ L.T.	0·07 = L.T.	8,260
Pitching	34,330 „	@ „	0·70 = „	24,031
Puddle	7,100 „	@ „	0·29 = „	1,420
Concrete	17,300 „	@ „	2·20 = „	38,060
Lime masonry	52,600 „	@ „	1·40 = „	73,640
4-1 cement masonry	2,940 „	@ „	2·00 = „	5,880
2-1 „ „	4,300 „	@ „	2·50 = „	10,750
Metalling	900 „	@ „	0·50 = „	450
Regulating appliances ...	2,250 sq.m.	@ „	16·00 = „	36,000
Lock gates	320 „	@ „	44·00 = „	14,080
Drawbridge... ..	...	...	...	3,000
Pumping	...	...	...	20,000
Steel piling... ..	1,440 metres	@ L.T.	15·00 = „	21,600
Total =				<u>L.T. 257,171</u>

(2) *Diversion of the Tigris* :—

Excavation	5,710,300 c.m.	@ L.T.	0·06 = L.T.	<u>342,623</u>
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(3) *Diversion of the Hai Branch :—*

Excavation 1,881,000 c.m. @ L.T. 0·02½ = L.T. 47,040

(4) *Regulating head for the Hai Branch :—*

Earthwork	13,744 c.m.	@ L.T. 0·03	= L.T.	412
Metalling... ..	126 "	@ "	0·50	= " 63
Puddle	1,204 "	@ "	0·20	= " 241
Pitching	2,593 "	@ "	0·70	= " 1,815
Concrete	2,079 "	@ "	2·20	= " 4,574
4-1 cement masonry ...	271 "	@ "	2·00	= " 542
2-1 " " ...	795 "	@ "	2·50	= " 1,988
Lime masonry	6,296 "	@ "	1·40	= " 8,814
Regulating appliances...	311 sq.m.	@ "	20·00	= " 6,221
Total			L.T.	<u>24,670</u>

(5) *Main drain and bank :—*

Excavation 5,400,000 c.m. @ L.T. 0·02 = L.T. 108,000

(6) *Irrigation canals earthwork :—* Same as Euphrates L.T. 118,700

(7) *Drains :—* " " " L.T. 58,700

(8) *Masonry works :—* " " " L.T. 26,339

(9) *Irrigation outlets :—* " " " L.T. 51,000

(1)	L.T.	257,171
(2)	"	342,623
(3)	"	47,040
(4)	"	24,670
(5)	"	108,000
(6)	"	118,700
(7)	"	58,700
(8)	"	26,339
(9)	"	51,000
Total... ..	L.T.	1,034,243
Contingencies 33½ %	"	344,747
Grand total	L.T.	<u>1,378,990</u>

Alternative project 1, 4, 5, 6, 7, 8, 9, as above.

(2) *Tigris diversion :—*

Earthwork 4,956,360 c.m. @ L.T. 0·05 = L.T. 247,832

(3) *Hai diversion :—*

Earthwork 400,000 c.m. @ L.T. 0·02½ = L.T. 10,000

Paragraph 18.—BASRA IRRIGATION.

(1) *Basra Barrage :—*

Earthwork in Diversion	480,000 c.m.	@ L.T.	0·05 =	L.T.	24,000
Pitching in reserve ...	20,000 „	@ „	0·70 =	„	14,000
Bank	120,000 „	@ „	0·02 =	„	2,400
Earthwork	87,500 „	@ „	0·07 =	„	6,125
Pitching	16,640 „	@ „	0·70 =	„	11,648
Puddle	2,700 „	@ „	0·20 =	„	540
Metalling	450 „	@ „	0·50 =	„	225
Lime masonry	12,170 „	@ „	1·40 =	„	17,038
4-1 cement masonry ...	780 „	@ „	2·00 =	„	1,560
2-1 „ „	2,330 „	@ „	2·50 =	„	5,824
Regulating appliances..	1,175 sq.m.	@ „	16·00 =	„	18,800
Pumping	...	...	...	„	15,000
Piles	740 metres	@ L.T.	20·00 =	„	14,800
Total ...					<u>L.T. 131,960</u>

(2) *Repairing banks of old Euphrates :—*

Earthwork	1,100,000 c.m.	@ L.T.	0·03 =	L.T.	33,000
Protection for bank ...	...	...	...	„	15,000
Raising bank in marshes	...	...	...	„	30,000
Total ...					<u>L.T. 78,000</u>

(3) *Canals :—*

Earthwork	16,500,000 c.m.	@ L.T.	0·03 =	L.T.	495,000
„	1,250,000 „	@ „	0·02½ =	„	31,250
Bridges on Zobeir road	...	...	...	„	5,000
Total ...					<u>L.T. 531,250</u>

(4) *Drains :—*

Earthwork	280,000 c.m.	@ L.T.	0·02½ =	L.T.	7,000
Siphon	...	...	...	„	650
Total ...					<u>L.T. 7,650</u>

(1)	...	...	...	L.T.	131,960
(2)	...	...	...	„	78,000
(3)	...	...	...	„	531,250
(4)	...	...	...	„	<u>7,650</u>
Total ...				L.T.	748,860
Contingencies 33½ %				„	<u>249,620</u>
Grand Total ...				L.T.	998,480

Reclaiming land in marshes in blocks of 5,000 hectares :—

Banks fully protected per hectare	L.T. 4'00
Drainage cuts „ „	„ 0'50
Masonry works „	„ 1'00
Pumping installation at site... .. „	„ 3'00
Per hectare =	L.T. 8'50
50,000 hectares @	L.T. 8'50 = <u>L.T. 425,000</u>

Alternative project for Basra Barrage (drawing No. 74) :—

Earthwork... .. 111,600 c.m.	@ L.T. 0'04 = L.T. 4,464
Pitching 12,200 „	@ „ 0'70 = „ 8,540
Lime masonry 16,940 „	@ „ 1'40 = „ 23,716
Shutters 900 „	@ „ 20'00 = „ 18,000
Sheet piling 1,400 metres	@ „ 15'00 = „ 21,000
Pumping „	„ 10,000
Ashlar 360 c.m.	@ L.T. 4'00 = „ 1,440
Earthwork in diversion 960,000 „	@ „ 0'05 = „ 48,000
Total ..	<u>L.T. 135,160</u>

Cost of project on Drawing No. 76 (part of main project) :—

Basra Barrage	L.T. 131,960
Euphrates Bank... ..	„ 78,000
Canals	„ 177,500
Drains... ..	„ 7,650
Total	L.T. 395,110
Contingencies 33 $\frac{1}{3}$ %	„ 131,710
Grand Total	<u>L.T. 526,820</u>

Paragraph 19.—SUBSIDIARY WORKS ON THE HINDIA BARRAGE.

(1) *Excavation of two canals :—*

Earthwork 1,021,700 c.m.	@ L.T. 0'01 $\frac{1}{2}$ = <u>L.T. 15,325</u>
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(2) *Masonry works :—*

Head regulators on the Euphrates ... 2	@ L.T. 960 = L.T. 1,920
Road bridge pipes 20	@ „ 160 = „ 3,200
Regulator heads for minors 4	@ „ 508 = „ 2,032
Irrigation pipes... .. 100	@ „ 30 = „ 3,000
Total... ..	<u>L.T. 10,152</u>

(1)	L.T. 15,325
(2)	„ 10,152
Total	L.T. 25,477
Contingencies, 33 $\frac{1}{3}$ %	8,493
Grand Total	<u>L.T. 33,970</u>

(2) *Beled subsidiary barrage* (drawing No. 71) :-

Earthwork	110,136 c.m.	@	L.T.	0.07 =	L.T.	7,710
Pitching	66,951 "	@	"	0.70 =	"	46,866
Puddle	9,293 "	@	"	0.20 =	"	1,859
Lime masonry	16,111 "	@	"	1.40 =	"	22,567
2-1 cement masonry ...	1,085 "	@	"	2.50 =	"	2,713
Steel piling	1,240 metres	"	"	15.00 =	"	18,600
Pumping	...	...	...	=	"	10,000
Total ...						<u><u>L.T. 110,315</u></u>

(3) *Diversion of the Tigris* :-

Earthwork	5,577,000 c.m.	@	L.T.	0.05 =	<u><u>L.T. 278,850</u></u>
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(4) *Damming the Tigris* L.T. 5,000

(5) *Regulator head of Dijail canal* :-

Earthwork	10,284 c.m.	@	L.T.	0.03 =	L.T.	309
Metalling	450 "	@	"	0.50 =	"	225
Pitching	835 "	@	"	0.70 =	"	585
Concrete	830 "	@	"	2.20 =	"	1,826
Puddle	220 "	@	"	0.20 =	"	44
Lime masonry	2,870 "	@	"	1.40 =	"	4,018
4-1 cement masonry ...	74 "	@	"	2.20 =	"	148
2-1 " "	220 "	@	"	2.50 =	"	550
Regulating appliances..	95 sq.m.	@	"	16.00 =	"	1,520
Total ...						<u><u>L.T. 9,225</u></u>

(6) *Masonry works* :-

Two bifurcations, each twice, Drawing No. 33 (1), or

	4	@	L.T.	1,195	=	L.T.	4,780
Minor heads	5	@	„	508	=	„	2,540
Bridge road pipes	40	@	„	160	=	„	6,400
			Total ...	L.T.			<u>13,720</u>

(7) *Pipe crossings near Tigris for flood irrigation* :-

50 pipes	3'	@	L.T.	250 =	L.T.	12,500
10 "	4'	@	"	335 =	"	3,350
5 "	5'	@	"	450 =	"	2,250
Total =						<u><u>L.T. 18,100</u></u>

(8) *Irrigation pipe culverts for 210 kilometres* 800 @ L.T. 30 = L.T. 24,000

(9) *Earthwork of canals* :-

Earthwork... ..	1,840,000 c.m.	@	L.T.	0.02 =	L.T.	36,800
"	5,210,000 "	@	"	0.01½ =	"	78,150
Total ...						<u><u>L.T. 114,950</u></u>

(10) <i>Earthwork of drains...</i>	2,150,000 c.m. @ L.T.	$0.01\frac{1}{2} =$	<u><u>L.T. 32,250</u></u>
(1)	L.T.	225,503	
(2)	,,	110,315	
(3)	,,	278,850	
(4)	,,	5,000	
(5)	,,	9,225	
(6)	,,	13,720	
(7)	,,	18,100	
(8)	,,	24,000	
(9)	,,	114,950	
(10)	,,	32,250	
Total ...	L.T.	831,913	
Contingencies, $33\frac{1}{3}\%$	,,	277,307	
Grand Total ...	L.T.	<u><u>1,109,220</u></u>	

Paragraph 21.—THE NAHRWAN.

(The lower Nahrwan canal project, drawing No. 42).

(1) *Barrage on Dyala :—*

Earthwork	89,350	c.m.	@	L.T.	0·05	=	L.T.	4,467
Pitching	10,468	"	@	"	0·70	=	"	7,328
Lime masonry	33,567	"	@	"	1·40	=	"	46,993
Puddle	5,481	"	@	"	·20	=	"	1,096
2-1 cement masonry...	2,087	"	@	"	2·50	=	"	5,217
Regulating appliances..	720	sq.m.	@	"	1·00	=	"	720
Piling	550	metres	@	"	15·00	=	"	8,250
Pumping	...	...	...	...	...	...	"	5,000
Metalling	300	c.m.	@	L.T.	0·50	=	"	150
					Total ...		L.T.	79,220

(2) *Diversion of Dyala* (drawing No. 42):—

Earthwork 857,375 c.m. @ L.T. 0.05 = L.T. 42,870

(3) *Excavation of lower Nahrwan :—*

Earthwork ... 3,725,400 c.m. @ L.T. 0.02 = L.T. 74,320

(4) *Nahrawan canal head* (drawing No. 54):—

Earthwork	6,441 c.m.	@	L.T.	0·05	=	L.T.	322
Puddle	360 "	@	"	0·20	=	"	72
Pitching	646 "	@	"	0·70	=	"	452
Concrete	631 "	@	"	2·20	=	"	1,388
Lime masonry	1,848 "	@	"	1·40	=	"	2,587
4-1 cement masonry ...	47 "	@	"	2·00	=	"	94
2-1 " " ...	231 "	@	"	2·50	=	"	578
Metalling	45 "	@	"	0·50	=	"	23
Regulating appliances..	63 sq.m.	@	"	20·00	=	"	1,264
				Total ...		L.T.	6,780

(1)	...	...	...	L.T.	79,220
(2)	...	...	...	"	42,870
(3)	...	...	...	"	74,320
(4)	...	...	...	"	6,780
Total...				L.T.	<u>203,190</u>

Alternative A.—The Upper Nahrwan canal project.

(1 A) *Upper Nahrwan canal* (drawing No. 9) :—

Earthwork... .. 7,161,000 c.m. @ L.T. 0.02 = L.T. 143,220

(2 A) *Canal head* (drawing No. 61) = L.T. 10,000

(1 A) L.T. 143,220

(2 A) " 10,000

Total... .. L.T. 153,220

Approved project.

(1) *Dyala diversion* :—

Earthwork 100 metre wide channel 4,410,800 c.m.

" 200 metre " " 4,576,000 "

8,986,800 c.m. @ L.T. 0.04 = L.T. 359,572

Contingencies, 33½ % " 119,828

Total... .. L.T. 479,400

(2) *Dam across Dyala*... .. 66,380 c.m. @ L.T. 0.20 = L.T. 13,300

(3) *Lower Nahrwan* :—

Earthwork 5,588,100 c.m. @ L.T. 0.02 = L.T. 111,760

(4) *Minor Canals* :—

Earthwork 1,700,000 c.m. @ L.T. 0.01½ = L.T. 25,500

(5) *Irrigation outlets* 1,000 c.m. @ L.T. 30 = L.T. 30,000

(6) *Masonry works* :—

Head regulators 10 @ L.T. 508 = L.T. 5,080

Road bridge pipes 60 @ " 160 = " 9,600

Total... .. " 14,680

(7) *Escape head on Dyala* (drawing No. 54) L.T. 6,780

(1) L.T. 479,400

(2) " 13,300

(3) " 111,760

(4) " 25,500

(5) " 30,000

(6) " 14,680

(7) " 6,780

Total... .. L.T. 681,420

Contingencies, 33½ % " 227,140

Grand Total... .. L.T. 908,560

Drawing No. 32.

Canal head from Left Euphrates canal for Radwania, Mahmudia and Iskanderia canals :—

Earthwork	2,790 c.m.	@	L.T.	0·02½ =	L.T.	70
Pitching	36 „	@	„	0·70 =	„	25
Masonry	467 „	@	„	1·40 =	„	654
Regulating appliances..	18 sq.m.	@	„	10·00 =	„	180
			Total ...	L.T.		929

Canal head from Left Euphrates canal for Abu Goraib, Nahr Melcha and Kutha canals :—

Earthwork	3,150 c.m.	@	L.T.	0·02½ =	L.T.	79
Pitching	36 „	@	„	0·70 =	„	25
Masonry	630 „	@	„	1·40 =	„	882
Regulating appliances..	27 sq.m.	@	„	10·00 =	„	270
				Total ...	L.T.	1,256

Head on Euphrates river of Upper Nahr Melcha and Kutha canals :—

Earthwork	4,200 c.m.	@	L.T.	0·02½ =	L.T.	105
Pitching	185 „	@	„	0·70 =	„	130
Masonry	476 „	@	„	1·40 =	„	667
Regulating appliances..	32 sq.m.	@	„	10·00 =	„	320
Metalling	24 c.m.	@	„	0·50 =	„	12
				Total ...	L.T.	1,234

Head on Euphrates river of Radwania, Mahmudia and Iskanderia canals :—

Earthwork	3,200 c.m.	@	L.T.	0·02½ =	L.T.	80
Pitching	150 „	@	„	0·70 =	„	105
Masonry	373 „	@	„	1·40 =	„	522
Metalling	20 „	@	„	0·50 =	„	10
Regulating appliances..	21 sq.m.	@	„	10·00 =	„	210
				Total ...	L.T.	927

Drawing No. 33.

Typical head regulators of canals taking off the rivers (Type 1) :—

Earthwork	2,639	c.m.	@	L.T.	0·03	=	L.T.	79
Metalling	24	"	@	"	0·50	=	"	12
Pitching	185	"	@	"	0·70	=	"	129
Masonry	470	"	@	"	1·50	=	"	705
Regulating appliances..	27	sq.m.	@	"	10·00	=	"	270
					Total	...	L.T.	1,195

Drawing No. 33 (Type 2).

Earthwork	2,043 c.m.	@	L.T.	0.03	=	L.T.	61
Metalling	24 "	@	"	0.50	=	"	12
Pitching	167 "	@	"	0.78	=	"	117
Masonry	360 "	@	"	1.50	=	"	540
Regulating appliances..	23 sq.m.	@	"	10.00	=	"	230
Total ...						<u>L.T.</u>	<u>960</u>

Drawing No. 33 (Type 3).

Earthwork	1,750 c.m.	@	L.T.	0.03	=	L.T.	52
Metalling	24 "	@	"	0.50	=	"	12
Pitching	139 "	@	"	0.70	=	"	97
Masonry	277 "	@	"	1.50	=	"	415
Regulating appliances..	18 sq.m.	@	"	10.00	=	"	180
Total ...						<u>L.T.</u>	<u>756</u>

Drawing No. 34.

Kutha and Babylon bifurcation regulators :—

Earthwork	3,200 c.m.	@	L.T.	0.03	=	L.T.	96
Pitching	200 "	@	"	0.70	=	"	140
Masonry	675 "	@	"	1.40	=	"	945
Regulating appliances..	51 sq.m.	@	"	10.00	=	"	510
Total ...						<u>L.T.</u>	<u>1,691</u>

Drawing No. 35.

Proposed Akkar Kuf drain head :—

Earthwork	5,300 c.m.	@	L.T.	0.04	=	L.T.	212
Pitching	400 "	@	"	0.70	=	"	280
Puddle	70 "	@	"	0.20	=	"	14
Masonry	1,050 "	@	"	1.50	=	"	1,575
Metalling	60 "	@	"	0.50	=	"	30
Regulating appliances..	63 sq.m.	@	"	10.00	=	"	630
Pumping						"	200
Total ...						<u>L.T.</u>	<u>2,941</u>

Drawing No. 36.

Proposed head regulator for Right Tigris canal :—

Earthwork	9,800 c.m.	@	L.T.	0.05	=	L.T.	490
Pitching	700 "	@	"	0.70	=	"	490
Puddle	200 "	@	"	0.20	=	"	40
Masonry	1,740 "	@	"	1.50	=	"	2,610
Metalling	80 "	@	"	0.50	=	"	40
Regulating appliances	96 sq.m.	@	"	10.00	=	"	960
Pumping						"	500
Total ...						<u>L.T.</u>	<u>5,130</u>

Drawing No. 37.

Siphon for Right Tigris canal under a flood canal :—

Earthwork...	...	...	...	15,500	c.m.	@	L.T.	0·05 =	L.T.	775
Piching	...	...	...	500	„	@	„	0·70 =	„	350
Masonry	...	...	...	3,300	„	@	„	1·50 =	„	4,950
Regulating appliances	...			96	sq.m.	@	„	10·00 =	„	960
Pumping	...	...	...	...	...	...	...	...	„	500
								Total...	L.T.	7,535

Drawing No. 38.

Ordinary road bridge for Akkar Kuf drain :—

Earthwork	2,600	c.m.	@	L.T.	0·04 =	L.T.	104
Pitching	100	"	@	"	0·70 =	"	70
Masonry	400	"	@	"	1·50 =	"	600
Metalling	60	"	@	"	0·50 =	"	30
				Total ...	L.T.		804

Drawing No. 39.

Ordinary regulator for Akkar Kuf drain :—

Earthwork...	...	...	...	4,900	c.m.	@	L.T.	0·04	=	L.T.	196
Pitching	...	...	...	370	"	@	"	0·70	=	"	259
Puddle...	...	...	...	70	"	@	"	0·20	=	"	14
Masonry	...	...	...	660	"	@	"	1·50	=	"	990
Metalling	...	...	...	60	"	@	"	0·50	=	"	30
Regulating appliances	...			54	sq.m.	@	"	10·00	=	"	540
								Total	...	L.T.	2,029

Drawing No. 40.

Left Euphrates canal head :—

Rock cutting	16,630	c.m.	@	L.T.	0·10	=	L.T.	1,663
Pitching	675	"	@	"	0·70	=	"	472
Concrete	561	"	@	"	2·20	=	"	1,232
Lime masonry	1,769	"	@	"	1·40	=	"	2,477
4-1 cement masonry..	48	"	@	"	2·00	=	"	96
2-1 " "	229	"	@	"	2·50	=	"	572
Metalling	45	"	@	"	0·50	=	"	23
Regulating appliances..	74	sq.m.	@	"	16·00	=	"	1,184
					Total ...		L.T.	7,719

Drawing No. 43.

Ordinary road bridge on canals :—

Earthwork	...	...	...	...	730	c.m.	(@	L.T.	0·03	=	L.T.	22
Metalling	...	...	...	...	24	"	(@	"	0·50	=	"	12
Masonry	...	...	...	...	172	"	(@	"	1·50	=	"	258
									Total	...	L.T.	292

Drawing No. 43.

Ordinary regulating head of minor canals :—

Earthwork	1,575 c.m.	@	L.T.	0·03 =	L.T.	47
Pitching	40 „	@	„	0·70 =	„	28
Masonry	196 „	@	„	1·40 =	„	274
Metalling	17 „	@	„	0·50 =	„	9
Regulating appliances..	15 sq.m.	@	„	10·00 =	„	150
				Total ...	<u>L.T.</u>	<u>508</u>

APPENDIX P.

Discharges.

Discharges of the Tigris at Bagdad (British Residency gauge).

Date.	Gauge.	Area in square metres.	Velocity in metres per second.	Discharges in cubic metres per second.	REMARKS.
26/11/08	29·55	1,120	0·49	543	Watts and Moore. River falling. Calm.
23/2/09	32·15	1,966	1·10	2,156	J. Willcocks and Mustafa Ibrahim, river raising. Slight wind upstream.
17/4/09	33·30	2,275	0·84	1,885	Roushdy and Hamdy, river falling very fast. Slight wind downstream.
25/4/09	34·09	2,480	2·00	4,945	W. Willcocks and Tabor. River rising fast. Calm.
26/4/09	34·64	2,622	1·62	4,270	Tabor, maximum gauge of the year. Fall begun. Calm.
28/4/09	34·07	2,475	1·40	3,472	Tabor. River falling. Calm.
7/5/09	33·03	2,205	1·10	2,435	Apted. River falling. Calm.
19/5/09	33·21	2,252	1·30	2,907	Roushdy, Neguib and Bauer. River steady. Calm.
4/6/09	32·23	1,997	0·90	1,797	Apted and Moore. River falling. Calm.
23/6/09	31·17	1,710	0·68	1,175	Apted and Tabor. River falling. Calm.
7/7/09	30·34	1,505	0·72	1,088	Mustafa Ibrahim and Roushdy. River falling. Calm.
22/9/09	28·73	1,062	0·31	332	Watts and Apted. Calm.
29/10/09	28·67	729	0·46	335	Bauer. Calm.
27/11/09	31·20	1,718	0·91	574	Apted and Roushdy. Calm.
14/12/09	32·08	1,947	1·24	2,417	Watts. Steady. Calm.
17/7/09	30·04	1,428	0·45	656	Apted and Moore. Calm.

Discharges of the Tigris and its branches.

Date.	R. L. of water surface.	Area in square metres.	Velocity in metres per second.	Discharge in cubic metres per second.	REMARKS.
9 12 08	13.45	1,522	0.66	1,008	Tigris at Koot. Watts Apted. Calm.
9 1 09	12.24	974	0.76	743	Tigris at Koot. Tabor and Ashkar. Calm.
3 1 09	7.32	1,010	0.50	510	Tigris above Amara. Apted El-necavé. Calm.
2 1 09	7.34	662	0.46	308	Tigris below Amara. Apted El-necavé. Calm.
10 12 08	7.32	648	0.60	392	Tigris below Amara. Watts and Moore. Calm.
16 12 08	5.53	235	0.45	167	Tigris below Machaira. Watts and Moore. Calm.
19 12 08	3.88	150	0.66	99	Tigris at Devil's Elbow. Watts and Moore. Wind downstream.
4 1 09	12.70	60	0.21	13	Hai branch near head. Tabor and Ashkar. Calm.
4 1 09	12.68	30	0.33	10	Hai branch near head. Tabor and Ashkar. Calm.
10 12 08	13.45	56	0.51	29	Hai branch near head. Apted and El-necavé. Calm.
17 6 09	14.95	334	0.60	200	Hai branch near head. Watts and Moore. Calm.
10 12 08	7.32	472	0.69	328	Chala branch. Watts and Moore. Calm.
3 1 09	7.32	458	0.59	271	Chala branch. Apted and El-necavé. Calm.
4 1 09	7.24	419	0.50	211	Chala below bridge. El-necavé.
4 1 09	7.27	118	0.17	20	Machera below bridge. El-necavé.
31 12 08	7.81	520	0.36	189	Bitera near head. El-necavé.
14 12 08	6.60	258	0.34	88	Majar Kabir. Watts and Moore. Calm.
16 12 08	5.53	145	0.49	71	Machera. Watts and Moore.

Discharges of the Euphrates and its branches.

Date.	R. L. of water surface.	Area in square metres.	Velocity in metres per second.	Discharge in cubic metres per second.	REMARKS.
8/2/09	51.94	690	0.90	623	Euphrates at Hitt. Elnecavé.
2/3/09	52.74	882	0.64	565	" " Watts.
8/3/09	52.54	884	0.85	723	" " Watts & Moore.
13/5/09	55.29	1,500	1.82	2,740	" " Elnecavé.
26/5/09	54.93	1,414	2.06	2,478	" " "
28/5/09	54.79	1,330	2.03	2,305	" " "
29/5/09	39.40	1,028	0.90	940	Euphrates at Abu Goraib. Tabor and Apted.
3/1/09	29.35	722	0.68	501	Euphrates at Hindia. J. Willcocks.
5/1/09	29.49	654	0.75	494	" " "
14/1/09	29.42	728	0.77	563	" " Rushdy.
6/5/09	32.30	1,345	2.26	2,584	" " Tabor.
13/5/09	31.85	1,228	2.36	2,465	" " Rushdy.
6/6/09	30.93	1,325	1.34	1,785	" " Santo Simo.
2/6/09	30.79	1,298	1.26	1,640	" " "
6/1/09	27.17	728	0.57	418	Hindia branch. J. Willcocks.
6/5/09	31.10	1,345	2.30	2,633	" " Tabor.
13/5/09	30.60	1,258	2.11	2,262	" " Rushdy.
6/6/09	29.58	1,164	1.29	1,524	" " Santo Simo.
2/6/09	29.42	1,138	1.03	1,177	" " "
8/6/09	29.32	1,132	1.03	1,166	" " Cugnin.
14/6/09	29.16	1,112	1.03	1,152	" " "
13/5/09	31.75	150	1.19	179	Hilla branch. Rushdy.
6/6/09	30.93	95	0.55	32	" " Santo Simo.
9/6/09	30.79	82	0.59	57	" " "
14/6/09	30.75	75	0.58	44	" " Cugnin.
26/6/09	30.34	50	0.50	25	" " Lagionopol.
2/7/09	30.10	38	0.33	13	" " "
4/7/09	30.01	35	0.22	6	" " "
7/7/09	29.90	30	0.16	5	" " "
9/7/09	29.84	25	0.20	5	" " "
9/10/09	21.58	470	0.71	336	Hindia branch upstream of Shamia.
10/10/09	21.46	255	0.82	217	Shamia branch at head.
11/10/09	21.40	130	0.75	86	Kufa branch at head.
20/10/09	17.86	234	0.87	203	Shamia branch at Shamia.
26/10/09	59.82	16.9	0.37	6.2	Abu Goraib canal 6 kilom. from head.
25/3/09	38.00	8.7	0.50	4.3	At Abu Gurdania mud bridge.
24/3/09	36.76	4.1	0.34	1.4	" Skheil bridge.
23/3/09	35.44	3.7	0.33	1.2	" Menassir canal.
8/3/09	44.18	31	0.45	14	Azazia canal.

Rushdy.

APPENDIX R.

Railways.

“It became evident, early in the history of the Chenab Canal, that a railway for transport of produce was very urgently required. The requisition for this railway came from the Railway Department unexpectedly; it had not been contemplated in the programme of the time being, and some delay occurred before funds could be made available. It is scarcely too much to say that the success of the colonization scheme was seriously threatened by the difficulty the settlers experienced in conveying their enormous produce to the market. This need has now been so fully recognized that in the case of the newly opened Jhelum Canal, a similar railway down the centre of the Jech Doab is being constructed, and a considerable portion of it will probably be open for traffic by the time an urgent need for it arises.”

This is a quotation from the completion Report of the Chenab Canal in Northern India, a canal traversing lands similar to those of Mesopotamia in their climate and in the condition in which they found themselves before the canal works were carried out. Here is a description of the country from the original report:— “The country was one of extreme desolation. The rainfall was only 5 inches per annum, and one might travel for miles without seeing a living thing. The distinct features of the landscape was the camel thorn. The only inhabitants of the country were the indigenous tribes known as the Janglis and their herds. The Janglis were a people of pastoral and nomadic habits, eking out a precarious existence by means of their camels and cattle.” In such a land, so like great part of Mesopotamia, canals have introduced in a few years nearly a million of inhabitants, and the resurrection of the country has been so rapid that its very success was jeopard ed by a railway not being able to be made quickly enough to transport the enormous produce.

A lifelong experience in India and Egypt has firmly impressed on me the maxim that in the arid regions of the earth water should be monopolised for irrigation and railways for transport. You cannot leave the waters of the rivers in their channels for purposes of navigation, and at the same time take them out of their channels and irrigate the country with them. For navigation you may substitute railway transport; for purposes of irrigation nothing can take the place of water.

In countries depending entirely on irrigation the railways should follow the banks of the main canals and traverse the centre of the tracts they mean to serve. Now the Bagdad railway is a desert railway, and though it will put Bagdad in communication with east and west, it will not serve the irrigated parts of the delta of the two rivers. I therefore show on drawing No. 52 the different alignments of the railways which would serve the country we hope to irrigate. On the map itself are given the main features of the different lines, and the task of

selecting the best line and estimating its cost may be left to railway engineers. I confine myself to a statement of the probable quantity of produce such a railway would have to transport. The area to be irrigated between Bagdad and Nasria will be 750,000 hectares, and if from this area we export so much as represents the rents calculated in paragraph 22 of the report, we shall have to handle annually 375,000 tons of cereals and 1,250,000 cwt. of cotton. As the country is famous for its breed of animals, there will be a considerable movement of live stock, but I have no idea of what the numbers will be.

W. WILLCOCKS.



