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Report
on the
Lloyd Barrage and Canals
Project in Sind

BY

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MAP OF SIND.

LLOYD BARRAGE AND CANALS PROJECT IN SIND

Report

CHAPTER I

INTRODUCTORY

The Lloyd Barrage and Canals Project which has its headworks on the Indus River at Sukkur is the largest single irrigation scheme undertaken in any part of India, and the proposals which led up to it were under consideration and discussion for over twenty years prior to its sanction in April 1923. Its construction was put in hand in the month of July of the same year. The project is the latest development in the process of improvement and extension of the primitive inundation canals which has been going on ever since the British occupation of Sind in 1843.

The aim of the project is to provide an assured supply to an area of about 2 million acres which is at present receiving an indifferent supply from the inundation canals, to improve the character of the supply by making it perennial and to increase the irrigated area by about $3\frac{1}{2}$ million acres. The total area irrigated at present, including the 2 million acres referred to, being about $3\frac{1}{2}$ million acres, the effect of the new project will be to double the cultivated area dependent on river water in the Province of Sind.

2. On account of the great size, huge cost and vast implications, the project has been viewed by the public with a certain amount of mistrust and apprehension from its very inception. It is unusual in any country for a scheme of this magnitude to be undertaken without rousing opposition, without interfering with local or other vested interests or running counter to opinions held by some sections of the public or other. At the time of sanctioning the scheme the Secretary of State laid stress on the fact that as Irrigation was a Provincial subject under the Government of India Act of 1919, the responsibility for financing the scheme rested entirely with the Bombay Government. This was the first time that the burden of financing a new irrigation project of this magnitude was thrown on the Bombay Government. The apprehensions felt by the public were partly due to the circumstance that the Bombay Government had encountered difficulties in prosecuting another large undertaking, namely, the Bombay Back Bay Reclamation Scheme, started in May 1920, the estimates of which had been exceeded and which had resulted in a growing debt, and disappointed public expectations.

Opposition from Local Interests

3. There is also a certain amount of opposition due to interference with the water supply to existing irrigation in Lower Sind. It is feared that the Barrage at Sukkur would lower the river levels and diminish

the supply now received, particularly at the beginning and end of the kharif season, by the Fuleli Canal in the Hyderabad District and the Lower Sind Canals along both banks of the river situated in the Karachi District.

Some of the important Zamindars in Upper and Central Sind expect that, under the Barrage Scheme, there will be stricter control of water, which will interfere with the slack methods and easy practices, to which their labourers are accustomed at present, and put them to increased expense in watering their crops in future.

Engineering and other Objections

4. The engineering aspects have also come under criticism. A discussion on the scheme took place in June 1922 before the Royal Society of Arts, London, on a paper read before that Society on *Irrigation Enterprise in India* by Mr. F. W. Woods, C.I.E., late Chief Engineer, Irrigation Department, Punjab. Several prominent Engineers and public men connected with India took part in the discussion and the occasion revealed a considerable diversity of opinion. It has been alleged that the designs were wrong, the constructive methods were inefficient, the area to be irrigated was exaggerated, the country would be ruined by water-logging, there would be excesses over estimates, and the scheme would never pay financially.

Decision to obtain outside opinion

5. The scheme has been criticised by various parties and interests. The Members of the Legislative Council frequently interrogated Government on the various aspects of design and construction and the probable future course of the scheme. The discontent once found expression even in Parliament. As opposition to the scheme gathered force, the Bombay Government decided to obtain the opinion of an Engineer unconnected with the scheme and, at a meeting of the Legislative Council held on 7th March 1927, gave the public an assurance that they would have the works examined by an outside expert and that they had requested the Secretary of State to send out a competent Engineer for the purpose.

Subsequently however Government decided to have the investigation carried out by Engineers in India. In a letter dated the 1st May 1929, the Bombay Government invited us "to inspect and report on the engineering aspects, both technical and administrative, of the construction of the Lloyd Barrage and Canals in Sind" and expressed a hope that we would be able to submit our report by the 1st September 1929. On a reference being made by us at a later date, the Government informed us that "the financial aspects of the scheme as a whole were outside our terms of reference."

Inspection Tour

6. After a preliminary study of the Government papers received on the subject we met in Bombay on the 6th June and went over some of the plans and papers in the Government P. W. D. Secretariat relating to the Scheme. A few days later we proceeded to Sind arriving

in Karachi on 15th June. After two conferences in Karachi with the Chief Engineer, Lloyd Barrage and Canals Construction Works, and the Superintending Engineers in charge of the various Circles under him, we visited Sukkur and inspected the Barrage Works there between the 21st and 28th June. The cofferdam on the right bank end of the river bed was still in position and the floor and piers there were kept unwatered at the time of our visit. While at Sukkur we also inspected the upper reaches of the Canals which take off from the Barrage and some masonry and other works in progress along them. From Sukkur we journeyed to Larkana and, after seeing some of the works and a portion of the country around, returned to Karachi on 1st July.

On account of heavy rain and interruption of communications, our tour over the left bank of the river was delayed. On the 22nd July we proceeded to Nawabshah and visited the Sakrand Agricultural Farm and canals in that vicinity. From Hyderabad we saw the head works and a portion of the Fuleli Canal, and from Mirpurkhas we had glimpses of the Jamrao Canal and of some of the new canals and distributaries under construction. At each of these places we obtained help and information from the Superintending Engineer of the Circle concerned. We met all the Executive Engineers under the Barrage Administration and discussed local irrigation problems with most of them as also with some of the Engineers of the regular Sind Public Works Department. Both in Karachi and in the mofussil we met several leading public men, representative Zamindars and cultivators. We enquired into the progress of the works and obtained the views of many of these gentlemen on matters connected with irrigation, and the developments likely to follow the construction of the Barrage Scheme.

Acknowledgments

7. We collected the information required for this report by inspections of the works in progress, by interviews as explained above with the Engineers, Zamindars and cultivators, and by a study of the printed reports on the project, and perusal of the records and correspondence in the several offices we visited. We desire to express our obligations to Mr. C. S. C. Harrison, C.I.E., Chief Engineer, Lloyd Barrage and Canals Construction Works, for placing freely at our disposal whatever information was wanted and for sending round circulars to the Superintending Engineers and Executive Engineers employed on the scheme to afford us every facility and help in our investigations. We are also indebted to the Chief Engineer in Sind for asking his officers to meet us in the several towns or camps we visited and render assistance.

Terms of Reference

8. We have found some difficulty in interpreting our Terms of Reference quoted in paragraph 5 above. There are parts of this report in Chapters VIII and IX which, strictly interpreted, may not

come under the category of "engineering aspects" If they are found superfluous, we request that no notice may be taken of them.

Since our investigation was intended to clear up doubts and difficulties raised in public controversies, we felt a mere recital of the engineering features, designs, methods of construction or quality of work done would not have thrown sufficient light on the points at issue, and it might have made the report a pointless dissertation. We have interpreted the Terms of Reference as an invitation to us to express our opinions on the scheme viewed as a complete irrigation project. The report deals mainly with its engineering features, other aspects being introduced to the extent deemed necessary to present a connected picture.

In view of the public criticisms of the scheme we have devoted a whole Chapter to the examination of the statements of critics. We have throughout kept in view that what is expected of us is not merely opinions on matters which have formed the subject of controversy but also constructive suggestions to develop the work into a productive undertaking as quickly as possible.

Tables and Map

9. Tables giving the essential facts and figures explaining the scope of the Barrage Scheme and a Map of Sind showing the positions of the main barrage and canals are printed as annexures to this report.

CHAPTER II

PREVIOUS HISTORY AND BRIEF DESCRIPTION OF SCHEME

10. The Province of Sind, including the State of Khairpur, has a culturable area of about 13½ million acres, of which nearly 3½ million acres are annually cultivated yielding a land revenue of about Rs. 105 lakhs. In the greater part of Sind the yearly rainfall is negligible, and only 10 per cent. of the cultivated area is dependent on it. On the rest of the area there can be no crops without an artificial supply from the river. Irrigation lies at the very root of the prosperity of Sind,

The River Indus brings down abundant supplies of water, the discharge rarely falling below 22,000 cusecs, while the average is as high as 110,000 cusecs. From where it enters the Province of Sind, the river is generally in deltaic formation, flowing along an elevated ridge of soil alluvially formed by its own deposits. The indigenous system of irrigation by inundation canals takes advantage of this physical peculiarity. The device is primitive; a cut is made at right angles, and, after a short distance, the canal takes a course parallel to the river commanding low-lying lands away from the marginal ridge.

Drawbacks of Inundation System

11. The old irrigation works have been improved and extended during the British Administration of the country at a cost of about Rs. 3.5 crores. Scientific methods have been introduced into the

design, construction and control of the canals, and many of them have been provided with head regulators. But there are inherent drawbacks in this method of irrigation. The cultivation at present dependent on river inundations is principally kharif, and even this is subject to the detrimental effects of fluctuation in the river water levels; the low water supplies in the winter season can be tapped only to a small extent, and that too under very favourable conditions. Besides liability to poor crop outturns and even distress from loss of harvest arising from vicissitudes of supply, there is a limit to expansion of cultivation. The success of new undertakings can be purchased only at the expense of those already in operation.

Gradual Development of new Scheme—Engineers Associated with it

12. This unsatisfactory state of affairs drew the attention of British Engineers so far back as the year 1847, when Colonel Walter Scott put forward a suggestion for the construction of a bar across the river between Sukkur and Rohri. A project for a canal from Rohri towards Hyderabad came up for consideration in 1872 and again in 1892, only to be abandoned each time. For nearly 60 years projects for the control of the Indus at Sukkur were mooted, considered and rejected. Dr. T. Summers resuscitated the subject in 1904, and the Government of Bombay also felt the necessity of taking active steps in this direction. Besides Dr. T. Summers, various other Engineers, viz., Messrs. A. Hill, H. F. Beale, F. St. John Gebbie, C. M. Lane and A. A. Musto, have been associated with this project at one stage or another until it assumed its present form. The Government of India, early in 1906, sent out Sir John Benton to visit Sind and enquire into the possibility of providing this Province with perennial irrigation. His successors Sir Michael Nethersole and Sir Thomas Ward also actively advised the Bombay Engineers in maturing proposals which ultimately led to the present scheme.

Fluctuation in the supply to existing irrigation was causing serious difficulties, and it was felt that a more intensive cultivation of the land and improvement in the conditions of agriculture were called for; it was regarded that if further neglected the situation was likely to grow worse on account of the increasing cold weather withdrawals of water in the Punjab. A regulating weir or barrage was considered necessary to remove these disabilities, the harnessing of the River Indus being viewed as a protective measure to safeguard the interests of Sind.

It was at one time suggested that the eventual requirements of Sind would demand the construction of three weirs, respectively, at

1. Mithankot,
2. Sukkur or Sehwan,
3. Kotri or Jherruck.

But the expense of constructing so many structures on a deltaic river of the size of the Indus was prohibitive, and attention was confined to one to begin with, and that the most promising project. In December

1910 the Government of Bombay submitted their recommendation supported by estimates for the construction of a Barrage, just upstream of the rocky gorge at Sukkur, and for a large canal taking off from above it on the Rohri side. Having regard to the difficulties and problems to be encountered, the Governor of Bombay at the time remarked that his Government would willingly seek the advice of an expert American Engineer upon the proposals made, because if an inadequate waterway came to be provided at the barrage the effects would be serious, causing the river to deflect to the west with disastrous consequences.

Earlier Scheme Referred to a Committee in London

13. The estimates amounting to Rs. 7,81,70,727 were forwarded to the Secretary of State by the Government of India with their Despatch No. 30 P. W. of 24th October 1912. The Secretary of State thereupon appointed a Committee in London consisting of Col. J. W. Ottley and Messrs. L. M. Jacob, W. L. Cameron and A. L. Webb, to whom the scheme was referred for report. Along with the scheme were sent to the Committee Dr. T. Summers' publications dealing with his alternative proposal for the Rohri Canal which suggested a postponement of the Barrage, and also the notes by Sir Steyning Edgerly calling attention to the position of the Larkhana Collectorate and commenting on the effects of the withdrawals of water in the Punjab.

The report of the Committee was issued in December 1913. The Committee were not satisfied in regard to the main justification advanced for the project, viz., that injury had been caused, or was threatened, by abstraction of water from the Indus and its tributaries in the Punjab; and, on the evidence before them, they found themselves unable to advocate sanction to the very expensive scheme of perennial irrigation put forward as a protective measure. They expressed the opinion that it was not likely that a scheme could be evolved which would prove productive. As regards the alternative proposal of Dr. T. Summers, they examined the situation that would be created, and were opposed to an experiment involving a large expenditure and great risk, especially when such a canal could not be regarded as a safe perennial source of supply, and, as an inundation canal, it would probably not be productive.

On the engineering side the Committee drew attention to the many serious difficulties presented by the site selected for the construction of any form of weir or barrage, and indicated the possibility of a suitable site being found a few miles further downstream, where founding a barrage on sand throughout would be a less formidable undertaking, besides minimising the risk of avulsion.

It was held that so long as Sind remained an inundation canal country, heroic measures were premature. But the Committee finally recommended that a complete project should be prepared and kept in readiness in case the necessity for perennial irrigation should become imperative. Such a measure, even though unremunerative, would, they thought, be justifiable for other and wider reasons. The Secretary

of State, while refusing sanction to the scheme, commended the various suggestions made by the Committee to the careful consideration of the Government of India.

View Held and Action Taken by Government of Bombay

14. The Government of Bombay were not satisfied with this view of the case. They felt that, although a quantitative determination of the effect of the Punjab withdrawals on the river supplies was not possible, there was reason to believe that, in the unfavourable conditions of a low river bed combined with a scanty flow from the catchment area, the withdrawals might appreciably affect the water levels at the early and late *abkalani* periods of the inundation canals. Further, they were disinclined to acquiesce in a policy of stagnation or to be content to regard Sind as a purely inundation country for all time. From the physical features, character of soil and demand for water they felt there was great scope for improvement in agriculture, and there was little doubt that irrigation would flourish and its extension would be greatly beneficial to Sind.

In order that the high expense of a barrage might be justifiably embarked upon, it was realised that the bountiful supplies of the Indus should not be dealt with piecemeal, but that the scope of the project should be increased with a view, on the one side, to steadying the supply to as many existing canal systems as possible, and, on the other, to providing for extension of irrigation. Surveys were accordingly re-started in 1916 and a revised project was ultimately put forward in 1920 as a productive work designed to give assured supplies of water to the country on both banks of the river. The estimated cost, as amended by the Government of India, amounted to Rs. 18,35,47,543 exclusive of Rs. 8,14,532 incurred on surveys and investigations, while the returns on the sum-at-charge, 10, 20 and 30 years after completion, were computed at 5·57, 8·97 and 10·5 per cent. respectively and it was anticipated that the scheme would become productive in nine years after completion.

Secretary of State's Sanction in 1923

15. The Secretary of State accorded financial sanction to the project remarking that, in respect of advances by the Government of India, the local Government should be charged interest at the actual rate at which the Government of India may borrow *plus* proportional share of flotation expenses. The project was thereafter laid before the Bombay Legislative Council, and the following Resolution was recorded by that body at its meeting held on 9th June 1923 :—

“ This Council approves of the Sukkur Barrage Project as sanctioned by the Secretary of State and recommends to the Governor in Council that the work should be commenced as soon as possible.”

The work was accordingly commenced with effect from 1st July 1923.

Objects of Barrage Scheme

16. The objects of the Barrage Scheme may be briefly said to be—
- to keep out silt from Canal mouths, that is, at their Head Regulators;
 - to maintain in the canals a steady supply at a fairly constant level and to render cultivation immune from the injury due to short or fluctuating supplies ;
 - to enable higher duties to be realised and better outturn of crops than under the older canals ;
 - to convert large areas of lift irrigation into flow ;
 - to render possible the cultivation of more valuable or useful crops ;
 - to enable a larger proportion of land to be irrigated ; and
 - to provide agricultural employment to the population all the year round.

Main Outlines of Scheme

17. The scheme, as sanctioned, comprises the following works :—

(1) A Barrage with a bridge-way across the river Indus $3\frac{1}{2}$ miles below the gorge at Sukkur, fitted with sluice gates capable of holding water up to R. L. 194·5.

(2) A group of canals on the left bank consisting of :—

(a) Rohri Canal.

(b) Two kharif Feeder Canals to provide for the needs of the Khairpur State.

(c) A new cut to the Eastern Nara and improvements to the Eastern Nara channel.

(3) A group of Canals on the right bank consisting of :—

(a) North Western Canal.

(b) Central Rice Canal.

(c) Southern or Dadu Canal.

(4) Drainage and protective works as required in the irrigated tracts.

(5) Works required for a more rapid drainage of the Manchar Lake, the overflow from which at present adversely affects the development of cultivation under the Central Rice and Dadu Canals.

A few modifications have been made during construction and the latest estimate puts the cost at Rs. 20·04 crores. Excluding the Khairpur Feeders, the canal system, as now projected, comprises 679 miles of main canals, 1,042 miles of branch canals and 4,499 miles of distributaries and minors, the quantity of earthwork to be excavated being 5,550 million cubic feet. The aggregate discharging capacity at the head of all the canals, excluding Khairpur feeders, is 42,427 cusecs, of which 32,212 is allotted to perennial canals. These latter canals, when in full working order in the winter season, will require a minimum supply of 23,802 cusecs. The gross command dependent on the Barrage for assured supplies is 7,275,813 acres and the culturable area 6,558,263 acres, of which 5,379,465 acres are expected to be irrigated ultimately, as compared with 2,035,636 acres at present watered by the inundation canals (Appendix III). The scheme

embraces the whole of the irrigated tract in Sind with the exception of some 700,000 acres at the northern end of the Province and about 600,000 acres at its southern end.

CHAPTER III

ENGINEERING FEATURES—GENERAL

Discharges of the River Indus

18. The maximum flood on record in the River Indus occurred in 1914 and amounted to 949,000 cusecs when it gave a reading on the Bukkur gauge of 17·0 feet against the highest recorded reading of 17·9 feet taken in 1896. It was considered by Mr. H. F. Beale when he was Superintending Engineer, Indus River Commission, that the greatest flood would probably never exceed 1,100,000 cusecs, but he advised, in order to provide for the safety of the barrage, that it be taken as 1,500,000 cusecs.

The average discharge of the river is computed at about 110,000 cusecs and the minimum discharge as observed on 4th April 1917 amounted to 17,568 cusecs. But this minimum was exceptional and of short duration. The river discharge rarely goes below 22,000 cusecs at present. For the demands of any canal system likely to be needed for Sind, at the present time, the capacity factor will be high. For nearly the full period, whether in the kharif or rabiseason, the demand can be adequately met.

Necessity of a Barrage

19. The abstraction of water in the Punjab from the tributary components of the River Indus has increased from 1,400 cusecs in 1867-68 to 28,000 cusecs in 1921-22, and the additional withdrawals contemplated by the Sutlej Valley Project amount to 7,000 cusecs. The Punjab has other projects also under consideration. Although no reliable data are available the withdrawals of water in the Punjab must be affecting the supply at Sukkur and there can be little doubt that increasing abstraction like this is a menace to the future of Sind agriculture.

To meet this situation it was necessary to make arrangements in Sind to raise the level of supply of river water and control its distribution by constructing a barrage.

Scope of the Project

20. The primary object of the scheme is to improve in respect to level and quantity the supplies needed for existing irrigation during years in which the natural flow is low and unfavourable. A secondary object is to provide for the extension of irrigation to as large a new area as the supplies available allow of, in order to admit of the project fulfilling the conditions of a productive work. The canal system as designed provides for the utilization of a maximum supply of 46,457 cusecs in the inundation season and a minimum of 23,802 cusecs in the rabi

season. The latter discharge is determined by the minimum water supply in the river as given in paragraph 18 above.

The project, as it is being carried out, is designed to secure the following results :—

- (1) Provision of an assured kharif supply for 298,000 acres in Khairpur Territory.
- (2) Improvement in the conditions of supply for the present inundation kharif irrigation of 1,510,332 acres.
- (3) Extension of kharif irrigation by 685,472 acres.
- (4) Converting the present area of 525,304 acres, which is largely *bosi rabi*, to regular rabi.
- (5) Extension of rabi irrigation by 2,658,357 acres.

Thus the total kharif irrigation aimed at is 2,493,804 acres and the total rabi 3,183,661 acres, making a grand total of 5,677,465 acres. The area in British Territory alone, *i.e.*, excluding Khairpur, will be 5,379,465 acres.

Assumed Intensity of Irrigation too high

21. The gross area commanded in British Territory is 7,275,813 acres, and the proportion of irrigation contemplated in the latest revised proposals is about 74 per cent. on gross area, against 71 per cent. of the proposals in the sanctioned project. Under the perennial canals, the features of winter cropping according to the revised proposals are as under :—

Canal	Commanded area	Rabi area proposed	Percentage of winter irrigation	Canal supply
	Acres	Acres		Cusecs
Rohri	2,831,024	1,376,778	48·63	10,090
Eastern Nara	2,179,294	944,700	43·34	8,164
North Western Canal	1,064,960	516,609	48·51	3,211
Southern Canal	656,921	345,574	52·60	2,337
Total	6,732,199	3,183,661	47·29	23,802

It will be seen that it is proposed to irrigate nearly half the whole area commanded, in the rabi season, and, in the case of the Southern Canal, somewhat more than half.

The scheme is a large and bold one and it contemplates great changes in the conditions of the tract. The turning on of a very large volume of water throughout the year into a flat country, which had hitherto been supplied only during a portion of the year, brings to the forefront one great risk, *viz.*, water-logging and salt efflorescence.

The soil of Sind drains with difficulty and facilities for drainage are poor or non-existent. Within the area affected by the barrage scheme, the river continues its course in a single channel and there are no branches to act as separate outfalls. The Eastern Nara with Dhoro Puran affords

some relief ; but the valley on the western lateral, besides being exposed to hill torrents, has no such outfall, and the water can only return to the river when its level is low. Further the soil in this region is highly impregnated with salt. Evaporation in the climate of Sind is excessive and water as it evaporates leaves behind injurious salts on the surface resulting in *kalar* land, and there is not sufficient rain to wash away the salts.

Water-logging is no idle threat. It has already become the most serious problem in the Punjab, where, chiefly owing to the intensity of cultivation, the subsoil water table has risen rapidly to an embarrassing extent, so much so that the Punjab Government have found it necessary to appoint a Drainage Board to formulate schemes for the arrest and prevention of water-logging.

In Sind, there may be, as is contended, seams of sand below the surface affording an effective subsoil drainage. No systematic subsoil survey has, however, been carried out so far, and it has yet to be ascertained to what extent the sand is obstructed by bars of clay. What information there is, is disquieting. The country commanded by the Rohri Canal is described as subject to water-logging, the Eastern Nara tract is known to have a high spring level and to be unhealthy, while on the Right Bank the extent of subsoil flow is very great, and the conditions are not favourable to extensive rabi cultivation. In the Collectorate of Nawabshah we were informed that four out of every five wells dug in the region turn out to be brackish, and that deep ploughing usually results in bringing salts to the surface.

For these reasons and from the analogy of the Triple Canals Project in the Punjab, it does not seem prudent to raise the intensity of the perennial canals to more than 60 per cent. of the gross area. In other words the extent of perennial irrigation should be restricted to 4,039,319 acres. Deducting 1,788,334 acres provided under kharif, this means a rabi area of 2,250,985 acres, which would need a minimum supply of a little over 17,000 cusecs. Including the area under the non-perennial Central Rice Canal, our forecast of total annual irrigation is 4,446,789 acres, as against the latest figure of 5,379,065 acres given by the Chief Engineer.

Suggested extension to feed Fuleli and Lower Canals

22. A supply larger than 17,000 cusecs is ordinarily available from the river in the winter season, and if it is to be effectively utilised, it is necessary to extend the benefits of the Barrage Scheme over a wider area.

The channel of the Eastern Nara river, is very conveniently situated for the transmission of water from the Barrage to tracts situated far down the left bank of the river. The Nara, which has a fall of 9 inches a mile, is being canalised, and there will not be any serious increase in cost in making it carry a larger supply. The transit losses in a natural valley like this would not be great. Except in the reaches adjoining dhands, where water in the Nara bed might be higher than the surrounding sub-surface spring level, percolation might be ignored, and the principal loss

would be that due to evaporation. Transmission of an additional supply over some 115 miles to the Jamrao weir is thus feasible at no great cost and without much loss of water.

It is considered that advantage should be taken of this favourable feature of the Nara. So far as the general levels of the country are concerned, there is *prima facie* good reason to believe that a canal alignment is practicable from the Jamrao head to areas lower down the left bank of the river. The area under command of the Rohri canal, after the 161st mile, is about 14 lakhs of acres, that of the Fuleli is 17 lakhs, and there are also Hassan Ali and the other Indus canals of the Fuleli Division. It may be practicable to feed even the Pinyari canal. As work on the Rohri Canal system is well advanced, it is perhaps undesirable to interfere with the present arrangements connected with it. But a large area still remains to be served in this region and the cost of a separate barrage near Kotri or Jherruck for the purpose would be prohibitive.

The water level at the Jamrao Regulator is at R. L. 104.2 and sufficient head is available to feed the Fuleli canal, the F. S. L. of which at its head is R. L. 63.70. The connecting canal need not be made to carry the full discharge for the area to be irrigated. What is required is to link up these existing inundation canals with the Barrage system by feeding them with Barrage water just to the extent of the shortage experienced when the river level is low. Between Jamrao and Fuleli two alignments suggest themselves. An entirely separate canal from Jamrao weir to the Fuleli head would be about 84 miles long; an alternative might be to widen the Jamrao canal as far as mile 31 and to take a feeder from there to tail into the Fuleli at mile 25 where the Gaja distributary takes off, the total length then becoming about 92½ miles. The cost is likely to be somewhere in the region of Rs. 150 lakhs.

This is merely a rough indication and the whole question will need to be gone into in great detail. It is necessary to carry out this investigation, because as shown above the present proposals are not likely to suffice for the utilisation of the entire supply available in the river to the best advantage. It is in any event important to have projects ready for the irrigation of Lower Sind in view of the extensions contemplated in the Punjab. If a barrage is necessitated by the abstraction of water in the Punjab, the Lower Sind canals must be held to be affected in common with the other canals; and the Barrage will further aggravate the situation for the former. An extension of area that is rendered possible in this way will, besides arresting loss of revenue under the Lower canals, improve the financial prospects of the Barrage Scheme itself. We recommend that the proposal be carefully investigated in all its aspects.

Unfavourable Features of the Rohri and Southern Canals

23. From the point of view of area irrigated the Rohri canal is regarded as the most important part of the scheme. But this canal from the point of view of cost and returns is not so favourable as several of the others, and it would have been better to have restricted its length by

transferring some of the irrigation at its tail end to be served from the Nara. The canal further suffers from the disadvantage that it does no service in its head reach which lies for a considerable distance in Khairpur Territory.

The Southern or Dadu Canal is distinctly a weak member of the scheme, as it runs side by side with the Central Rice Canal doing little or no irrigation for a distance as much as 90 miles. The merits of such a design were discussed at the Irrigation Conference of 19th January 1918, and, both at this conference and afterwards in his technical note which accompanied the Government of India Despatch No. 23-P.W., dated 16th December 1920, Sir Thomas Ward expressed himself as disinclined to accept the three canals proposal on the right bank. In the technical note referred to he remarks that "it is possible when the comparative estimates have been duly considered it will be found that the better arrangement will be to have one perennial and one non-perennial canal." We concur in the opinion that it would have been a better arrangement to have had one non-perennial canal to serve both the Central and the Southern areas on the right bank. In the talukas of Dadu, Johi, and Sehwan, some of the land may be suitable for rabi crops, but this area is not an agricultural Klondyke to have warranted the construction of a long separate canal for itself. A great part of the tract is low-lying being on the foreshore of the Manchar Lake which keeps up the subsoil water at a high level, the outlet of the Lake not being serviceable during a part of the year. Further it lies below a heavily cropped rice area, where it would be difficult to get cultivators to undertake extensive winter cropping.

The scrapping of existing canals also does not seem to have been a sound policy. It would have saved a large sum of money, had only a feeder from the Barrage been given to the Ghar and the Western Nara Canals, these canals being extended and improved to the requisite extent. The returns under the Southern canal will not be favourable, even if all that is expected of it should materialise. Taking the revenue expected 10 years after commencement of operation, this canal compares with its sister non-perennial canal as shown below:—

Name of Canal	Estimated cost including share of Barrage as apportioned in the project	Net increase of revenue 10 years after completion
	Rs. lakhs.	Rs. lakhs.
Central Rice Canal	257·53	17·7
Southern Canal	228·82	9·7

The disadvantage of very long canals in this tract is obvious. Excluding the cost of the river head works, while the rate per cusec of

canal capacity is only Rs. 1,943 for the Central Rice Canal, that for the Rohri Canal is Rs. 5,258, and for the Southern Canal Rs. 6,402.

Irrigation beyond the West Nara Drainage

24. We consider that the project should not have concerned itself with irrigation of the high lands across the West Nara Valley. This valley with the Mirzo reservoir and the Manchar Lake, is the collecting basin for a hill drainage of some 30,000 square miles of country, which cannot be freely discharged into the river Indus at all times. The proposal is to provide a flood protective bund no less than 156 miles long to divert the hill torrents. Whether, having regard to the heavy floods from the various *Nais* which have to be diverted by it, the protective bund could be considered safe against frequent breaches is problematical. In any case this feature will still further tend to the raising of the spring level.

The whole area proposed to be protected is nearly 525,000 acres, of which 185,000 acres are situated under the North Western Canal and 340,000 acres under the Rice and Southern Canals. In the latter area the submersion that takes place is chiefly due to breaches in the Indus River bund near Talti. To the extent of incurring the expenditure required for reclaiming such portions of the area as were being occasionally submerged by river action and providing irrigational facilities for it, it was right that the project should have borne the charge.

CHAPTER IV

DESIGN AND CONSTRUCTION OF BARRAGE AND HEAD REGULATORS

Selection of Barrage Site

25. The most convenient situation for a barrage is in the vicinity of the Bukkur gorge, where the river has a steady flow in a confined channel. The largest area of land on both banks can be commanded from here, and materials for construction are obtainable within easy distance. The site first chosen was above the gorge and the chief reason for the choice was the presence of rock there. But the rock met with is not hard enough to stand severe scour when subjected to the rush of great masses of water, and the deep rift below constituted a danger from retrogression of levels. The selection of this site would have introduced a serious element of difficulty and expense into the construction. The risk of avulsion towards the west had also to be considered.

As suggested by the London Committee the present site $3\frac{1}{2}$ miles downstream of the old one was finally selected. The barrage structure here rests on sand, but sand is no drawback to stability, while the special difficulties of construction have been reduced and risks in other directions minimised. Between the gorge and the barrage site the river passes through high natural banks and the heading up at the barrage during floods will be appreciably less.

General Description

26. The Barrage rests on a wide masonry floor founded on sand protected by aprons of concrete blocks and stone pitching, and by curtains of steel sheet piling to check the creep of water. Resting on this floor are piers of stone masonry placed 60 ft. apart with gates working between them to raise the river water to the required full supply level. There are 66 openings, of which seven towards the left bank end and five towards the right bank are separated from the centre spans by divide walls, to serve as scouring sluices. The piers carry two separate arches, one 8 ft. wide and another 5 ft. with a gap of 13 ft. between the two, for accommodating the steel structure and machinery for working the gates. A continuation of the same piers on the downstream side carries a lower bridge with a 16 ft. roadway and footpaths, to establish communication between the two banks of the river. The length of the bridge is 4,926 ft. or just under a mile. The parapet of the high level bridge is 66 ft. above the floor level and 40 ft. above the highest flood level, that of the road bridge being 23 ft. lower.

Joined to the abutment of the Barrage on either bank is a masonry river wall taken upstream, in which are placed the Head Regulators of the various canals. In continuation of the Regulators are built upstream guide banks, along the natural banks of the river, which are pitched with stone. The waterway allowed for the head Regulators is 32 spans of 25 ft. each for the four left bank canals, and 23 spans of the same width for the three canals on the right bank.

Construction Work

27. The main line of Barrage was laid out from towers constructed at the two ends one on each bank. The foundations had to be constructed on sand at the bottom of a great river. It was not a work that could be got through in a single season, and the construction of substantial cofferdams each season, and dismantling the same and recovering the piles before the close of the season, presented exceptional difficulties which have been a constant source of anxiety to the officers concerned.

The floor has to be constructed in the dry within large cofferdams, formed by single rows of interlocking steel sheet piling 40 to 50 ft. long enclosing a section of the river bed, and supported on the inside by sand banks. Dredging is then done to a depth somewhat below the level required for the foundations, and after the pit is unwatered, labour is employed to complete the remaining excavation. When the pumps lower the water to below the foundation level, the floor masonry is laid and over it a paving of 15" cement concrete. The downstream side of the floor has a coping of ten-ton concrete blocks laid on the apron and the upstream and the downstream ends are protected by a talus of stone pitching.

Labour and material are conveyed over water by barges and pontoons. The stone used is lime stone. That obtainable in large

blocks is of a soft variety which lends itself to dressing and has been used for the voussoirs of the Regulator arches, copings, parapets and string courses. For the bigger spans of the Barrage arches, reinforced cement concrete is being used as giving a better factor of safety. The other quality of stone obtainable is harder, but cannot be had in large blocks. It is suitable only for random rubble masonry, concrete and pitching.

Progress of Works

28. The floors and the piers of 39 spans of the Barrage and of all the canal Head Regulators have been constructed together with the connecting wing walls and the upstream river walls on the two banks. The work of superstructure is well advanced. On the right bank the gate bridge arches of the five scouring sluices and the arch of the land span have been completed; on the left bank seven road bridge arches over the scouring sluices are nearing completion. The stone arches of the Regulators on the right bank have been constructed, and the arches of the Regulators on the left bank will soon be finished to enable transport of material over it by light railway for the next season's work. The remaining 27 spans of the Barrage in the centre of the river will be taken up next year, and, with the construction of the divide walls in 1931, all under-water work will be completed. The Barrage is expected to be ready by March 1932.

The provision for Barrage works in the second revised recapitulation is Rs. 593 lakhs (*vide* Appendix VI). The expenditure incurred to end of June 1929 was Rs. 357·6 lakhs leaving a balance of Rs. 235·4 lakhs for future expenditure on unfinished work.

Principal Features of Design

29. The principles which usually govern the stability of structures built on sand have been observed in preparing the design for the floors. The length of creep adopted is 17 times the hydrostatic head, as against 14·2 at the Esna Barrage on the Nile and 15·0 at the Narora weir on the Ganges. The co-efficient is the same as that taken for the Jamrao weir which is founded on similar material and which has stood successfully.

The floor level in the barrage section which in the original design was placed at R. L. 176 has been raised to R. L. 177 in actual construction, giving the downstream talus a slope of 1 in 10 with a view to limit the disruptive action under standing wave conditions to the heavy solid pavement. This raising was permissible as the lowest mean bed of the river does not usually go below R. L. 177. At the same time it is proposed to raise the top level of the main Barrage gates from R. L. 194·5 to R. L. 195·5, and of the scouring sluice gates, still higher to R. L. 198·5. This change was decided on last hot weather.

A peculiarity of the river bed at this site is that its level changes constantly within very wide limits, 6 to 7 feet or even more, and at the site selected for the barrage there is a distinct bar, the bed of the river

being normally higher than what it is a mile or so upstream. It is a drawback of the site that a large quantity of scoured material churned up by the river currents rushing through the gorge gets periodically deposited here, and the situation that will be created by holding up water to any considerable depth must be viewed with misgivings. Silting will proceed much more rapidly than under ordinary conditions, and much of the sand rolled forward on the bed and the silt and clay carried in suspension will be trapped. The natural process of denudation will be interfered with and heavy shoaling is likely to take place; the tendency will be generally towards the formation of a delta in the ponded area, the barrage keeping open suitable passages through the under sluice sections. If the barrage gates are not opened often and river water is held up to a high level as a normal state of things, it might perilously add to the avulsion risk. These considerations will have to be borne in mind in the future regulation of the flow of the river through the Barrage.

Head Regulators

30. The considerations which have been kept in view in designing the Head Regulators as constructed are:—

- (1) That by working the scouring sluices, it will be possible to keep the silt in the approach channels to a lower level than that of the bed attained by the river in its natural state; and
- (2) that the discharge through regulators per foot run of sill should be in the vicinity of 40 cusecs.

Experience has shown that no great reliance can be placed upon the effect of scouring sluices in keeping down silt. If the highest mean bed level of the river is liable to rise in the month of June to about R.L. 184, the regulator intake sill ought on no account to be kept below that level. A perfect non-silting draw-off is essential and we agree with the suggestion put forward by Mr. C. G. Hawes, Executive Engineer, that this should be provided by raising the sills to R.L. 184 wherever they are lower now.

The mean velocity of the current of entry at the scouring sluices should not materially exceed that in the canals and it should, if possible, be kept in the neighbourhood of 3 feet per second. Water issuing with a higher velocity of entry will receive a check immediately it enters the canal and silt is liable to be deposited as a consequence at the Canal mouth. The design of the Regulator sluices does not take this contingency into account.

Barrage and Regulator Gates

31. Sufficient details of the design of the gates or lifting gear are not available. It was stated [that the steel gates, which will be electrically operated are being obtained from Messrs. Ransomes and Rapier. This firm is well known and their designs may be accepted.

The method of assembling and erecting the gates has been carefully considered. The gates will be brought in sections on to the gate bridge arches over the grooves, and the finished gate will be lowered from towers temporarily fixed on the piers. During erection the heavier gate parts will be handled by two ten-ton electric cranes and the lighter parts by a Scotch derrick.

Quality of Work, Estimates, Rates, etc.

32. With reference to the quality of work done on the Barrage, we find that the cement concrete mixture used in the blocks for the apron in 1 : 6 : 12 with a skin 4" thick of 1 : 3 : 6. A richer mixture should have been used for greater strength and safety, particularly for the skin where it should have been 1 : 2 : 4. The lime obtainable is not very good and the mortar prepared from it did not seem to us to be of the high quality required. The stone available is not suited for ashlar work and the courses of masonry in the piers are only 6" to 8" deep. It would have been better to have built the masonry up to R.L. 202·0 in cement.

The excess on the Barrage estimates is large and demands some cement. At the time of submission to the Secretary of State, the Government of India included in the abstract of the estimate, an additional sum of Rs. 255 lakhs classifying it under "unforeseen works." This amount had been wholly absorbed by the Barrage works, leaving nothing for any of the other works in the project. Chiefly on account of the uncertainties under cofferdams, the cost of service works has risen from Rs. 47·46 lakhs to Rs. 60·46 lakhs. But the heaviest excesses have been on construction works proper. The rate originally provided under dredging was low and the dredgers have not given a satisfactory output. A good deal of the work intended to be performed by dredgers has had to be done by manual labour and this has materially added to the expenditure.

The rates provided in the original estimate were in some cases very low. At the same time the revised rates seem to us to be high for a locality like Sukkur where materials required for construction are procurable within easy distance. Our visit was of short duration and we were not able to understand clearly why stone at quarry, lime mortar, and haulage are costing so much as they are.

The provision of Rs. 255 lakhs made by the Government of India was no doubt intended to cover possible excesses under machinery, plant, steel and iron work needed for the Barrage, as there was apprehension at the time that, on account of the unsettled state of labour in England, the prices might go up. But the aggregate excess on these items has been only Rs. 37·62 lakhs. If we leave this out of account and also the provision under Service Works, Establishment, Buildings, etc., the estimated expenditure on construction works proper has risen from Rs. 96·85 lakhs in the original estimate to Rs. 242·30 lakhs or roughly 2½ times. In addition, a sum of Rs. 27·24 lakhs is retained under "unforeseen items" in the revised recapitulation.

CHAPTER V

DESIGN AND CONSTRUCTION OF CANALS

Principal Features

33. The principal features of the canal system as now projected will be understood from the following table:—

Item	I Rohri Canal	II Eastern Nara	III North Western Canal	IV Central Rice Canal	V Southern or Dadu Canal	Total
1	2	3	4	5	6	7
Area commanded (acres).	2,831,024	2,179,294	1,064,960	548,614	656,021	7,279,913
Proposed annual irrigation—						
(a) Kharif ..	685,165	700,400	261,626	407,470	141,148	2,196,804
(b) Rabi ..	1,376,778	944,700	516,000	....	345,574	3,183,661
Total ..	2,061,943	1,645,100	778,235	407,470	486,717	5,379,465
Intensity of irrigation on area commanded (per cent.).	72·83	75·49	73·08	74·95	74·09	73·93
No. of Regulator spans of 25 feet width each.	12	16	6	13	4	51
Discharge at the head of canal (cusecs)—						
(a) Kharif ..	10,887	13,389	5,009	10,215	2,337	42,427
(b) Rabi ..	10,000	8,104	3,211	....	2,337	23,902
Transit loss in Main Canal and branches (cusecs).	2,216	3,729	682	1,165	612	8,403
Length of main canal (miles).	209	221	36	82	131	679
Bed width of main canal (feet).	247	346	165	243	92·5	....
Full supply depth (feet).	12·0	11·5	10·2	11·75	9·6	....
Total length of branches (miles).	303	451	180	60	48	1,042
Total length of distributaries and minors (miles).	1,847	1,214	638	315	485	4,499

The canals have been carefully aligned and the designs worked out from the tail upwards to the head regulator in accordance with modern practice. The duties adopted at distributary head are 43·5 acres per cusec for rice, 87 for other kharif crops, and 174 for rabi crops. Allowance for percolation and evaporation is made at 8 cusecs per million square feet of wetted perimeter, except in the case of the channel of the Nara River where the loss is expected to be less. Non-siltating

channel sections have been provided wherever possible. There are, however, a few cases in which, owing to the flatness of the country, the necessary surface fall could not be had. The limit laid down for distributary slopes is 1 in 10,000, but we understand that this has been found to be necessary only in rare cases.

For main canals the depth of dry earth allowed over the toe of saturation gradient is only 2 feet, and for branches 1 foot. The usual practice is to give more; an extra foot in each case would have been better.

The number of regulators proposed is greatly in excess of what was provided in the sanctioned estimate and what it is usual to allow in a tract where the command is so good as it is here. Our view is that in actual execution regulators should be built only where they are absolutely necessary. Supplies may have to be held up near the tail but this is seldom necessary in the upper reaches. Regulators are practically stop-dams which require staff to operate who may use their positions to their own advantage.

Usually outlets are allowed only on minors and distributaries discharging less than 100 cusecs; outlets are not given direct from the bigger channels. It is proposed to provide semi-modules at the outlets so that the discharges may be unaffected by variations in water level at the rear.

Special Designs and Research

34. The work of design of bridges, regulators, falls, etc., is standardised in the Central Designs Division, and the most economical types are adopted, embracing features that in practice have proved satisfactory. The latest ideas are obtained from the Sutlej Valley Project in the Punjab, and from the results of experiments carried out in Poona by the Superintending Engineer, Irrigation Development and Research Circle. Experiments are also being made by the Executive Engineer, Central Designs Division, on a laboratory scale at the Barrage Head Quarters at Karachi.

Duties and Capacities

35. In the general acceptance of the terms—

- (1) Duty at distributary head is the area which an average supply of one cusec will irrigate, and
- (2) Maximum capacity duty is the area irrigated per cusec of capacity provided at canal head.

The latter includes allowance for transit losses along the canal and for the increased supply required by crops during periods of pressure.

The average distributary head duties provided are reasonable and not impossible of realisation. But we are not so satisfied in regard to the carrying capacities provided for the canals. We agree that the "overlap" allowance does not present any serious difficulty, where seasons are not restricted to four month periods but extend to six months. Extra capacity is, however, needed to meet the demand at times of pressure, and, if this margin of capacity be not allowed for, the distributary head

duty becomes the maximum—not average. There must be no stinting of water throughout the growth of a crop, and in Sind heat waves add to the difficulty and occasion a rush for water. Careful experiments have shown that, for a crop like rice, the maximum capacity should be not less than 30 per cent. above the average, and in the case of dry crops not less than 20 per cent. Sind being a rainless tract, the whole of the supply in the kharif season, and not merely a part, is given by artificial waterings, and the percentage extra allowance might be lower, namely, 20 per cent. and $12\frac{1}{2}$ per cent. for wet and dry crops respectively. Canal capacities would therefore appear to err on the side of being rather low.

Canal Construction

36. In canal construction, earthwork accounts for 60 per cent. of the total expenditure. Its volume is so large that it would have meant immense organization and trouble to have got it done by manual labour. The climate of Sind is to some extent unfavourable for carrying out work by manual labour. The regular working season extends only to four months, it is liable to be interrupted by epidemics at times and there is water difficulty in some places besides. It was considered inadvisable to rely solely upon manual labour for earthwork excavation, and resort was had to the use of dragline machines of which 46 of various sizes have been purchased. In spite of the great assistance received from dragline excavators, the highest quantity of excavation done in any one year so far was in 1928-29. It then amounted to 101·44 crores of cubic feet against 113·93 million cubic feet done on the Sutlej Valley Project in 1926-27. The programme of work is based on the expectation that the distribution of the excavation work between machines and manual labour will be about half and half.

The extensive employment of steel bridges calls for a remark. It may be true that steel bridges cost less, but masonry structures last much longer, need very little maintenance and employ local material and labour. In places where water is not available steel bridges might be necessary, but the water difficulty is not general.

It is noticed that borrow pits have been permitted in the beds of canals. Sir Thomas Ward had suggested that in no case should these be excavated in the bed and there is much in favour of that advice. Pits dug inside, below bed level, do not silt up fully but give rise to wide silt berms. If such pits have to be dug on account of expensive land, they should be in several rows with ample spaces between.

Progress of Works

37. The quantity of earthwork done up to date is 277 crores of cubic feet leaving 278 crores of cubic feet still remaining to be done. Against 199 crores of cubic feet on the right bank, 118 crores of cubic feet or 60 per cent. has been completed. The quantity of earthwork done on the Rohri Canal is 103 crores of cubic feet or 43·5 per cent. of the total on that Canal; on the Eastern Nara it is 56 crores of cubic feet or 46·67 per cent. of the total. A number of road bridges and regulators have

been constructed, and work on others, including railway bridges, is in progress.

The Rohri Canal especially is behind time and it seems desirable to increase the number of Divisions in this Circle by transferring establishments from other Divisions from which they could be spared.

The major portion of the work is expected to be finished in good time to enable the canals to be opened by April 1932 ; some work will remain thereafter on the Khirtar Branch, on the tail portion of the Rohri, and on the extensions and improvements to the Nara system, which may take another two years. At present sanctions are not sufficiently ahead of execution. The total estimated cost of canal works is Rs. 1,146 lakhs and against this, working estimates to the extent of Rs. 472 lakhs still remain to be sanctioned.

Drainage and Flood Protection Works

38. On the Manchar Drainage scheme some progress has been made on the Drain and Regulator works. The outlay required for this work is estimated at Rs. 35·04 lakhs.

The revised provision allowed for the minor drainage works is Rs. 92·97 lakhs. The Barrage Engineers intend to wait till the canals are opened and study weak points for some time during actual operation before putting these works in hand. To some extent this is sound policy, but the natural drainage of the country as a whole is very unsatisfactory, and the widening and deepening of such main lines of drainage as the Dhoro Puran and the provision of other outlets to carry away surface drainage are an urgent necessity.

The main West Nara Valley drain and the flood protective bunds are roughly estimated to cost Rs. 70 lakhs. Investigations in regard to these works are being carried on but the work is mainly agricultural and only such portion of the cost as may fairly be deemed debitable to irrigation will be charged to the project.

CHAPTER VI

ORGANIZATION—ADMINISTRATION—MACHINERY AND PLANT

Preparations to Start Work

39. The work was ordered to be started from 1st of July 1923, and Mr. C. S. C. Harrison was appointed Chief Engineer in administrative control from that date with Mr. A. A. Musto for charge of the Barrage Circle. Four other Superintending Engineers and seven permanent and temporary Executive Engineers joined their duties on various dates by the 15th October 1923. The officers were at first principally occupied in organising their Offices, recruiting staff, selecting sites for buildings, and preparing working plans and estimates. The main and branch canals were then realigned to suit the close contour survey, which had been specially undertaken for the Barrage area in anticipation of sanction to the project. After compiling details of areas under each canal, the final designs were taken up and re-examined. The requirements in

the way of special tools and plant needed for the work were also gone into and arrangements made for ordering out the same.

Organization Engineering and Other Establishments

40. The control of works is vested with the Chief Engineer who guides the whole plan of operations, progress of works and selection and ordering out of special machinery, plant and stock. He is assisted by two Personal Assistants, and has also under his direct control the Central Designs Division and the Draglines Division, which latter looks after the mechanical side of the working of the Dragline Excavators.

For the executive direction of operations, the estimate provides for 6 Superintending Engineers and 30 Executive Engineers. One of these Superintending Engineers was to be in charge of the Drainage Circle, but that Circle has not been opened. Much of the work pertaining to the Drainage Circle on the right bank is being done by the Superintending Engineer, Western Circle. There are at present 5 Circles, the Divisional and Sub-divisional charges being 22 and 82 respectively. Each Superintending Engineer has been given a Personal Assistant.

The establishment other than Engineering consists of a Special Revenue Officer who attends to land acquisition, sales, rectangulation work, etc., and a Medical Staff consisting of one Inspecting Officer, one House Surgeon and two relieving Medical Officers with eleven subordinates, to look after medical and sanitary work. There is an Audit Officer in whose office the account correspondence is as far as practicable centralised; and the office and indoor work of the Executive Engineers is reduced to a minimum compatible with punctual submission of accounts and the maintenance of a continuous record of rates and expenditure. The accounts are pre-audited and, wherever plant is employed, a proper costing system is maintained.

Experiments with new crops, crop breeding, duty of water, etc., are being carried on at the Sakrand Farm, which was started and is maintained by debit to the Barrage Project estimates. The supervision and control of the staff are under the Director of Agriculture who has his headquarters at Poona.

System of Control

41. Good discipline is maintained throughout the administration, and the two Divisions under the direct control of the Chief Engineer are doing technical or skilled work which has resulted in economy and efficiency in their respective spheres of duty. The Chief Engineer also holds conferences with his Superintending and Executive Engineers to take stock of progress, to discuss methods of construction, working rates, etc.

Nevertheless work is going on to a certain extent in water-tight compartments. Some of the Executive Engineers we met, although quite alert in their own special spheres of work, seemed to be insufficiently acquainted with what was going on outside their Divisions. We should have liked to see them more in touch with the general design and scope of the operations on the whole project.

Expenditure on Establishment

42. The yearly expenditure on works and Establishment, and the percentage of establishment charges are given in the following table :—

Year	No. of circles	No. of Divisions	Expenditure in Lakhs of rupees		Percentage of establishment to works
			Works	Establishment	
1923-24	5	15	23.69	8.78	37.1
1924-25	5	17	87.35	20.71	23.7
1925-26	5	21	170.94	24.58	14.4
1926-27	5	23	118.91	28.18	23.7
1927-28	5	23	168.08	30.73	18.3
1928-29	5	24	182.85	34.66	19.0
			757.82	147.64	19.6

These percentages are on the total works expenditure and if the cost of imported machinery, structural steel and gear be deducted, the average percentage of establishment charges will rise to 36 on a works cost of Rs. 407 lakhs. When work is done on this scale with the aid of mechanical appliances, establishment charges ought to be particularly low. We understand however that the Chief Engineer hopes to effect a substantial reduction in this amount by the time the work is completed. Excluding the first three years in which the work was mainly one of preparation and ordering out the machinery, the percentage rate on the Sutlej Valley Scheme was 22.4 in the 4th year and it dropped to 13.1 in the 5th year. In the latter year the outturn of work was as high as Rs. 287.58 lakhs, and it should be possible to achieve a similar or higher rate of progress on the Lloyd Barrage and Canals Project.

Expenditure on Buildings

43. The expenditure contemplated in the revised recapitulation on buildings has also risen from Rs. 64.85 lakhs to Rs. 87.61 lakhs, an increase of Rs. 22.76 lakhs. The excess is practically all on the Barrage and the Rohri Circles, and buildings of the value of Rs. 59.6 lakhs have been constructed so far. Some of the buildings at the Head Works will no doubt be sold later; nevertheless the provision seems high. Ordinarily provision for buildings on works of such magnitude should not exceed 3 per cent. on cost of works. In the present case the percentage works out to 5.23 on the total works cost and 6.62 on works cost less value of machinery, plant and iron work. Considering that a number of irrigation bungalows already exist in the Barrage tract, it seems very desirable that further expenditure under this head should be restricted as far as possible.

MACHINERY AND PLANT

44. The total cost of machinery, plant and iron work imported amounts to Rs. 350 lakhs of which Rs. 80 lakhs is for steel gates and iron work. The more important plants are :—

- Power plant.
- Quarry plant.
- Dredgers and floating plant.
- Railway Permanent Way and Rolling Stock.
- Dragline plant.

In what follows we shall endeavour to give a brief description of each of these with our observations thereon.

Machinery and Plant at the Barrage

45. From the nature of work at the Barrage, it was necessary to make a liberal use of machinery and mechanical power. The machines employed are mostly worked by electric power generated in a central power station by Diesel Engines. From this central station overhead lines are carried to the various points where power is required, and two submarine cables 4,500 feet long of 3 core H. T., each weighing 16 tons, have been laid across the river for supply to the left bank.

The following are operated wholly by machines actuated by electric motors :—

- Pumping.
- Pile extracting.
- Mortar mixing.
- Workshop machine work.
- Water-supply.
- Electric light and fans.

The following work is partly done by machinery electrically driven and partly by hand :—

- Hoisting by cranes.
- Stone mixers.
- Stone dressing.
- Actuating the compressors.

46. The stone crushers, drills and channeler are driven by oil engines, and steam is employed for transport, dredging and pile driving.

Power Plant

The power units are internal combustion crude oil engines of the Diesel type driving generators which are directly coupled to the engines. There are two sets of Mirrlees Engines each of 300 B.H.P. driving generators of 175 K.W., two sets of Fullager Engines each of 750 B.H.P. driving generators of 500 K.W.; and two sets of Swiss Locomotive Engines also of 750 B.H.P. each. The Mirrlees and Swiss Loco. Engines are of the ordinary 4 stroke, and the Fullager Engines are 2 stroke double acting. The total B.H.P. of the engines is 3,600 and the capacity of the generators 2,350 K.W.

The plant which has cost Rs. 14·89 lakhs has been found to be much too big for the work it has had to perform. The power of motors installed on works is 3,071 H.P., and the actual highest steady load so far has been about 1,300 B.H.P. only. This is not surprising. Some of the demand was at night time, and the steady load for such operations as, for instance, lifting would be under 1/5th of the motor power. Allowing for the liberal provision rightly kept as a safeguard for pumping, and providing for a spare set, an Engine power of 2,000 or 2,100 B.H.P. was all that was required for the work. Also for economy of working, the Engines should have been all of one type instead of three different types.

Quarry Plant

47. A large amount of stone is required and the blast holes are drilled by means of pneumatic drills operated by 300 cubic feet "sentinal" compressors worked by a 63 B.H.P. Ruston Oil Engine. For metal, stone crushers of the Acme type, with elevating and screening plant, have been installed and are worked by 47 B.H.P. Crossley Oil Engines. Ashlar and arch stones are obtained from the Rohri quarry where a channeler operated by a 550 cubic feet compressor has been installed, and the blocks are cut by wire-saws and transported to the stone dressing shop. The workshop machinery consists of circular diamond saws, frame saws, rip saws and planing machines. The cost of the quarrying plant installed is Rs. 5·25 lakhs and that of the stone dressing plant Rs. 3·6 lakhs.

In the project it was proposed to use Rohri cut stone for arches of the Barrage and of the Canal Head Regulators, and for all parapets, pilasters, string courses, etc. By a subsequent decision to have the barrage arches made of reinforced concrete, the demand has been reduced by about 6 lakhs of cubic feet or more than half the quantity originally required. Much of the stone dressing plant as also of the quarry plant will therefore be idle in future.

For the last two years quarrying of stone is being done by contractors, and, now that the work of the Quarries Division has been reduced, it might be advisable to combine this and the Stores Division into one.

Floating Plant

48. The floating plant consists of two 20" Suction Dredgers, three paddle steam tugs, two 25-ton electric floating cranes, four 10-ton floating cranes, a number of barges, pump pontoons, pile driver pontoons, motor launches, tugs, heave-up boats and sundry craft, the whole purchased at a cost of over Rs. 65 lakhs.

The Dredgers supplied by Messrs. Lobnitz & Co., have given much less than their specified output—2,000 to 3,000 cubic feet per hour against 6,000 cubic feet expected,—and the ships have cost more than double the figure provided in the original project. The project rate for dredging was Rs. 8 per 1,000 cubic feet. Prior to 1927 owing to matted brushwood and submerged tree trunks having been encountered, the outturn was very small, and the cost of operating alone was Rs. 33-6-0 per unit,

the depreciation charges being Rs. 24-2-0 extra. A short distance from the river banks, the bed is of sand with comparatively few obstructions, but the rate for 1927-28 inclusive of depreciation was still as high as Rs. 34 on the left bank and Rs. 23-13-0 on the right bank. A good deal of the work intended to be done by dredgers is being carried out by hand labour at heavy cost. It would have been better had a few electrically driven sand pumps erected on barges been employed for the purpose.

Railway Plant

49. The lead from the two quarries on the left bank to the Barrage is $5\frac{1}{2}$ and 3 miles, and from the quarry on the right bank it is $2\frac{3}{4}$ miles. The track laid is 42 miles of broad gauge and the rolling stock consists of 10 locomotives and 570 waggons. There is also a light railway, 2 feet gauge, with a length of 17 miles and a rolling stock of 8 locos and 650 tip-waggons for running out building materials over the work. The total expenditure incurred is Rs. 25·4 lakhs.

The amount of materials required to be transported daily was not very large and the haulage was also short; even during the busy season the ton-mileage was under 4,000 a day. A broad gauge railway with so heavy a rolling stock was not needed, and break of gauge is also an uneconomical arrangement. A light railway 2'-6" gauge throughout would have served the purpose quite satisfactorily, haulage under a mile being done by cooly labour.

The rate for haulage is said to be from 4 to 6 annas per ton mile. Carts could have done much of the work at this rate, and in that case the large capital outlay would have been saved. The project estimate allowed 2·4 pies per ton mile, which, of course, was an impracticable rate; but it should have been possible with a light railway to have attained a rate cost of under $2\frac{3}{4}$ annas.

Dragline Excavators

50. Under canals, the chief item of expenditure is on dragline machines. A fleet of 46 machines of various sizes has been purchased from time to time at a total cost, including accessories, of Rs. 106 lakhs. The larger sized machines, of which 6 are English (300 Ruston) and 3 American (320 Bucyrus), have a reach of 120 to 155 feet with buckets of 8 to 5 cubic yard capacity. Of the medium and small sized machines, there are 5 English and 32 American with booms varying from 35 feet to 85 feet and buckets 4 cubic yard to $\frac{3}{4}$ cubic yard capacity; these are oil Diesel Engine driven, with the exception of two which are Diesel electric excavators. The excavators are all of the full circle single bucket type, which could be readily converted into shovels, but, owing to the large radius of working and depth of cut, shovel types would not have been suitable. All together the machines weigh over 300 tons and it is stated that they form the largest fleet ever employed on any one work.

For the efficient maintenance of these excavators, a well equipped workshop has been provided, where repairs and renewals can be effected and where a reserve stock of spare parts is kept.

The case for employment of machines hinges on the question of time. The total quantity of earth-work to be excavated is estimated to be 555 crores of cubic feet and, up to the end of April 1929, 257·2 crores of cubic feet of excavation had been done, of which the machines were responsible for 161·31 crores of cubic feet and manual labour for only 95·89 crores of cubic feet. From a big sized machine, the largest output per month is said to be 40 lakhs of cubic feet and the average has been about 19½ lakhs of cubic feet.

The average rate of working for all the dragline excavators has been Rs. 9·97 per 1,000 cubic feet. This is inclusive of depreciation, but does not take into account interest charges on the cost of the machines. Most of the work done by the machines is in the head reaches of the main canals, where the lead is from 250 to 300 feet, and the lift 20 to 30 feet. For the excavation of branches and distributaries, the medium and small sized machines are intended, and the average rate for these machines, with a length of boom of 35 feet to 55 feet has been Rs. 7·30, against Rs. 7·89 the average rate paid for excavation by manual labour. This is the only comparison that may be made of competitive prices between machines and manual labour. Work is not generally of the same kind and the two methods of excavation are best regarded as supplementing each other.

Excavators usually work in pairs, and, as output has been increasing, the rate is going down. The machines work better in clay or loam than in very sandy soils, and, under the conditions in which they have had to work in Sind, the Diesel engines with low fuel consumption have given superior results to the steam engine, in spite of the disadvantage of high temperature. The elasticity of the steam engine is more than counterbalanced by the difficulty of transporting coal and the lack of suitable water for boilers. The 30-B Bucyrus machines have obtained a working rate of Rs. 5·27 per 1,000 cubic feet with an average output of 5·6 lakhs cubic feet per month. On larger Diesel machines electric power offered easier and quicker control, and the Diesel electric machines (C-24 Bucyrus) function similarly to the steam engine; the working rate for these has been as low as Rs. 2·47 per 1,000 cubic feet exclusive of depreciation.

On the whole the employment of dragline excavators has been a success. They have helped greatly to stabilise rates and to leave undisturbed the local agricultural and labour conditions, while a work of this magnitude is being carried on. With machines there is less chance also of incorrect measurements and fraud.

CHAPTER VII

IRRIGATION DEVELOPMENTS

51. It being understood that a start will be made to work the new Barrage Scheme from the beginning of the kharif season of 1932, the future development of irrigation and the success of the scheme as a productive undertaking will depend largely upon the efficacy of the measures adopted in the immediate future to prepare the area and

the people for the use of the new perennial supply as soon as it becomes available. We will now briefly refer to these measures.

PREPARING LAND FOR IRRIGATION

Land Sales

52. Within the Barrage zone, there is an area of about 1,700,000 acres of uncultivated culturable land belonging to Government. Of this area, it is proposed to set apart 50,000 acres towards peasant grants and about 350,000 acres towards grants to Zamindars at concession rates. The balance of 1,300,000 acres will, it is understood, be sold by public auction. The Special Revenue Officer is developing proposals to dispose of the available land on the most advantageous terms. A beginning should be made to sell lands in localities where the demand is keenest. The plots intended for sale may be marked on maps along with the roads or cart tracks which would give access to them from the nearest towns or villages. A clear statement of the conditions governing the sales might be prepared and issued as early as practicable for the information of the public. Every facility should be given to the poorer cultivators to participate in the purchases. If these preparations are made soon and the policies connected with the sale speedily settled, it will enable the cultivators to take advantage of the new supplies from 1932.

It is understood that the sale proceeds of these lands are not likely to be less than Rs. 10 crores but as it is proposed to spread the sales over a period of 20 years, the money will only come in slowly.

Rectangulation Survey

53. A White Paper issued by Government in July 1929 has stated that in order to secure the proper distribution of water and facilitate the alignment of water courses, the area under command is being divided into rectangular plots. The main rectangulation work is being done by the Survey of India who have undertaken to divide the land into plots of half a square mile each. The Special Revenue Officer is doing the sub-rectangulation work and is parcelling out the land into 16, 32, and 64 acre plots. He estimates that the cost of rectangulation and construction of water courses will together come to about Rs. 2-8-0 per acre and it is proposed to recover this charge from the Zamindars and cultivators who will benefit by the scheme.

Soil Surveys

54. Soil surveys were carried out under the supervision of Messrs. Baker and Lane and the results are described in their report issued with Bombay Government Resolution No. W.I.-11055 dated 20th August 1919. The work done so far is of a preliminary character, though very valuable, and it is understood that this investigation will be taken up again after irrigation has developed to an appreciable extent. It is considered that further soil surveys at the present stage will not be of much immediate value.

Construction of Water Courses

55. It is proposed to construct water courses in all new land at the cost of the owner or occupant. There will be no difficulty in recovering the charge (about Rs. 2 per acre) incurred on this work because the land will be sold on the understanding that such charges will be borne by the owner. In the case of lands already in possession of Zamindars the cost of remodelling will be less and as already remarked it will be borne by the occupant. The justification for this measure is that under the new perennial supply, production from land will be much higher than at present and the land itself will appreciably rise in value.

Establishing Connection between New Canals and existing Water Courses

56. In many places new canals and distributaries under the Barrage Scheme are being constructed across areas irrigated by the older inundation canals and very soon the new canals and accessories have to be joined on to the old water courses. There are at the present time two sets of Executive Divisions, one under the Chief Engineer in Sind and the other under the Chief Engineer, Barrage Project. It is understood that from 1930 a beginning will be made to amalgamate the older maintenance divisions of the P.W. Department with the new divisions, wherever construction work may be approaching completion. If the policies to be followed in this respect are determined and early orders passed, it will result in substantial economies in the long run.

Crop Waterings—Crop Rotation

57. The ordinary cultivator in Sind has not learnt the benefits of crop rotation though some progressive Zamindars are practising it with advantage. Crop rotation will help to aerate the soils and increase production. The system of waterings will vary with the nature of crop rotation practised.

Under the older inundation canals the distribution of water beyond the outlet is practically uncontrolled at present. Sometimes a fine is levied, under a penal clause of the Irrigation Act for wilful waste or misuse of water, but as it leads to unpopularity with the cultivators and the Revenue Department, it is stated that the Canal Officers are chary of exercising their powers in this respect.

Water will be more valuable in future since under the Barrage Scheme it will have cost more to make it available for cultivation. The best method of distributing is by delivering measured quantities according to the area and nature of crops to be watered. If the outlet delivers a constant supply the regulation of water to individual fields should be done on a regular schedule approved by the Irrigation Department. Measuring devices locally known as semi-modules are provided on some of the canals, such as the Jamrao and the Nasrat, and we noticed that both the Engineers and the cultivators concerned expressed themselves as satisfied with their use.

Wherever the cultivators are prepared to purchase water in bulk by measurement, it would be the best arrangement to come to for every one concerned. It is hoped that very soon some enterprising cultivators and water companies will come forward, as is done in countries like Italy, to take water by measurement and pay for it.

The Irrigation Engineers have yet to solve the problem of supplying just the quantity of water required by the crops and no more, and they might usefully carry on a propaganda to secure economies. The economical use of water will be greatly facilitated if the Zamindars are induced to co-operate with the Canal Officer in its equitable distribution after it leaves the outlet. All holes and hollows will have to be stopped before any scientific irrigation can begin. Except in the case of rice, an excess supply of water will injure the crops or it will lead to water-logging and other attendant evils.

Selection of Crops

58. At present the most popular and most extensively grown crop is rice which is roughly 25 per cent. of the total cropped area in the Barrage tract. A large area on the right bank of the river is low land and cultivation there is predominantly rice. Larkhana is noted for the excellent rice produced in that district. In the rice area every bit of land can be cultivated. In the case of *kalar* (salt) lands on either bank they have to grow rice or nothing else. In the tract commanded by the future Central Rice Canal the same land has been growing this crop for 30 or 40 years and it has undergone no noticeable deterioration.

The staple food of the people of North Sind is wheat and juar, in Karachi the population use rice and in Hyderabad and Central Sind all three are used.

The policy of the Irrigation Department under the Barrage Scheme is to extend rabi irrigation with a view to get the best value for the water and to provide employment to the cultivator all the year round. The principal crops aimed at for the future are cotton and wheat. The cotton crop does not grow on the right bank but it is the key crop on the left bank after rice. Next to lack of an assured supply, one reason why people have not yet taken to rabi is that the crops are occasionally injured by frost.

Both cotton and wheat, are liable in some years to suffer by over-production or foreign competition. Wheat is at present imported from Australia. On a recent occasion in the United States of America, Indian corn was used as fuel for boilers for lack of a proper market. When the Barrage authorities speak of perennial canals, they imply that the water supply will be perennial and not the crops. Gradually, intensive cultivation which requires more effort and better organization should be encouraged. Sugarcane, tobacco and dates will, we understand, be the most profitable crops for this purpose. Larkhana is too cold for sugarcane but that crop can be grown with profit between Nawabshah and Hyderabad where the Zamindars are confident that it will pay in spite of occasional frost.

Water Rates

59. In preparing the estimates of revenue at the end of ten years the average water rate taken is Rs. 5·42 per acre. At present the Zamindars are in possession of large areas of land and in order to retain their claim over it they are not required to cultivate or pay for more than one-fifth of that area annually. The inundation canals hitherto afforded little scope for rabi cultivation because the water supply was scanty, but wherever they had water, they were using it. On the remodelled canals of the Nara system, the Zamindars raise a crop on one-third of their land and leave the remaining two-thirds fallow.

All land brought under the command of the new canals should be assessed to the water rate after making a reasonable allowance for land which must be necessarily left fallow. For the more constant and assured supplies available under the Barrage Scheme, an enhanced water rate will have to be recovered, if the Scheme is to prove a financial success.

Irrigation Act and Canal Rules

60. The present Bombay Irrigation Act is not suited to the conditions in Sind, and amendments to it have long been overdue. The Canal Officer delivers the water at the outlet and he is not concerned what happens to it afterwards. There are no share lists for distribution of water which is attended to by the Zamindars themselves, and the more powerful among them get the largest share. The control and regulation of water beyond the outlet should in future be exercised under appropriate rules prepared under the Act after the latter is amended by the local Legislature. The future Act should give powers to restrict rice and kharif crops wherever necessary in order to facilitate the new policy of extending rabi irrigation. The White Paper referred to above states that the report of a Committee on the subject of amendment of the Irrigation Act appointed in 1926 and a further report submitted by the Commissioner in Sind in February 1928 are both at present under the consideration of Government. A just and equitable distribution of water in close co-operation with a Panchayat or a Committee of cultivators will go a long way to promote the orderly growth of irrigation and prosperity in the tract.

Work of the Agricultural Department

61. At present the work done by the Agricultural Department specially for the Barrage Scheme is limited to the maintenance of the Sakrand Farm in Nawabshah District where experiments in new crops, in new varieties of cotton, in cross breeding, etc., are being carried on. The principal crops experimented with are cotton, wheat, juar, bajri and berseem. About 200 acres are annually utilised for this experimental cultivation.

The chief duties of the staff of the Agricultural Department will be to carry on crop experiments at demonstration farms, to render assistance to Canal Officers in the selection of crops to be watered under various soil conditions, and to advise cultivators in regard to the selection of

crops and the most profitable methods of cultivation. They will have to render technical help and advice in regard to the following:—

- Soil analysis, selection of crops and crop rotation ;
- Selection of seed, manure and farm implements ;
- Use of modern agricultural machinery ;
- Remedies for salt impregnation, diseases of crops and insect pests ;
- Fruit farming and mixed farming ;
- Dairy industry and sheep farming.

For these purposes the experts of the Agricultural Department have to co-operate with the officers of the Revenue and Irrigation Departments on the one side and with the cultivator, the trader and the exporter on the other.

Future progress of work in this Department will depend largely on the capacity of the expert placed at the head. At present the Director of Agriculture is not able to visit Sind often and give his personal attention to its agricultural problems. It will pay Government, in view of the great interests involved, to get the services of a real expert, if possible a man with an international reputation, for a period of, say, three years. Otherwise the best alternative is to give the technical officers employed on the Sakrand Farm a chance to show what they can accomplish. They seem to be in want of more funds and a proper programme.

Much original work and hard thinking is needed in this field. The Agricultural Department to be really useful on a scheme like this should be in close touch with the experts and agencies connected with Agricultural Research in countries like England, the United States of America, Germany and Japan. The Department should also take an interest in the statistical and economic side of agriculture.

Roads

62. Locomotion in Sind except by rail is at all times difficult through lack of good roads. It is stated that out of a total length of 11,426 miles of roadway, less than 100 miles are metalled. In most parts cheap stone metal required for surfacing is not available and broken brick is costly. Government have had this subject under consideration for a long time. An Executive Engineer was placed on special duty to investigate the question and the investigation resulted in the submission of a report and preliminary estimates amounting to Rs. 4.51 crores. The White Paper says that the report is under scrutiny and a policy for financing the work will be shortly formulated.

There does not seem to be much prospect of Government being able to spare any large sums of money to this work until the Barrage works bring prosperity to the tract. But roads and irrigation works mutually help each other and any reasonable outlay on roads at this stage cannot fail to prove a profitable investment. We consider that a beginning should be made by constructing a few hundred miles of hard surface roads to connect the more important centres of population. According to Appendix B to the White Paper the expenditure proposed under roads is half a lakh in 1930-31 and Rs. 5 lakhs after 1939-40, that is, some time

after the canal system has begun to earn. For reasons stated above we consider that it would be a great advantage to the financial prospects of the Barrage Scheme if a beginning were made in road construction by spending about Rs. 5 lakhs annually from the next official year.

CHAPTER VIII

OTHER ASSOCIATED DEVELOPMENTS

Farm Management

63. In order to utilise canal water to the greatest advantage and to derive full benefit from it, agriculture should be practised as an industry with modern implements and machinery and under expert management. As a rule the aim should be to grow as far as possible crops which give the highest money value.

Success whether in agriculture or an industry will depend on *capable management* and for successful agriculture a class of farm managers and, to a lesser extent, experts in agriculture, engineering and commerce should be brought into existence. If a sufficient number of these is spread among the agricultural population, each trained manager or expert will become the inspiring centre of a group of agricultural farms and farmers to extend the benefits of irrigation and crop production.

Books and pamphlets on modern methods of farming and farm accounts as practised in Western Countries might be made available for the use of the Zamindars. Estimates of production for different varieties of crops and model farm accounts for a dozen or so typical farms might be prepared and circulated. There are already a few enterprising Zamindars here and there in the Barrage area who understand modern methods of farming and farm accountancy. What is wanted is an organization to bring these together and provide them with the necessary facilities to practise high class agriculture. The Sind Zamindar is not accustomed to save money and the illiterate *haris* or labourers working under him are extremely poor. Both these classes will require capital and by providing them with necessary credit facilities, Government will be benefitting agriculture and indirectly also Government revenue.

Manure is not used for the staple kharif crops because the silt in suspension in the river water dispenses with that need to a certain extent. For growing richer or money crops both organic and artificial manures will be required. Facilities should be created to enable the cultivators to purchase manures, seed and agricultural implements.

In recent years powerful labour saving machinery has come into use particularly in the United States of America, by means of which the population employed in agriculture is reduced while the volume of agricultural production has gone on increasing. Mechanised farming replaces manual labour in various farm operations, and since there is not enough population in Sind for the new developments, the use of farm machinery by the more enterprising Zamindars may be specially encouraged.

Business Organizations

64. For the successful pursuit of agriculture, several forms of business organization, associations, companies, etc., should be called into existence to render the services needed by the rural population as irrigation develops. Some agency with sympathetic leanings should work for this under the supervision of Government. For instance it will be necessary to examine in what form credit facilities should be supplied, and to what extent, from agricultural banks, land mortgage banks or co-operative credit societies. Co-operative societies have to be organised for marketing and purchase of manure, seed and farm implements. Facilities should be given where possible to sell water to Zamindars and water companies by measurement.

According to the White Paper issued by them, the Government of Bombay have appointed a Standing Committee and they intend appointing an Advisory Committee. In determining the functions of these bodies the recommendations of the Agricultural Commission and recent developments in foreign agriculture should be taken into consideration.

Very recently the President of the United States of America appointed a Federal Farm Board, consisting of the Minister for Agriculture and eleven other members nominated by him, the object being to encourage the organization of co-operative societies and "to furnish leadership, initiative, expert judgment and seasoned business experience to the farming population of the country." One of the duties of the Board is to foresee and try to prevent overproduction and attempt to work out new uses for agricultural products.

The American Board of Agriculture acts as an Intelligence Department by providing agriculturists with valuable information of every kind. The Department's office of Farm Management specialises on the farm business including cost of production and on the various phases of country life betterment. The Sind Zamindars and Cultivators need similar guidance to help themselves.

Administrative Developments

65. The White Paper makes provision for the creation of two more administrative districts to cope with future increase of population and growth of work due to Barrage irrigation. In reply to our enquiry whether there was enough population to carry on agriculture, a high officer of Government stated that applications for land were pouring in and that there would be no difficulty in obtaining all the labour that will be needed. We understand that a Cattle Committee has been appointed under the Chairmanship of the Special Revenue Officer, which is attending to the question of increasing cattle to supply milk and milk products, and organic manure for the crops. As cattle are being actually exported from the Province, it is understood that the number needed for the future needs of agriculture could be easily obtained.

In Appendix B to the White Paper, Government have made some provision under Education in accordance with the recommendation of

the Agricultural Commission. From what we have stated above under Farm Management, it will be clear that technical education is needed to train graduates and experts in agriculture and commerce. There is an Engineering College already in Karachi and provision has to be made for the other forms of collegiate education needed and also for establishing agricultural and business schools in Hyderabad and other district centres. In the primary and secondary courses, the education of the future citizen should be given an agricultural and business bias.

It would be a good thing if a rough economic survey is carried out in Sind along with the 1931 Census. The statistics gathered from such a survey will be a convenient starting point for the measurement of progress under the new conditions. Complete agricultural statistics should be maintained from year to year. An attempt might be made also to bring a few model villages into existence in the Barrage area to serve as patterns for others in village planning and scientific agriculture.

River Discharge Observations—Hydrographic Surveys

66. Gauge readings and discharge observations are being taken at various points of the river by a special staff working under the Executive Engineer, Indus Discharge Division. In future the work and responsibility for this class of observations will increase and all phases of river supply, levels, discharges, etc., associated with the Barrage Scheme will require special attention. The water levels and discharges at the mouths of the Fuleli and other lower canals will need to be kept under close observation for a period of at least five years in order to be able to deal effectively with the problem of future shortage in the supplies to those canals.

Under the understanding between the Governments of Punjab and Bombay, special observations of river supplies have to be carried on during the next ten years in order to determine the effect of the withdrawals in Punjab, on the Barrage supply in the cold weather.

There is an impression that the hydrography of the Indus River is not receiving the attention that it deserves and that the officers entrusted with the work are changed too often to permit of their specialising in the subject. Sections of the river bed will have to be taken annually both above and below the Barrage and at selected points for about 15 miles above the river to watch the effect of Barrage operation on the river course. Levels should be observed also frequently at all weak points of river bunds along both banks of the river.

For the more effective control of floods in future the changes in the river course and of bed levels at strategic points should be under close and constant observation. If a prosperous population is to be brought into existence, flood protection measures, or safety first, should receive the earliest attention. The Province is periodically undergoing great privations including loss of life and cattle due to ravages from floods.

Subsoil Water Levels—Drainage Works

67. The effect on the subsoil water levels will not be felt until after the new canal system has been in operation for some time. The country is flat and the river runs along a ridge. The future progress of irrigation will depend upon the extent to which the subsoil water level is kept under control in the irrigated tracts. It is understood that observations of water levels of wells are being taken in the Barrage area during the months of April and October. It has been suggested that observations should be taken also in the month of December in future.

It is said that in parts of Punjab, some of the drainage cuts excavated before the canals came into operation were afterwards found to be misplaced. The Chief Engineer is anxious that this lesson should not be lost on Sind. He proposes to take drainage works in hand after irrigation from the new canal system has been practised for some time and its effects on the subsoil water levels are clearly known. The problem of subsoil water and drainage is vitally connected with the success of the Barrage Scheme and it should receive the closest attention of the Engineers who will have charge of the Scheme in future.

Bureau of Research

68. Extensive scientific investigations and research will be necessary under both hydrodynamic and agricultural aspects of Barrage irrigation. The conditions of the region are not exactly similar to those of other parts of India, not excluding Punjab. There is no rain for many months. The record of summer temperature is the highest in India and there is frost in winter. The Province has its own special local problems to solve.

It is necessary to bring into existence a combined Research Station to carry on scientific investigations in irrigation and agriculture. Research work in irrigation should embrace the following subjects:—

- (i) Duty of water under varying conditions of soil and crops.
- (ii) Discharge observations for velocities in channels and through flumes, modules, outlets and orifices generally.
- (iii) Continuous study of river discharge observations and changes in the river course and bed levels.
- (iv) Rise in the subsoil water table in various parts of the tract.
- (v) Observations for shoaling in the river bed and silting in canals, distributaries and minors.

Research work to be attempted under Agriculture has already been referred to in paragraph 61 above.

The Bureau of Research will have enough work to begin with if it tries to collect and compile the scientific data already available in the various canal offices in Sind.

The new Bureau should have a Committee of Advice consisting of 3 to 5 officers belonging to the engineering and agricultural professions, with known leanings or aptitude for scientific investigation.

A large size model of the river prepared in clay or other material showing the levels of the riverain tract including bunds will be a useful means of bringin home to the public mind the weak points of the river and river bunds.

CHAPTER IX

COST AND RESULTS

69. As stated before, the construction of this project was started in July 1923 and it has been in progress for over six years. From the experience gained during this period it is possible to make a surer forecast of how the scheme may shape, what further expenditure may be needed and what results should be expected from it.

Cost of Project

70. The project estimate as originally sanctioned by the Secretary of State amounted to Rs. 18.35 crores. The Chief Engineer first prepared a revised recapitulation without altering the amount and this was sanctioned in a Bombay Government Resolution dated the 7th September 1925. After some further experience of construction and closer examination of details, the Chief Engineer prepared a second revised recapitulation amounting to Rs. 20.04 crores and submitted the same to Government on 3rd February 1928. Although this second recapitulation is not formally sanctioned, work is proceeding in accordance therewith, presumably with the approval of Government. The original sanction is exceeded by Rs. 169 lakhs so far. An abstract of the revised estimate is given in Appendix VI which shows both estimate and expenditure, side by side, under the principal heads of the project as they stood at end of May 1929. It will be seen that the total cost of the works proper is Rs. 1,761 lakhs and the value of work executed against it is Rs. 774 lakhs or roughly 44 per cent. Including establishment and tools and plant the total direct charges in the estimate amount to Rs. 1,976 lakhs and the expenditure against them Rs. 976 lakhs or roughly 49 per cent.

Precautions to avoid Excesses over Estimate

71. The Chief Engineer is confident that there will be no excess over his latest revised estimate of Rs. 20.04 crores which he states will be the very outside figure. We were assured that he has so organised things and is in such close touch with details that the occurrence of unforeseen excesses seems improbable. Should however occasion arise to exceed any of the sectional estimates already sanctioned, such excesses should be met by corresponding savings, if necessary by omitting or postponing some of the less urgent works.

Such postponement in this case seems feasible. The extent of additional irrigation expected in 10 years from the date the canal system comes into operation is about 1,700,000 acres. The further extension expected after that period will be roughly 1,710,000 acres (Appendix III). It should be possible to effect some appreciable savings by postponing the construction of distributaries and other connected works

required for areas which are not likely to be cultivated for 20 or 30 years more. We are aware that there will be difficulty in picking out such areas for exclusion but an effort should be made. No object is gained by completing the works for the entire area so far in advance of their actual use.

Completion Programme

72. As explained before, the Chief Engineer estimates that it would be possible to complete the Barrage and the bulk of the canal works so as to make water available for irrigation from the commencement of the kharif season of 1932. It is important that this programme should be rigidly adhered to, for any delay would mean increased charges under establishment and debt, and postponement of returns. We noticed that the Engineer officers in most Divisions felt confident in their ability to complete the works assigned to them by the dates fixed by the Chief Engineer. If the estimate is not to be exceeded the amount to be expended during the next three years, omitting such works as drainage cuts, etc., which will necessarily have to be taken up after commencement of operation, will be about Rs. 750 lakhs. This will mean a yearly outlay of Rs. 250 lakhs. The expenditure in the current year is expected to be Rs. 280 lakhs. The heaviest sections of the canals, it should be remembered, have been completed already.

Chief Engineer's latest Forecast—Two Stages of Development

73. The latest forecast of revenue and expenditure prepared by the Chief Engineer shows that at the end of 10 years from commencement of operations (1932), the area brought under irrigation would be 3·7 million acres (including the area of 2 million acres under the older canals), the gross revenue Rs. 199 lakhs and working expense Rs. 46 lakhs, leaving a net revenue of Rs. 153 lakhs. Deducting the assumed present net revenue from the 2 million acres of old irrigation estimated at Rs. 36 lakhs, the net increase of revenue will be Rs. 117 lakhs. On a capital outlay of Rs. 20·04 crores, this increase of revenue represents a return of 5·8 per cent. This may be considered the First Stage of irrigation development.

At the end of 30 years from the date of commencement of operation, it is expected that the irrigation will grow up to 5·4 million acres and the gross revenue to Rs. 299·50 lakhs. After deducting working expenses estimated at Rs. 67·78 lakhs, the net revenue expected is Rs. 231·72 lakhs. After deducting from this the present net revenue of Rs. 36 lakhs as before, the net increase of revenue will be Rs. 195·96 lakhs or 9·78 per cent. on the capital outlay. This may be called the Ultimate Stage of development.

The Chief Engineer's Estimate of Revenue Results

74. The Chief Engineer's estimate of returns as furnished to us closely follows what the Government of India prepared at the time of transmitting the project for the sanction of the Secretary of State. According to the definition in the Public Works Code, an irrigation project is regarded as a productive work if at the end of 10 years from the

date it comes into operation, it is able to give a return equivalent to the interest charges on the sum-at-charge. If we assume that all accumulations of interest in excess of the estimate of Rs. 20·04 crores will be met from the proceeds of land sales, the net return derived at the end of 10 years, taking interest at 5½ per cent., should be not less than Rs. 110 lakhs.

Government Forecast of Expenditure (White Paper)

75. We have already drawn attention to an important Memorandum recently issued by the Bombay Government in the shape of a White Paper entitled "Sind and the Lloyd Barrage" which deals with the various questions awaiting settlement.

The White Paper gives only forecasts of expenditure but not of income or revenue. It is stated that Government are having a fresh examination made of figures under the latter head and that a separate report will follow. We presume that is because the policies to be adopted are still under their consideration, Government have desired us not to go into the financial aspects of the scheme as a whole. We have therefore not attempted to prepare a financial forecast of our own but, since the question is under the consideration of Government, we trust it may not be out of place to offer a suggestion or two in this connection based on our scrutiny of the circumstances of this project.

(1) Appendix A to the White Paper puts the capital cost of the scheme including interest at Rs. 25·25 crores up to end of year 1934-35. According to Appendix B the yearly instalments from 1935-36 for repayment of capital and interest charges in this connection will be Rs. 145 lakhs per annum.

We have assumed that it will be possible, and that every effort will be made, to meet all the charges for interest and sinking fund in excess of the original estimate of Rs. 20·04 crores, from the proceeds of land sales. For reasons which will be fully explained in Chapter XI, we consider there is a strong case why the responsibility of financing this project should be taken over by the Government of India together with a reasonable share of the prospective revenues from the scheme.

(2) Appendix B to the White Paper gives a forecast of expenditure under 7 heads which include new measures and developments, other than engineering, for promoting irrigation under the Barrage Scheme.

Some small additions to this expenditure seem necessary as in our opinion they will prove highly beneficial. Since the development of agriculture is part of the work of preparation for the future the recurring expenditure under it should, we think, be Rs. 1 lakh in 1930-31 rising to Rs. 3 lakhs in 1935-36.

Similarly provision should be made not only for primary education but also for higher education in agriculture, engineering and commerce, to make available a fair supply of technically trained men for future needs and developments. A sum of Rs. 1 lakh may be advantageously expended under this head in 1930-31 and Rs. 2 lakhs from 1931-32. The

amount may be further increased from 1932-33 when the new Barrage irrigation will begin to earn revenue.

76. Under *Roads* it is suggested that no time should be lost in making a beginning, and a recurring expenditure of Rs. 5 lakhs per annum may be incurred from 1930-31. Expenditure under this head will be a very remunerative outlay. The roads help to open up the country and by their doing so, land sales will fetch better prices and marketing conditions will be greatly facilitated. The cultivators will be enabled to earn more and pay increased water rates to Government. Only those roads and cart tracks should be taken up at first which will help the future irrigation.

The increased expenditure under these three heads will on an average amount to Rs. 6 lakhs per annum for the three years 1930-31 to 1932-33. After the latter year, the net revenue from irrigation will be large enough to justify a more liberal outlay on all such improvements.

We agree with the Chief Engineer that it should be possible to obtain a return of not less than 5½ per cent. on capital outlay at the end of 10 years to bring the work under the definition of a productive undertaking. But there is a large amount of work to be put in, much of it outside the sphere of engineering, in order to achieve this result; and we would urge that no time be lost in formulating definite policies and creating agencies to give effect to the proposals contemplated in the White Paper and the recommendations made in Chapters VII and VIII of this report, for securing progressive development of irrigation and revenue.

It should be remembered in this connection that if the work by any chance fails to earn enough within 10 years from commencement of operation to bring it under the definition of a productive work, the loan to the Government of India will become repayable in 30 years instead of 50 and there will be a corresponding increase in the burdens on the local Government.

CHAPTER X

CRITICISMS AND OBJECTIONS EXAMINED

Need of a policy and programme to allay apprehensions

77. A considerable amount of criticism has centered round this project from the time its principal features came to be known. Almost every phase of it has been attacked at one time or another. As stated in Chapter I, there have been criticisms in Parliament, in the Bombay Legislative Council, by representative Zamindars and cultivators and by writers in the public Press. Several retired Engineers have taken part and objected to some feature or other of the project. The Members of the Bombay Legislative Council, particularly those coming from outside Sind, have concerned themselves chiefly with the financial aspects of the scheme in which their constituencies are specially interested. Their fear is that the estimates may be exceeded, as estimates have a tendency to do through delays in execution or other causes, that interest charges on the debt may go on accumulating, and that the scheme may prove unremunerative in the long run and throw a heavy burden on the Bombay tax-payer. These apprehensions will continue to grow until a

workable programme of development and finance satisfactory to all interests, and understood by all the parties concerned, is devised and consistently given effect to.

ENGINEERING CRITICISMS

Danger of Shoaling and Avulsion

78. Objection has been taken to the site chosen for the Barrage. It is urged that obstruction to the flow is liable to disturb the regimen of the river bed and that any considerable depth of ponding is likely to cause the Indus to desert its present course above the gorge, leaving a costly barrage high and dry.

While there is no likelihood of the river short-circuiting near the site, its course above the gorge cannot be said to be free from the risk of avulsion, whether a barrier is erected or not. A barrier will no doubt enhance the risk, but the proposed Barrage is not a solid weir, its floor is placed at a sufficiently low level and there is left a wide enough waterway through it to ensure that existing conditions are as little interfered with as possible. The difference of water level between the gorge and the barrage site in the inundation season when the river will be carrying most silt determines the limitations of afflux at the latter site, and it is possible with due attention to these limitations to maintain the river course stable.

Silting at Canal Head

79. There will certainly be silt trouble at the heads of some of the canals as designed; the Nara Regulator is a veritable silt trap if worked with a sill at R. L. 181.64 and we have therefore suggested the raising of the sills to R. L. 184.00 wherever they are below that level.

Value of "N" in Kutter's Formula

It is stated that in calculating canal discharges too low a value is assumed for "N" in Kutter's formula. The opinion expressed at the Simla Irrigation Conference of 1904 was that a value of .02 for "N" in Kutter's formula was suitable for large canals and of .0225 for small canals and branches, and this view is supported by numerous observations since made. The canals in Sind will be smoother the soil being finer than in the Punjab, and they will carry a good deal of silt to lute up the wetted area. The value of "N" assumed for this project may be accepted as quite reasonable. Several years must elapse before the cultivation under the canals can reach its full development. During the earlier years the value of "N" is immaterial, but as years go on and cultivation extends, it is not unreasonable to hope that the canal efficiency will improve and the value of "N" will be .02 or even less.

Duties objected to as too high and unrealisable

80. There is anxiety on the part of some Zamindars that the duties have been placed too high. They are now getting at times a larger discharge than is proposed to be given under the new scheme.

Through the courtesy of the Chief Engineer in Sind we are enabled to furnish the following comparison between the figures giving the average

withdrawals of water for the canals in the Barrage zone during the years 1924 to 1928, and those allowed in the Project.

Month	Draw off of canals in Barrage area					Discharges allowed in the Project
	1924	1925	1926	1927	1928	
April	..	..	..	..	..	30,871
May	.. 641	..	.. 2,487	..	.. 4,134	40,041
June	.. 12,025	.. 14,574	.. 11,036	.. 5,357	.. 29,780	46,457
July	.. 43,224	.. 38,839	.. 25,751	.. 27,861	.. 37,082	46,457
August	.. 54,266	.. 53,026	.. 48,483	.. 51,126	.. 36,633	46,457
September	.. 29,642	.. 9,309	.. 39,270	.. 20,631	.. 26,854	46,457
October	.. 3,944	.. 1,053	.. 2,476	.. 1,897	.. 2,915	27,121

The draw off by the present canals in the month of August was certainly greater in four years out of five, but it is obvious that the total quantity of water supplied during the kharif season was very much less than what is proposed to be given in future. The supply in the month of May was negligible, that in June was much below requirements, while in the month of September the crops must have suffered badly owing to shortage of water in at least one year (1925).

The duties proposed as average distributary head duties are, in our opinion, reasonable, and the comparison we have made should clear up any anxiety on this score. We realise that the kharif area in the project is larger than what is now cultivated and also that better outturns from crops are expected. But it is desirable on sanitary and other grounds that no more water should be applied to land than is necessary. This may demand more labour from the cultivator but it should be forthcoming.

As to the carrying capacities proposed for the canals, we have said that they are rather on the low side. The quantity of irrigation water required for a crop varies greatly at different times and the actual rate of supply needed during a period of pressure has to be provided for. With a view to economise in channel section the heavy waterings are given by rotation for a period extending to two or even two and a half months. The project proposals, however, contemplate running the canals at full supply for four months, which is carrying this desire for economy too far. It practically amounts to making the maximum capacity duty coincide with the average duty for the crop period.

Intensity of Cultivation too high

81. The basis of the sanctioned project was that 87 per cent. of the commanded area was available as culturable and that 81 per cent. of this latter area could be brought under irrigation. Objection has been taken to both these ratios and the intensity of irrigation is considered too high.

In the latest revised proposals the percentage of available culturable area to gross area has risen to 90.1 and that of irrigated to culturable

area to 82. This means that the intensity on the gross area, will be 74 per cent. as against 71 per cent. in the sanctioned proposals. There can be no objection to these high intensities on the Central Rice Canal, but on perennial canals they seem objectionable, for reasons explained in Chapter III. We do not think it safe to raise the intensity above 60 per cent. on gross area; we should even prefer a lower figure. In their order No. W. I. 8601, dated the 30th August 1918, the Bombay Government referring to the forecast of rabi area remarked that "it was not expected that this area would be reached at a near date but provision was to be made for it. In the financial estimates only 27 per cent. of culturable would probably be estimated as the rabi area". This would bring the intensity on gross area under 50 per cent.

OBJECTIONS FROM ZAMINDARS AND CULTIVATORS

82. The people under the Rohri and the North Western Canals are in favour of the Barrage scheme and the Zamindars of the Central Rice Canal are opposed to it. At present these latter can take as much water as they choose so long as it is available, and the farm labourers can water their crops at their leisure. When water is doled out by measurement in future, the labourers have to be in constant attendance and the cost of cultivation will grow. The Zamindars will also be put to some expense in remodelling their water courses (karias). These minor inconveniences should be put up with in view of the greater good the scheme will do by providing a steady, in place of the present precarious, supply.

The chief objection to the Barrage scheme comes from the cultivators under the Fuleli Canal near Hyderabad, the supply to which is expected to be curtailed. We consider that an effort should be made to extend the benefits of the Barrage scheme to areas under the Fuleli Canal and also to areas lower down the river on the left bank by increasing the discharge in the Nara River and we have made a definite suggestion to this end. We have not had time to work out detailed proposals but we trust that the necessary investigations will be carried out.

It has been brought to our notice that this extension might be objected to by the Government of India on the ground that it would entail the withdrawal of larger quantities of water from the river than is provided for in the project. The Government of India embargo can only apply to withdrawals in the rabi season, and this is not what we are contemplating. In the kharif season no doubt a larger draw off will be necessary under our proposal but the excess quantity drawn off will be only a part of what is running to waste in the river at present. Lower Sind cannot be deprived of the supplies it was getting hitherto, and our suggestion merely amounts to saying that a part of these supplies should be delivered at a higher level.

We understand that the cultivators along the Karachi Canals are not likely to be affected to the same extent as those under the Fuleli Canal.

CRITICISMS RELATING TO CONSTRUCTION

Extent of Lift Irrigation

83. It is alleged that canal beds have been lowered and that it would lead to increase in lift irrigation to the detriment of canal revenue. There will be some lift irrigation, but we understand that it will not be appreciable and not likely to exceed 5 per cent. of the total area except in the Nara tract where old conditions will more or less continue.

Expenditure on Staff, Buildings, Quality of Work, etc.

84. Objection has been taken to the scale of expenditure on staff and buildings and it is also alleged that the quality of the masonry at the Barrage is inferior. We have specifically dealt with these matters in paragraphs 31, 42 and 43 to which we would invite attention.

Expenditure on Tools and Plant and Steel and Iron Work

85. The extensive use of mechanical excavators is objected to on the ground that it deprives employment to Indian labour to that extent. The investment in tools and plant and steel and iron work is also considered excessive. We do not share the view taken with regard to the excavators, but we consider that for a work of this nature which involved an expenditure of no less than Rs. 3½ crores on special tools machinery, plant and other steel and iron work, more thorough preliminary enquiries should have been made. An Officer—preferably the one selected for the future control of the work—should have been placed on special duty to visit works in progress and examine machines and plant used under similar circumstances in Europe and in America. Further more, the selection of machinery should not have been left to the discretion of any single Engineer. One or more Mechanical Engineers of experience or a Committee of such Engineers should have been associated with him in ordering out the machinery. Had those precautions been taken it would have resulted in economies besides hastening progress on construction. Mere visits to Manufacturers' works or consultations with the Director General of Stores or the Consulting Naval Architect could not serve the purpose.

FINANCIAL OBJECTIONS

86. Lastly we come to the apprehensions felt regarding the financial prospects of the scheme. A great many objections proceed from this cause.

It is said that to credit the enhanced revenue from rice cultivation to the Barrage project is unfair. The Barrage scheme will confer a great benefit by giving steadier supplies over the full period of the rice season instead of the unsatisfactory supplies obtained at present and it is therefore fairly entitled to the enhanced revenue.

Objection is taken to the provision in the estimate to debit to the Barrage project the cost of the Khirtar Branch of the North Western Canal in Baluchistan Territory. The anxiety of the Sind people in this respect is probably due to the preferential treatment accorded on the Desert Canal, owing to which it is alleged that the Bombay Government

has suffered an aggregate loss of Rs. 31·74 lakhs, the net loss during the year 1923-24 alone being estimated at Rs. 1·15 lakhs. We understand that the Government of Bombay have already addressed the Government of India in this matter and it is likely that the latter Government will pay for the Baluchistan share of the work and take over the net revenue from irrigation in that quarter.

Doubts are entertained that the provision made for working expenses in the forecast of irrigation and revenue will not be sufficient. The rate adopted, inclusive of charges on account of maintenance of the head works is Rs. 1·26 per acre of cultivation, and it is based on the assumption that the high intensity of irrigation expected will automatically reduce the acreage rate. We have misgivings whether the high intensity of irrigation assumed will be attained. But whether it is ultimately realised or not, a higher allowance for working expenses will have to be made for the early stages during the time the cultivation will be developing. It is not possible to forecast conditions 30 or 35 years hence, but the working expenses 10 years after completion of the project will certainly be more than Rs. 1·26 per acre. The Jamrao Canal may have had that rate 25 years ago, but for the quinquennium 1922-27 the actual rate was as high as Rs. 2·72 per acre. With greater intensity of irrigation this figure will no doubt be reduced, but it cannot be expected to go down so low as Rs. 1·26. The cost of labour has risen and the revenue and irrigation establishments needed for the efficient working of canals on modern lines will necessarily be expensive.

It is said that the work may take more time than was estimated and in the meantime there will be no returns while interest charges will go on accumulating. The original programme of construction has not been adhered to in some respects; the progress on the Barrage for instance is 18 months behind the original forecast. Some allowance should be made in the case of the Barrage because, on account of the difficult nature of the work, the time required for construction could not be accurately estimated. However, as a set off to this delay, there has been a speeding up of construction under canals, nearly all of which are expected to commence working by April or May 1932. A great effort is being made to realise this expectation.

Doubts are also entertained whether the land sales will bring in sufficient money to make an appreciable contribution to the capital required or to reduce the borrowings or meet the interest charges thereon. This must for the present remain an uncertain factor but the chances of realising appreciable sums from this source will depend on the rapidity with which preparations indicated in Chapters VII and VIII are made including the opening up of the country by roads and village tracks.

It is stated that the estimated cost of the project is liable to be further exceeded. This is a very real fear. In the case of the Lloyd Barrage Scheme there is already an excess of Rs. 169 lakhs. It is reported that in the case of the Sutlej Valley Project, an estimate of Rs. 1,460 lakhs sanctioned in 1920 has been exceeded by 916 lakhs. Our enquiries however go to show that very great care is being taken by the Chief

Engineer to control excesses and if the same higher engineering staff remains in control of the works, it should be quite possible to complete the project within the revised figure of Rs. 20·04 crores.

We have dealt, we believe, with all the principal points which have been the subject of comment or animadversion in this connection. The project is the biggest irrigation scheme of its kind undertaken in any part of the world and it was not to be expected that it would escape searching scrutiny from various interests and points of view. The work is a *fait accompli* and no useful purpose will be served by prolonging controversies. It is now the duty of every official and of every patriotic citizen not to dwell on old objections but to accept conditions as they are and offer constructive suggestions and otherwise help forward the interests of the scheme.

CHAPTER XI

ACTION FOR THE FUTURE

The Scheme an All-India Responsibility

87. According to the White Paper issued by Government the capital expenditure on the scheme including interest charges is expected to amount to Rs. 25·25 crores by the end of 1934-35. The actual capital outlay excluding interest charges is expected to be Rs. 20·04 crores. An idea may be formed of the magnitude of this outlay when it is stated that the total cost of *productive irrigation works* so far constructed in the whole of British India is roughly Rs. 75 crores. The expenditure on the Lloyd Barrage project will amount to nearly 27 per cent. of that amount. The project if developed on sound lines will revolutionise economic conditions in Sind and there can be no doubt also that it was a desirable work to undertake in the interests of India as a whole.

But Sind is a sub-Province with a population of only 3·28 million souls or 16·9 per cent. of the total population of the Bombay Presidency and 1·03 per cent. of the whole of India. The sub-Province is not contiguous to the boundaries of the rest of the Presidency. Next to those of Sind, the people who would take advantage of the Barrage Scheme will be not the inhabitants of the rest of the Bombay Presidency, but the people of the Punjab, Marwar, Cutch, Makrana and other Provinces and States which surround Sind. Much of the benefits of the scheme outside Sind will go not to the Bombay Presidency but to the people of these other parts of India. As much as 83 per cent. of the population of this Presidency has no interest in the project except to the extent of being responsible for the debt involved, till the work is able to pay for itself.

Before the Government of India Act of 1919 came into force, productive irrigation works in whatever province situated were being financed by the Central Government who also received the net revenues from them. They had, under their control, a large number of productive works all over India. Some of them were highly remunerative, some gave moderate dividends and there were others under construction which did not give any returns at all. Any losses due to interest charges on the latter

two classes of works were made good by the large number of completed works of the first class. So, when formerly an irrigation work of this description was under construction or was being developed, it formed one of many, and the entire body of productive works gave a handsome return of 7 to 10 per cent. In the case of the Lloyd Barrage and Canals Scheme, not only has the capital cost to be met by the Bombay Government but also the interest charges during construction because there are no large productive works under that Government to bear or share such charges.

In the United States of America the Central Government provide the capital and construct large irrigation works (locally termed Reclamation Works) and on completion hand them over to the local State authorities for operation, the responsibility of the State being limited to the repayment of the capital in easy instalments but without any charges for interest. The Central Government's liberality in this respect is dictated by the consideration that such works increase the prosperity of the country as a whole, and that every new work is a prospective source of direct and indirect revenue to the Central Government.

It will be seen too that the cost of the project compared to the yearly revenues of the Bombay Government is abnormally high and the finances of this Government have been none too prosperous since the close of the War. This work is without question an all-India responsibility and its burden should be borne by the broader shoulders of the Central Government. To construct one of the world's greatest schemes in a detached sub-Province containing a population of a little more than 1 per cent. and to make a Presidency with 6 per cent. of that total population, the bulk of which does not share in its benefits, responsible for the whole cost seems hard on the latter. The Government of India recommended the scheme at a time of transition when the hardships it would entail were not fully realised and it is but fair that they should now come to the rescue.

Principal Points for Attention

88. We have said enough to show that although the construction part of the scheme is being pushed through rapidly, preparations for irrigation and other associated developments have lagged behind. We will now state categorically the principal points which require attention and the manner in which in our opinion that attention may be bestowed.

(i) Every precaution should be taken that there will be no excess over the revised estimate of Rs. 20·04 crores. This should be secured, if possible, by calling for a special review or report on the progress of capital expenditure at the beginning of every half year.

(ii) All necessary steps should be taken to ensure that irrigation is speedily developed so that the scheme may retain the character of a productive undertaking by earning a sufficient return on the sum-at-charge within 10 years from the commencement of operation.

If this result is secured, the scheme will at once become popular and the public will not grudge the further outlay needed to carry it through to the ultimate stage contemplated.

(iii) The ultimate stage of the scheme aims at a high intensity of cultivation and high returns on the project, namely, 9 to 10 per cent. It would not be safe to assume that these results will be achieved without adopting special methods or making efforts out of the ordinary. The intensity of cultivation assumed may not be fully realised. In that case the extent of area under Barrage irrigation should be increased and preparations made to grow high-rated crops by adopting scientific methods of cultivation. This result will not follow as a matter of course with ordinary routine methods ; a higher form of organization and administration will be needed to stimulate effort on the part of every one concerned.

The measures and developments necessary for (ii) and (iii) are described in Chapters VII and VIII. They are required on a moderate scale for the *first stage*, and in an intenser form to achieve the results aimed at for the *ultimate stage*.

(iv) From the extraordinary occurrences in Sind due to heavy rain and floods reported within the past few weeks, the impression is strengthened that what the province most wants is protection from floods and relief by means of drainage works.

This is its primary need. Unless safety of life and property is first secured, the chances of building up a profitable agriculture and prosperous peasantry in Sind are not very reassuring.

Action for the Future

89. The White Paper issued by Government deals in detail with most of the subjects requiring action for the future. The first of these is funds. Money is required for construction and to meet interest charges on the capital borrowed. And funds are also required for carrying out measures needed to extend irrigation rapidly and the several associated developments enumerated above.

There is no difficulty about money required for the construction of the project. The Government of India are lending the sums needed although they are only acting as bankers. The responsibility for financing the scheme at present rests entirely with the Bombay Government. We have stated that it would be in the fitness of things to appeal to the Government of India to take over, as a special case, the responsibility or a share of the responsibility for the capital outlay including interest charges, and also a reasonable share of the profits from the scheme.

As regards funds required for building roads, strengthening the agricultural staff, etc., it is believed that all the demands can be met from the sum of Rs. 10 lakhs provided from the Famine Fund supplemented by a grant of Rs. 6 lakhs from the general revenues up to the end of the year 1934-35. Thereafter all such charges might be met from the revenues of the project.

Rapid decisions should be taken on all pending questions. We believe the decisions have been delayed on account of, next to lack of funds, the difficulty of obtaining the consent of the Legislative Council. We will only repeat that the success of the scheme from every point of view will

depend upon the thoroughness and speed with which decisions are taken on all problems awaiting settlement and upon the capacity of the agency employed to give effect to them.

We have stated before that Government have appointed a Standing Committee and are contemplating the appointment of an Advisory Committee. It would be well to make the best use of these bodies but in order that they may function effectively it will be necessary to have two Executive Officers or Secretaries who, besides working with the two bodies, will be also directly responsible to Government. One officer will be required to deal with matters pertaining to irrigation and another for all work connected with land, civil administration and other associated educational and economic developments. It is unnecessary for us to go into further details.

A large modern irrigation scheme like this will not yield its best results to routine methods and to the primitive business organization which is at present seen in the rural areas. The new developments should be on scientific and up to date business lines. If the necessary measures are adopted on the scale they are needed, there is every prospect of the scheme fulfilling the expectations formed of it in the ultimate stage.

CHAPTER XII

GENERAL SUMMARY—PRINCIPAL RECOMMENDATIONS

View of Scheme as a whole

90. The Lloyd Barrage and Canals Project was developed into its present shape at a time when optimistic views prevailed in the country regarding production and trade, and high expectations were entertained of an economic upheaval. When the Government of India sent up the project to the Secretary of State in December 1920 the public had no definite conception of what the normal condition of things would be after the War. Although much labour and care had been bestowed on the preparation of the project, the final estimates seem to have been put together in a hurry at the time of their submission to the Government of India. In the belief that the provision made in the estimates was insufficient, the Government of India added to them a sum of Rs. 255 lakhs before transmitting the project, with their approval, for the sanction of the Secretary of State.

The scheme is one of unusual magnitude and responsibility. This single scheme when completed is expected to add about $3\frac{1}{2}$ million acres, or over 15 per cent., to the existing irrigation in British India under all Government irrigation works for which capital accounts are kept. Sind is an undeveloped tract with an unfavourable climate and a working population the majority of which is illiterate and ease-loving. In no other part of the world is to be found a work constructed under conditions closely resembling this to serve as a guide. The river constantly shifts its course, its behaviour is uncertain and treacherous and its hydrography is not correctly known. Critics have foreshadowed danger from avulsion, shoaling, silting of canals, water-logging and the like. Last year there

was a sudden unusual rise in the river level which caused interruption to progress of works in the river bed. In the current year we have witnessed abnormal rainfall in parts of Sind which flooded low areas, this was followed by a panic on the bursting of the Shyok dam and, within the past few days, heavy rain in the Punjab has led to a disastrous inundation in many parts of Sind, the full effects of which are not yet correctly known. With such experiences before us, who can say that there are no elements of risk in the Barrage Scheme ?

But Sind needed an irrigation project which could give an assured supply for its cultivation, and the new project is expected to increase the irrigated area to twice its present size. The production will be probably quadrupled. It is not to be expected that a great complicated scheme of this magnitude will be perfect in all its details. Natural conditions will not lend themselves favourably in every direction and no big undertaking of this size can be carried out without risks and without interfering with some local interest or other. Should unforeseen risks or difficulties arise in future the resources of engineering should be able to cope with them. We have dwelt on some of the defects at length but taking the scheme as a whole we can think of no better or clearer alternative. The scheme is expected to make an appreciable addition to the production and food supply in this part of India and it will bring prosperity to Sind.

The chief characteristic of the undertaking is its boldness of conception and unusual size. The Government of India as well as the Secretary of State have complimented the Bombay Government on the perseverance and breadth of vision displayed by them in putting it forward. It also reflects great credit on the individual Engineers and Administrators who were associated with its preparation, or advanced it to the stage of sanction. The works are being executed under the supervision of Engineers, of whom the controlling staff belong to the permanent service of the Bombay Public Works Department which is a guarantee that the execution of the works is proceeding on a high plane of integrity and efficiency. We have nothing but praise for the services these officers are rendering and the whole of this large scheme is controlled and administered with admirable devotion and energy by the present Chief Engineer Mr. C. S. C. Harrison, C.I.E.

CONCLUSIONS SUMMARISED

91. We have, particularly in the last two Chapters, recorded our views on the more important features and needs of the project, including most points which have been the subject of controversy. We have given prominence to certain fundamental questions that await early settlement. Our main conclusions may be summarised as follows :—

(i) The site selected for the Barrage is a favourable one and the engineering designs of the scheme, save those to which we have taken exception, are suitable and satisfactory.

(ii) Difficulties may arise from shoaling in the river bed, silting of canals or water-logging over large tracts of country but such difficulties should be kept under scientific observation and timely remedies applied.

(iii) Judging from the difficult work already completed in the river bed, the successful construction of the Barrage seems assured. The construction of the other parts of the scheme is also proceeding satisfactorily.

(iv) The details of the scheme were not as fully worked out or checked as they might have been before construction was actually commenced. Better preliminary preparation might have reduced the costs and proved an advantage in other ways.

(v) Machinery and plant might have cost less had details been gone into more fully with the assistance of a firm of Consulting Engineers or a Committee of Mechanical Engineers accustomed to handle large workshops or factories.

(vi) Having regard to the flatness of the country and the insufficiency of free outlets for water poured on to it, the intensity of irrigation assumed seems too high. The acreage rate of working expenses assumed will be found to be too low, at least in the initial stages of operation.

(vii) The capacity of the canals might have been slightly larger to provide for sudden abnormal demands that arise in the kharif season.

(viii) The Scheme was needed to enable Sind to obtain its legitimate share of the Indus waters along with the Punjab, and for the more economical use and distribution of the available supply between the two Provinces.

(ix) The value of agricultural production in the ultimate stage of the scheme may amount to Rs. 30 or 35 crores annually as against about Rs. 8 crores obtained at present from irrigation works of all classes in Sind.

(x) The Scheme is a potential source of great prosperity for Sind and the people of the Province as a whole welcome it.

PRINCIPAL RECOMMENDATIONS

92. The following is a summary of our suggestions for ensuring the future uninterrupted progress of the scheme and its success as a productive undertaking :—

(i) The Chief Engineer has a programme according to which the Barrage and the main canals will be completed and the greater part of the project brought into operation by 1932. He may be requested to furnish half-yearly reports to show how the expenditure is shaping as compared with the estimates, to make sure that the financial programme is rigidly adhered to.

Unless special circumstances intervene, there should be as few changes as possible till 1932 in the personnel of the Engineering staff of the higher grades responsible for the programme.

(ii) The work should be completed within the revised estimate of Rs. 20·04 crores or including interest charges Rs. 25·25 crores by 1934-35. A special effort should be made to complete all working estimates and obtain or record sanction to them by 31st March 1930.

(iii) Excesses over estimates, if any, should be met by effecting corresponding savings, by the omission or postponement of some of the non-essential works required for the ultimate stage.

(iv) As the scheme is not expected to earn enough to pay the full interest charges on borrowed capital for 10 years after completion, or for nearly 20 years from commencement of construction, the Government of India should be approached to take over the whole or a substantial share of the debt and with it also a reasonable share of the future revenues from the scheme, the principal reason being that the scheme is too big a financial proposition for the Presidency to handle with its slender resources, till the work begins to pay.

If this is not done and if the land sales fail to bring in substantial proceeds, the charges on the revenues of the Bombay Presidency may prove a heavy burden and a source of continued embarrassment to the Bombay Government, for a long term of years.

(v) The first consideration of the Irrigation Department should be to make the work productive within 10 years from date of opening so as to give early relief or assurance to the tax-payer. This is a practical step of the highest importance to give confidence to the public.

(vi) It should be possible soon to reduce the establishment and overhead charges and effect economies by combining the Sukkur Barrage Construction Divisions and the Regular Maintenance Divisions of the Public Works Department in Sind.

(vii) Several questions connected with the preparations for the future are pending settlement, and rapid decisions seem necessary. The delay if prolonged will adversely affect the progress and eventually the financial prospects of the scheme.

(viii) River discharge observations should be taken and surveys made to watch the bed levels and changes in the river course, according to the latest needs of the Barrage project.

(ix) The effect of the Barrage scheme on the gauges at Sukkur and Kotri and on the full supply levels of the Fuleli and Karachi Canals should be observed regularly for at least 5 years after the scheme comes into operation in order to ascertain the extent to which their supplies will be permanently affected and to provide the remedies they call for.

(x) Estimates may be prepared after survey for the proposal to feed the Fuleli Canal and if possible also other lower left bank canals through the Nara River.

(xi) The effect of Barrage irrigation on the sub-soil water levels of the irrigated tracts and the tendency to water-logging should be closely watched. Detailed projects for the necessary drainage cuts and channels should be kept ready so as to be able to put the necessary works in hand the moment circumstances necessitate their execution.

(xii) A Bureau of Research should be established and scientific investigation and research in irrigation and agriculture (described in

Chapters VIII and IX) should be commenced and vigorously pursued. This work will be found to be invaluable for the financial success of the scheme.

(xiii) The Bombay Irrigation Act and the Rules framed under it require modification to suit the future needs of the Barrage Scheme. The necessary amendments may be carried out by legislation as early as possible.

(xiv) A concise account of the scheme should be prepared giving a summary and a complete description of the works and estimates as being carried out. A list should be appended to it of the principal publications and reports issued by Government. Such a publication is badly needed by the Engineers themselves and their staff. It will be greatly appreciated by the members of the Legislative Council and the general public. We ourselves felt the need of one.

(xv) The Executive Engineers and lower officers should have opportunities of discussing and becoming acquainted with the entire scheme. More frequent meetings and consultations among the Engineers of all grades will be helpful in spreading a knowledge of the scope and objects of the scheme among them so as to ensure their putting forth initiative and giving closer co-operation in future.

(xvi) The policies followed by Government in the solution of the questions pending settlement should be widely made known so that the cultivators, particularly the poorer classes among them, may have all the facilities needed to secure plots of land for themselves, to improve them and practise irrigation in a profitable manner. Suitable propaganda to make its policies, objects and future prospects widely known will smoothen the path of the Scheme.

(xvii) As this is a quasi-commercial undertaking the issue of a Barrage Bulletin once a month similar to those published by Hydro-Electric and other productive schemes in other parts of the world is also recommended. The undertaking is unique and sufficiently big and important to justify the issue of such a publication.

M. VISVESVARAYA,
ALI NAWAZ JUNG.

Bombay, 18th September 1929.

LLOYD BARRAGE AND CANALS PROJECT,

APPENDIX I.

Area, Population, Cultivation, etc., in Sind.

1	Total area of Sind (excluding Khairpur State).	41,795 square miles or 26.75 million acres.
2	Total culturable area	13.77 million acres (excluding 0.28 million acres in Kalat Territory).
3	Area under cultivation (average of 5 years ending 1926-27).	3.52 million acres (including 88,496 acres irrigated in Kalat Territory under the Sind P. W. D.).
4	Area at present irrigated in Barrage zone.	2,035,636 acres as per 1919-20 Barrage project.
5	Anticipated ultimate area of irrigation in the Barrage zone.	5.38 million acres (exclusive of the area to be irrigated in the Khairpur State but inclusive of irrigation in the Nasirabad Tahasil of Kalat Territory).
6	Population of Sind	32,79,377 (of which 5,46,579 is urban).
7	Population in Barrage zone ..	About 2,000,000.
8	Present Revenue from irrigation in Sind (average of 5 years ending 1926-27).	Rs. 90,38,000 Gross (excluding Rs. 2,33,000 for sale of occupancy rights). Rs. 42,83,000 Net.
9	Net Revenue assumed for purposes of financial forecast in the 1919-20 Barrage project.	Rs. 35,76,127 (for area included in Barrage zone).
10	Total mileage of roads in Sind ..	11,426 miles.
11	Mileage of metalled roads ..	98 miles.
12	Total length of existing Railways in Sind.	1,103 miles.
13	Total length of existing Railways in Barrage zone.	628 miles.
14	Average annual rainfall in Sind ..	5.88" (average of 10 years ending 1926-27).
15	Average annual rainfall in Barrage zone.	5.54" Do.

LLOYD BARRAGE AND CANALS PROJECT.

APPENDIX II.

Statement showing month by month minimum supply in the River Indus at the Barrage Head Works at Sukkur.

Month	1917	1918	1919	1920	1921	1922	1923
1	2	3	4	5	6	7	8
January	24,153	38,523	21,784	31,526	31,030	37,955	32,449
February	23,304	29,500	25,727	33,392	30,188	35,804	40,234
March	17,722	28,083	27,117	35,980	22,532	38,140	60,743
April	17,568	83,611	59,180	48,134	36,234	44,066	58,188
May	27,000	124,635	81,320	64,054	60,915	80,550	110,548
June	122,000	300,702	135,136	105,077	90,860	171,409	162,413
July	260,438	208,025	327,930	296,350	187,884	306,211	250,575
August	358,714	264,103	406,175	216,545	333,818	347,410	333,393
September	178,511	92,901	147,893	102,600	141,315	215,027	114,528
October	68,297	41,851	52,445	44,296	65,886	53,572	54,142
November	46,695	31,230	31,848	34,305	39,783	39,783	39,195
December	35,587	24,648	31,017	29,472	36,073	33,361	36,554

Month	1924	1925	1926	1927	1928	Discharge required according to latest revision of project.	Discharge provided in the 1919-20 project.
1	9	10	11	12	13	14	15
January	30,076	40,657	31,702	31,982	29,013	23,802	22,756
February	29,356	35,595	28,859	27,900	27,859	23,802	22,756
March	34,299	31,559	24,785	25,534	41,264	25,339	23,454
April	55,312	30,330	36,406	30,590	45,614	30,871	29,029
May	88,474	48,887	61,126	47,876	110,962	40,041	39,541
June	106,425	106,653	122,193	106,335	242,463	46,457	45,926
July	290,882	348,896	182,425	142,301	334,055	46,457	45,926
August	413,295	232,838	345,664	322,131	276,920	46,457	45,926
September	150,832	108,451	167,609	95,285	108,457	46,457	45,926
October	70,757	44,019	66,730	46,784	49,104	27,121	25,897
November	48,060	45,536	41,833	35,748	40,739	24,604	23,540
December	39,187	36,258	37,256	30,124	40,125	26,714	25,756

Note 1.—The figures in Column 14 represent the proposed total withdrawals from the River Indus at the Barrage Head Works from month to month. They include losses in transit at the rate of 8 cusecs per million sq. ft. of watted perimeter. The transit losses in the Eastern Nara are however expected to be lower than those assumed by about 500 cusecs.

Note 2.—It will be noticed that the discharges available in the river in some months of the year will occasionally fall short of the supply required.

LLOYD BARRAGE AND CANALS PROJECT

APPENDIX III

Maximum and minimum river discharges, extent of irrigation, etc.

1	Maximum discharge of the Indus recorded at Sukkur.	949,000 cusecs (on 1st August 1914).
2	Maximum discharge for which the Barrage has been designed.	1,500,000 cusecs.
3	Minimum discharge recorded at Sukkur.	17,568 cusecs (on 4th April 1917).
4	Full supply discharge of the Barrage Canals at their Head Regulators in kharif season.	46,457 cusecs.
5	Minimum discharge required in rabi season.	23,802 cusecs.
6	Gross area commanded ..	7,275,813 acres (excluding Khairpur State area).
7	Culturable area commanded ..	6,558,863 acres (excluding Khairpur State area).
8	Percentage of culturable to gross area	90.1.
9	Anticipated ultimate annual cultivation.	5.38 million acres (excluding Khairpur State area).
10	Percentage of cultivation to culturable area.	82.0
11	Percentage of cultivation to gross area	73.9
12	Area at present irrigated in the Barrage zone.	2,035,636 (according to 1919-20 project).
13	Area expected to be brought under irrigation 10 years after completion of Barrage.	3,669,625 acres.
14	Area expected to be brought under irrigation 30 years after completion of Barrage.	5.38 million acres. (Same as item 9.)
15	Total length of main canals ..	679 Canal miles* (excluding Khairpur Feeders).
16	Total length of Branches ..	1,042 Canal miles (excluding Khairpur Feeders).
17	Total length of Distributaries and Minors.	4,499 Canal miles (excluding Khairpur Feeders).

* A canal mile is taken as 5,000 feet.

LLOYD BARRAGE AND CANALS CONSTRUCTION

APPENDIX IV

Statement showing existing and proposed irrigation and cost of irrigational facilities

No.	Name of Canal	Cost of Canal system with share of Barrage and Regulators	Discharge at head of Canal		Existing irrigation 1919-20 project		Total
			Kharif Cusecs	Rabi Cusecs	Kharif	Rabi	
1	2	3	4	5	6	7	8
	<i>Left Bank</i>	Rs. Lakhs	Maximum	Minimum	Acres	Acres	Acres
1	Rohri Canal ..	787.29	10,897	10,090	537,300	120,000	657,300
2	Eastern Nara ..	447.74	13,389	8,184	356,618	128,061	484,679
	<i>Right Bank</i>						
1	N. W. P. Canal ..	302.14	5,099	3,211	221,642	104,860	326,502
2	Central Rice ..	257.53	10,215	..	269,476	46,974	316,450
3	Dadu Canal ..	238.82	2,837	2,337	125,296	125,409	250,705
	Total ..	2,003.52	42,427	23,802	1,510,332	525,304	2,035,636
	Share of Khairpur State (a).	25.63	4,030				
	Grand Total ..	2,029.15	46,457				

No.	Name of Canal	Irrigation 10 years after completion of Barrage	Anticipated irrigation 30 years after completion of the Barrage			Cost per cusec of canal capacity in column 4	Average cost per acre brought under irrigation in the whole tract including existing irrigation
			Kharif	Rabi	Total		
1	2	9	10	11	12	13	14
	<i>Left Bank</i>	Acres	Acres	Acres	Acres	Rs.	Rs.
1	Rohri Canal ..	1,255,000	685,165	1,376,778	2,061,943	7,529	37
2	Eastern Nara ..	1,052,350	700,400	944,700	1,645,100	3,344	27
	<i>Right Bank</i>						
1	N. W. P. Canal ..	618,758	261,626	516,609	778,235	5,925	39
2	Central Rice ..	407,470	407,470	..	407,470	2,521	63
3	Dadu Canal ..	336,047	141,143	345,574	486,717	8,085	47
	Total ..	3,669,625	2,195,804	3,183,661	5,379,465	4,801	37
	Share of Khairpur State (a).		298,000	..	298,000		
	Grand Total ..				5,677,465		

(a) Share of Barrage only. The cost of the Khairpur feeders and their head regulators is included in the Rohri Canal.

LLOYD BARRAGE AND CANALS PROJECT.

APPENDIX V

Anticipated Financial Results of the Project.

No.	Name of Canal	Estimated cost including cost of Head Regulators and Share of Barrage	Anticipated ultimate cultivation (30 years after completion of Project)	Present net Revenue as per 1919-20 Project from Irrigation in the Barrage zone
		Rs. Lakhs.	Acres	Rs. Lakhs.
1	Rohri Canal	767.29	2,061,043	10.75
2	Eastern Nara	447.74	1,645,100	8.88
3	N. W. P. Canal	302.14	778,235	4.61
4	Central Rice Canal	257.53	407,470	7.88
5	Dadu Canal	228.82	486,717	3.63
	Total ..	2,003.52	5,379,465	35.76
6	Share of Barrage recoverable from Khairpur State	25.63		
		2,029.15		

No.	Name of Canal.	Net Revenue 10 years after completion of the Project		Net Revenue 30 years after completion of Project		
		Amount	Percentage return on Capital (a)	Amount	Percentage return on Capital (a)	Net revenue per acre of cultivation
1	Rohri Canal	34.5	4.50	65.3	8.51	3.17
2	Eastern Nara	35.2	7.99	66.1	14.76	4.02
3	N. W. P. Canal	17.8	5.90	25.9	8.53	3.32
4	Central Rice Canal	17.7	6.88	21.7	8.40	5.31
5	Dadu Canal	9.7	4.25	17.0	7.42	3.49
	Total ..	114.9	5.83	195.96	9.78	3.64
6	Share of Barrage recoverable from Khairpur State.					

Note.—(a) The percentage returns on capital are calculated without taking into consideration the accumulated interest charges.

LLOYD BARRAGE AND CANALS PROJECT.

APPENDIX VI.

Present estimated cost and value of work executed.

Item No.	Name of Canal	Provision in the 2nd Revised Recapitulation	Value of work executed up to 31st May 1929	Remarks
1	2	3	4	5
		Rs. Lakhs	Rs. Lakhs	
1	Barrage and Head Regulators ..	593	320	The latest forecast shows that there will be a saving of Rs. 23 lakhs in the provision under the 2nd Revised Recapitulation.
2	Rohri Canal	476	174	
3	Eastern Nara	217	86	
4	N. W. P. Canal	181	81	
5	Central Rice Canal	148	65	
6	Dadu Canal	120	44	
7	Manchar Drainage	26	4	
	Gross Total works ..	1,761	774	
	Less salvage value ..	-105	..	
	Total works ..	1,656	774	
	Establishment	288	153	
	Tools and Plant	32	19	
	Suspense .. ..	....	30	
	Total, Direct charges ..	1,976	976	
	Indirect charges	54		
	Grand Total	2,030		
	Share of Barrage recoverable from Khairpur State ..	-26		
	Net Total	2,004		

Cost of project as sanctioned by the Secretary of State in 1923. Rs. 18.35 crores.

Cost of Project according to the 2nd Revised Recapitulation submitted to Government by the C. E., L. B. & C. C. on 3rd February 1928. Rs. 20.04 crores.

Expenditure incurred up to 31st May 1929 .. Rs. 9.76 crores.

Date of commencement of works .. July 1923.

Date by which works are expected to be ready for opening. March 1932.

Total length of canals of all sizes to be excavated .. 6,220 canal miles.

Total quantity of earthwork to be excavated in the whole length. 5,550 million cubic feet.

Total quantity of earthwork completed up to 31st March 1929. 2,466 million cubic feet.

Average quantity of earthwork done per month by machines and by hand labour. 50 and 30 million cubic feet respectively.

Maximum quantity of earthwork executed in any one month by machines and hand labour. 156 million cubic feet.

Total length of canals excavated up to 31st March 1929 comprising chiefly the largest sections. 1,100 miles.

Cost of Dragline Machines employed in excavation work. Rs. 1.06 crores.

Cost of machinery and plant including steel gates at the Barrage. Rs. 2.50 crores.