THE
Future of Sind.

SUKKUR BARRAGE SCHEME.

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A LIFE AND DEATH ISSUE.

I.

Before we can explain the objects and scope of the Sukkur Barrage Project, we must understand something of the country and the people to be affected, and the defects of the system of irrigation which has served the country for the past centuries.

The Province of Sind is bounded on the west and north by great ranges of mountains—The Khirtar Range which stretches for hundreds of miles in seried ridges into Baluchistan. On the south it is bounded by the Arabian Sea from Karachi to the Ran of Cutch, about half of the sea coast being pierced by the numerous active or dead months of the estuary of the River Indus. On the east it is bounded by, and includes, part of the great Indian Desert, a vast stretch of barren country covered at intervals with ridge after ridge of windblown sand hills.

The tract of country with these inhospitable neighbours has, however, one great friend and saviour—the River Indus—which traverses the whole Province from north to south.

Indeed, the province owes its actual existence, in its present form, to this great river, and to its subsidiary overflow channels, of which the principal are the Nara River, and the Pinyari, Fuleli, and Baghar Dhands, all of which have now been canalized. By overflowing its banks for centuries, and spreading its eternal burden of silt over the surrounding country, the river has formed the wonderfully fertile alluvial lands which comprise the useful portion of the Province, and the whole of the culturable area.

The Province is about 350 miles long, from north to south, and varies in width from 250 to about 120 miles. Its total area is about 30,000,000 acres of 47,000 square miles ; or slightly less than the area of England. Out of this area about half, or 23,500 square miles, is occupied by mountains, hills, and broken rocky country, or by sandy desert ; leaving 23,500 square miles, or say 15,000,000 acres, of culturable soil.

The territory of His Highness the Mir of Khairpur, which penetrates the Sind boundaries on the east, has an area of about 6,000 square miles

and a population of about 200,000. Only about 1,250 square miles, or 800,000 acres, of the State are culturable, the remaining area consisting of ranges of limestone hills, or desert and sand hills.

LIVING ON THE SOIL.

The population of Sind in 1921 was 3,279,377 of whom roughly three-quarters were Mahommedans and one-quarter Hindus. Of this population about 40 per cent. live by direct labour on the land, about 10 per cent. by revenue from land, a large number on the care of cattle, sheep and camels, and the great bulk of the remainder in trading in the necessities of life, and in domestic service. Only about 2 per cent. of the population live by the arts and industries, and about 4 per cent. live by mendicancy.

Thus it will be seen that Sind is almost solely dependent on agriculture for its existence.

We now have to see how this agriculture is carried on. It is perhaps a platitude to state that agriculture demands three essentials,—soil, water, and labour ; but in the East generally, and in Sind in particular, the coincidence of the three factors is often difficult to secure. Water is usually the greatest difficulty, and this is particularly so in Sind. The average rainfall in Sind is only about 5½ inches per annum, and is at best very precarious. Most of it falls in July and August, and usually in a few heavy showers. Hence it is practically impossible to do any cultivation on rainfall, though this will provide valuable grass for grazing cattle, etc. Thus in the year 1917-18, when rainfall was very copious, 73 per cent. of the crops were raised on irrigation; and in the year 1915-16, when rainfall was low, 99 per cent. of the crops were irrigated. The importance of irrigation in Sind cannot therefore be over-estimated.

These facts may appear dry-as-dust, but, as the Sindhi knows to his cost, there is a worse thing than dry-as-dust facts, and that is dry-as-dust land when he is depending on it for his existence.

It is necessary to understand these facts before one can appreciate the position of the cultivator, and the value of an assured canal water supply to him.

RIVER OF LIFE.

Since, then, the Sindhi cultivator had plenty of good land available, and sufficient labour, but nature failed to provide him with a rainfall on which he could raise a crop, he was left to look for some other means of obtaining the necessary water. He naturally turned to the inexhaustible supply of water flowing past his lands in the channel of the River Indus. Now the Indus has a regular seasonal fluctuation in its surface level, and in the quantity of water it passes.

This fluctuation of level has a maximum of about 20 feet rise, in flood season over the lowest water in the cold weather, at Sukkur, 400 miles from the sea ; at Kotri, 120 miles from the sea, the maximum

fluctuation is about 17 feet. The Indus has a special peculiarity, which it shares with the Mississippi and few other rivers, namely, that throughout its course in Sind (which is really the delta of the river), it runs along the *top of a ridge* and not in the bottom of a valley. The land on either side of the river banks slopes away from the river to lower levels than the banks themselves. The river has formed, and is still forming, this ridge for itself. In the flood season, June to September, the waters of the river are very heavily charged with silt, brought down from the mountains in which it rises. In a year of moderately high river, the water is confined with the banks, *i.e.*, within the river channel (varying in width from ½ to 5 miles) cut in the top of the ridge. In a year of high floods, the water overflows these banks, and flows down the slope on either side right across the country—sometimes for 50 or 60 miles, unless stopped by artificial banks built along the river margin. This country, on either side, is covered with vegetation, either naturally sown grass and jungle, or crops on cultivated land. This vegetation checks the flow of the water and causes it to deposit its silt. Most silt will be deposited at the beginning of the checking action, *i.e.*, near the banks of the river, and thus, these banks are raised higher and higher with each succeeding flood, and the slope of the country, away from the river banks, is gradually made steeper. The slope however is very flat, and often not visible to the eye, but is readily detected with the surveyors' level, and is sufficient to assist in the distribution and flow of canal water on the land, as will be described later.

Further, the surface of the river water is not itself level, but has a slope, in the direction of flow, varying from 1 foot per mile in the Punjab, to as little as 1 foot in 4 miles near the sea. This slope is necessary to cause the water to flow towards the sea. In the irrigated portions of Sind the average slope of the river is about 1 foot in 2 miles. The slope of the land, in a direction parallel with the river is about the same as that of the river surface; but the land also has a slope *away* from the river as already explained. If therefore a canal is cut diagonally away from the river bank, and the water surface of the canal has the *same* slope as the river, the surface of the water in the canal will gradually become at a higher level than the land, at some distance from the head of the canal. Hence river water which, at the river bank, is not high enough to flow on the land, will be sufficiently high to do so over other lower lands further inland, if carried to them in a canal. Moreover in a large canal the surface slope of the water may be made flatter than that in the river, and hence a further gain in level, compared to that of the land, can be gained for every mile the canal is carried. For centuries, the Sindhi has partly realized this, and has excavated canals from the river, which would convey water to his lands, and flow thereon, when the river is at a high level. If the water in the canal was at too low a level to flow over his lands, he erected Persian water-wheels on the canal side, and lifted the water, into the small channels of his fields, sufficiently high to flow over the ground. This operation is, of course, slow and expensive, requiring many bullocks to work the wheels. This is known as "Lift" irrigation.

When the water flows, by gravity, direct from the canal on to the fields, these are said to have "Flow" irrigation.

THE PRESENT CANAL SYSTEM.

It is evident that the water level in such canals must depend upon and vary with, the water level in the river at their heads, and from what has been explained of the lie of the land and river, it is obvious that only at moderately high levels of the river will the canal water flow on the lands watered by these canals.

Between Sukkur and Sehwan on the Right Bank of the river, the country falls more steeply away from the river than in other parts of Sind, and in this area, the oldest indigenous canals were able to give flow cultivation to large tracts of land, when there was a moderate level in the river. In other parts of Sind the older canals made by the Mirs of Sind, before the British conquest, gave mostly lift-irrigation, except to small low areas, and perhaps during the height of the river flood. The highest levels of the river seldom last for more than a few days in any one year, and cannot be depended on for the raising of crops. But a moderately high river, sufficient to give flow irrigation to some lands, and lift irrigation to a much larger area, can be expected in most years, to last for about 3 to 4 months, June to September,—a sufficient period to grow the hot-weather crops of Sind. All canals designed to work under these conditions, *i.e.*, with their supplies depending on the natural flood level in the river, are known as Inundation Canals. Since the British came to Sind, they have improved, or remodelled, most of the old indigenous canals, and have made many new inundation canals. Most of these canals are designed to get their full discharge, and full level, when the river gauge at Sukkur reads 12 feet, (it varies from a maximum of plus 17·9 to a minimum of minus 2·4 feet), a level which, in a good year, can be expected from about the 15th June to the 15th September.

Most canals are completely closed for silt clearance during the cold weather, and are reopened between the 15th May and 1st June. If the river is favourable a fair supply then enters the canals.

In Sind, all the canals except four, *viz.*, the Jamrao, Mithrao, Fuleli and Sukkur Canals, are purely inundation canals, *i.e.*, they flow only during such periods as the river is high, and for the remainder of the year are dry and useless. On an average, the period of flow may be taken as from the 1st June to 30th September, *i.e.*, a four months' working season. For the rest of the year no cultivation is possible on the areas served by these canals, except by means of wells, or crops grown without watering, and dependent on the land having been flooded deeply before cultivation. Such crops are comparatively small in area.

ITS DEFECTS.

Hence the cultivator depends, almost exclusively, on getting his crops watered during a four months' season. The result is that a great

deal of labour, (both manual and cattle labour), has to be concentrated in this short season, and for the rest of the year is comparatively idle. This is one of the primary difficulties in maintaining a large area of cultivation. Incidentally, there is involved, in many districts, a serious famine of even drinking water during the dry season, which increases the difficulty of retaining labour on the land. But even during the four months of flow the cultivator may meet with serious difficulties.

Most inundation canals in Sind are now provided with head regulators, and are designed more or less to give the discharge required for their commanded areas, when the river is at a moderate level, such as may be expected in a normal year for the greater part of the four months. But in almost every year there are periods, of longer or shorter duration, during which this moderate level is not attained. At such periods, not only is the supply deficient in quantity, but it will probably be at too low a level to flow on to lands which normally receive flow water. The inevitable result is that zamindars take all the water they can get, whenever it is available, and in this way have acquired extravagant habits in the use of water. On the other hand when the river rises above the moderate level necessary for full supply, if the canal is not provided with a head regulator, an excessive supply passes down the canal, and either breaches the banks, and causes flooding in numerous places, or flows to the low lying portions of the area, generally at the tail, and floods those.

This again tends to extravagance in the use of water, when it is high enough to be available, as well as to flooding of low lands ; and increases the tendency to grow in low lands, crops such as rice, which do not suffer by very excessive watering. Thus it is seen that inundation canals lead to extravagant watering, whether the river level is below, or above, the normal required level.

AGRICULTURE A GAMBLE.

As regards the effect on the character of the people, and on their methods of cultivation, here again they are most deleterious. The river frequently rises to a good level early in the season, and then sometimes falls and remains low for a long period ; or it may fluctuate several times ; or it may remain at a fair level and then rise steadily, giving what is classed as a good inundation. The exceptional zemindar is industrious and enterprising, and he will prepare his land and sow his crop at the first moment sufficient water is available in the canal. The supply remains good for a fortnight or three weeks, the seed germinates, and the crop appears flourishing. Suddenly the canal drops and supply ceases, while the young crop slowly withers and dies. The zemindar ploughs it out, and again sows on the next rise, with a similar result. Again he sows, and perhaps this time the river keeps steady, and he is able to bring his crop to maturity, but we have seen cases of 3 separate sowings of cotton, all withered in this way, and finally a poor crop of jowar or bajri only obtained.

Thus cultivation becomes a pure gamble against the river, and only the strongest in moral and financial assets can maintain a steady interest in

their land, and even these may be totally unable to prevent disastrous failures in their crops. On the other hand the careless and negligent zemindars, in a good year, will reap almost as good a harvest, from a late sown, carelessly tended crop, as their most industrious neighbours. The soil is rich, the climate very regular and suited to the crops, and, given the necessary supply of water, which is almost entirely dependent on chance, a good crop will be realized, whereas no amount of care and expense in cultivation, will save the crop, if the river is unfavourable. The inevitable tendency is for the zemindar to become careless and lazy, to adopt a fatalistic attitude, and leave results in the lap of the gods; taking all they send him with both hands, and submitting with resignation or indifference when the fates are unpropitious. The result is the typical Sindhi zemindar, and the average cultivation, we see everywhere in Sind.

But there are still many keen zemindars who, with a fortunate season, will produce as fine cultivation and crops as any in the world.

THE HARVEST.

The principal crops grown in the hot season are rice, jowari and bajri, (both millets), and cotton. There are a certain number of wells in Sind from which irrigation is performed, but generally, the soil and water level is such that wells are difficult to construct and give a very small supply. Where they exist, crops are always grown in the cold weather, and will be usually wheat. In addition to this, a large area is cultivated annually on what is known as "bosi" cultivation. For this, the land is flooded from canals, near the end of the inundation season, to a depth of about 1 foot, all over the land, which is enclosed with earthen banks to contain the water. This water is allowed to soak into the land, and, as soon as possible, the area is ploughed, and sown with wheat, which will then grow during the cold weather, without further watering; or it may be assisted by one or two waterings from wells.

Oil seeds are also grown in this way, or more usually, on rice lands after the rice crop is cut. For Sindhi cotton crops, the cultivator takes water as early as he can get it, *i.e.*, in May or June; and if a water supply were available in March and April, the much more valuable American and Egyptian cottons could be grown. Cotton also requires water late in the year, and can with advantage be watered upto the end of October. This is seldom, if ever, possible at present.

The crops grown in the flood season are known as Kharif crops, and those grown in the cold season as Rabi crops. The Rabi crops require far less water, and less labour, than the Kharif, and if water were available they should therefore be much greater in area than the Kharif crop.

Actually in the whole of Sind the average Kharif cultivation is 72 per cent. of the total cultivation, and the Rabi only 28 per cent.

On the Punjab Perennial Canals, the average Kharif cultivation is 43 per cent. of the total, and the Rabi 57 per cent. of the total; while on the Lower Chenab, and Lower Jhelum Canals, the Kharif is 35 per cent., and the Rabi 65 per cent., of the total cultivation on those canals.

This difference, in the relation between areas of Rabi and Kharif crops in the Punjab and Sind, is not due to any decrease in the proportion of total culturable area, sown with kharif, in the Punjab. On the contrary, as the following figures show : For whereas in Sind, the Kharif cultivation is only 22 per cent. of the total culturable area commanded by the canals, on the Punjab Perennial Canals, the Kharif crops are 28 per cent. of the culturable commanded area. While in Sind the Rabi crops are only 9 per cent., and in Punjab Rabi is 37 per cent., of the culturable area commanded. Thus it will be seen that, on similar culturable areas, the Punjabi grows nearly 30 per cent. more kharif crops, and over 300 per cent. more rabi crops, than the Sindhi. The total cultivation in Sind is only 31 per cent. of the culturable commanded area, while on the Punjab Perennial Canals it is 65 per cent., and is steadily increasing as the new canals develop their commands.

In our next article we shall explain why the present system of inundation canals cannot be improved, and why new canals cannot be designed to give reliable supplies, in both the hot and cold seasons, unless assisted by a Barrage or weir.

AN IMPERATIVE NECESSITY.

II.

In our first article we explained the present system of irrigation in Sind, by means of inundation canals, and showed their limitations and unreliability, and the unfortunate effect they have on the character of the Sindhi and his crops.

We showed that with a fall of the level of the Indus, below the level for which the canals are designed, the supply in the canals becomes too small to supply the crops already sown. We also showed that moderately low-level water in the river can be made to flow on to lands some distance away from the river. It may therefore be asked, why cannot the canals be designed to give their full supplies with lower levels of the river,—levels which can be depended on for a sufficiently long season to ensure the growth of the summer crops, or even for the whole year? We will first see why the existing canals cannot be remodelled to meet such conditions.

Now summer crops require water for about 4 months,—say, June to September inclusive. If a zamindar's lands are at such a level that, with the full supply level in the canal, he can get water to flow on to his lands, he can utilize all his cattle and men for ploughing, sowing, and cultivating his land, and he will keep only sufficient cattle and labour for these purposes. If the canal falls below the full level, and his land is at the canal banks, he could, at great expense and trouble, erect a water-wheel on the canal side, and lift water to irrigate his crop; but this is very seldom done, and the crop is left to die. Usually his land will be fed by a watercourse from the canal, the watercourse taking only the top 3 or 4 feet of water in the canal, so that with a drop in canal level, his watercourse may altogether cease to flow, and he is helpless, and his crops must die. These conditions apply to the great majority of "flow" lands in Sind.

Thus the *level* of the water in the canal is of primary importance to the man with *flow* lands. In the case of *lift* lands, the zamindar always has his water-wheels in position, and cattle and men available for working them, in addition to the cattle and men required for cultivation.

A rise or fall in the level of the canal, therefore, make slittle difference to him (except to decrease or increase the work of lifting the water) so long as the *quantity* of water in the canal is sufficient for his needs. But obviously, lift irrigation must be far more expensive than flow irrigation, and the latter is therefore always desired, and must be provided wherever

possible ; and hence the water in the canal should be maintained at full level throughout the season.

INUNDATION CANALS.

Now it would be possible to make inundation canals, to obtain full supply level for a four months' season, provided that level was sufficiently low to be sure of the river level not going below it during this season. The river level frequently falls, in June and September, as low as 6 feet at Bukkur ; but this level may be safely assumed as always obtainable, in any year, from June to September, and canals could be designed always to have full supply at such a level of the river. But only very small areas of Sind could be irrigated, by flow, with such a level, from existing canals, however remodelled, or from any new canals, unless of great length ; and the greater part of the area of the province would get only lift cultivation. As lift irrigation is so much more expensive, and requires so many more cattle and men, than flow irrigation, a compromise is effected, and canals are designed to get their full supplies only when the river is considerably higher—about 12 feet on Bukkur. This level may be expected in *a very good year*, to last from June to September, but in years of average, poor, or bad inundations, it frequently falls below, sometimes for weeks at a time, and by as much as 4 to 7 feet ; and the canals then suffer, both in the quantity and level of their supplies. At such times of deficiency in a canal, only one thing can be done to assist matters. By making regulators, at intervals, across the canals, and closing one of these regulators entirely, or partially, for a few days, the water level in the canal, immediately above the regulator, can be raised, and the channels leading off the canal, near the regulator, can thus be given their full, or nearly full, level, as long as the regulator is closed. Having done this at one regulator for a few days, that regulator is fully opened, and another regulator closed. Thus, successive lengths of the canal are given improved supply, for a few days each, in turn. This is what is known as rotational working of the canal. Such rotations cannot increase the *quantity* of water entering the canal, but merely raise its level by steps ; hence all crops, by turn, will get a reduced supply, in proportion to the total supply entering the canal. But these rotations have one serious disadvantage to the canals. They reduce the velocity of the water flowing in them, and thereby cause silt to be deposited in the bed of the canal. This may not be serious in the lower reaches of a canal, as the silt can usually be scoured away when the regulators are opened; but at the head of the canal, when the first section is rotated, it is liable to cause silt bars in the head of the canal, and in the river itself in front of the canal. There is no means of removing these bars in the river, and they will reduce the quantity of water entering the canal; and in some cases eventually stop the flow into the canal altogether, as they may rise to the surface of the river water, and completely block the canal entrance. The lower a canal bed is excavated, relative to the surface of the river water, the more rapidly will the canal become choked, because it draws off the lower, more silt-laden, water of the river.

DIFFICULT TO DESIGN.

Thus it is seen that even for the summer crops only, it is difficult to design an inundation canal to give a satisfactory supply, *at the constant level required*, to flow on to the land.

Still more difficult would it be, in fact, almost impossible, to design a canal to give a supply *all the year round*; for the water level in the river falls to zero, on the gauge at Bukkur, almost every year, for some weeks, and often to 1 or 2 feet below zero, *i.e.*, from 13 to 15 feet below the level for which present canals are designed to have their full level and supply. Actually, at present, there are only two canals in Sind—the Eastern Nara, and the Fuleli Canals—which can take any water at these low levels. Both are natural river channels which have been canalized and have outlets to the sea. Their cold weather supply is a very small proportion of their full discharge, but is useful as far as it goes. The Eastern Nara gives frequent, and increasing, trouble during the season, owing to silting in its head, and in the river at its mouth. Yet this canal system has the very great advantage of a large escape into the sea, so that large quantities of silt can be scoured out of the canal channel into the sea. The Fuleli has a similar advantage, and has given very little trouble from silting in consequence, but the rabi discharge is very small, and the rabi cultivation, which is entirely "lift," is only 14 per cent. of the total cultivation on the system. Both these systems have their canal beds at a very low level, to enable them to take lowest river water, and both can get their full supply level with a very moderate river, and cannot be further improved.

ANOTHER GREAT DIFFICULTY.

Another great difficulty—in fact the greatest difficulty—with these inundation canals, is that their heads must be made at, or near, the natural bank of the river. But except at three points in the whole of Sind, where rock occurs, the river banks are not fixed points. The river is continually eroding its bank on one side, or the other, and silting up the opposite bank lower down; the alteration of the bank sometimes being as much as half a mile in a single season. Besides this, the river very often cuts across the narrow neck of land enclosed in a sharp bend, leaving the latter high and dry, perhaps miles away from the river. Hence a canal head (and its regulator) may be entirely eroded away, in one or two seasons; or it may be left high and dry, completely cut off from the river. In the former case, the canal may be choked with eroded silt, in a few days or weeks, or left at the mercy of the highest floods, owing to the demolition of its head regulator. In the latter case the supply is partially, or entirely, cut off, and will necessitate the making of a new head channel for the next season, which will be equally liable to disaster.

The foregoing explains, roughly, the position as regards the possibility of remodelling, or improving, the existing canals. The whole case contains many other complications and difficulties, of too technical a nature to describe in a popular article for the layman; but sufficient has been said to show the hopelessness of the present system, for any intensive development of the country.

We now come to the possibility of making new systems of canals, depending on the natural river level, but to flow all the year round ; that is to say, their heads must be capable of taking their cold weather supply from the river at its lowest levels.

The first essential of such a canal is, that its head shall be located at a point where the river bank is permanent, and not liable to heavy silting or erosion. There are only three places in Sind where these conditions can be even approximately assured. One is at the Sukkur-Rohri gorge, where the banks are of rocks on both sides ; one at Kotri, where the hills approach both sides closely, and the banks are of very hard clay ; and one at Jerruck, where rock again forms the banks.

SILTING OF RIVER BED.

None of these sites, however, is protected from silting of the river bed, whenever the full flood discharge is reduced. The most favourable site of all is that at the Sukkur-Rohri gorges. On both banks, lengthy canals could be made, which could supply flow water, with the aid of slight rotations, to the lands beyond about 50 miles from their heads, at a very moderate level of the river, say 5 or 6 feet on the Bukkur gauge. But this level is only available in the river under present conditions from June to September. In other months, a much reduced supply only, could be passed into the canals, and it would be necessary to resort to very extreme rotations, in order to give flow water to lands under these conditions : while the supply available would only be sufficient for an area of rabi crops, less than half the area of kharif ; whereas the country, and people, and cattle, are capable of growing twice as much rabi as kharif.

Moreover, these canals would be unable to give flow water to the lands, in about the first 50 miles from their heads, much of which has at present a flow supply. Such lands therefore would have to be left on their present sources of supply, (existing inundation canals), or else converted to lift irrigation, which is unthinkable. Assuming for the moment that these great canals were made, they would irrigate great tracts of country, at present irrigated by existing canals taking off the river further downstream, and also much additional land. Hence the present withdrawals, now taken off the river between Rohri and Hyderabad, on the left bank, and between Sukkur and Sehwan, on the right bank, together with the extra withdrawals required for the new lands, would all be concentrated at the heads of the new canals at Sukkur-Rohri. Hence any failure of these heads, due to silting in the river, against which there is no protection, would affect vast areas, now dependent on a large number of canals spread over a long stretch of river ; only a few of which canals fail, in any one year. Thus the risk to cultivation, from failure of the canal head, would be very greatly aggravated. But there is another vital effect of such new canals to be considered. It has been shown, that the existing canals, supplying the lands in the first fifty miles of the new canals, must remain as the source of supply for those lands. Now as soon as the great withdrawal of the new canals is concentrated at the Sukkur-Rohri gorges, it will appreciably lower the river level there, and the smaller the discharge in the Indus,

and the lower its level, the more serious will be the lowering effect of the concentrated withdrawals. Such times, of comparatively low river, occur in June and September, and in these months the new canals would probably lower the river level at Sukkur, and below, by about 1 to 2 feet. This lowering, of an already low river, would be fatal to the cultivation on the remaining existing canals. If a new canal were made, on one bank of the river only, such as the Rohri-Hyderabad Canal proposed by Dr. Summers, the effect of its withdrawals would be less than that shown above, (about half), but that effect would then affect all the existing canals on the right bank of the river, already needing an improved supply, as well as the remaining existing canals on the left bank, including the great Eastern Nara system. Such new canals can therefore only be made on the following conditions :—

CONDITIONS FOR NEW INUNDATION CANALS.

(*a*) Their heads cannot be protected from silting in the river in front of them.

(*b*) They would ruinously affect all remaining inundation canals in the most vital months.

(*c*) They would vastly increase the area, (dependent on them) to which the risk of failure of crops would be caused, by silting at the head of the canals.

These are risks which would give pause to any reflective Government, before launching on such a scheme, even if no alternative were possible ; and it is doubtful whether the possible advantages would counterbalance the *positive losses*, and the *possible risks*.

But when it is possible to avoid all these disadvantages and risks, and moreover, to give an infinitely superior water supply to all lands; and to reap a far greater profit to the country, no sane Government could consider the risky scheme. It will be shown that an alternative scheme is both feasible, and advantageous in every way, and this brings us to the scheme for the Sukkur Barrage and Perennial Canals Project, now being undertaken by the Government of Bombay.

THE OBJECT OF A WEIR.

We will now explain the object of a weir, or barrage, on a river, and its effect on the supply of canals, taking off the river above it.

Weirs may be of two distinct classes, or of combinations of those two classes.

First is the solid weir. This consists, usually, of a great wall of solid masonry, built right across the river. All water flowing past the weir must flow over the top of it, or over a lower portion known as a waste weir ; so that the water on the upstream side must always be at least level with the top of the masonry weir (or the waste weir). In times of flood, all water still has to pass over the top of the weir, so that the flood level is raised by the height of the weir. Such weirs are therefore generally used, where a raising of the flood level is unimportant, and will do no damage;

while, at other seasons, the water is kept, always, at least as high as the top of the weir.

The second class of weir is one which is designed to offer as little resistance as possible, to the passage of floods in the river, and therefore not to cause any considerable increase in the flood level, which might submerge lands above it, or in other ways cause dangerous conditions. At the same time, the weir must be capable of manipulation, so that, when the natural level of the river is lower than required, it can be raised to the desired level by means of the weir. This is usually effected by moveable gates, or sluices, of some kind, which can be opened, or closed, at will.

THE SUKKUR BARRAGE.

The Sukkur Barrage is a weir of this second class, and consists of a solid masonry floor, laid at the bed level of the river. On the floor, stand bridge piers, at long intervals, and in the piers are vertical grooves, in which the ends of great steel gates abut. These gates can be raised, by means of machinery fixed on a bridge above, so as to be at any desired level, and, in the flood season, they are lifted right clear of the river, which is then entirely unobstructed, except by the bridge piers. When the natural level of the river sinks, below that required for the canals, the gates are lowered into the water, sufficiently to offer such resistance to the flow of the river under them, that the surface of the river, upstream of the gates, rises to the required level. All surplus water in the river, not required for the canals, will always be passed *underneath* the gates, and whenever the natural river rises high enough for the canals, the Barrage gates are lifted right clear of the river.

Now it has been shown, that for the proper development of Sind, it is essential that the canals should be able to maintain a constant level, sufficient to give flow irrigation at all seasons, to the lands served by them, and that this can only be effected if the water level, at the head of the canal, is kept quite, or nearly, constant. It has also been shown that the only constant level which could be guaranteed, dependent on a *natural* river level at the heads of canals, would be at far too low a level, to be of any use to the great majority of the lands. But with the Sukkur Barrage Scheme, all canals will have their heads just above the Barrage, and here it will be possible, by manipulating the gates of the Barrage, to head up the surface of the river to the desired level, at any time in the year; so long as the total quantity of water, required for all canals, is flowing in the river. Thus the primary condition for the canals—a *constant level* at head, all through the year—is obtained.

EXCLUDING SILT FROM CANALS.

But the Barrage also gives a second very essential service to the canals, *viz.*, it keeps the river clear of silt, in front of the canal heads, and enables only upper water of the river, which contains only light silt, to be admitted into the canals.

It is hardly necessary to describe in detail how this is effected, but it is sufficient to state that the canal head regulators have permanent

masonry cills, from 6 to 9 feet higher than the floor of the Barrage, while, by manipulating the Barrage gates, the bed of the river in front of the canal heads, can be scoured free, whenever desired, of any silt deposited there. Thus, with canals fed from above the Barrage, we can absolutely guarantee, to all canals, the full level and discharge they require, all the year round. This supply being constant, it can be distributed with the greatest accuracy to all branches and distributaries, and from the latter, to the village water courses, and thence to the fields. Thus the cultivator will know, for a certainty, that he will get his water supply flowing on to his land, with perfect regularity, and in full quantity, on the days appointed, and necessary, for his crop. His labour and cattle can be allotted their regular tasks, and kept fully employed, all the year round, and he will know that, so far as water requirements are concerned, he can sow his crop when desired, and be certain of watering it until it is ready for reaping. Compare this with the present system of utter uncertainty, and the immeasurable advantage of the proposed system is self-evident.

Our next articles will give a brief description, and some leading particulars, of the Sukkur Barrage, and the great canals to be fed by it and the anticipated agricultural and financial effects of the scheme.

A HISTORY OF THE PROJECT.

III.

We explained in our two previous articles, the present condition of Sind cultivation and irrigation, and the possibilities for development. It was also shown how impossible it is to remodel the existing inundation canals, or to make new canals, dependent on the *natural* level of the Indus, to give an assured supply of irrigation, even in the summer season ; and much less for the whole year. We showed the necessity and advantages of having a weir, or barrage, to control the *level* of the Indus, at the heads of any new canals ; and how, by means of such a Barrage, we could *guarantee*, to all canals fed from it, an *assured supply* of water at *a constant level*, high enough to flow on to the fields, all the year round ; thus enabling cultivators to grow vast areas of crops in the cold weather, and to keep their labour and cattle fully employed all the year round, instead of for only four months as at present. We now come to the various proposals, which have been made, to improve the existing conditions ; and as the present Sukkur Barrage and Canals project is the outcome of all these proposals, it is necessary to give a brief resume, of the long history of the project, in order to understand the present scheme.

A LITTLE HISTORY.

After the conquest of Sind by the British in 1842, they formed a Canal and Forest Department in 1843. The first result of this department was a Report by its Superintendent, Lt.-Col. Walter Scott, in 1846-47 in which he described the survey operations carried out in Sind, the methods of maintaining irrigation in the existing canals, and a general description of the methods of cultivation and irrigation hitherto adopted. He then explained the works he considered necessary for the improvement of the system. He stated that most rivers, from which the supply of canals was drawn, were wholly, or partially, stopped by dams, to regulate the level of the river. He believed such dams could only be built on rocky beds, and the only rock site available in Sind was that above the Sukkur-Rohri gorges. He considered that a dam built at this site would be certain to cause a diversion of the river above the gorges ; and a solid weir, of the type he assumed, possibly would have done so. Hence he found it was necessary to consider improvements to the canals, without the assistance of a dam to regulate the river. His proposals were merely to do silt clearance in the best of the existing canals, and to close those which were redundant. Nothing was done, however, and the Department was abolished in 1849 ; but was reformed, two or three years later, under Lieut. (afterwards General) Fife, R. E.

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best populated, and most valuable land in Sind. This estimate was returned to Fife for making accurate surveys, and revising the project, and was re-submitted by him in 1859. The Bombay Government recommended it to the Home authorities, for commencement as soon as funds permitted. From 1859 to 1867, the matter remained in abeyance. In the latter year, a revised and larger scheme was submitted by Captain Le Mesurier. This was returned for further revision. In 1869 the Secretary of State drew attention to the need for improving the irrigation of Sind, and stated that the Rohri-Hyderabad Canal, then under investigation, would test the suitability of such canals, for the proposed complete new system of perennial canals for the whole of Sind. In August 1869 a revised project, for a still larger Rohri Canal, was prepared, but the Commissioner in Sind gave it very limited support, and expressed very mistaken views, on the superiority of lift over flow cultivation. In 1871, the Government of India asked the Bombay Government to prepare projects, for perennial canals for the whole of Sind ; each work to be designed as a link in the complete system.

In 1872, the Viceroy, (Lord Northbrook), visited Sind, and ordered the abandonment of the Rohri Canal Project, and the preparation of a project for the Jamrao Canal. In 1877 and 1880, the Secretary of State drew attention, very forcibly, to the need of improving the irrigation of Sind. In 1881 the Government of Bombay reported that, although feasible, they did not consider perennial canals, on either bank, were necessary. They recommended the construction of a small Rohri Canal, and of the Jamrao Canal taking off the Eastern Nara. In 1882, the Government of India endorsed these views, in submitting the scheme to the Secretary of State.

The matter was then dropped, until 1890, when Lord Reay, Governor of Bombay, wrote a note on the subject, and commended Fife's proposals for further enquiry. In 1892 a Committee was appointed under Sir Evan James, Commissioner in Sind, and they reported unanimously that the Rohri Canal was not needed, and was a financially unsound project. They recommended, instead, the improvement of existing canals and the early construction of the Jamrao Weir, and Jamrao Canal, ex-Eastern Nara, and the final abandonment of the scheme for perennial canals. They did not even consider the Right Bank of the river. The Government of Bombay accepted their recommendations, but were not prepared to abandon, entirely, the principle of high level perennial canals. As a result, large sums were expended on improving existing canals.

THE BARRAGE APPEARS.

In 1901-03 the Indian Irrigation Committee discussed the possibility of constructing a weir at Sukkur, with high-level perennial canals on both banks of the river, on the lines of Fife's proposals. The Committee considered this scheme was feasible, but not necessary. The site suggested to them, for the weir, was just above the Sukkur-Rohri gorges, but the Committee considered that more suitable alternative sites might

be found, and they recommended that the whole scheme should be investigated. In 1904 Dr. Summers, then Superintending Engineer, Indus Left Bank Division, toured all through the country, which would be served by the Rohri Canal, and was so convinced of its desirability, that he requested permission to make a survey, and prepare a project, for a feeder from Rohri to the Dad Canal. He pointed out that a weir at Sukkur, to supply new canal systems on both Right and Left Banks, would eventually be needed, but he thought his proposed feeder to the Dad would be sufficient for many years to come. Ten months later, he had modified this view, and asked permission to extend his project to Hyderabad, and beyond.

In March 1906, the Government of Bombay instructed him to report on the possibility of extending the proposed new canal, to the south of Hyderabad, and thus provide for all lands on the Left Bank.

THE SCHEME DEVELOPS.

In 1906, the Government of Bombay submitted to the Government of India, preliminary plans, and a rough estimate, for a canal from Rohri to Hyderabad, prepared by Dr. Summers.

In submitting this estimate, they asked for sanction to an estimate, for preparing detailed surveys, and accurate plans, for this canal, and also for a Barrage at Sukkur. They stated that these two works formed a part, only, of the complete scheme, which would include—

(a) A Barrage at Sukkur to supply :—
(b) The Eastern Nara System.
(c) The Rohri Hyderabad Canal.
(d) A Right Bank Canal starting at Sukkur.

And they promised to send the report on the Right Bank Canal, then under preparation, at a later date. Throughout their letter, and the accompanying notes by the Chief Engineer for Irrigation, they emphasized the necessity of the Barrage, for the benefit of both the Rohri Canal, and all the other canals of the scheme. The Chief Engineer showed that, the Rohri Canal could not be considered alone, but must be taken with the other canal systems, and with the Barrage.

In December 1906, the Government of India sanctioned the estimate for preparing the projects for the Rohri Canal, and the Barrage, and generally accepted the views of the Government of Bombay, as regards the rest of the scheme.

In January 1907 the Government of Bombay issued orders for the preparation of projects for the Sukkur Barrage, and for the Rohri Hyderabad Canal to be fed by the Barrage. In February 1907, they called for estimates for the Right Bank Canal from Sukkur, and for the development of the Eastern Nara Systems, in conjunction with the Barrage.

THE CONTROVERSY.

In March 1909, the Under-Secretary to Government, Public Works Department, addressed Dr. Summers, stating that it was understood that His Excellency the Governor, (Sir G. Clarke—afterwards Lord Sydenham), had been *prima facie*, impressed with a contention, said to have been put forward by Dr. Summers, that the Rohri Canal should be made before the Sukkur Barrage. The Under-Secretary pointed out that this was contrary to all opinions, and orders, hitherto issued.

In reply, Dr. Summers merely states that, in the 4 years since he recommended that schemes for Right and Left Bank Canals with a weir, should be investigated, he had held a very decided opinion that the Rohri-Hyderabad Canal should come first, and that the information he had collected in that 4 years, had strengthened this opinion.

This appears to have been the origin, or first public appearance, of the long-drawn controversy on this subject, which Dr. Summers is still carrying on.

In March and April 1909, Dr. Summers wrote to the Collectors, of districts affected by the Rohri Canal, asking them to give estimates of revenue from such a canal, worked as an inundation canal without a Barrage, on the assumption that such a canal would give an assured Rabi Supply.

In June 1909, Dr. Summers' attention was called, by the Government of Bombay, to the fact that the above letters, to the Collectors, were contrary to the orders of Government, which were, that the Canals should be made, in conjunction with a Barrage. Government stated that they considered it an erroneous assumption, that a canal without a Barrage could give a guaranteed Rabi supply, which was an essential condition for the success of the Canal.

In his reply, in October 1909, Dr. Summers explained that, as he saw the scheme for canals, with Barrage, at the assessments proposed, was not likely to be a productive work, he had called for the necessary information, to prepare a project for the Rohri Canal, without a Barrage.

In November 1909, Government confirmed their orders for the canals with Barrage, as a complete scheme, but permitted Dr. Summers to submit his alternative on condition the general project was not delayed.

A MAKESHIFT.

Thus it will be seen that Dr. Summers design for the Rohri Canal, without a Barrage, was not projected for sound irrigation reasons, but was merely a makeshift, intended to overcome the difficulty of presenting a profitable project. In his design, he was able to provide only a small rabi discharge, (less than half the kharif discharge), and at a level 5.3' below his designed full supply level, on which he depended for commanding the land by flow. Hence to obtain the necessary levels, he had to work by rotation, heading up 5', and running his canal at less than half the designed non-silting velocity, [illegible] was almost certain to occur.

In October 1909, a project for the Eastern Nara Improvements, prepared by Mr. Vachha, Executive Engineer, amounting to Rs. 161 lakhs, was submitted. In June 1910, Dr. Summers submitted alternative projects, (a), for the Rohri Canal, with the Barrage, amounting to Rs. 510 lakhs, and (b), without a barrage, 2 alternatives, amounting to Rs. 532 lakh, and Rs. 548 lakhs, respectively.

In June 1910, was also submitted a project for the Right Bank canal, prepared by Mr. Shrinivasarao, Executive Engineer, amounting to Rs. 530 lakhs.

In June 1910, a final revised project for the Sukkur Barrage, was submitted by Mr. Beale, amounting to Rs. 219 lakhs.

In May 1910, the Commissioner in Sind, (Mr. W. H. Lucas), submitted his report to Government on the combined scheme. He recommended that the Barrage and Rohri Canal be first constructed, the Eastern Nara Improvements when required, and that the Right Bank Canal, as designed, was unsuitable, and should be redesigned, for part only of the area.

In July 1910, the Chief Engineer for Irrigation submitted to the Bombay Government, the combined project, for the Barrage, and the three great canal system, *viz.*, the Rohri Canal, the Eastern Nara System and the Right Bank Canal System. He recommended for sanction only the estimates for,

The Barrage - - - - -	Rs.	2,19,34,767
Rohri Canal - - - - -	,,	4,49,75,788
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He stated that, the project prepared for the Right Bank Canal was not suitable, and he did not therefore recommend it, or submit it for sanction.

He suggested this project should be revised, and the works built later.

He emphasized the absolute necessity for giving an assured supply to all canals in the rabi season, and stated this could only be secured by means of the Barrage.

MORE ALTERNATIVES.

In September 1910, Dr. Summers submitted his alternative project for constructing the first two sections of the Rohri Canal before the Barrage. The Chief Engineer for Irrigation criticized this proposal very adversely, and showed that the rabi supply would fail in many years, even if the canal did not silt up, which he considered very probable.

In December 1910, the Government of Bombay submitted the combined projects to the Government of India, and recommended only the Barrage, and the Rohri Canal, projects. They proposed that the Right Bank, and the Eastern Nara Projects, should not be considered for the present. The projects recommended amounted to 871 lakhs of rupees and showed that, in the 12th year after completion, the next revenue

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would be nearly Rs. 34 lakhs per annum, which represented 4 per cent. interest on the capital cost. They also considered that a scheme should be devised, early, for the Right Bank Canals, as the existing canals on this bank would be adversely affected by the Barrage and Rohri Canal.

In October 1912, the Government of India submitted the whole scheme to the Secretary of State, who appointed a committee of engineers, in London, to report thereon.

The Committee consisted of Col. Sir J. Ottley, and Messrs. Lionel Jacob, W. L. Cameron and A. L. Webb.

Their report was issued in December 1913, and briefly their conclusions were:

(*a*) that the project was unnecessary as a protective work;

(*b*) that it was not productive, and was premature;

(*c*) that the proposal to make the Rohri Canal, without a Barrage, was attended by too grave risk of failure to warrant its execution, especially as it did not assure a Rabi supply;

(*d*) that an alternative site for the Barrage, to be founded on sand, should be investigated, at some point below the Sukkur gorge;

(*e*) that although the scheme was premature, and unproductive, they recommended that a complete scheme be prepared, and kept in readiness, in case the Punjab withdrawals adversely affected the supply to the existing Sind canals.

In view of this report, the Secretary of State declined to sanction the project, and drew attention to the views of the Committee, which he recommended for the consideration of the Government of Bombay.

BOMBAY INSISTENT.

The London Committee's report was received by the Government of Bombay in March 1914, and, in September 1915, the latter again addressed the Government of India on the subject. They requested permission to open a special project district, for the whole scheme.

They pointed out that, although the Punjab withdrawals could not be shown to have had any very definite effect on the river level, and discharge, at Sukkur, yet at periods of low river, in the critical months, these withdrawals might have an appreciable effect.

They declined to accept the views of the London Committee, as to the prematureness of the scheme, and the absence of necessity for improving the present conditions of irrigation in Sind.

That to regard Sind as an inundation country, purely and simply, and deny it the benefits of a perennial water-supply, such as was enjoyed by the Punjab and United Provinces, was to adopt a policy of stagnation, to which they could not subscribe.

They made tentative proposals, for preparing a new scheme, to include the Barrage, the Rohri Canal, and the Right Bank Canals, and for a new head to the Eastern Nara Supply Channel.

In March 1916, the Government of India approved of the preparation of revised plans and estimates, for a complete project for a Barrage below the Sukkur gorge, with two large canals, taking off above it, on the Right and Left Banks of the Indus, to provide perennial irrigation to the area commanded. Their letter was accompanied by a Note from the Inspector-General of Irrigation, (Mr. Nethersole, C.S.I.), in which he generally agreed with the Government of Bombay.

With regard to making the Rohri Canal without a Barrage, although he considered it might be quite feasible to make such a canal to work satisfactorily by itself, the risk of its silting could not be ignored, and quite apart from this, the main, and insuperable, objection to such a scheme was that it would seriously affect the efficiency of the inundation canals, lower down, on the Right bank of the river.

FINAL EFFORTS.

In October 1915 an Executive Engineer was placed on special duty, to revise the Barrage Project; and, in May 1916, submitted a report, and outline project, for the whole scheme. These proposals were approved, but owing to the war, nothing was done between May 1916 and June 1918, when the preparation of the present project was vigorously taken in hand.

A senior Collector and an Executive Engineer were placed on special duty, in 1918, with a large staff, to make a thorough soil survey of the areas to be served. They submitted their report in March 1919. Another Executive Engineer, with a large staff, was on special duty from January 1918 till July 1920, to re-design, and estimate, the whole scheme for Barrage and Canals. The complete present scheme was submitted to the Government of Bombay, through the Commissioner in Sind, in July 1920. This present project provides for a Barrage, at a new site below the gorges, and for great systems of perennial canals on both banks of the river. The total amount of all estimates is about 18⅛ crores of rupees. The general lines and details of the scheme had been discussed by all local officers, and by the Government of Bombay, and the Government of India, during the preparation of the project and the Commissioner in Sind was, therefore able to submit the complete project, at once, to the Government of Bombay, with his full approval and recommendation. The Government of Bombay submitted it, with their full approval, to the Government of India on 30th July 1920, strongly recommending it for the sanction of the Secretary of State. The Government of India submitted it to the Secretary of State in December 1920, and the Secretary of State intimated his sanction, to the technical and administrative sides of the project, and to the estimates for works, in the House of Commons on the 2nd and 3rd August, and in the House of Lords on the 9th August 1921. There has been a great deal of opposition to the scheme in England, engineered by Dr. Summers, who prepared the 1909 Rohri Canal Project. His contention is that the Rohri Canal should be constructed before the Barrage, or any of the other canals, because, he argues, that thereby, there would be large saving in interest on outlay for the construction of the Barrage.

A HISTORY OF THE PROJECT.

IV

In our three previous articles, we described the present condition of Sind, its possibilities for development, the necessity of substituting perennial, for inundation, irrigation, and the history of the various proposals, made during the past 70 years, for this purpose.

We showed how these proposals have led up to the present complete scheme, for a Barrage near Sukkur, and for great systems of perennial Canals, on both banks of the river, which will obtain a guaranteed supply of water, at a constant high level, all the year round. We shall now describe the principal aspects of this present sanctioned project, which is known as the Sukkur Barrage Canals Project of 1919-20.

The scheme consists of the Barrage itself, across the River Indus, 3 miles below Sukkur, and seven great new Canals. The head regulators of all canals are made immediately above the Barrage, which can completely control the river level, and keep the approach channels to the canals, clear of silt.

THE NEW CANALS.

The canals are divided into two systems, one on either bank of the River, viz :

1. The Right Bank Canal System, comprising (*a*) two great new perennial canals, the North Western Perennial Canal, and the South Eastern Perennial Canal, and (*b*) a third great new canal, known as the Central Rice Canal, which will flow only from May till September, and be entirely closed for the remainder of the year.

2. The Left Bank Canal System which comprises the following Canals, (*a*) Two large high level canals, for supplying the whole cultivable territory of His Highness The Mir of Khairpur.

(*b*) A great perennial supply channel, to feed the Eastern Nara River, from which a number of existing canals are fed. All these canals will be remodelled, and most of them enlarged.

(*c*) A great new perennial canal—the Rohri Hyderabad Canal.

THE BARRAGE.

We will first describe the Barrage itself, and its subsidiary works. The Barrage is a great masonry structure, or bridge, spanning the whole width of the river Indus, and is literally a series of great sluice gates, which can be raised or lowered, at will, to control the level of the river

above them. It is located 3 miles down-stream of Bukkur Island, which lies between the two deep river gorges at Sukkur and Rohri. The traveller by train, from Karachi to Quetta, passes over the great Landsdowne cantilever bridge, which spans the river gorge between Rohri and Bukkur Island, and the girder bridge spanning the other gorge between the Island and Sukkur. Three miles below these bridges, and within sight of them, will be the great Barrage. In the 1909 Barrage Project, the site chosen for the Barrage was just upstream of Bukkur Island, because, at this point, limestone rock is found in the river bed, and it was supposed that this would make a good foundation. But to avoid dropping into the deep gorges, it was not possible to make the Barrage in a straight line, normal to the river. In following high rock in the bed, the form of the Barrage had to be a rough half hexagon, pointing upstream, and only the central portion of this hexagon was directly facing the general direction of the river. (See sketch No. 1.)

SITE OF THE BARRAGE.

The river swings from side to side, in different years, above the gorges, and seldom approaches them directly. Hence in most years, one, or two, sides of the half hexagon, *i.e.*, one-third, or two-thirds, of the whole length of the Barrage, would have been obliquely inclined to the direction of the river; this would have caused great obstruction to the passage of floods through it, and would have raised the level of these floods considerably. The level sill of the Barrage sluices would also have obstructed the entrances to the gorges, and the combined effect, of these two forms of obstruction, might have had a serious tendency to cause the river to break through its banks above Sukkur, find a new channel for itself, and desert its present course through the gorges. This is what is meant by an avulsion of the river. Did this occur, the Barrage, and all canals, would be useless. Great training works, or guide banks, for miles upstream, would have been necessary to minimise this danger. Moreover, the rock, on which it was proposed to build this Barrage, is known to be very porous, and is probably not very thick, so it is doubtful whether it would have proved a satisfactory foundation; as the officer who prepared the project, Mr. Beale, himself recognized.

For all these and other reasons, this site for the Barrage was not a satisfactory one, and, on the recommendation of the London Committee, a new site was looked for.

A SAFE SITE.

The site now chosen is an ideal one, for a different type of Barrage to that proposed in 1909. Being three miles downstream of the gorges, the latter are not interfered with in any way, and the river floods above them are left free, to swing naturally from side to side, and to find their own channel into these deep gorges, through which they rush with great force, as they have done for hundreds of years past. After passing the gorges, the two streams of the river unite again below Bukkur Island, and flow steadily onward for the next three miles, in an almost straight,

and gradually widening, channel, which gets more and more shallow and regular, as it approaches the site for the present Barrage. In this three mile length, the banks, for the first mile or so below the gorges, are of rock, and for the rest of the distance are good firm clay. The surveys, available for the past 40 years, show that these banks have remained almost unaltered, proving that the river has formed for itself a channel, which is a natural suitable orifice for the streams issuing from the gorges. No alteration is proposed to these banks. On the contrary, they are to be protected with stone facing, and a protective stone apron, to ensure that they shall remain unaltered.

A few hundred feet downstream of the Barrage site, the river resumes its normal behaviour in Sind, *i.e.*, it swings from side to side in different years, so that, if the Barrage were built any further downstream, training works would be necessary above it, to ensure that the river should approach it normally. A study of the hydraulic conditions of the river also shows that, at the site selected for the Barrage, the river has formed a natural bar, which automatically regulates the conditions of the stream, above and below it. The Barrage is to be built on this bar, and its floor will imitate the average natural conditions, so that its effect on the river, in flood, should be almost nil. Calculations show that, with a flood half as great again, as the largest flood ever measured, the Barrage will only raise the natural level of the river by barely one foot at the Barrage, and will have no effect at, or above, the gorges 3 miles upstream. It is only in the highest floods that there could be any cause for anxiety, as to the effect of the Barrage on the river, and, as shown above, this effect is negligible.

Accordingly, there is no danger, from the Barrage, of that oft mentioned bogey—an avulsion of the river above the gorges.

A NATURAL SITE.

At the Barrage site, the river bed, throughout its width, is composed of fine sand and silt, and this continues for a great depth, as shown by borings. The Barrage foundation, or floor of masonry, will be built in this sandy bed, on principles well understood in India and Egypt; in both of which countries, many Barrages have been built on similar foundations. The top of the floor will be slightly lower than the average natural bed level of the river in the flood season, but as the width will be slightly decreased, the waterway provided will be almost the same as in natural conditions. This solid masonry floor, on which will stand all the superstructure of the Barrage, is protected from scour, both upstream and downstream, by great aprons of loose stonepitching, designed to fall gradually, as scour occurs, and thus form a stone-pitched slope, on both sides of the Barrage.

THE BARRAGE SLUICES.

The superstructureof the Barrage consists of a series of big masonry piers, 60 feet apart, carrying two great bridges, side by side, right across the river. One bridge is at a high level, and is required for suspending, and operating, the great sluice gates of the Barrage. These gates, of which

there will be 66, are each 63 1/4' long and 18 1/2' high, are built of steel girders and plates, and will weigh about 50 tons each. Their ends slide in grooves in the piers, and they are suspended on steel cables, counter-balanced by great weights of reinforced concrete, from the electrically operated machinery, fixed on the deck of the high level bridge. The gates can be lowered, to rest on the floor of the Barrage ; or raised right up, till they are 8 feet clear of the highest estimated flood ; or they can be set at any intermediate level. And every gate can be operated independently of all others.

The Head Regulators, of all the canals, are situated just upstream of the Barrage, on either bank. Whenever the river is at a very moderate flood level, 12 feet on the Bukkur gauge, it will be high enough to give the full level to all canals, and the Barrage will not be needed. As soon as the river rises to that level, therefore, all sluice gates of the Barrage would be raised, clear of the river, and the latter left unobstructed.

NEW ROAD BRIDGE.

Side by side with the high-level bridge for the gates, is another bridge at a lower level, carrying a roadway for vehicular traffic, and two foot-paths. It will connect the main roads on the Right Bank, from Shikarpur and Sukkur, with those on the Left Bank from Rohri and Khairpur. The high-level and low-level bridges are carried on the same piers, and are of similar design, in limestone masonry. The length of each bridge is 4,926 feet, or just under a mile; or about 5 times the length of London Bridge. The parapet of the high-level bridge is 77 feet above foundations, 66 feet above the floor level, and 42 feet above the highest flood level. The parapet of the road-bridge is 23 feet lower, or 19 feet above the highest flood level.

The whole superstructure will be built of creamy-white limestone masonry, with eliptical arches, and relieving buttresses and string courses. It will present a very fine appearance, massive but elegant, and will harmonize with the vivid colouring on this fine stretch of the great river, which is one of the few really beautiful spots, throughout its length, in Sind.

FEEDING THE CANALS.

Immediately above the Barrage, on both banks, commence the head regulators of the great canals. These are at right angles to the Barrage, and consist of great masonry works, similar in a design and appearance, to the Barrage itself. The openings between piers are each 25' width, and can be partially, or wholly, closed by tiers of three steel gates, working in grooves, one behind the other, in the masonry piers. These gates are so arranged that they can be lowered to any desired level, so that water entering the canals, from the river, will pass only over the tops of the gates, thus excluding the bottom water of the river, which is heavily laden with silt. The lowest gate can be completely lowered behind a permanent masonry sill, which stands from 6 to 9 feet above the floor of the Barrage, so that any accumulation of silt in front of these sills cannot enter the canals, but can be drawn through the *Barrage* sluices, and passed down the river.

The gates are suspended from machinery, fixed above, on a special high level bridge, as in the Barrage, and all gates will be operated electrically. Behind the gate-bridge, will be a lower-level road-bridge, on the same piers, to carry vehicular and foot traffic over the canals, to and from the Barrage Road-Bridge.

COST OF RIVER WORKS.

As already explained there will be three great canals on the right bank, each with separate head regulators, and four great canals on the left bank, also each with separate head regulators.

Between each two regulators, and connecting their river faces, will be massive masonry retaining walls. The regulators on the right bank, with the connecting river walls, will stretch for a distance of 1,160 feet upstream from the Barrage, and those on the Left Bank for a distance of 1,320 feet; where they meet the natural river banks, which are pitched with stone from these points, as far as the natural rocky banks, at Sukkur and Rohri respectively. The river banks will also be heightened by earthen bunds, on both sides of the river, the river-side slope of the bunds being in continuation of the natural bank of the river, (which will be dressed to a regular slope of $1\frac{1}{2}$ to 1, before the stone pitching is laid), and similarly protected with stone facing. The top of the bunds will be 25 feet, or 40 feet wide, and will form splendid river side roadways, connecting the towns of Sukkur and Rohri, respectively, with the Barrage Road-bridge, and thence with one another. On the downstream side of the Barrage, short curved guide banks will run from the abutments, to meet the river banks on each side. The estimated cost of all these great works on the river is Rs. 569 lakhs, or say £3,800,000 sterling. The Assouan Dam cost £2,900,000.

THE GREAT CANALS.

Some brief explanation of the system adopted is necessary. In parts of Sind, there are great areas of country which are cultivated almost exclusively with rice crops during the flood season. On such lands, water is not required at any other season. A second crop (of oilseeds) is often grown on rice lands, after the rice is reaped, but such crops require no watering, as the soil is already thoroughly soaked by the rice-crop waterings, which are very heavy. On other great areas no rice is grown, but during the flood (or Kharif) season, other crops, such as cotton, jowari, bajri, etc., are grown. These are usually known by the misnomer "Dry" crop, in contra-distinction to the "Wet" crop, rice, which is grown in standing water. After these "dry" crops are reaped, and in adjoining lands, rabi crops can be sown, and watered till matured.

On any given "dry" area, (*i.e.*, non-rice area), the maximum area of rabi crops, will be not more than 2 to 3 times the kharif crop area, and as rabi crops require about half the quantity of water taken by kharif crops, the total quantity of water required for rabi crops, on any given area, will be about the same as, or slightly more than, for the dry kharif crops on that area.

Now if one canal supplies both rice areas and dry crop areas, the canal must carry, in the kharif season, sufficient water for

(*a*) the rice area,

(*b*) the kharif crops on the "dry" area,

And in the rabi season it will only require to carry sufficient water for the rabi crops on the "dry" area, *i.e.*, about equal to the water required for (*b*) above.

Hence if the rice area is large, the canal will have to carry a very much larger quantity of water, in the kharif season, than in the rabi season. It is impossible to work a canal, satisfactorily, if the discharge required in one season is very much less than in another season; since a constant level is required in the canal, to give flow water to all lands.

Now on the Right Bank of the river, in the area commanded by the Barrage, there is a very large tract of rice lands, in one compact block in the middle of the area: while the remaining lands, on all sides, are suitable for "dry" kharif and rabi crops. If all these lands were supplied by one great canal, it would require a discharge, in the kharif season, of 19,446 cusecs (cubic feet per second) and in the rabi season, only 6,164 cusecs. Such a canal would be unworkable.

A RICE CANAL.

A separate canal has, therefore, been designed to supply the rice area only, and is known as the Central Rice Canal. It will have a discharge of 12,346 cusecs. For comparison, it may be stated that the maximum discharge of the River Thames is just under 15,000 cusecs. This canal has a length of 87 miles, with 294 miles of branches, and 48 miles of distributaries. At the head of the canal, it will have a bottom width of 291 feet, and at ground level 330 feet; and a depth of $12\frac{3}{4}$ feet.

For comparison, the Suez Canal is 72 feet wide at bed, and 202 feet at surface, with depth 26 feet; and is 99 miles in length.

The Manchester Ship Canal is 120 feet wide at bottom, and 172 feet at surface, with depth 26 feet.

The Central Rice anal is provided with 7 cross-regulators, with all of which are combined road-bridges, to cross the canal. Besides these, there are 11 other road-bridges over the canal. This canal, being designed to supply rice and other kharif crops only, will be opened in April, and closed at the end of September, each year. It will supply 466,162 acres of rice crops, and 27,261 acres of other kharif crops, annually; or an area slightly greater than that of the whole County of Surrey, or Oxfordshire, in England. Its estimated cost is Rs. 2,33,08,000, or say £1,554,000.

RIGHT BANK PERENNIAL CANALS.

The remaining areas, on the Right Bank, are suitable for perennial irrigation, and contain a comparatively small area, of existing rice cultivation, to be provided for. These areas can be most conveniently served by two separate canal systems, one—the North Western Perennial Canal—

to supply the lands to the north and west of the Central Rice Canal area, and the other—the South Eastern Perennial Canal—to supply the areas to the East and South of the Central Rice Canal area.

The North Western Perennial Canal will have a maximum discharge of 4,313 cusecs, and a minimum of 3,275 cusecs, in the Kharif and Rabi seasons, respectively. Its length will be 97 miles, with 117 miles of branches, and 363 miles of distributaries. At the head of the canal, its bed width will be 165 feet, and at ground level 200 feet (about the same as the Suez Canal), while the depth will be 9½ feet. It will be provided with 9 cross-regulators, with all of which, road-bridges are combined; and there will be a further 9 road-bridges across the canal. The canal will flow at full level all the year round, and will supply water to 215,000 acres of cotton, and other "dry" crops, 54,000 acres of rice, and 546,000 acres of rabi crops, (wheat, oilseeds, etc.), or 815,000 acres of cultivation, annually; or a greater area than the whole of Gloucestershire. Its estimated cost is Rs. 1,67,36,000, or say £1,116,000.

The South Eastern Perennial Canal will have a maximum discharge of 2,767 cusecs, and a minimum discharge of 2.056 cusecs, in the Kharif and Rabi seasons, respectively. Its length will be 140 miles, with 30 miles of branches, and 294 miles of distributaries. At the head of the canal, its bed width will be 93 feet, and at ground level about 135 feet, while the depth will be 9¾ feet. It will be provided with 9 cross-regulators, with all of which are combined road-bridges; while there will be a further 23 road-bridges, spanning the canal. The canal will flow at full level all the year round, and will supply water to 111,000 acres of cotton, and other "dry" crops, 41,000 acres of rice, and 347,000 acres of rabi crops, (wheat, etc.), or 499,000 acres of cultivation, annually; or again, slightly greater than the whole area of Surrey. Its estimated cost is Rs. 1,41,00,000, or say £940,000.

DRAINAGE.

A great system of Main, and Branch, Drains is provided for the whole canal system on the Right Bank; the Main Drains being generally common to, and separating, the Rice Canal area, and the Perennial areas. There will be, altogether, 115 miles of Main Drains, and 280 miles of Branch Drains. All these eventually discharge into the great Mancher Lake, at the extreme south end of the area. From this Lake, a great high-level drainage channel, 1,000 feet wide, with a low-level drainage channel 100 ft. wide, and 10 ft. deeper, excavated along its centre, is provided. These channels will be 12½ miles long, and they will empty into the river, when the latter is at moderate, and low, levels. With a high river level, the river water is higher than the Manchar Lake, and at present flows into, and fills, the latter, at such times. To prevent this in future, a great head regulator will be built across the drainage channels, to close them completely during high river periods, but permit them to flow into the river, as soon as it falls sufficiently. The cost of this drainage Channel and Regulator is estimated at Rs. 78,31,000 or say £522,000 (apart from the cost of the Main and Branch Drains in the Canal areas, which is included in the cost of the canals).

THE ROHRI CANAL.

The Rohri will be a perennial canal, flowing at full level all the year round. It will have a maximum discharge of 10,250 cusecs, and a minimum of 8,800 cusecs, in the kharif and rabi seasons, respectively. Its length will be 205 miles, with 203 miles of branches, and 2,100 miles of distributaries. At the head of the canal, its bed width will be 253 feet, and at ground level about 290 feet, (nearly half as wide again as the Suez Canal), while its depth will be 13 feet. It will be provided with 16 cross-regulators, with all of which road-bridges will be combined, and there will be a further 44 road-bridges across the canal. There will be 398 miles of Main Drainage Channels, and 371 miles of branch drains. The canal will supply water to 677,000 acres of cotton, and other "dry" crops, 21,000 acres of rice, and 1,355,000 acres of Rabi crops, (wheat, oilseeds, etc.), or, to 2,053,000 acres of cultivation, annually ; or a greater area than the whole of the East and North Ridings of Yorkshire. Its estimated cost is Rs. 408 lakhs, or say £2,720,000.

THE EASTERN NARA SYSTEM.

The works on this system will consist of a great new Supply Channel, from the Barrage, to feed the existing Eastern Nara River and its branch canals. The Nara River will be canalized, throughout, by the construction of banks on both sides ; and all existing branch canals will be enlarged, or remodelled, and one new branch constructed. These branches, which are themselves great canals, include the Jamrao, Mithrao and Thar Canals besides a number of smaller ones. As redesigned, they will all be supplied from one, or other, of the three existing weirs on the Nara River, which will enable the required supply to be given to each, at a constant level, throughout their irrigating seasons. The Thar Canal will be greatly enlarged, and remodelled as a Rice Canal ; and will flow only from April to September, and be entirely closed for the rest of the year. All other canals will be perennial, and will flow at full level all the year round.

The new Supply Channel will have a maximum discharge of 12,200 cusecs, and a minimum of 6,612 cusecs, in the Kharif and Rabi seasons, respectively. The length of the new Channel will be 15 miles, and the canalized length of the Nara River, which it supplies, will be 242 miles. The Supply Channel will have a bed width of 350 feet, and at ground level a width of about 390 feet, or nearly double the width of the Suez Canal. Its depth will be 11½ feet. The total length of all branches will be about 495 miles, with 1,240 miles of distributaries. On the main Canal, (Nara River), there will be one head regulator, 3 weirs, with regulators and bridges, and 3 road-bridges across the new Supply Channel. On the branch canals, in the irrigated areas, there will be many bridges ; but none exist at present, or, are necessary, on the main Nara River, as it flows through uninhabited country. There will be 110 miles of new main drains with 300 miles of branch drains ; while all existing drains, on the Jamrao Canal system, will be improved, and new drains made, where necessary. The system will supply water to 406,000 acres of cotton and

other "dry" kharif, (including 31,200 acres in the Khairpur State), 240,000 acres of rice, and 915,000 acres of rabi, (wheat, etc.), or to a total of 1,561,000 acres of cultivation, annually, or nearly equal to the whole area of Devon, the third largest country in England. Its estimated cost is Rs. 2,39,92,000, or say £1,600,000.

IN KHAIRPUR STATE.

As the present sources of supply to the existing inundation canals, in the territory of His Highness The Mir of Khairpur, will be interrupted by the new British Rohri Canal, and as His Highness very wisely wished his State to benefit by the Barrage, two new feeders will be constructed; to supply the whole area of the State, under the entire supervision and control of the State authorities. His Highness the Mir has agreed to pay a share of the cost of the Barrage, whatever it may amount to. The whole cost of the new Head Regulators, and the new Feeders, for the State, amounting to Rs. 20,40,000, or say £136,000, will be borne by the British Authorities. His Highness the Mir has permitted the passage of the Rohri Canal, for a length of 50 miles, through his State, which lies between the head of that canal, and the area it will irrigate in British Sind. No irrigation will be done, in Khairpur State, from the Rohri Canal, as His Highness prefers to have his own separate system. The share of the cost of the Barrage, debitable to the State, has been calculated as follows.

For the British Canals, each canal will be debited, with a share of the total cost of the Barrage, in proportion to the total final anticipated area of cultivation, (kharif plus rabi), to be done by such canal.

In the case of the Khairpur State, the area, on which its share of the Barrage has been calculated, has been taken as the Kharif cultivation only; no charge being made for the very valuable bosi-rabi crops which are provided for. If desired, the canals can flow from the beginning of May until December. The supply provided is sufficient for 303,000 acres of cotton and other "dry" crops, and this is the figure on which the State's share of the Barrage cost is based. It will amount to about Rs. 23,96,000, or say £160,000. But the water provided, is also sufficient for, at least, another 175,000 acres of bosi-rabi crops, or a total cultivation of, at least, 478,000 acres. The State has asked for only 250,000 acres, annually. The full level of the water supply can be absolutely guaranteed, as long as the canals are open.

There will be two channels, the East, and West, Khairpur Feeders, one on either side of the Rohri Canal.

The West Feeder will have a discharge of 2,094 cusecs. Its length will be 1¼ miles, to the point where it meets the existing system of canals.

The East Feeder will have a discharge of 1,940 cusecs. Its length will be 12 miles, to Khairpur town, where it will meet the existing canal system.

These fine feeders, with their guaranteed supply, will provide for a vast development of cultivation, and increase of prosperity, in the State.

The present average cultivation is less than 200,000 acres per annum, so this can be increased by nearly 150 per cent.

SOME TOTALS.

Thus it will be seen that the Sukkur Barrage and Canals Project provides sufficient water for the eventual cultivation of the following areas, in British and Khairpur Territories.

823,000 acres of rice.

1,739,000 acres of cotton, jowari; etc.

3,338,000 acres of rabi crops (wheat, oilseeds, etc.)

Total 5,900,000 acres of cultivation, annually, in a total commanded area of 8,132,000 acres, in British and Khairpur territories. This is an increase of 3,522,000 acres, over the present average cultivation of 2,236,000 acres annually. The total cost of the project will be Rs. 1,836 lakhs, or say £12,240,000. For comparison, it may be stated that, the total area of Egypt is 8,460,000 acres, while the total cultivation is 5,400,000 acres. Thus the Sukkur Barrage Project will provide for 500,000 acres more cultivation, annually, than there is at present in the whole of Egypt.

In our next article we shall deal with the agricultural, and economic, aspects of the project.

ITS ECONOMIC ASPECT.

V.

As already explained, in our last article, there is a large area, on the right bank of the River, in which rice has been grown, almost exclusively, for many years past. The greater portion of this rice crop, fortunately, is in a compact block of country, for which a separate rice canal has been designed, and all such established rice lands will be given a guaranteed supply of water, at constant level, and ample for the crop, for a longer season than it now gets a very uncertain supply. The existing inundation canals, supplying rice lands, are extremely and unavoidably wasteful, owing to the fluctuation in the water level of the canal. The outlets and distributaries have to be made large enough, and low enough, to take a moderate supply from the canal, when the water level in it is low. When the canal-level rises to full supply, or above, many of these outlets take far more water than necessary, especially if their channels run into low grounds. Such surplus water does little, or no, good to the crops it supplies, and deprives higher lands, and lands further down the canal, of their fair supply. Moreover, the zemindar, fearing a possible and probable drop in the canal level, naturally takes all the water he can get at times of good supply, to tide him over periods of deficiency.

ECONOMY IN DESIGN.

With the new canals a constant level can be maintained, in the main and branch canals, all through the season, so that the outlets, to the distributaries and water courses, can be accurately designed, to give the required supply, and will give that supply all through the season. Hence, while still giving a good supply to the crops, all the time they are growing, the new canals will be much more economical than the present ones. Even so, the supply of water allowed for each acre of rice will be slightly greater than is actually given, throughout the season, on several existing, and successful, rice canals in this area ; so that, with the future certainty and regularity of the water level, it should give a very liberal water supply to the crops. The " duty " of water, for which the new canals have been designed, is for one cusec of water, at distributary heads, to every 43½ acres of rice crop. The existing Gul Mahomed Wah gives an actual duty of 44.9 acres per cusec, while the Dhamrao Canal gives 42.9 acres per cusec. Both canals grow the best kind of rice, but have fluctuating supplies, depending on the level of the river, and must, therefore, be wasteful. They correspond to distributaries of the new system.

PLENTY, BUT NO WASTE.

The proposed " duty " is considerably higher than the present *average* duty, of the rice canals in Sind, but as explained, the present canals are wasteful, with no advantage to the crop. Their low duties are due partly to excessive supply at some periods, when great quantities of water run into depressions, and waterlog the country.

The advantages of the constant supply, to be given by the new canals, will be very great. The date of opening the canals, each year, will be announced weeks beforehand, so that the cultivators will know exactly when to make their preparations. The canals will open early in April, much earlier than at present, enabling the cultivators to sow their seed beds early, and give their crop a long season, at the most suitable time of the year. From the time they are opened, till the day they close, (at the end of September), the cultivator will be absolutely certain of obtaining his full supply, at full level, for his crops ; so that all the present uncertainty and fluctuation will vanish, and the cultivator be sure of a good crop, so far as the water is concerned.

OTHER RICE CANALS.

There is a similar area, of purely rice cultivation, at the tail of the Begari Canal, and this will be supplied by a branch of the Central Rice Canal, and be given a similar rice supply from April to September only. Another similar rice area exists on the Eastern Nara System, and is fed by the Thar Canal. This canal will be enlarged and remodelled to develop the tract as a rice area only. On all these rice areas, no rabi water supply will be given, as their canals will be closed from October to March, but there will be a large amount of dubari crops, *i.e.*, crops grown on the rice lands after the rice crop is cut, and which will grow on these saturated lands without further watering. Such crops are not only restorative to the soil, but have the great advantage of taking up and utilising the excess water in the soil, and thereby assist the drainage operations, and the prevention of water logging. In order to encourage their use, no water rate will be charged.

RICE AREAS ON PERENNIAL CANALS.

Besides these purely rice areas, to be supplied by rice canals, there are considerable patches of rice cultivation in the areas to be served by the new perennial canals.

On a perennial canal, rice is a very extravagant crop to provide for, and also makes it difficult to obtain a more or less equal demand for water from the canal, in the kharif and rabi seasons, since the rice area requires no rabi water. Hence rice is not to be encouraged on the perennial canals, but all lands which had been cultivated with rice, for ten years, at the time of the soil survey in 1918, will be given a rice supply. Rice crops, which had been started within those ten years, are not considered as having established a claim to a rice supply, and will not be given it. The justification for this is that, such new rice crops have been obtained at the expense of the cultivators, at the tails of the present canals, who are thereby being ruined ; and secondly, that such lands are nearly all fit for other kharif crops and for wheat cultivation in the rabi season, and are not alkaline, like the great rice areas. Such new rice lands will, therefore, be given a water supply for other kharif crops, and for rabi crops, but will not be given a water supply for rice.

COTTON, AND OTHER KHARIF, CROPS.

The cotton, and other kharif, crops are usually grown on higher lands than rice, and are, therefore, still more handicapped by a fluctuating water level in the canal. Naturally, therefore, the cultivator takes as much water as he possibly can get, whenever it is available, to tide him over probable times of shortage. Hence, under present conditions of irrigation, the actual quantity of water used in the season, to produce a satisfactory crop, is bound to be wasteful. The advantage of a regular and constant water level in the canal, will be very great, and lead to much more effective use of the water. This is already shown, in Sind, by the much higher duties obtained on the Jamrao Canal System, (which is partially secured by a weir at Jamrao), than on the ordinary inundation canals of Sind. The average duty obtained, at the heads of branches of the Jamrao Canal, (which correspond to the distributaries of the new system), is 85 acres per cusec, while three of them give over 90 acres per cusec, and one, over 100 per cusec. For the new systems of canals, which will have an absolutely guaranteed level and supply, for the whole year, the duty on which the distributaries have been designed, is 87 acres per cusec ; a very slight increase over the actual present *average*, on the Jamrao Canal, with its ill-secured supply, and much below the figure adopted in the Punjab, where the designed duty, at distributary heads, is usually taken as 100 acres per cusec. For successful cotton cultivation, an assured supply, for early sowing in March and April, and for final waterings in October, is essential. This is never obtainable, now, on the Jamrao Canal, but will be guaranteed on the new canals. The other kharif crops such as jowar, bajri, etc., require about the same quantity, per waterings, as cotton, but for a somewhat shorter season. The same duty of 87 at distributary heads has been allowed for these crops, and will give a very liberal supply, as it will be certain, and at constant level, whenever required. In every new canal, the design has been worked out from the tail, upwards ; each distributary being given the required supply, for the area to be grown on it, and the branches and main canals, from which the distributaries are fed, are designed to carry this supply for all distributaries, plus the losses due to evaporation, and percolation, in such branches and main canals ; accurately calculated, from their length and wetted perimeter. The total kharif supply, required on each distributary, is found by calculating the supply required for rice lands, at a duty of 43½ acres per cusec, allowing for 30 per cent. of the rice area being shown in April, (that is, ample for all seed beds), 75 per cent. of the area requiring full water in May, (*i.e.*, transplantation proceeding rapidly), and the whole area requiring full water throughout June, July, August and September. For cotton crops, provision is made for 70 per cent. of the full area, as requiring full supply in March ; and the whole area from April to September ; while 80 per cent. of the area is assumed to require water throughout October, (the remainder being reaped early). For other kharif crops, it is assumed that one-sixth of the full area will be very early sown, and require water in March ; 75 per cent. of the full area in April ; and the whole area throughout May to September. This is a far longer

season than those crops ever have at present, and will give vastly improved results, especially with the ample supply allowed, at constant level.

THE RABI OR COLD SEASON CROPS.

At present, there is no canal in Sind, which has an assured supply of water in the cold weather. There are only four canals which have any supply at all, throughout the year. Of these, the Sukkur Canal and the Fuleli Canal have only a very small cold weather supply, (a mere fraction of their full summer discharge), at a very low level, depending entirely on the winter level of the river. But these small supplies are fully utilised and eagerly taken by the cultivators, for growing crops of wheat and oil-seeds. The other two canals are the Mithrao and the Jamrao Canals. Both are supposed to obtain a regular cold-weather supply from the Eastern Nara River, headed up by weirs at the heads of the Canals. But the Eastern Nara River gets its supply from the Indus at Rohri, and as the Indus is at present uncontrolled by any weir, or barrage, the supply entering the Nara Supply Channel, in the cold weather, is extremely small in many years, and in some years has failed altogether. The result is that, the Canals dependent on it have never had a regular, or reliable, supply in this season. In the first few years after the Jamrao Canal was opened (1901), the people expected a regular cold weather supply, and it happened that the Nara Supply Channel worked fairly well for those years. As a result, the rabi sowing increased by leaps and bounds, from nothing, to 132,526 acres in 1905-06, or to about 75 per cent. of the maximum kharif crop. Then came years with a poor water supply in the cold weather, and this destroyed the confidence of the cultivators, and ruined their crops, so that sowing decreased in the following years. Although, since then, there have been some years with a good cold weather supply, the cultivator has never regained his confidence, but, remembering how often the supply has failed him, has restricted his rabi sowings to a comparatively small area. But there is not the least doubt that, once a good reliable supply is provided, and the cultivator has confidence in it, and can foresee his requirements of labour and seed, the rabi sowings will increase enormously; and eventually every drop of water available will be utilized. This has been the invariable experience in the Punjab, and elsewhere, when a reliable perennial supply has been substituted for an irregular inundation supply. Rabi crops require only about half the quantity of water that is required for equal areas of cotton and other kharif crops. Hence if the canals run full in the cold weather, they can provide sufficient water for twice as great an area of crops in the rabi season as they can supply in the kharif season. Such an expansion of the rabi crops, (at present very small), will take place gradually, and it is estimated that the full area, possible and provided for, on the new canals, will only be reached 30 years after completion of the canals. Judging by experience in the Punjab, this is a very safe estimate, and it is probable that the full area will be sown much sooner, and thereby greatly increase the revenues of the canals, as well as the prosperity of the people.

PRESENT CULTIVATION.

The present cultivation, in the commanded areas, varies considerably in the different areas (see table below), and depends almost entirely on the water supply available. Thus, in the Rohri Canal tract, where rabi waterings are never available from the present canals, the cultivation in the rabi season is very small, and is *bosi* rabi, *i.e.*, crops grown in the rabi season, by giving the land only a heavy watering at the end of the kharif season, before sowing the rabi crop, and perhaps assisting it from wells. Even this crop is eagerly grown, wherever water can be obtained. On the Right Bank, there is very little rabi in the rice areas, and this little is almost entirely unwatered *dubari*. The rice areas are not fit to grow watered rabi, as they are heavily saturated for the rice crop. In the North Western Perennial Canal area, there is, at present, a small rabi supply available in some of the canals, and this is eagerly utilised for wheat cultivation, the present proportion, *i.e.*, one of rabi crops to two of kharif crops, being a very good ratio for inundation canals. The rabi is capable of a vast increase when a guaranteed water supply is available. In the South Eastern Perennial Canal area, the proportion of rabi crops is abnormally high, for an inundation canal tract, but this is due to the long riverside strip of land, lying outside the river bunds, and the lands round the great Munchar Lake. Most of these lands are flooded annually, by the rise of the river, and cannot be cultivated in the kharif season, but are available for a rabi crop, as soon as the water drains back into the falling river. In these tracts, therefore, the people are already accustomed to doing far more rabi than kharif cultivation. The following table shows the average cultivation, in the five years ending 1917 :—

PERENNIAL CANALS.

In Commanded Area of	Kharif cultivation.	Rabi cultivation.	Total cultivation.	Percentage of culturable area cultivated.	Kharif and Rabi proportions of total cultivation.
Rohri Canal - -	643,581	92,650	741,231	29·2%	87·5% 12·5%
N.-W. Canal - -	221,642	104,860	326,502	33%	68% 32%
S.-E. Canal - - -	125,296	125,409	250,705	42%	50% 50%
Mithrao Canal - - -	*103,000	23,000	126,000	25·6%	82% 18%
Jamrao Canal - - -	161,000	90,000	251,000	33%	64% 36%

* 75,000 acres is rice cultivation and 28,000 other Kharif.

RICE CANALS.

Central Rice Canal .. -	269,476	46,974	316,450	58%	85% 15%
Thar Canal - - -	51,250	Nil.	51,250	35%	100% Nil

Before the construction of the perennial Lower Chenab Canal in the Punjab, its commanded area was served by inundation canals. The proportion of rabi and kharif in the total cultivation was then about 25 per cent. rabi, and 75 per cent. kharif ; whereas in 1915-1916, with the new perennial canal, 71 per cent. of the cultivation was rabi, and only 29 per cent. was kharif, although the actual area of kharif had greatly increased. This shows the great increase of rabi cultivation which follows the introduction of a perennial water supply.

PROSPECTIVE CULTIVATION AFTER FINAL DEVELOPMENT.

The culturable area of any given tract, is found by deducting, from the gross area of such tract, the total unculturable area, (as found by the soil survey), and also a further deduction of 6 per cent. of the gross area, to allow for lands occupied by canals, roads, villages, etc. The intensity of cultivation to be provided for, in the culturable area, varies with the different canal systems, according as they are to supply a large area of rice lands, or not. Distinct rules are used for

(*a*) The Rohri Canal.

(*b*) The Perennial Canals, of the Right Bank, and of the Eastern Nara, System.

(*c*) The Rice Canals, of the Right Bank, and of the Eastern Nara, System.

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The rules adopted are as follows :—

(*a*) The Rohri Canal.

27 per cent. of the culturable area will be provided for cotton and other kharif cultivation. About 1 per cent. of the culturable area will be allowed a rice supply,—*i.e.*, only the present established rice area.

54 per cent. of the culturable area will be given rabi supply, *i.e.*, the total intensity of annual cultivation will be 82 per cent. of the culturable area.

(*b*) The Perennial Canals of the Right Bank and Eastern Nara.—The area of established rice cultivation, (as found by the soil survey), is assumed to be 95 per cent. of the areas suitable for rice, the balance, 5 per cent., being depressions, and occasional fallows. The rice cultivation area is thereof multiplied by 100-95 to give the area of rice lands. This area is deducted from the total culturable, leaving the balance of culturable land, suitable for perennial cropping. Of this perennial culturable area, on any given distributary, the total intensity of cropping is taken as 82 per cent. (as in the Rohri Canal area). Out of this total of 82 per cent., the ratio of rabi to dry kharif is varied, between 2 to 1 and 3 to 1, so as to give the rabi discharge of the channel, as nearly equal as possible, to the total kharif discharge, (rice plus dry kharif).

(*c*) Rice Canals of the Right Bank and Eastern Nara Systems—90 per cent, of the culturable area is taken as being rice land, and 10 per

cent. as being suitable for dry kharif crops. Of the rice lands, 95 per cent. is allowed for rice cultivation every year, and of the dry kharif lands 50 per cent. is allowed for cultivation each year, so that total cultivation is 90·5 per cent. of culturable, annually.

DISCHARGE OF CANALS.

The full designed seasonal discharges, required at canal heads, for the final development of cultivation, as above, are shown below :—

Canal.	Total Kharif Cultivation and discharge.		Rabi Cultivation and discharge.	
	Acres.	Cusecs.	Acres.	Cusecs.
Left Bank.				
Rohri Canal - - - -	698,300	10,250	1,355,000	9,900
Khairpur State Feeders - -	298,000	4,034	200,000 (bosi-rabi)	3,000
Eastern Nara System - -	646,000	12,300	914,500	6,787
Right Bank.				
Central Rice Canal - -	493,423	12,346	Nil	Nil
N.-W. Perennial Canal - -	269,127	4,313	545,922	3,639
S.-E. Perennial Canal - -	151,367	2,787	347,471	2,525
	2,556,217	46,030	3,362,863	25,851

RATES OF ASSESSMENT PROPOSED.

The present average rate of assessment for rice crops varies in different districts from Rs. 4-3-0 per acre to Rs. 6-8-0, according to the security of the water supply; the higher rate being charged on the Jamrao Canal, where the supply is fairly well assured. For the guaranteed supply, to be given by the new canals, for a much longer season, the rates proposed vary slightly, with the varying conditions of the tracts. On the Right Bank, which is suited for the highest grades of rice, the rates proposed are somewhat higher than on the Left Bank, where, in the Rohri Canal, and Eastern Nara, tracts, the soil is not quite so suited for the highest grades of rice, and the rates charged are, therefore, slightly lower (see table below). On the other hand, cotton is already well established on the Left Bank, and the conditions very favourable, while on the Right Bank very little cotton has yet been grown, (owing to unfavourable water supply) and it needs encouragement. The rates on the Right Bank are, therefore, somewhat lower, for the first 20 years, than on the Left Bank. Rabi rates are the same on both banks, as the conditions are similar. The present, and proposed, rates are shown in the tables below, from which it will be seen that the increased rates, for a guaranteed *flow* supply, for a long season, as compared with the present unreliable supply, which frequently fails to give flow water, are not much higher than the present maximum rates, Unwatered Dubari, on rice lands, at present pays a small rate, but in future would be free, in order to encourage restorative crops. On the Right Bank there will be small areas, not commanded by *flow* water. These will have a *lift* supply, and the rates charged will be *half* the flow rates.

The great areas of existing lift lands, at present, pay assessments of about *two-thirds* the flow rates. For the financial forecasts, kharif cultivation in Jagir lands, has been assessed at one-quarter the rates charged to Governement lands, and the rabi cultivation at one-half the rabi rate for Government lands. These Jagir lands have always had a (more or less precarious) kharif supply, but the proposed rabi supply is entirely new, and they can take or leave it as they wish. There is no doubt it will be eagerly taken. Whether or not such a great rebate for these lands can be justified is doubtful, but it has been allowed, for safety in the estimates.

The new canals will be opened in sections, at different periods, as work progresses. Until each given area is converted to the new water supply it will remain on its present rates of assessment. As soon as converted the new rates will apply to each such section, for ten years; then the next higher rate will apply for ten years ; and thereafter the highest rate will apply.

Crop.	Proposed Rates of Assessment. *All for Flow supply*			Present Rates of Assessment.		
	First 10yrs.	Second 10yrs.	Third 10yrs.	Flow maximum.	Flow plus lift maximum.	Lift. maximum.
LEFT BANK CANALS.						
Rice .. -	7-0	8-0	9-0	7-8	..	..
Cotton - -	5-8	6-8	7-0	5-0	4-4	3-8
Other Kharif -	4-0	4-0	4-8	3-4	2-11	2-2
Rabi (wheat and oil-seeds.	5-0	6-0	6-0	4-4	3-10	2-14
Leguminous (kharif for rabi). -	2-8	3-0	3-0	same as other kharif or rabi.		
RIGHT BANK CANALS.						
Rice - -	8-0	8-0	10-0	5-12	..	..
Cotton - -	5-0	6-0	7-0	3-0	..	..
Other Kharif ..	4-0	4-8	4-8	3-12	..	3-2
Rabi. (wheat and oil-seeds) - -	5-0	6-0	6-0	..	4-12	4-0
Leguminous (kharif or rabi) - -	2-8	3-0	3-0	same as other kharif or rabi.		

LIFT RATES HALF ABOVE.

ANTICIPATED GROWTH OF CULTIVATION.

As already stated, the final anticipated area of annual cultivation is 81 per cent. of the culturable area. The present area of cultivation is about 43·5 per cent. of culturable. The increase, from the present intensity of 43·5 per cent, to final intensity of 81 per cent., after 30 years, is assumed to occur very gradually, year by year; but as rice extends very rapidly when a good supply is available, there will be a large increase almost immediately the new canals are opened. The following statement shows the present, and estimated, cultivation under the whole scheme. The increase is more rapid on the rice canals, and less rapid on the perennial canals.

	Acres.
Present annual cultivation in this area and percentage of culturable area *now* commanded (4,677,000)	2,036,037 43·5 p.c.
Total culturable area under the project	6,529,705
Anticipated cultivation ten years after opening of canals and percentage of culturable	3,440,288 52 p.c.
Anticipated cultivation twenty years after opening	4,060,828 65 p.c.
Anticipated cultivation thirty years after opening and thereafter	5,308,408 81 p.c.

On the Punjab perennial canals, the actual intensity of annual cultivation is well over 90 per cent. of the culturable area, while in some of the largest rice areas in Sind, the present annual cultivation exceeds 75 per cent. of the culturable area.

The project forecast, would therefore, seem to provide a very safe estimate of the probable growth of cultivation.

The following figures show the approximate present quantities of crops grown, and exported, and the anticipated future quantities, after final development of the tracts affected by the project. They give some indication of the enormous increase which may be expected in the export of commodities, such as wheat, cotton, rice, etc., which are in world-wide demand. It is believed that the figures shown for exports, would necessitate doubling the present capacity of the Port of Karachi, and possibly increasing the capacity of the North-Western Railway ; while numerous feeder railways would find a lucrative field of enterprise, in carrying the produce to the main railway. Apart from the direct revenue, from the sale of water and land, on which the productivity of the scheme is calculated, there will be further great indirect gains to the State, due to the enormous increase of traffic on the North-Western Railway, and at the Port of Karachi : while the increased trade and wealth of the Province will react on income-tax, and other sources of revenue. No credit is taken in the project for any of these gains to Government, which will be due entirely to the construction of the Barrage and Canals. The construction of these great works will also have important and beneficial political effects, both in Sind and Baluchistan.

Approximate quantities of crops in the Barrage Canal areas :—

Crop.	As grown at present. Tons.	Anticipated after final development. Tons.
Wheat	68,600	935,000
Rice	280,000	515,000
Cotton	52,000	190,000
Jowar and other crops	300,000	575,000
Exports	183,000	1,380,000

In a final article we shall deal briefly with the financial side of the project.

THE FINANCIAL ASPECT.

VI.

In our five previous articles on this subject, we gave a full account of the present and proposed systems of irrigation in Sind, and a brief description of the proposed Sukkur Barrage, and the great canals to be fed by it. We also explained the present and proposed systems of assessment for water and land rates, and the revenue to be derived therefrom.

In this final article on the subject we shall explain briefly the financial aspect of the scheme.

DEFINITION OF A "PRODUCTIVE" PUBLIC WORK.

In submitting a Project for a Productive Public Work, for the sanction of the Secretary of State, the Public Works Department has to show that the scheme, as estimated, satisfies the following condition, *viz.*,

"There must be good reason to believe that the revenue derived from it will, within ten years after the probable date of its completion, repay the annual interest on the capital invested, calculated at 5 per cent. (now 6 per cent,) but in preparing a project for sanction no deduction is to be made from the total capital outlay on account of anticipated excess of revenue over simple interest.

"*Note*: Capital invested includes (1) Direct charges, (2) Indirect Charges, and (3) all arrears of simple interest, if any, *i. e.*, balance of total interest over total net revenue."

AN EXPLANATION.

One point in this definition will immediately strike the business man, *viz.*, that only *simple* interest on outlay is to be calculated. Actually, of course, Government must bear the cost of *compound* interest charges until such time as the project revenue is sufficient to meet the annual simple interest. This is to say, Government must meet the annual interest charges, on all accumulated arrears of simple interest, until such time. But such compounding charges are not debited to the Project, and are usually met from the general revenues of the country, for this reason, *viz.*, that after the project becomes "productive," *i.e.*, after the revenue from it is *more* than sufficient to meet the annual interest charges, no credit is given to the project, in reduction of capital outlay, for any such surplus revenue, which all goes to the general revenues of the country. But such surplus may be applied to paying off the accumulated arrears of interest. **A simple example** will explain this.

Suppose the total direct and indirect expenditure on a project is 1,000 lakhs of rupees, and that by the time the work becomes "productive"

(say 6 years after completion), the accumulated arrears of simple interest amount to 150 lakhs. Then the total "capital invested" in that year is 1,150 lakhs, and the interest charges on this sum at 6 per cent. per annum come to 69 lakhs. If the net revenue from the project is 70 lakhs, the project is "productive" and pays 6·1 per cent. Assume the net revenue goes on increasing with the development of irrigation, as follows :—

	Net revenue.	*Surplus over simple interest.*
7th year after completion	75 lakhs per annum	6 lakhs.
8th ,,	80 ,,	11 ,,
9th ,,	85 ,,	16 ,,
10th ,,	90 ,,	21 ,,
11th ,,	95 ,,	26 ,,
12th ,,	100 ,,	31 ,,
13th ,,	105 ,,	36 ,,
14th ,,	110 ,,	41 ,,
15th and thereafter	115 ,,	46 ,,

Then in each year, from the 6th year onwards, there is a surplus over the simple interest charges, *i.e.*, the net revenue gives a return varying from 6·1 per cent. in the 6th year, to 10 per cent. in the 15th year and thereafter, on the total capital invested. As will be seen this surplus amounts to a very large sum, and by the 13th year has more than paid off the 150 lakhs of arrears of interest. In the next year the surplus far more than compensates for the compounding charges which Government had to pay, on the 150 lakhs of arrears of simple interest, which accumulated during the years of construction and up till the 6th year after completion. After the 14th year all such surplus is gain to Government revenues, and is not applied to the reduction of the capital of the project.

Many "productive" works in India, if credited with their surplus revenues, could bear all compound interest charges, and also wipe off the whole of their capital cost, in a few years after reaching completion.

THE ORIGINAL FINANCIAL FORECAST.

Having now explained the method of accounting, adopted in the preparation of the financial forecast of an irrigation project, we will examine that of the Sukkur Barrage Canals Project of 1919-20. At the time this project was prepared, the orders of the Secretary of State were that interest should be calculated at 5 per cent. per annum. (This has now been increased to 6 per cent.) The cost of the project will be 1,844 lakhs for direct and indirect charges, and it was shown on this 5 per cent. basis that, in the 9th year after completion, the accumulated arrears of simple interest amounted to 356 lakhs, making the total capital invested Rs. 2,200 lakhs. The net revenue in that year was shown to be 115·5 lakhs, or 5·17 per cent. on the total capital invested: *i.e., on a 5 per cent. basis* of calculation, the project was "productive" in the 9th year after completion, since the net revenue exceeded the interest charges.

GIVING AWAY VALUABLE LANDS.

This net revenue included revenue from water rates (as detailed in our last article), and also interest at 5 per cent. on realizations from the occupaney fees, obtained for the grants of vacant Government lands. These occupancy fees, credited to the project, were based on ridiculously low estimates of area and value, simply because,—as they were not needed to ensure the productivity of the project,—the archaic practice hitherto ruling in Sind, of giving out vast areas of valuable land to the local zamindars, at a mere fraction of their value, was assumed to continue. Thus it was assumed in the project that, out of a total area of over 1,500,000 acres of unoccupied culturable lands, only 540,000 acres would be paid for at all, and that these 540,000 acres would produce only 10 rupees per acre, in occupancy fees, or a total of Rs. 54 lakhs. The price at which similar good lands are sold privately in Sind varies from Rs. 300 to Rs. 1,000 per acre, according to water-supply and locality. Thus, in the Project, credit was taken for interest at 5 per cent. on Rs. 54 lakhs only, from the sale of lands. Even so, the Project was "productive" on a 5 per cent. basis of calculation.

THE INCREASED COST OF BORROWING.

When the Secretary of State's orders were received to increase the basis of calculation from 5 per cent. to 6 per cent. for borrowed capital, the financial prospects of the scheme had to be entirely re-casted, and with the original proposal for raising revenue, the Project was no longer "productive."

With the increased cost of borrowed capital, and the original revenue, the latter did not exceed the interest charges on total capital invested (included accumulated arrears of interest), until the 16th year, after completion, when it would pay 6·17 per cent. In the 10th year after completion it would pay only 4·95 per cent. With the revenue originally estimated for, the scheme is therefore not a "productive" project, and cannot be sanctioned as such.

NEED OF FURTHER REVENUE.

Hence, unless this great beneficial Project was to be abandoned, it was necessary to find some means of increasing its productivity.

No one can contend that any portion of the areas affected has a satisfactory water supply at present, and the cultivators and landholders themselves are the most insistent on improvements being carried out; so there could be no question of abandoning the Project until further efforts had been made to improve the financial prospects.

It was not considered prudent to reduce the estimate of capital cost of the works, though there may be savings under some heads, owing to the steady reduction in the cost of plant and machinery. It was, therefore, necessary to increase the revenue.

THE POSSIBILITIES.

This could be done in several ways, *viz.*,

(*a*) By hastening the period of construction, and therefore reducing interest charges.

(*b*) By accelerating the estimated rate of development of irrigation.

(*c*) By increasing the charges for water.

(*d*) By increasing the area of lands to be disposed of, and the price at which it should be sold.

(*e*) By selling lands before completion of the works, or before irrigation begins, and from the proceeds help to pay the interest charges during construction.

Each of these possibilities will be examined below :—

(*a*) The programme of construction has been worked out on a fairly conservative basis, allowing for rapid and efficient progress with the most up-to-date methods. It is quite probable that the period allowed for may be improved on, and the works completed in considerably less time, but it would be unwise to base the success of the Project on this probability. No change is, therefore, proposed in this programme.

(*b*) The rate at which, in the Project estimates, cultivation is calculated to increase in the present occupied areas, and to extend into the present unoccupied areas, is based on an extremely safe estimate ; and in actual practice, this estimate is almost certain to be surpassed very greatly. But so many factors affect this matter,—chiefly the confidence and industry of the people,—that it is advisable to retain a very safe estimate, which allows for possible set-backs, and the training of the people by easy stages. No change is therefore proposed in this estimate.

LOW ASSESSMENTS.

(*c*) The assessments proposed in the Project are consolidated assessments for water and land rates. As shown in our last article, these are based on an incremental scale, increasing after 10 years and 20 years from the date of commencement of the new water-supply. The rates for the first 10 year period, undoubtedly are pitched very low for the vastly improved regular water-supply that will be given to all crops ; and it is the opinion of many experts that the rates of the second 10 year period might be applied from the very eginning. Many zemindars also admit that still higher rates could easily be paid for an assured supply of water, but very few of them are able to believe that the new works really will give them that security of supply, which they have never yet experienced in Sind, with the existing inundation canals. It is one thing for the engineers designing the project, and the officials who

will administer it, to know for a certainty that this security can be absolutely guaranteed. But it is quite another matter to make the cultivator believe and realise this, before he has actually seen it, and has experienced the security for some years. He and his ancestors have been so accustomed to alternating periods of a few good years, followed by a few, or more, bad years, that until he has seen the good supply last for several years continuously, he cannot be expected to attain full confidence in this security. Hence, it is advisable to keep rates considerably lower than the actual value of the water, and not greatly above present rates, until the cultivator has gained experience, and realises that it is an excellent investment for him to pay a good water rate, and thus obtain a greatly increased value for his crops. Moreover, it is *unnecessary* to charge all cultivators with higher rates of assessments than those already proposed, if those zemindars obtaining *other* advantages pay a fair value for them, as will be explained in the following paragraphs.

ARCHAIC CUSTOMS.

(*d*) The new canals are designed not only to improve the water-supply of existing cultivated lands, but to give this improved supply to vast areas of new lands, now unoccupied for want of water, but which will grow excellent crops, and be of great value, as soon as a regular water-supply is given to them.

As already stated, there are more than 1,500,000 acres of such unoccupied culturable lands, which are the property of the State. There would have been a far greater area of such lands, available for sale, had not immense areas been given out in past years to present landholders in Sind, who already had far more lands than they could cultivate. Such lands have been given away or "sold" at ridiculously low valuations. Thus, in the past 20 years ending 1920-21, no less than 923,000 acres of good culturable land, in the Barrage Canals Zone, were given out to present landowners, on payment of a total sum of Rs. 36,85,000 or at an average price of less than Rs. 4 per acre. In the last of these 20 years, namely, 1920-21, the area given out was 7,081 acres at an average price of Rs. 24·3 per acre. One of the curses of Sind to-day is that most of the land is in the hands of landholders who own far more land than they can cultivate, even in years of favourable water-supply.

The reason of these great grants of land is an archaic custom of half recognising a claim known as the "Mohag" rights of existing landholders. This Mohag claim has never been clearly defined, and indeed has never had any real recognised meaning. It probably originated in the following way. When two neighbouring zemindars each excavated a water-course from a canal, to irrigate his own lands, if these lands were separated by a strip of unoccupied Government land of reasonable width, each zemindar was supposed to have a claim, superior to that of any third

party, to obtain the grant of half this strip of land. Similarly, if on any frontage of his holding, lay a strip of unoccupied land, the granting of which to another man would have cut off communications, or caused serious inconvenience, to the existing zemindar, the latter was supposed to hold a prior claim to the grant of such land.

In some few cases there was a reasonable justification for allowing such claims within moderate limits, but the custom has been abused and expanded to such an absurd extent, that any zemindar will now claim, under his Mohag, all unoccupied lands anywhere in his neighbourhood, with no limit apparently, except the horizon ; and no rules have ever been formulated to define the limits of grants under these claims. There are undoubtedly some cases where the grant of small areas to outsiders might cause considerable inconvenience to present landholders, and in such cases the latter should be given preferential treatment and the first option of purchasing. But such conditions can never apply to large blocks of unoccupied land, of 50 or 100 acres, or more, and they do not even apply to the great majority of the smaller blocks.

GENEROUS TREATMENT FOR PRESENT LANDOWNERS.

It is proposed, therefore, to provide for all such claims on a very liberal basis, by reserving for individual consideration all blocks of small area, which may, or may not, be granted on preferential terms to neighbouring landowners, as may be found equitable.

In the whole Barrage Zone, out of 1,500,000 acres of unoccupied culturable land, an area of 350,000 acres, consisting of small blocks, has been thus reserved ; and for estimating purposes only, it has been assumed that this area will be granted at an average price of Rs. 15 per acre. These lands will all be given an absolutely assured flow water-supply all the year round. As noted above, the average price on which lands were granted in 1920-21 was Rs. 24·3 per acre, and these lands have at present only an uncertain and fluctuating water-supply for four months in the year.

It will be seen, therefore, that the assumed price for future grants is a very low estimate, and covers a very great area. In actual practice it will certainly be found that far less area has any claim to preferential treatment, and that the assumed price is much below a fair preferential value of the land. However, these variations will merely create an extra reserve in favour of the Project, and give a very wide margin of safety.

FAIR AND BUSINESSLIKE SALES OF LAND.

The remaining area of 1,150,000 acres of unoccupied culturable lands, in the Barrage Canals Zone, is all in large blocks, for which there can be no preferential claims ; and this area is, therefore, available for sale to the highest bidders.

The Project cannot be carried out unless extra revenue can be obtained, and there is no conceivable justification for increasing the proposed water rates to *all* zemindars, in order to give away this great area of vacant

lands, at prices far below their true value, to *some* zemindars with no vestige of claim to them. By selling these lands at reasonable prices, to the many who desire to buy them, it will be possible to keep the assessment for water-supply at a reasonable figure for *all* zemindars, on both existing, and newly, cultivated lands.

These principles having been defined, it remains to arrange a programme of sales on the most beneficial and economical plan.

A PLAN OF OPERATIONS.

Innumerable plans may be devised, and it is only necessary to describe one such feasible scheme, and to show its financial results. In the first place, it must be noticed that for the construction of these great works, both for the Barrage itself, and for all the great Canals, a very large quantity of expensive plant and machinery will be required from the very commencement to ensure rapid execution of the Project. The capital required to purchase all this plant and machinery must be borrowed, and interest has to be paid on it from the very start, while no assessment revenue will come in, until irrigation begins in the 7th year after commencement of works.

If no lands are sold until irrigation begins, then the interest charges, in the first seven years, must be paid entirely from further borrowings, on which again interest must be paid.

Hence, the sooner lands are sold the less will be the borrowings and the compound interest charges to be paid.

ADVANCE SALES AND VALUES.

But if lands are sold several years before irrigation commences, or before the works are in full swing and have given the prospective purchasers some confidence in the approaching water-supply, it cannot be expected that such sales would realise the eventual full value of the lands when irrigation is available.

The reduced prices to be obtained for such advance sales cannot be calculated by ordinary rules for discounting the present value of a future sum. The actual prices realised will be less than such calculations would show. The question of confidence and speculation will enter very largely into such prices, and here an intimate knowledge of the people, and of the present conditions, is required to forecast approximately what prices may be expected.

It would certainly be more profitable to borrow all capital, and sell no land, until irrigation had already begun ; but in order to reduce borrowings, and also in order to enable new lands to be prepared for irrigation, and the people and cattle organised, as soon as water is available, it is desirable to sell some areas in advance at lower prices.

The areas to be sold each year in advance will actually be decided at the time, and can be adjusted to suit the demand, the prices realised, and the sum required, to affect most beneficially both the people and the Project.

But for estimating purposes, a scheme must be assumed, and the following description is of one such feasible plan, and shows the financial results which would follow from its adoption.

A PROGRAMME OF SALES.

Sales in open auction would commence in the third year after starting construction, *i.e.*, four years before irrigation begins. At the same time would begin grants of the small blocks at the preferential rates, to those having real claims to preferential treatment for such lands. In this year about 10,000 acres would be sold in open auction, and about 10,000 acres granted on preferential rates. The price assumed for the auctioned lands in this year would be only Rs. 100 per acre. Sales would increase regularly from the third to the seventh year (when irrigation begins), and in the latter year would be about 38,000 acres auctioned, at an assumed full price of Rs. 150 per acre, while 30,000 acres of small blocks would be granted at the preferential rate of Rs. 15 per acre. Thereafter, sales would increase steadily, year by year till the seventeenth year (10 years after commencement of irrigation), when a maximum area of 66,000 acres would be sold by auction at Rs. 150 to Rs. 250 per acre. Up till this time 90 per cent. of the lands sold by auction would be first-class lands, and 10 per cent. would be second-class lands unavoidably intermixed with the former. Thereafter, the remainder of the second-class lands would be disposed of, from the 18th to the 26th years, at an assumed rate of Rs. 50 per acre, by annual areas diminishing from 65,000 acres in the 18th year, to 35,000 acres in the 26th year.

From the 8th year till the 15th year, 30,000 acres annually, of small blocks, would be available for granting at the assumed preferential rate of Rs. 15 per acre.

By this plan, the total area of land disposed of up to the 26th year from commencement of works would be as follows :—

(*a*) *By auction.*

605,000 acres of first-class lands.

520,000 acres of second-class lands.

1,125,000 acres total.

(*b*) *By grant at Preferential Rates.*

350,000 acres of first and second-class lands.

SAFE ESTIMATES.

It may be noted that, in the above forecast, the maximum price assumed for first-class rice lands is Rs. 250 per acre, and for first-class perennial lands is Rs. 150 per acre, when water is actually ready to flow on the lands. While for second-class lands the price assumed is only Rs. 50 per acre. All these lands will be given an absolutely assured water-supply all the year round, for perennial lands, and six months for the rice lands.

When it is remembered that the present water-supply from the irrigation canals to rice lands, never lasts longer than 5 months, and often fluctuates badly and that these lands now sell at prices varying from Rs. 300 to Rs. 1,000 per acre according to quality, water-supply and locality, it will be realised that the above estimated rates are extremely low.

For perennial lands there is no comparison available in Sind, as there is nowhere a real perennial supply ; but at recent Government auction sales (1919-20) of waste lands in the Punjab, the price realised for land of average agricultural quality was over Rs. 1,000 per acre.

It is obvious, therefore, that the rates assumed above, namely, Rs. 150 per acre for first-class lands, and Rs. 50 per acre for second-class lands, are also extremely low estimates.

A HANDSOME RETURN ON OUTLAY.

But with these assumed rates, and the programme of sales outlined above, the Project would become productive, *i.e.*, pay more than 6 per cent. on all capital invested (including accumulated arrears of interest), in the third year after completion of works, or in the 15th year from commencement of works. In the 10th year after the completion of works (the test year according to P.W.D. Code), the Project would pay 10·4 per cent. on capital invested : in the 20th year after completion it would pay 13 per cent. and in the 30th year after completion, and thereafter, it would pay 14·6 per cent., on all capital invested. All accumulated arrears of interest would be paid off by the 9th year after completion of works.

The maximum amount of capital which must be borrowed will be about Rs. 16 crores.

The final capital invested will be Rs. 1,836 lakhs, and the final net annual return, at 14·6 per cent. represents a net profit to Government (after paying all interest charges), of 8·6 per cent. on the capital outlay, or a *net surplus of Rs.* 158 *lakhs per annum* for the benefit of the general revenues of the Province.

Thus it will be seen that this great Project can be carried out with vast benefit to the people of Sind, and at the same time to the very great profit of the Presidency as a whole.

The estimates of the cost of all works have been based on careful and sufficiently liberal rates, which should not be exceeded, and may probably be found more than sufficient ; while it is hoped that the above explanations show that the estimates of revenue, from all sources, are based on most conservative low rates.

THE LEGISLATIVE COUNCIL'S OPPORTUNITY.

It is expected that the Secretary of State for India will very shortly signify his approval to the proposals of the Government of Bombay for financing the work. It will then only remain for the Bombay Legislative Council to approve the whole Project and permit the start of construction.

It can hardly be doubted that our wise legislators will approve this great scheme, which will bring such abounding prosperity to Sind, and such great profit to the funds of the Presidency. They may also take some legitimate pride in reflecting that they are inaugurating what is by far the greatest irrigation scheme in the world.

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