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JOSEPH CUBITT, Vice-President,
in the Chair.

No. 1,318.—“On the Value of Water, and its Storage and Distribution in Southern India.”¹ By GEORGE GORDON, M. Inst. C.E.

It is not intended in this Paper to discuss the value of water in its widest sense, or to consider the indirect benefits which would follow the control and abundant distribution of the enormous wealth of water now, for the most part, rolled into the sea—benefits among which are to be reckoned, the prevention of famines and of scarcity in the districts concerned, as well as the permanent improvement of agriculture, and the numberless social and political advantages resulting from enhanced prosperity and increase of population.² The object of this communication is rather to afford, from well-authenticated data, some means of estimating the more direct profits of works of irrigation which have been, or could be, undertaken as commercial speculations in the present day. For this purpose some preliminary remarks on the works employed for storage and distribution, on the ancient and modern systems, seem needful.

I. TANK IRRIGATION.

The existing tank irrigation dates chiefly from ancient times. The number of tanks, large and small, in Southern India is enormous; some of them attain the dimensions of lakes, others suffice only for the irrigation of a few acres. They may be divided into three classes: 1st. Where advantage is taken of a narrow gorge in a range of hills, to close the passage of a river, by a dam or embankment of considerable height, and so to convert the valley above into a lake. 2nd. Tanks formed by the construction of embankments across one or more streams in the flat country, this class being often of considerable superficial extent, but compara-

¹ The discussion upon this Paper occupied portions of three evenings, but an abstract of the whole is given consecutively.

² The population of the Bellary district, which is unirrigated, is 109 to the square mile. The irrigated districts of Tinnevely and Tanjore support populations of 343 and 442 to the square mile respectively.

tively shallow. 3rd. Such as may be considered intermediate between the 1st and 2nd classes.

Most of the tanks of the 1st class are now ruined. In many cases the earthen embankment has been breached, in consequence of the water finding a passage along the outside of the discharge culvert, which was generally placed under the embankment, and not in a tunnel at a distance. The dams were, it is believed, invariably made of earth, without any puddle core, and the inner slope was always protected with heavy stone pitching.

The Author is not aware that high masonry dams were ever constructed for storage purposes in Southern India; but there is, near Ahmednuggur, in the Bombay Presidency, an instance of the combined use of masonry and earth, in a dam for a large ancient tank, described by Colonel Fife, R.E., in the Roorkee Prof. Papers, Vol. V. This dam, however, was never finished.

The number of disused tanks, of all sizes, is very remarkable. Many of these are not breached, but the discharge culvert is left open, and no water is collected. In many cases this is, probably, owing to the bed of the tank having been gradually raised by silting, and converted into so productive a soil, that it yields as much as, or more than, could be obtained by means of the diminished quantity of water applied to the comparatively barren soil below the tank; but generally it results from the ascertained fact, that the rainfall in some districts has materially diminished (markedly so even within the memory of man), on which account the tanks would never fill, and in most years would receive so small, and especially so uncertain a supply, as to render wet cultivation to any large extent not to be depended on. Dozens of such abandoned tanks are met with in the hilly parts of the Ceded Districts; as, for instance, along the foot of the inner slope of the eastern Ghâts, where, in many cases, both the bed of the tank and the cultivated land below it have reverted to jungle.

A good specimen of the tanks of the first kind is one which the Author was deputed to examine a few years ago, with a view to its restoration. A short description of it will afford an idea, both of the construction of ancient works and of the untrustworthy nature of the data which old works seem to afford for the construction of new works.

Description of the Mudduk Masoor Tank (Plate 7, Fig. 1).

This great work is believed to have been constructed under the Annagoondy dynasty, about four centuries ago. It was formed by an embankment, resting on the sides of a narrow

gorge through which the river Choardy passed, supplemented by two bunds, or dams, on saddles in the range of hills; that on the east being 1,350 yards, and that on the west 670 yards from the main bund. The length of the main bund is 550 yards on the top. The inside slope, of $2\frac{1}{2}$ to 1, in some parts 3 to 1, was revetted with large stones, up to a cubic yard in bulk. It is from 945 to 1,100 feet broad at the base, and is now from 91 to 108 feet high. There was a sluice under the dam at the east end about the level of the ground. The dam is composed of a strong red earth, with a considerable admixture of gravel, taken from the sides of the hills on which it rests. The east supplemental bund has its base 74 feet above the sluice in the main bund, and had also a sluice under it at the ground level. The west supplemental bund, the breaching of which destroyed the tank, seems to have been of similar construction to the others, and its base was perhaps 50 or 60 feet above the bed of the tank. There is no trace of any waste-weir, and it is probable that the want of this was the cause of the ruin of the tank. On the main bund there are what seem to be traces of the water having topped it, and having cut into the rear slope in two deep gullies. The west bund had, probably, a sluice in it which weakened it, as cut stones were found in the river some way down. After this bund was breached, the water cut into the ground on which it stood to the depth of 100 feet, and would have completely emptied the tank but for a reef of rock some distance from the dam, on the inner side, which now causes a waterfall 25 to 30 feet in height, and retains about 10 feet of water in the tank. On this reef a weir has been built.

From the heights of the dams and the levels of the sluices, it is probable that the depth of the tank was 90 or 95 feet, and at that level its area would have been 40 square miles, and its contents about 1,400 million cubic yards of water. The drainage basin is about 500 square miles, and three-fourths of it lies within the jungly district containing the spurs of the western Ghâts. It is found, from observations of the discharge of the river, that a good average monsoon supply would not exceed 668 million cubic yards, or 16 inches running off. It is not probable that the average annual rainfall so near the Western Ghâts has diminished much, although it may, to some extent, from land having been cleared of jungle; nor is there anything to show that the ancient tank filled every year. The difference between the present supply, and what it must be supposed to have been when the tank filled and was breached (even supposing that to have occurred in an exceptional year) is probably owing, in part, to the construction of small

tanks on some of the feeders. The tank, as proposed to be restored, would have contained about 644 million cubic yards; and the results are given subsequently. As regards capacity, this is the largest reservoir in Southern India of which the Author can find any record.

Tanks of the 2nd Class : Flat-country Tanks.

These are so numerous in some districts that, looking at a map, it would appear as if as much land is occupied by tanks as is left to be irrigated by them; and where the tanks are very shallow, this would be necessary for complete irrigation. But in reality, many of these tanks are breached or abandoned, and their beds cultivated. The embankments of flat-country tanks are often of great length, not unusually 1 mile or 2 miles, while that of the Veeranum tank is 12 miles, and the ruined bank of the Poonairy tank, in the Trichinopoly district, is said to be 30 miles in length. Their height is generally inconsiderable, being, in many hundreds of cases, only sufficient to hold 10 feet, or even 6 feet of water. Some works, however, of this, or of the intermediate class already mentioned, are (or were) 20, 40, and even 60 feet deep. The inner side is generally revetted with stone, and has a slope sometimes of 1 to 1, but oftener of 2 to 1, or more. In some cases it is a masonry wall backed with earth. Clay puddle is not used in forming the banks, but the best earth in the immediate neighbourhood is employed, and the dimensions are made large and sometimes excessive. The height above the water-level varies; for instance, the Nundyal tank bund (Fig. 4, Plate 7) is, at one place, 18 feet high, 2 feet above the water-level, 16 feet wide on the top, with an inside slope of 1 to 1 and an outside slope of $2\frac{1}{2}$ to 1. The Kolevoy (Fig. 5) tank in the Nellore district has a bank 36 feet high, 9 feet above the water-level, a top width of 12 feet, and slopes, inside and outside, of $1\frac{1}{2}$ to 1.

Tanks of the 3rd, or Intermediate Class.

Of this class, the Darojee tank (Fig. 6), in the Bellary district, is a good example. The embankment is about 2 miles in length, and rests on two rocky hills, two small hillocks being also included in the line of the bank. The area, when full, is about $2\frac{1}{4}$ square miles. Its height is about 40 feet, the depth of water being 26 feet at the level of the waste-weir. This is of modern construction, and 400 feet long, the old native one having been breached. The contents of this tank are roughly estimated at 25 million cubic yards.

II. CHANNEL IRRIGATION.

As the smaller streams in Southern India are merely torrents which quickly carry off heavy falls of rain and then become dry again, their powers of supply being reckoned by hours at a time rather than by weeks or months, they are, if utilized for irrigation at all, in most cases intercepted by chains of tanks of the 2nd or 3rd class built across their course. Therefore it is only the more important rivers that can supply means of extensive irrigation by channels diverted from them, and it is believed that all of these rivers were, to some extent, laid under contribution in former times.

Naturally their deltas formed the best ground for irrigation, and, consequently, the Godavery and the Kristna deltas, and the lands in the lower parts of the course of the Pennair, Palar, Cauvery, &c., have been, to a large extent, irrigated for ages, and the works have been much extended and improved by the British Government. It is chiefly from these exceptionally favoured districts that the wonderful—and in some cases almost incredible—results of channel irrigation have been obtained. As descriptions of many of these works are accessible to the members, it seems unnecessary to occupy time in giving any account of them in this Paper, further than to say that, with one important exception, the conditions under which they were constructed are as favourable as they could be, viz., ground sloping moderately towards the sea and from the river—the source of supply, so that distribution of the water commences almost immediately; the absence of deep or hard cuttings in the canals; and, in the case of the modern improvements, the presence of a considerable population accustomed to the construction of such works and alive to the advantage of their extension. The one disadvantage referred to is the difficulty of constructing and maintaining weirs across the wide sandy beds of the rivers. This was beyond the skill of the native constructors. Very interesting accounts of some of these works will be found in the Professional Papers of the Madras Engineers, and in the Government records in the Library of the Institution.

But it is not only in the deltas that the rivers are tapped. In the middle reaches of the large rivers also there are many ancient weirs, generally admirably situated, but of rude and imperfect construction, so that many are ruined and others require extensive annual repairs. Advantage was usually taken of a reef of rocks running across the river, the low places being filled in with rubble,

faced on both sides with large blocks of stone laid dry, occasionally fastened together. There is some leakage through the body of these native weirs, but not sufficient to account for the fact that, although they are not provided with scouring sluices, the bed of the river on the upper side of them has in several cases not been raised, as is the case where weirs have lately been built with scouring sluices at one end or both.

Where new weirs have been built on rock, they are generally of masonry, with a vertical or slightly battering face on the lower side. It is frequently necessary to protect the rock from the action of the falling water by a water cushion, formed by a low wall built a short way below the weir. The Author has seen a block weighing several tons picked out of what seemed, before the weir was built, a solid bed of gneiss with no visible seams; the height to the crest of the weir was, speaking from memory, not more than 7 feet, and there may have been 5 or 6 feet going over the crest. The Author knows of no rule for determining the depth of the water cushion, by the height of the fall and the volume of the water. The greatest depth of the hole formed by the water-fall in the new outlet of the Mudduk Masoor tank is 24 feet. At the low state of the river, the height of the lip of the fall is $27\frac{1}{2}$ feet above the surface of the water below. In ordinary states of the river, the general depth of the cushion, or well, is to the height of the fall as 3 to 4 where the greatest action takes place, and 1 to 2 in the other places. At the Gairsoppa Falls, in the Western Ghâts, the Rajah fall, which through its whole height falls clear of the rock, is 825 feet high, and the pool into which it falls is 138 feet deep in the low state of the river. Perhaps 8 feet on the edge of the fall would be the depth in floods, and then the surface of the cauldron below, if it could be said to have one, would be raised many feet: it would be impossible to measure it. An experimental fall on the Baree Doab canal (Fig. 3, Plate 7) had a height of 6·9 feet, depth of well 9 feet, and 3·6 feet on the crest, which gives the depth of the well to the height of the fall as 3 to 4; and it is said the water had no injurious effect on the bottom of the well, and that a bottle, loaded so as to be of the same specific gravity as the water, and passed over the fall, did not reach the bottom by a foot and a half.¹ As an illustration of the force of the water, where the volume and height are both considerable, but by no means exceptional, a sketch from measurements by Major

¹ The subject of water cushions is one which is well worthy of attention, but is too extensive to be included in this Paper.

Johnson, Assoc. Inst. C.E., is given in Fig. 2, showing the boil of the water below the Sreeramadavara dam, in Mysore.

In sandy-bedded rivers, the modern practice is to build the weir on a foundation of wells filled with concrete, to give it an apron sloping about 1 in 12 from the crest, with a toe wall, and if the slope is long, one or more intermediate walls, also built on wells, and below all a broad layer of rough rubble of large dimensions. A good example of this kind is the Madras Irrigation Company's weir across the Pennair, near Cuddapah, of which a description will be given to the Institution by Mr. Higginson, M. Inst. C.E.

All the ancient irrigation channels from above weirs, that have come under the Author's notice, have far too great a fall, and consequently cannot get away from the river, and thus only a narrow strip of land is irrigated; the sides and bed of the channel get cut away in some places, and the material deposited in others, so that annual repairs and clearing out are necessary. There is also invariably a great waste of water in distribution; but as the surplus runs into the river it is not lost, being picked up again at the next weir. The tail of one channel generally overlaps the head of the next for some distance in the native system. There can be little doubt that this system of numerous weirs and small channels, with a rapid fall, is radically wrong, when applied to large rivers for extensive irrigation. On smaller rivers, having a steep fall, say of 10 feet or more per mile, rocky beds, and widths so moderate as to make the cost of the weir a small part of the whole work, it may sometimes be well applied—the more so as in such situations the soil is likely to be of a light and porous nature, requiring a large quantity of water to be spread over it, and delivering the surplus by drainage into the river again. Generally speaking, however, in the case of large rivers, it will be found more economical to take off a canal of larger dimensions from one head. The surface fall of the water can then be much less than in a channel the depth of which is small; the canal will rapidly recede from the river bank, and command, compared to its length, a much larger area of land; it will wind less, as it will cross the drainage valleys higher up, where they are less deep; these drainages will require less expensive aqueducts and approaches; there will be a shorter length of unproductive canal at the head (from the off-take to where the canal level is high enough to deliver water on to the surface of the ground); and it will supply water to lands and villages where it is more urgently needed than it is close along the banks of a river. Careful estimates, however, are needed, in each case, of considerations on the other side. For instance, the canal must not be made of so large

a capacity that a great part of the water must be carried very many miles before it can be used. The cost of distribution, too, must be considered. Although the natural channels of streams can often be used to convey part of the water to the fields, it is generally the case that, for extensive irrigation, artificial channels, carried down the ridges crossed by the canal, are more economical, but they must not be too long.

It is desirable that a main canal should command a much greater area of arable land than the water it carries can irrigate constantly. Some land may not be suitable for irrigation at all; and in no case could all the land be converted from dry to wet cultivation under many years, as three times the population would be required to cultivate it. There should, therefore, be facilities for completely irrigating detached areas at considerable intervals, and for giving occasional irrigation to dry crops. This last would be an immense boon, since in many parts complete failure of the crops now grown happens every few years from drought, and a good crop is a rare exception; while from one to three waterings would insure a good crop every year. A failure of the crop means a famine; and although, in the few districts traversed by railways, food and seed grain for next year could, at a great cost, be provided for the people, fodder, and, above all, water for the cattle, could not, and they must be driven away or perish. At one large military station, so great was the scarcity of water in the early part of the year 1871, that arrangements were actually completed for carrying water a distance of 8 miles on railway-trucks for the use of the inhabitants. As to drink water thus provided would be contrary to the religious obligations of caste-men, their dismay was great. Fortunately, a heavy rain furnished a supply for two or three months.

III. DISTRIBUTION OF WATER.

The large storage tanks already described as of the 1st class do not have more than a limited area of land irrigated immediately from them. Their duty is to store flood-water which would otherwise run to waste, and to let it down the river as it is required, to supplement, if necessary, at the end of the season, the regular monsoon supply for the first crop, or to give a supply for a second, and to be distributed either by channel irrigation from the river, or from the flat-country tanks, if it is used to supply them. From the 2nd and 3rd class of tanks the distribution is generally effected directly, beginning close under the tank, the water being let out

on to the land by sluices at different levels. In some cases, however, as in that of the Darojee tank already mentioned, the water is also carried down the beds of the intercepted streams and picked up by weirs put across them at intervals; but this is the less frequent plan. One advantage of it is, that the drainage and also the superfluous water from the fields, for it is always wastefully used, are not lost.

Distribution from a canal is most economically effected when the latter runs along a ridge between two valleys, so that it can supply water on both sides; for the nearer the irrigated land lies to the supply the less do the distribution channels cost. This situation, in the case of a large canal taken from one of the main drainages of the country, can obviously happen only in rare instances. When the main canal is carried along sidelong ground crossing the drainage of the country, the main irrigating channels will generally be carried down the ridges between the streams, giving off secondary branches right and left. Occasionally, when the main canal passes by a cutting through a ridge crossing its course, a channel on a falling contour will be required on the upper, and another on the lower slope of such ridge, uniting when the crest of the ridge falls to their level. The first kind, or ridge channels, have the advantage of crossing no drainage, of being thus less liable to damage from heavy rains, and of commanding a given area with the least length of side channels. In most cases both kinds of channels will be needed. In the Ceded Districts, distribution can be carried out for 5s. per acre, including the sluices in the main canal bank, and all necessary works for crossing roads and streams built in a permanent manner, but excluding the cost of terracing the land to prepare it for wet cultivation,—this being done by the occupier.

Of course, any system of irrigation must include ample means of drainage. This is afforded naturally in the part of India under consideration, the fall of the country being generally steeper than is necessary. Only surface drainage is practised. For rice cultivation the water must not be carried off too rapidly, but should be retained for months at a depth of 6 inches on the surface of the ground, by surrounding the plots with a small bank, through which a slight stream is allowed to pass on and off. For dry crops the ground never holds too much rain: the more careful cultivators endeavour to retain, by small dams of dry rubble or boulders, the finer parts of the soil, which would otherwise be carried off by the very heavy rains; but, except in irrigated lands, drains are never cut, as far as the Author is aware.

IV. VALUE OF WATER TO THE CULTIVATOR.

The following three statements of the cost and profits of cultivation are given from information supplied to the Author by the Deputy Collector, who made the calculations from actual experiments on fields in the Bellary district. The prices of produce are those which prevailed before the great scarcity, amounting to a famine, in 1865-6.

(a). COST OF CULTIVATING AN ACRE OF CHOLUM (SORGHUM), the staple dry grain.

	<i>R. a. p.</i>	<i>R. a. p.</i>
Land cess.	1 8 0	Average. From experiments in the village of Amravutty; an ordinary crop.
Labour	2 6 2	
Use of cattle	5 8 7	
Manure	6 2 6	
Seed	0 9 10	
Fees to village servants	0 13 0	
Total expenses . . . . .	.. ..	17 0 1
RETURNS.		
Grain, 236 Bellary seers, at 18 per rupee.	13 1 9	
Straw, 2 loads	8 0 0	21 1 9
Net profit per acre Rs.		4 1 8
	or, £	0 8 2½

This dry crop is sometimes assisted by irrigation from wells, the water being raised by bullocks. The wells cost, in the Bellary district, from £30 to £100 each, and the cost of raising the water is said to be £4 12s. per acre. No well will supply more than three acres in that district. The Author has no results from actual experiment of the profits of such cultivation, but it is not probable that a greater direct profit can be made from it than from the dry cultivation. The gain is in the certainty of the crop.

To compare the above with the profit from rice cultivation, the water rate and the cost of preparing the land, or of converting it into terraced land, must be assumed. The former varies considerably, and was established when grain was much cheaper than it is now. It was the opinion of the collector of the Bellary district, in 1866, irrespective of the scarcity then prevailing, that the ryots could well afford to pay for new irrigation £1 per acre for the first crop, which is the most valuable; and the Author has been assured, both by cultivators themselves and by native revenue officials,

that they would be glad to do so. The Government Superintending Engineer for Irrigation recommended for that district a rate of 17s. for the first, and 13s. for the second crop. The Madras Government, however, decided that 12s. per acre for each crop should be the standard for calculations. As a matter of fact, ryots in the Nizam's country, adjoining the Bellary district, pay as much as £3 for wet land. In the following statements the Government rate of 12s. is assumed. The cost of preparing the land is taken at £1 per acre, which, at 12 per cent., the usual rate of interest, gives 2s. 6d., nearly, per acre per annum. (See Tables *b* and *c*, next page.)

The difference between this and two dry crops, supposing two could be got, is £17 10s. in favour of the wet crop.

Sugar-cane, however, as well as garden cultivation, which is also extremely profitable, would generally bear only a small proportion of the breadth of land that would be under rice and dry crops, and in the following Table I. (p. 388), showing the comparative yield of wet and dry crops, they are neglected.

As the Bellary district is peculiarly unfortunate in its annual rainfall, the above valuation of an average dry crop may be under the average of that in the districts which could be supplied with channel irrigation; and in the following Table, the average yield per acre in the Kurnool district and the prices there prevailing, which are lower than in Bellary, both of wet and dry crops, have been used for the purpose of comparison between wet and dry cultivation. It should be noted, however, that land irrigated from a river gives a better return than that under a tank by, it is said, 25 per cent. in those parts. Whether this is principally due to the brackish quality of the water locally collected, or to the insufficient supply from tanks, the Author cannot say; probably both causes contribute.

The following Table is intended to show the money value of irrigation, and the gross returns per acre which would be got by the construction of suitable works in the Ceded Districts, and in others similar to them in climate and other circumstances. Nos. I. and IV. are compiled from official statements of the average value of crops in the five years 1861 to 1865 in the Kurnool district. Nos. II., V., and VI. from actual experiments by the Deputy Collector in the Bellary district. No. III., col. 4, from the same source, and cols. 1, 5, and the rest from official statements in the revenue department. The price of grain is steadily increasing, when taken over a number of years; thus the price of rice in the Table, 1861-65, is double what it was in the disastrous famine year of 1854, and 78 per cent. higher than the average of the period

(b). COST OF CULTIVATING AN ACRE OF RICE.

	<i>R. a. p.</i>	<i>R. a. p.</i>
Land cess	1 8 0	{ For good land. Assumed Government proposal.
Terracing land	1 4 0	
Water rate	6 0 0	{ From experiments in the village of Chit- wady.
Labour	18 15 0	
Use of cattle and implements	11 0 0	
Seed	9 8 0	
Manure	2 10 0	
Village fees, &c.	3 12 0	
Total cost of cultivation . . . . .	.. ..	54 9 0
RETURNS.		
Paddy, 1,675 Bellary seers, at 18 per rupee	93 0 0	
Straw, 40 bundles	10 0 0	103 0 0
Net profit per acre.	Rs.	48 7 0
	or, £	4 16 10½

Or a difference in favour of wet cultivation of £4 8s. 8d. per crop per acre.

(c). COST OF THE CULTIVATION OF AN ACRE OF SUGAR-CANE, which requires the same quantity of water as an Acre of Rice, but spread over ten months, and thus liable to the double water rate, or Rs. 12.

	<i>R. a. p.</i>	<i>R. a. p.</i>
Land cess.	1 8 0	{ Assumed Government proposal.
Terracing land	1 4 0	
Water rate	12 0 0	{ From the Deputy Col- lector's experiments in Chitwady.
Labour	232 0 0	
Use of cattle, &c.	10 0 0	
Manure	50 0 0	
Plants, 6,000, at rupees 5 per thousand	30 0 0	
Fuel, 48 loads	48 0 0	
Village fees, &c.	8 0 0	
Total cost of cultivation . . . . .	.. ..	392 12 0
RETURNS.		
288 maunds of jaggerry, at rupees 2 per maund . . . . .	.. ..	576 0 0
Net profit per acre	Rs.	183 4 0
	or, £	18 6 6

TABLE I.

SHOWING THE COMPARATIVE YIELD

	DESCRIPTION OF CROP.	1.	2.	3.	4.
		Gross Value.	Deduction for Risk.	Gross Value for Assessment.	Cost of Cultivation and Conversion.
		R. a. p.	R. a. p.	R. a. p.	R. a. p.
	DRY CROPS.				*
I.	Grain, 243 Madras measures, at per Garce Rs. 278	21 1 9	$\frac{1}{4}$		
	Straw, 50 bundles, at 4 annas	12 8 0			
	Revenue returns, 5 years' average	33 9 9	8 6 5	25 3 4	15 8 1
II.	Grain, 236 Bellary measures, at 18 per rupee	13 1 9			
	Straw, 2 loads, at Rs. 14	8 0 0			
	Deputy Collector's experiment	21 1 9	.. ..	.. ..	15 8 1
III.	The same, with occasional Irrigation.				
	Grain, 333 Madras measures, at per Garce Rs. 278	28 15 0	$\frac{1}{6}$		
	Straw	20 0 0			
	Collector's official statement	48 15 0	8 2 6	40 12 6	15 12 0
	WET CROPS—RICE.				
IV.	Grain, 1,066, at per Garce Rs. 213	70 15 3	$\frac{1}{6}$		
	Straw	12 8 0			
	Revenue returns, 5 years' average	83 7 3	13 14 6	69 8 9	47 1 0
V.	Grain, 1,675 Bellary measures, at 18 per rupee	93 0 0	$\frac{1}{6}$		
	Straw	10 0 0			
	Deputy Collector's experiment	103 0 0	17 2 8	85 13 4	47 1 0
VI.	SUGAR-CANE.		$\frac{1}{6}$		
	288 maunds jagherry, at Rs. 2	576 0 0	96 0 0	480 0 0	379 4 0

* Col. 4. For details of cost, furnished by the Deputy Collector, see Sect. IV. *ante*.

† Col. 5. From the amounts in Col. 5, a sum of R. 1 2a. land rent, has to be deducted to show the clear profit to the cultivator. The rent has been deducted in Col. 11.

TABLE I.

of WET and DRY CROPS.

5.			6.			7.			8.			9.			10.			11.			
Net Value of One Crop.			Second Crop at Three- quarters First Crop.			Value of Water.			Sum of Cols. 5 & 6.			Assessment at Half Net Produce.			Profits of Water to						
															Cultivator One-third.			Works Two-thirds.			
R.	a.	p.	R.	a.	p.	R.	a.	p.	R.	a.	p.	R.	a.	p.	R.	a.	p.	R.	a.	p.	
†																					
9	11	3	..	..		..	..		..	..		4	13	6							
5	9	8	..	..		..	..		..	..		2	12	6							
25	0	6	..	..		15	5	3	..	..		12	8	3	5	1	9	9	2	6	
22	7	9	16	13	7	{12 12 6}			39	5	4	{11 4 0}			4	4	2	7	6	4	1 crop.
						{29 10 1}						{19 8 0}			9	14	0	18	10	0	2 ,,
38	12	4	29	1	3	{29 1 1}			67	13	7	{19 0 0}			9	11	0	17	14	0	1 crop.
						{58 2 4}						{34 0 0}			19	6	1	37	10	2	2 ,,
‡																					
90	12	0	..	..		81	5	6	100	12	0	50	0	0	27	2	0	52	12	0	{10 months' supply.

† Col. 5. It is generally reckoned in the Ceded Districts, that the profits per acre of sugar-cane are Rs 200, or a little more than those given in the Table, without the deduction for risk in Col. 4.

1856-60. The Author believes that the new settlement rates of assessment of land are about one half the clear net value of the crop, after a deduction for risk of loss by bad seasons, &c., has been made from the gross returns, of $\frac{1}{4}$ th for dry and $\frac{1}{4}$ th for wet crops; and column 9 in the Table has been made in accordance with this principle. It is probable that, in addition to the direct increased value of the crops, some further advantage would have to be given to the ryots, to induce them to convert their land from dry to wet cultivation, in districts where wet cultivation is but little known; and supposing the total advantage to be divided in the proportion of one part to the cultivator and two parts to the agency or works supplying the irrigation, the results are given in cols. 10 and 11. The sum of R. 1 2*a.*, to represent the average land cess already paid by the ryot to the Government, has been deducted in col. 11; it is not included in col. 4 because, to show the value of water applied to land already paying that dry rate, it is necessary to exclude it from all the items in col. 5, and it is assumed that this rent of the land is not raised, but only a charge is made for the water. As No. V. represents good land, it would, perhaps, be too much to assume that in average cases the out-turn would be as high as is entered in col. 8 of No. V. On the other hand, No. IV. is the result of tank irrigation; and the results ought, in dealing with river irrigation, to be increased 25 per cent. But even excluding No. V., and taking No. IV. as it stands, and excluding also No. VI., on account of the comparatively small area sugar-cane would occupy, the results of Nos. III. and IV. show that, provided a water-rate proportioned to the value of the water were fixed, irrigation would, even taking the most unfavourable cases, benefit the cultivator to the extent of 10*s.* and 8*s.* 6*d.*, and yield a gross return to the works of 18*s.* 3*d.* and 14*s.* 9*d.* per acre respectively in the two cases of occasional watering of dry crops and of rice or wet cultivation; and in the latter case, supposing water to be stored for a second crop, the gain to the cultivator would be 19*s.* 9*d.*, and the return to the works 37*s.* 3*d.*, which cannot be considered as other than very favourable terms to the former, who is not to be supposed to have expended any capital on the improvements beyond 1 rupee per acre for the conversion of the land, and this has been allowed for. As 18*s.* 3*d.* and 14*s.* 9*d.*, or the average of them, 16*s.* 6*d.*, represents the gross income from the sum expended on the construction of the canal and distribution channels, so (37*s.* 3*d.*—14*s.* 9*d.*) 22*s.* 6*d.* represents the gross additional return per acre from storage water applied to a system of works already constructed.

V. COST OF WORKS.

First, of canals as they are needed either to distribute water directly or to fill existing tanks. It has been laid down by the Madras Government, as a basis for calculation, founded on experiments made by their orders, that 2 cubic yards per hour, or 0.015 cubic foot per second, in the main canal is sufficient for the irrigation of an acre of paddy. Where more is used in porous soils, the surplus will, in a good system of distribution, be caught up again in the drainages and redistributed. For dry crops three waterings in the season, of 4 inches in depth, in years when the rainfall is at the lowest, and 2 inches, or 1 inch, in less unfavourable years, would suffice to insure a good crop of cholam. The first quantity is equal to 1 cubic yard per hour per acre, nearly. It is convenient, for the sake of comparison, to reckon the cost of a canal in terms of its carrying capacity at the head; and if the above allowance of water be assumed, the cost can readily be compared with the returns per acre. Table II. gives the cost of several works which have been constructed, or carefully estimated on data obtained from constructed works, in the Ceded Districts:

TABLE II.

NAME OF WORK.	Cost per Cubic Foot per Second at Head.	Cost per Acre.	Number of Acres Irrigated.
	£ s. d.	£ s. d.	
Kurnool Canal, for irrigation and navigation }	533 6 0	8 0 0	200,000
Bellary high level	439 0 0	7 6 2	150,000
Bellary low level	393 6 0	5 18 0	212,500
Toombaganoor Canal	526 14 0	7 18 0	55,000
Average	473 1 6	7 5 6	151,250

It is to be remarked that the Kurnool canal is also a navigable canal, which raises its cost considerably; probably $\frac{1}{3}$ th may be deducted to reduce it to its cost for irrigation only, that being the proportionate amount of cost found by estimates to be necessary to make other irrigation canals navigable. It would then cost per cubic foot per section, £426 12s., and per acre, £6 8s.; and the average would be reduced to £446 8s. per cubic foot per second, and £6 17s. 8d. per acre. The following is the cost, ascertained or estimated, of large canals in other parts of India:

TABLE III.

NAME OF WORK.	Cost per Cubic Foot per Second at Head.	Cost per Acre. ¹	Authority.
	£ s. d.	£ s. d.	
Ganges Canal with navigation }	497 12 0	7 8 9	Roorkee pamphlet.
Ganges Canal without navigation, assumed . }	398 1 7	5 18 5	½th deducted.
Barce Doab Canal	466 12 0	7 0 0	Capt. Forbes, R.E.
Sutlej Canal	353 6 0	5 6 0	Capt. Crofton, R.E.
Soane Canal	434 8 0	6 10 0	Col. Dickens, R.E.
Average	413 2 0	6 3 7	
The Orissa system . . .	200 0 0	3 0 0	Col. Rundall, R.E.

The Orissa system of canals is not included in the average, as the works are in a deltaic country. The low rate of cost bears out what has been already stated. It seems safe to assume, that canals large enough to irrigate 75,000 acres and upwards can, on an average, be constructed for £7 per acre, and that, with the distribution of profits before proposed, the outlay of £7 will yield a gross return of 16s. 6d. Deducting 2½ per cent. on the cost of construction for establishment, repairs, and collection of revenue = 3s. 6d. per acre, the net returns ought to be, at rates extremely favourable to the cultivator, 13s. per acre. The works, according to their magnitude, would occupy a good many years in construction; and although partial irrigation might take place after the head-works and one-half of the other works were constructed, still the whole profits could not be realized till some years after the works were complete. If 5 per cent. on one half the capital for ten years be added to the cost, it is brought to £8 15s. per acre, and the net profits would then be 7·4 per cent. This applies to channel irrigation only, where all the works have to be constructed; the profits would be greater were there tanks along the line of the canal and at its terminus which could receive a partial supply, for a second crop, or for flooding dry crops, during the time when the water was not required to be turned on to all the fields.

Secondly. In considering the cost of tanks, it is to be remembered that those of the 1st class, or storage reservoirs, would rarely be available for direct distribution, and would rather be consi-

¹ Of rice land at the Madras rate, 2 cubic yards per hour per acre.

dered as subsidiary to a system of works already constructed. The flat-country tanks, on the other hand, affording as they do means of directly distributing the monsoon supply, may be compared as a means of irrigation with the head-works and channels from a river. Those of the intermediate class add, in some cases, to the functions of the last mentioned, that of storing a certain amount of water for a second crop of rice, or of other grains which require a supply of water in the dry season. Taking the flat-country tanks first: it can well be believed that the old ones, constructed as they, no doubt, chiefly were by the voluntary, or sometimes forced, labour of the villagers whose lands they were to benefit, have, in the course of centuries, amply repaid the labour expended on them; but it would only be under exceptionally favourable circumstances, such as have never come within the Author's personal observation, that their construction would be a profitable investment for capitalists now. This is in a great measure owing to the loss by evaporation in shallow tanks. If the main slope of the country be assumed at as little as 8 feet per mile, and the lateral slope towards the stream to be closed at 10 feet per mile, then a rough calculation will give the contents of a tank whose greatest depth of water is 9 feet at about 3 million cubic yards; and, taking the evaporation¹ at 42 inches in four months on the mean area, it amounts to 2·18 million cubic yards, leaving only 820,000 cubic yards for irrigation, or sufficient for 205 acres. The cost of the work would be:

		R. a. p.	Rs.
Earthwork	C. Y. 52,792 at	0 2 0	6,600
Stone pitching	„ 4,200 „	0 8 0	2,100
Waste-weir and sluices	„ ..	..	2,000
Distribution to 205 acres . . .	„ ..	2 8 0	512
Contingencies, &c., 15 per cent. .	„ ..	..	1,588
Total	„ ..	Rs.	12,800

Or about £6 5s. per acre for an extremely favourable imaginary case, where it must also be assumed that the minimum rainfall would suffice to fill the tank. An actual example of this kind of tank, which intercepted the water of three streams and included cuttings to connect them, was estimated by the Author to cost £15,000 for 3 million cubic yards of available water, or about £25 per acre. As another example, both of the varying cost of flat

¹ One-third of an inch per day is the observed evaporation in the plains.

country tanks and of the value of water to a cultivator, the Author is acquainted with the following illustration. Chinna-veerappa, a wealthy landowner, had expended £2,500 on a tank, which was still unfinished, and would eventually cost at least £3,000, and be equal to the supply of about 240 acres. Adding the cost of distribution, this would be at least £14 per acre; and the man said it would pay him well. And there is no doubt of it; for the land would raise sugar-cane, and he would reap both the cultivator's and the capitalist's profit.

Although the construction of new works of this kind must be considered a doubtful investment, there are many cases where a small outlay in repairing breached banks, and in supplementing the water supply by digging catch-water drains, or diverting neighbouring streams into a tank, or even by the construction of feeders of considerable length from well-supplied rivers, would be speedily repaid; but without regular surveys it would be impossible to guess even at the number and capacity of tanks that might be thus restored. Many have so silted up that they are best left as they are. This silting up, and the consequent abandonment of flat-country tanks, though a matter of time, is also one of certainty.

The intermediate class of tanks show a better result, as might be expected from their greater depth (as a rule), and consequently less loss by evaporation. The Sholapore tank was estimated by Col. Fife, R.E., to cost about £100,000, which at Madras rates for rice would be £11 per acre. The loss by evaporation was estimated at 29 per cent.; the depth at the dam being 60 feet. This rate of £11 per acre for rice cultivation is stated for the sake of comparison; but rice is not the chief grain irrigated under it, and the net return of the tank was estimated to be 9 per cent. at the low rates of Rs. 4 for a four-months' crop. The Bourg reservoir in Ganjam, constructed by the Madras Government at a cost of £1,075, waters an area of 1,632 acres, and yields an increase on the old revenue of the land of £184 10s., or, deducting repairs, 16½ per cent.

The storage reservoirs of the first class which have been designed and estimated show a very different result from that given by the other classes. The Author is informed that the result of the investigations of the Bombay Engineers is that, in favourable cases, 700 cubic yards of water can be stored per rupee, which nearly agrees with his own estimates in detail of several reservoirs, one of which would store 750, another 425 cubic yards; while the restoration of the Mudduk Masoor tank previously described would yield 960 cubic yards per rupee. The evaporation, calculated

from observations, is $7\frac{1}{2}$ per cent. in the two proposed new reservoirs in seven months, and 5 per cent. in the Masoor reservoir if emptied in four months. A further deduction has to be made for evaporation in the course of conveyance to the fields to be irrigated, which will vary with each case. In these cases it will be $2\frac{1}{3}$ and 8 per cent. Assuming the correction for evaporation to be 12 per cent., and the allowance of water per acre at 5,000 cubic yards per acre, which is a little in excess of 2 cubic yards per hour, and adding, as in the case of the channels, 25 per cent. for interest during construction, the rate of storage becomes, for the proposed new reservoirs, 440; the Bombay rate, 493, and the Masoor reservoir, 674 cubic yards per rupee; and the cost per acre, £1 2s. 6d., £1, and 14s. respectively. Such storage reservoirs, when built on main rivers rising in the Ghâts, would have a supply that could always be reckoned on; and on the larger rivers the difficulty would be, not the filling of any reservoir, but the construction of one large enough to intercept a large portion of the floods of one season, or failing that, the disposal of the surplus water. As an example of this: in one of the proposed reservoirs just referred to, which had a depth of 160 feet at the dam (about the same as that built in the Gouffre d'Enfer in France), the water toward the upper end of the lake would overtop the summit of the water-shed of the river Toonga and the Gurget, a river flowing to the western sea; and yet the quantity of water contained by the reservoir would only be about $\frac{3}{4}$ ths of the ordinary monsoon supply. The above sites for reservoirs were selected as likely to be very favourable, the capacities of two of them being also very great; and therefore the rates are probably cheaper than the average at which water could be stored in rivers having a certain supply, and undoubtedly so as compared with those on rivers with a much more fluctuating supply. Taking the least favourable of these sites, however, 340 cubic yards per rupee, there is still only a prime cost, after all deductions, of £1 12s. 9d. per acre for giving a second crop of rice, or a crop of sugar-cane. The cost of establishment and maintenance on a masonry dam would not be great, and may safely be put at 2 per cent., or 7d. per acre, or even less. The additional maintenance of the channels would not exceed 1s. per acre; so that it will appear that an outlay of £1 12s. 9d. will return about £1 1s. This allows a large margin for the profitable construction of reservoirs on rivers having a less certain or regular supply.

The following estimates of Government works are examples of the profits to be made by repairing, improving, or adding to works

already in existence. In one instance, that of the Trivady Anicut in South Arcot, an expenditure on repairs of £1,100 or £1,200 produced a revenue of £3,000, or 250 per cent.¹

TABLE IV.

Name of Work or Project.	Nature of Works to be Constructed.	Cost per Acre.	Net Returns at Rs. 6 per Acre.
		£ s. d.	
Tambrapoorney	Weir and channels, and enlargement of old ditto.	2 12 0	16½
Kanagiri, in Nellore	Head works and channel to a tank which is to be enlarged.	3 2 0	} Not stated. ? 17
Muddoor, in Mysore	Weir and channels to old tanks	Not stated.	
Sreeramadavara, Mysore.	Ditto ditto ditto	2 3 1	45
Bhatodee, Bombay Presidency.	Restoration of old tank and channels.	6 0 0	27
			10

VI. GENERAL CONCLUSIONS.

As there seems to exist a general impression, that the estimates of the benefits of irrigation are merely estimates, more or less coloured by personal views, the Author has, in the statements of the comparative results of wet and dry cultivation, confined himself to ascertained facts, and has endeavoured to keep the estimates of returns on works within the limits of certainty, by excluding all doubtful or unascertainable profits, such as those from plantations for firewood (a very profitable investment where the earth can be kept sufficiently moist), water supplied to towns and villages for domestic and municipal purposes, water-power, &c. Also, he has taken as the standard of productiveness that of irrigation under tanks, and has not added the 25 per cent. additional crop said to be due to channel irrigation.

As this Paper is intended to deal with works for irrigation only, navigation is not included in either the cost or the returns; but the Author begs leave to make one or two remarks on this subject, on which so much opposition exists in the views of Engineers. This opposition he believes arises from each side attempting to form general conclusions, and to lay down a general rule founded on the observation of particular works, which in each case seem to bear out its advocate's views. The question does not admit of a general answer, either in favour of or adverse to the combination of irrigation and of navigation in one channel. Assuming that a navigable

¹ On the authority of the late Col. J. C. Anderson.

canal is desirable, if it can be constructed at a small outlay, the question whether an irrigation canal should be adapted to that use or not seems to depend for its solution mainly on two circumstances: first, the nature of the ground through which it passes, and, secondly, on its dimensions. If the former is such that a rapid current can be given to the water, it is very desirable to do so in cuttings, in order to reduce their cross section, and this generally to such an extent as would prevent upward navigation. If, on the other hand, the country is very level, as in deltas, and the soil so light that the velocity of the canal has to be small, then the addition of works required for navigation bears so small a proportion to the whole outlay, that to make the irrigation canal navigable is the cheapest way of attaining the end. Thus, in the Orissa scheme, the cost of the navigation works is said to be about one-eighth of the whole cost; and a complete network of navigable lines is obtained at an outlay of £650 per mile. In a less easy country the Author has found that when a canal has to carry from 150,000 to 500,000 cubic yards per hour, and when it has to pass through cuttings, it would be cheaper to have a separate navigation taken round, or in some other way avoiding the difficult parts, than so to enlarge the irrigation canal as to reduce its current within navigable limits. But when a canal has tapered down to 150,000 or 100,000 cubic yards per hour, then it is cheaper to combine irrigation with navigation in one canal. In a tract of country comprising both characters of ground, it was found that to combine a system of navigation with irrigation would add 25 per cent. to the cost of the latter, and would cost from £2,000 to £3,000 per mile, according to the dimensions of the work; but in difficult ground, if the canal were of large dimensions, carrying 450,000 cubic yards per hour, £6,000 per mile would be required to make it navigable. The parts of the canal used for navigation only would cost £1,200 or £1,500 per mile, exclusive of the locks, which, if 100 feet long and 20 feet wide, would cost about £200 per foot of lift. These rates per mile suppose a supply derived from the canal, and do not include headworks or storage reservoirs, as these works are supposed to be charged to irrigation, inasmuch as the water used for lockage would also be expended in the fields.

In the above estimates no account has been taken of the value of the land occupied by the works. It has generally a low value in such districts as require irrigation.¹ In the Orissa system of works it cost 1·8 per cent. of the capital expended; and in any

¹ Colonel Rundall's Report.

case it becomes quite insignificant, when compared with the indirect advantages accruing to Government from the improvement of the country by irrigation. The most obvious of these is the saving of remissions of land revenue, which have often to be made in consequence of partial or total failure of crops. There is also the relief from uncertainty in the amount of the revenue. In the irrigated districts of Tanjore, the fluctuations in the revenue have declined since the construction of the Government irrigation works from 52 per cent. to 3 or 4 per cent.¹ Other sources of gain to the State are—waste lands brought under cultivation, and so under a charge for rent; increase of the customs and taxation in general; and a large saving of money relief in times of famine. These gains cannot be estimated, and no account has been taken of them in the above calculations, except as a set-off against the value of the land.

No special notice has been taken in this Paper of the great and very remunerative works in the Kristna, Godavery, and Tanjore deltas, the works in the last yielding, according to an independent authority,² after deducting repairs and 5 per cent. on the capital, 23½ per cent. direct profits, and those on the Godavery from 50 to 60 per cent. They are omitted because these deltas are so occupied as to offer no opportunity of constructing new works on a large scale.

Table V. shows how the 12s. rate for water, fixed by Government a few years ago as the basis of all calculations for new works in the Ceded Districts, alters the aspect of matters regarding the profits of the cultivator and the supplier of water from that given by the "equitable" or "mutual benefit" rate adopted in Table I. The Author believes Table V. to be nearly correct, although, for reasons already mentioned, the returns may be a little understated.

Persons unacquainted with the native character will be apt to ask why, if irrigation works are so profitable, the natives have not already utilized every drop of available water; but this will be no ground of wonder to those who know their ignorance of the practice of any but their own neighbourhood, their worship of custom, and their habit of relying on their rulers to do everything for them. In the Godavery districts, on the completion of the works, the Government officers are said to have acted in a paternal manner to the ryots by turning the water on to their fields, with or without their consent, and they have been rewarded by the unexampled prosperity of the district.

¹ Colonel Baird Smith.

² Colonel Baird Smith.

TABLE V.

Kind of Works to be Constructed.	Cost of Works per Acre.	Water Rate.	Cultivator's Profit per Acre.	Net Return on Works per Acre.	Per Cent. of Capital.
	£ s. d.	s. d.	£ s. d.	£ s. d.	
1. Irrigation by channels for one crop of rice . }	8 15 0	14 10	1 8 0	0 11 3	6·7
	.. ..	12 0	1 10 10	0 8 5	4·3
2. Ditto ditto for occasional irrigation of dry crops }	3 2 0	18 4	1 9 6	0 14 10	23·9
	.. ..	6 0	2 1 10	0 2 6	4·0
3. Mean of 1 and 2, supposing equal areas irrigated, and three waterings to dry crops . }	5 18 6	16 7	1 8 9	0 13 0	11·0
	.. ..	9 0	1 16 4	0 5 6	4·6
4. No. 2 with one watering, and the water provided for the other two wasted or not used . . . }	3 2 0	6 0	2 1 10	0 2 6	4·0
	.. ..	2 0	2 5 10	0 1 6	Loss.
5. Mean of Nos. 1 and 4 . }	5 18 6	10 5	1 14 11	0 6 10½	5·8
	.. ..	7 0	1 18 4	0 3 6	3·0
6. Application of storage water to existing works, giving a second crop of rice . . . }	1 9 5	22 6	0 9 0	1 1 0	71·0
	.. ..	12 0	0 19 5	0 10 6	36·0
7. Combined storage and distribution works; two crops of rice . }	10 4 5	37 3	1 19 2	1 13 9	16·5
	.. ..	24 0	2 12 5	1 0 6	10·0
8. Ditto ditto, sugar-cane . }	10 4 5	105 6	4 13 0	5 2 9	50·0
	.. ..	24 0	8 15 3	1 1 3	10·0

The first rate in each case is taken from Col. 2, in Table I.; the second is the Government rate, and in Nos. 2 and 4 the rate allowed to the Madras Irrigation Company.

The object of this Paper will have been attained if it has shown :

First. That all works of irrigation benefit the cultivator to such an extent as will enable him to pay a water-rate equal to two-thirds of the increased value of his crop, and not exceeding one-half the net value, and still to leave his own profits by 100 to 400 per cent.¹ in excess of those derived from dry cultivation.

Secondly. That of the three kinds of works mentioned in Table V., under 1, 6, and 7, the storage of water for the raising of a second

¹ In sugar-cane cultivation 950 per cent.

crop, under distribution works already in existence, is the most profitable, and would, after paying one-third of the gross revenue to the existing works, still yield a net return of 46 per cent. on the outlay, and increase the revenue of the existing works, supposing them to have cost the average sum, by $4\frac{1}{4}$ per cent.

Thirdly. That the arbitrary rate of 12s. per acre is insufficient, on the data assumed by the Government, to yield a fair return directly on the average of new irrigation works, unless these include the storage of water, when the Government rate will yield a net profit, on storage and distribution works combined, of 10 per cent.

And Fourthly. That as a consequence of the last, the profitable employment of unguaranteed capital in irrigation works depends chiefly on the recognition of the principle, that the water-rate should be fixed with reference to the value of the crop produced. This value will, in all probability, continue to increase, as will also the cost of the works as wages increase; and unless the water-rate is fixed with due regard to the value of the water to the consumers, and to the cost of work in each district, many beneficial projects will remain unexecuted.

The communication is accompanied by a series of diagrams, from which Plate 7 has been compiled.

[MR. J. H. LATHAM.]

STORAGE OF WATER
IN SOUTHERN INDIA.

PLATE 7.

Fig: 1.

Fig: 2.

Fig: 3.

Fig: 5.

Fig: 6.