PAPER No. 228.

FINANCES AND ECONOMICS OF IRRIGATION PROJECTS.

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FINANCES AND ECONOMICS OF IRRIGATION PROJECTS.

I. INTRODUCTORY.

Economic Importance of its Canals to the Punjab.

There is a general feeling of pride in the mind of every Punjabi about the 'wonderful' canal system that the province of his birth can boast of. It may easily be classed as foremost in the world both in its conception as well as execution. But the actual economic importance of its canals to the province is perhaps not as clear to the majority of the people as it should be.

The total area of the British Punjab is 60,179,000* acres, out of which nearly 12,824,000 acres consist of *abadis*, mountains, river beds, roads, railways, canals etc. and are not available for cultivation. Area under cultivation† is 30,999,000 acres. About 14,380,000 acres are still lying as culturable waste and indicate the possibilities of further extension of cultivation. Forests cover an area of 1,976,000 acres.

Out of 30,999,000 acres cultivated about 15,000,000‡ acres are irrigated from sources shown below:—

	1935-36.
Government Canals	10,143,044 acres
Private Canals	414,877 ,,
Tanks	35,060 ,,
Wells	4,284,960 ,,
Other Sources	137,910 ,,
Total ..	15,051,851 acres

The above figures show clearly that Government canals are the most important single source, irrigating as much as 67 per cent. of the total irrigated area.

The total number of masonry wells in 1935-36 was nearly 300,000 and one well on the average matured 11 to 14 acres of land in both crops. The cost of irrigation by wells is, however, so heavy in comparison to irrigation from canals, that these well owners will gladly have their wells replaced by canal irrigation, if they have any option in the matter.

Now coming to the effect of canals on the provincial revenue, Table 1 shows the percentage of receipts from irrigation to the total revenue receipts.

* Board of Economic Inquiry, Publication No. 52, Table II page 5.
† According to 1935-36.
‡ Board of Economic Inquiry, Publication No. 52, Table V page 9.

*TABLE 1.

Year.	In thousand of rupees.		Percentage of column 3 to column 2.
	Total revenue receipts.	Net receipts from irrigation after deducting working expenses.	
1	2	3	4
	Rs.	Rs.	%
1921-22 ..	8,65,18	3,32,78	38
1925-26 ..	11,38,57	4,57,08	40
1929-30 ..	10,53,92	3,93,80	37
1934-35 ..	10,49,86	4,01,76	38
1936-37 ..	10,60,88	4,41,84	41

The above figures, however, are slightly misleading, as interest charges on capital spent on irrigation works have not been deducted from the irrigation receipts. Taking the interest charges into consideration the percentage of net receipts from irrigation both direct and indirect would reduce to about 30 p. c. of the total net revenue receipts. The total value of crops matured by Govt. canals in 1937-38 is estimated to be Rs. 40,31,68,364. Thus the economic welfare of the province is closely tied to its canals.

Essentials of Financial Success of Irrigation Projects.

Assuming that adequate supplies of water for irrigation purposes can be made available at proper times at a reasonable expense and suitable soil exists, the quantity and distribution of rainfall are the two factors that determine the necessity for irrigation.

Rainfall may vary from year to year. In certain years it may be possible to grow good crops without the aid of irrigation and irrigation works may be required only to ensure water supply in dry years. Whenever there is good rainfall the cultivators are unwilling to assume the

* Board of Economic Inquiry, Publication No. 52, Table VIII.

obligation to pay for irrigation water and however favourable engineering conditions may be, an irrigation project in such a tract can hardly be a financial success.

How the rainfall in the typical districts of the Punjab varies from year to year is shown by Table 2.

TABLE 2.

(SOURCE : STATEMENT 1 OF SEASON AND CROPS REPORTS).

Year.	Total rainfall during the year in inches.					
	Hissar	Lahore	Shahpur	Multan	Lyall-pur	Muzaf-fargarh
1926-27 ..	26·53	16·98	14·51	3·14	10·70	3·04
1927-28 ..	15·38	13·87	7·01	5·11	6·02	3·66
1928-29 ..	16·73	17·20	11·23	3·34	17·23	2·49
1929-30 ..	9·97	35·99	19·35	14·75	12·12	13·53
1930-31 ..	18·32	26·67	9·08	5·12	13·67	4·72
1931-32 ..	20·38	34·50	9·36	5·37	18·02	4·93
1932-33 ..	10·18	13·60	14·96	5·76	5·16	7·38
1933-34 ..	24·08	22·62	22·67	7·29	14·12	5·51
1934-35 ..	17·80	24·49	18·31	8·65	16·86	7·65
1935-36 ..	14·81	12·97	12·89	3·51	8·02	2·10
1936-37 ..	8·70	22·47	18·17	12·98	13·68	11·03

Not only does the total rainfall vary heavily from year to year, but it varies in its distribution at various times of the year. Thus the Punjab is eminently suited for irrigation.

The financial aspect of any project may be considered, firstly, from

the point of the financier, whether private or State, who has to incur the expenditure on the first cost of construction and subesequently realizes the cost incurred either by a system for repayment of the capital cost in a certain number of years (as is the case in United States of America) or by charging what is called the water-rate to meet the interest on the capital cost incurred and the annual charges on account of administration and maintenance.

Secondly, it may be considered from the point of view of the farmer, as the returns to the farmer must be commensurate with the costs he has to incur. The charges for the water supply or the *abiana* rate is not the only additional cost that the farmer has to incur on the introduction of irrigation. Usually the charges for water from an irrigation enterprise cover the cost of bringing the water to the boundary of each *chak*, but no further. The distributing system on the farm itself is put in by the farmer at his own expense. The cost of the farm distributing system naturally must vary from farm to farm with the topographical character of the land, the soil and the works installed. Irrigation requires that the surface of the fields should have fairly even slopes in order that water may be spread uniformly over the surface. This necessitates a certain amount of levelling, the exact amount depending on the natural topography. Such levelling is unnecessary where only *barani* cultivation is practised. For new lands a certain amount of expenditure has to be incurred by the farmer in clearing jungle and brushwood and putting some sort of shelter hut and fencing. In addition there are annual costs for maintaining the farm distributing system (watercourses) and for applying water to the land. When water is running on to the fields it is necessary to give constant attention to see that it is distributed properly. The above charges are peculiar to irrigation and due to irrigation. These charges are in addition to the usual cost of production. If irrigation is to be profitable to the farmer, it must produce sufficiently large returns to him to justify this additional cost.

It is obvious that if the returns to the farmer are not commensurate with the cost incurred by him, he will not take the water for irrigation and the corresponding return to the financier will be reduced.

No irrigation project can be said to be a financial success unless the returns both to the financier as well as the farmer are reasonably adequate. If the financier is the State, it may decide, for other considerations, to finance even at a loss, as has been the case in most of the Western countries where lessons of the Great War taught every country to be self-sufficient in matters of food supply. The Punjab Canals are, however, in a much happier position.

Scope of the Paper.

An attempt has been made in this Paper to present facts and figures from a financial and economic point of view in a manner easily understood. Loose generalizations have been avoided.

The Paper mainly deals with the Punjab weir-controlled canals. Figures of costs and returns for tube-wells and open wells have been given for the sake of comparison. A few projects from other Indian Provinces have been included. Here and there a comparison has been made with the United States of America.

Methods of financing irrigation projects have been dealt with and a comparison made of the Indian and American policies. Costs and returns both to the State and the farmer have been discussed at great length. The possibilities of expansion of irrigation have been examined both from a physical as well as an economic point of view. From the data presented in the Paper a plea has been put forward to revise the financial tests at present applied to irrigation works before they are undertaken.

Acknowledgements.

The main sources of information are the published Government reports. These, however, contain so much matter of an isolated interest that it is no wonder that little notice of such reports is taken by the public at large.

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Sources of information have been acknowledged in the text. The Author wishes to offer his apologies for any unintentional omissions. A complete bibliography is added at the end of the Paper.

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II. FINANCING OF IRRIGATION PROJECTS.

Development of Financial Policy in India.

Prior to 1854 all public works in India except railways were carried on by the Engineering Department of the Army under the superintendence

of a Military Board.* The expenditure incurred was treated as 'ordinary' and was charged against the revenue of the year; no capital or revenue accounts of the works were kept. For this reason it is difficult, almost impossible, in the case of the older works to find out their actual financial position.

The system of charging the cost of large productive works against yearly revenue was soon recognized as defective, and it was decided that only such works were to be charged against yearly revenue that came within the following† definition :—

> "Those relating to the maintenance and erection of civil and military buildings, the repair and construction of roads, and the other multifarious works necessary for the smooth and effective working of a great Empire."

Works of public utility such as railways, canals and harbours which were calculated to increase the wealth and promote the prosperity of the country were to be constructed from borrowed funds and treated as commercial undertakings. Of these latter works proper capital and revenue accounts were to be kept.

As in the case of railways, great pressure‡ was brought upon the Government of India in 1858 to promote irrigation under what was known as the "guarantee" system. A Madras Irrigation Company was formed with a Government guarantee of 5 p. c. upon a capital of one million pounds. A few years after, another private company called the East India Irrigation Co., undertook, without a guarantee, the construction of a system of irrigation canals in Orissa. About 1863 the status of guaranteed companies was so far assured and the East India Irrigation Company seemed to consider themselves so certain of success, that a proposal was actually made§ by the Secretary of that Company (1863) to purchase the works of the Ganges Canal from the Government. It was proposed that all returns up to 25 p.c. of the capital were to be retained by the Company, any surplus beyond that was to be divided between the Company and the Government.

The arrangement between the Secretary of State and the East India Irrigation Company soon became so involved that it was considered advisable to terminate the contract by the purchase of the works of the company at a price much above their market value. This sale was effected

* The Irrigation Works of India by Buckley (1880), Chapter I, page 1.

† Report of the Select Committee on Indian Public Works 1879, page iii.

‡ Report of the Select Committee on Indian Public Works, 1879, page vi.

§ Copies of despatches ordered to be printed by the House of Commons, 6th March 1867.

at a time when the company was practically bankrupt. The Madras Irrigation Company since its formation, except during one year, succeeded in meeting its working expenses. These two companies were the only ones connected with irrigation works in India.

In 1867 the Government decided that both the railway and irrigation works should be constructed by their own agency, which course was considered to be more economical and more easily controlled than the guarantee system.

It was in 1866 that the Government of India pointed out that what the Government desired was a permanent and persistent effort to carry out gradually a large extension of irrigation works. They desired to raise loans to be devoted exclusively to this purpose, for they feared that unless the principle of steady progress was definitely accepted, it would never be found financially convenient* to carry on works from beginning to end with proper vigour. The effect of depending from time to time upon the fluctuation of the money market would be the same as that of depending on occasional years of surplus revenue. In times of pressure the progress of works would be starved, and in times of financial prosperity attempts would be made to push forward schemes without experienced establishment or matured arrangements. The Secretary of State accepted this proposal of raising of loans necessary to construct productive irrigation works, the estimates of which had been thoroughly matured and of which reasonable expectation was maintained that they would prove remunerative. In consequence of this policy, great activity prevailed in the Irrigation Department during 1867 to 1869. Many schemes were proposed and surveyed and the staff of engineers was largely increased. The result was that a large sum of £10,569,935 was expended on irrigation works.† The depressed state of Indian finances just about this time created doubts as regards the wisdom of such great extension. The returns were not nearly as large as were predicted.

The Select Committee on Indian Public Works reporting to the House of Commons in 1879 said:—

> "The financial result of works of irrigation are in the opinion of your Committee the best test of their utility. A railroad may traverse, between its termini, certain districts which it does not materially improve, yet the work may be on the whole beneficial to the country. Unless, however, an irrigation work benefits the immediate locality in which it is placed, it can be of no use to outside districts."

* Copy of despatches ordered to be printed by the House of Commons, 6th March 1866.

† Appendix III, V & VII, Report of Select Committee on East India Public Works, 1879.

In accordance with the recommendations of the Select Committee referred to above, it was decided that the results of irrigation works in India should be tested as below :—

(*i*) By considering the capital cost of any work to be simply the sum actually spent on its construction.

(*ii*) By debiting the revenue account yearly with

(*a*) the simple interest on the capital cost of the works at the commencement of the year,

(*b*) the working expenses of the year.

(*iii*) By crediting the revenue account yearly.

(*a*) with direct receipts,

(*b*) with indirect receipts.

The difference between (*ii*) and (*iii*) for one year will show the profit or loss for that year. It was generally admitted at that time that irrigation works in India could not be expected to pay within 10 years of opening of the canal for irrigation, and this was, therefore, the period fixed for testing the financial results of any project. The actual test consisted in the project being able to earn sufficient revenue so as to pay a certain minimum return after deducting all working expenses on the sum-at-charge in the tenth year of its opening. The sum-at-charge is defined as the capital cost of construction plus the arrears of simple interest up to that year.

Before the introduction of the Reforms of 1921, all loans for the construction of productive irrigation works in the various provinces were raised by the Government of India in the money market of London and these were treated as advances made to the Local Government from the revenues of India at certain rates of interest fixed by the Central Government. After the Reforms, the Provincial Governments have raised loans on their own credit.

Development of Financial Policy in America.

The financing of land reclamation projects has undergone very heavy changes as a result of the experience gained from time to time. About 79 p. c. of the total irrigated area in the United States of America was financed by individuals, partnerships and corporations. Since 1910, irrigation enterprises by legislative action or carried on directly by Government agencies have been gaining rapidly in relative importance.

In 1884 an Act called the Carey Act, named after its promoter, was passed. This Act held out great promises but has so far accounted for less than 3 p.c. of the total irrigated area. It granted to each of the arid States up to one million acres of desert land subject to certain provisions for reclamation by the States. The works were executed through the agency of Construction Companies which provided the money for and built the works, these Companies having been authorized to sell water rights to parties buying the land from the States. The Carey Act contained a sound financial principle in that it permitted invested capital to earn, besides interest, a profit, commensurate with the risk involved.

The investors, however, were reluctant to avail themselves of this Act until a large margin could be assured.

Then came the Irrigation District Enterprises. These enterprises have been responsible for about 10 p.c. of the irrigated area. This method was comparatively independent of Government aid. According to this method laws were passed creating irrigation districts. The main financial features of this method were: funds were raised by the sale of bonds; interest, sinking funds and the cost of operation and maintenance were raised by assessment against the lands included within the district. The working of the Irrigation District method necessarily differed according to the property that was subject to the bond lien. Where the immediately existing land values, independent of any speculative element, left a large margin over the amount of the bond issue, the security was good and the method worked. On the other hand, where the existing land values were far below the bond issue, the security was uncertain and was dependent on numerous factors, such as under-estimated cost, insufficient water supply, faulty engineering and over-estimated rapidity of settlement. These carried varying degrees of risks and in the absence of an ample margin of security found a poor response. It was on this account that the *policy of reclamation had to undergo a material change and the Federal Reclamation Act of 1902 came into being. The area financed directly by Governmental financing agency amounted to 8 p.c. of the total development in 1920. The Federal Government actually puts up the money for reclamation and thus assumes financial responsibility. The Federal Act set aside a "Reclamation Fund" from the proceeds of the sale of public lands. This fund was meant to be a revolving fund, that is, the costs of constructing irrigation works to be repaid by the water users, go back into the fund and be used again for constructing other projects.

The original law provided that the cost of any project should be re-paid in 10 equal annual instalments, thus providing for a reasonably rapid turn-over of the fund. However, payments made did not amount to much, and in 1914 the period of repayment was

* Teele, Economics of Land Reclamation, page 165.

extended to 20 years, thus very much retarding the nominal rate of turn-over of the fund. Furthermore, the Secretary of the Interior was authorized to determine when the 20-year period of repayment shall begin. On one of the projects this period was delayed for as much as 14 years, thus making the period for repayment 34 years.

In 1924, the whole basis of repayment was changed, with the effect of extending very greatly the period of repayment. This amendment of the Reclamation Act provided for payments per acre of 5 p.c. of the average annual gross return per acre. It extended the period in the case of certain projects to 90 years and had to be modified in 1926. The amendment of 1926 provided a maximum repayment period of 40 years, leaving the details to the Secretary of the Interior.

As there is no interest on deferred payments, every extension of the period of repayment is to the advantage of the water users, but decreases the rate at which the revolving fund will revolve. To help this fund new legislation was enacted in 1920 providing that 52·5 p.c. of the receipts under the Oil Leasing Act and 5 p. c. of the receipts under the Federal Water Power Act shall go into the Land Reclamation Fund.

With the public lands largely disposed of the receipts from sale of public lands have become very small. With repeated extensions of the period of repayment and various "relief" acts postponing payments, repayments of construction costs have amounted to very little. Thus the Oil Leasing Act has become the principal source of revenue for the Land Reclamation Fund. The Water Power Act has not yet begun to yield any considerable revenue.

Under the Law, no interest on funds expended for construction is charged as a part of the cost.

This federal policy of reclamation has met with a certain amount of adverse criticism. It has been accused of constituting a heavy subsidy, but on the whole the federal reclamation policy has been defended on the score that the construction of large projects involving the reclamation of desert lands carries under present conditions risk out of proportion to profits and will not be undertaken by unaided enterprises for a long time and that stagnation of irrigation development may prove a serious detriment to the nation. Expansion of irrigation involves an ever-increasing expenditure per acre as it can only depend on residual stream flow necessitating relatively greater outlay for storage and because it usually requires longer average distance of water carriage. Table 3 taken from Mr. Henny's Paper* shows in a broad way the rising cost per acre for reclamation schemes in the United States of America:—

*Mr. Henny, Vol. 92, Paper No. 1666, page 557.
Transactions of the American Society of Civil Engineers.

TABLE 3.

Year.	Cost per acre.	
	Construction.	Annual maintenance and operation.
	$	$
1890 ..	7·96	..
1900 ..	9·04	..
1910 ..	15·85	1·07
1920 ..	26·81	2·43

Thus the costs of future projects per acre must necessarily be greater and the net receipts less, justifiying a change in the policy of handling reclamation projects by Government agency in place of private enterprise.

The Indian and American State Policies Compared.

Experience in India as well as in America led to the same conclusion that big irrigation projects cannot be undertaken by private enterprise. Private enterprise has some obvious points to its favour, but there are far too many uncertain factors connected with irrigation schemes to encourage private capital being invested in them. It speaks volumes for the early British administrators that they realized this fact right in the beginning, otherwise irrigation works in India could have never developed on the scale they have done.

In America a standing Land Reclamation Fund has been created from the income derived from the sale of public lands, and from oil and potassium leases. It is from this fund that irrigation projects are financed in the first instance. The capital cost without interest is then recovered from the farmer in not more than 40 years. After the complete repayment of this charge no further charge is made on this account. In addition a charge per acre is levied on account of annual maintenance and operation; this charge is payable yearly in advance and varies from year to year depending on the amount of water required.

In India the capital required for financing an irrigation project is raised on loan in the open market on Government security. This loan stands as a public debt till it is cleared from surpluses of provincial revenues in accordance with the rules of the Finance Department. Only the interest on this capital is met yearly from the revenue budget by debit

to the administrative accounts of the project. No attempt is made to recover the capital cost from the farmers whose lands benefit from the particular project. The farmer pays only a flat rate per acre for water based principally on the value of the crop harvested. Actual costs and returns to the State and the farmer will now be discussed.

III. COST AND RETURNS TO THE STATE.

Cost to the State Classified.

The cost to the State may be grouped under three heads :—

(*a*) Interest on the capital cost and arrears of interest for the construction period.

(*b*) Cost of administration.

(*c*) Cost of annual repairs and maintenance.

In the administrative accounts of a project, the capital cost is divided into direct and indirect charges.

Direct charges include the cost of :—

Works,

Establishment, and

Tools and Plant.

Indirect charges consist of two items :—

(*a*) Capitalized abatement of land revenue—this is taken at twenty times the annual amount of land revenue remitted on account of lands coming under the works.

(*b*) Audit and Accounts Establishment—this is taken as 1 per cent. on works expenditure, or the actual expenditure, where it is readily ascertainable as in the case of separate Audit and Accounts Offices constituted for specific projects.

Previously leave and pension charges went to the indirect charges, but from 1926-27 these are included in Establishment under direct charges.

Capital Costs of Various Irrigation Projects Compared.

Capital outlay (up to the end of 1937-38) per acre assessed (average of 3 years 1935-38) for various projects is given in Table 4.

TABLE 4.

Name of Canal	Year of completion of construction.	Outlay per acre assessed (1935-38).
		Rs.
Old Perennial Canals.		
Upper Bari Doab	31-3-79	17·29
Western Jumna	31-3-86	20·72
Sirhind	31-3-87	21·43
Lower Chenab	31-3-1900	19·65
Old Inundation Canals.		
Sidhnai Canal	31-3-86	5·09
Chenab Inundation Canals ..	31-3-95	6·1
Triple Canals.		
Lower Jhelum Canal ..	31-3-1917	24.73
Upper Jhelum, Upper Chenab & Lower Bari Doab.	31-3-1917	54·88
*Recently Constructed Canals.**		
Sutlej Valley Project (British) ..	31-3-1933	61·14
Sarda Canal (U. P.) ..	1930	72·74
*Canals under construction in the Punjab.**		
Haveli Canals,		
According to 1935 Project ..		55·49
According to total actual anticipated expenditure 1938 ..		36·25
*Projects under consideration in the Punjab.**		
Lesser Thal Project (1936 Estimate)	..	66·20
Bhakra Dam Project (Storage 1919 Estimate).	..	95·0

* Figures for these are calculated on the area to be irrigated on full development of the Project.

These figures show that in earlier projects capital cost per acre very much less than those in subsequent years. The great incr in cost is due partly to increased prices of labour and materials but r largely to increasing difficulties of construction and to the use of r permanent types of structures. In the case of inundation canals the ca cost per acre is the lowest, but it is obvious to even a casual studen irrigation that the best use of the available water is not made in inundation canals. The area that can benefit from the inunda canals is essentially limited in extent. In the case of earlier projects cost of canals constructed before the British period is also not include

It may be noted that for the Haveli Project the actual anticipated lay per acre comes to Rs. 36·25 only and compares very favourably the earlier projects. It is practically half of the recently constru projects and is only 63 per cent. of similar outlay on the Triple Cana

It is interesting to compare the figures of outlay per acre schemes other than gravity flow. The following cases are taken f other provinces and the United States of America :—

TABLE 5.

Name of Canal (system).	Capital outlay direct & indirect per acre (1935-36)
	Rs.
Divi Pumping system	86·3
State tube wells (United Provinces)	37·0
Ram Ganga (U. P. Storage)	153·7
Karol Bagh Tube-well Irrigation (Punjab) (Estimate 1938)	45·0*
†*United States of America* (1920 *Census*)	
All streams gravity	63·0
Streams pumped	77·0
Wells pumped	126·0
Stored storm water	185·0

* See Table on working expenses.
† Teele, Economics of Land Reclamation, page 206.

Name of Project	Year of Completion of Construction	Area assessed 3 years average (1935-38)	(1) Total Co to end of 1937-38.
1	2	3	4
		Acres.	Rs.
(1) Upper Bari Doab Canal ..	31-3-79	1,256,954	11,57,93
(2) Western Jumna .. Canal ..	31-3-86	990,032	13,24,06
(3) Sirhind Canal ..	31-3-86	1,231,589	11,36,31
(4) Lower Chenab Canal ..	31-3-1900	2,357,921	1,09,13,15
(5) Lower Jhelum Canal	31-3-1917	845,941	45,86,32
(6) Triple Canals ..	31-3-1917	2,005,139	1,48,13,53
(7) Sutlej Valley .. Project (British share)	31-3-1933	1,478,000* 1,449,702,	2,34,05,62
(8) Sarda Canals ..	1930	1,350,000† 1,014,053, (1935-36)	90,95,19
(9) Haveli Project Estimated 1935	..	965,344	2,29,16,00
1938 anticipated Actual	..	965,344	1,44,53,00

* Full Development
† Full Development

I. Works		II. Establishment.		III. Tools and plant		IV. Suspense.		V. Receipts on Capital Account.		Total Direct Charges.		Indirect Charges.		Total Direct and Indirect Charges.	
Cost per acre assessed.		Total cost to end of 1937-38.	Cost per acre assessed.	Total cost to end of 1937-38.	Cost per acre assessed.	Total cost to end of 1937-38.	Cost per acre assessed.	Total credit to end of 1937-38.	Credit per acre assessed.	Total cost to end of 1937-38.	Cost per acre assessed.	Total cost to end of 1937-38.	Cost per acre assessed.	Total cost to end of 1937-38.	Cost per acre assessed.
19		20	21	22	23	24	25	26	27	28	29	30	31	32	33
Rs.		Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs	Rs.	Rs.	Rs.	Rs.
13·26		36,20,826	2·87	7,38,397	0·58	62,887	0·05	1,00,892	0·08	2,09,91,575	16·7	7,46,183	0·59	2,17,37,758	17·29
15·67		40,68,121	4·10	2,88,903	0·29	29,182	0·03	2,92,136	0·29	1,96,13,472	19·81	9,02,972	0·91	2,05,16,444	20·72
14·77		49,10,321	3·98	21,14,780	1·71	1,08,213	0·08	1,75,425	0·14	2,51,58,199	20·42	12,43,686	1·01	2,64,01,885	21·43
15·46		81,36,544	3·45	9,18,242	0·38	2,76,932	0·11	4,26,329	0·18	453,66,096	19·23	9,69,587	0·41	4,63,35,683	19·65
19·39		33,44,927	3·95	4,93,343	0·58	1,43,639	0·16	89,113	0·10	2,03,99,633	24·11	5,23,774	0·61	209,23,407	24·73
44·17		1,55,43,951	7·75	89,64,013	4·47	4,84,900	0·24	60,63,201	3·02	10,75,11,303	53·61	25,48,226	1·27	11,00,59,529	54·88
52·24 53·26		1,31,97,643	8·93 9·10	12,18,041	0·82 0·84	9,59,527	0·65 0·66	38,09,104	2·57 2·62	8,87,80,850	60·06 61·24	15,96,774	1·08 1·10	9,03,77,624	61·14 62·34
58·79 78·27		1,62,56,123	12·04 16·03	15,46,831	1·14 1·52	9,13,264	0·67 0·90	33,00,000	2·44 3·25	9,50,74,984 including Rs. 2,85,344 for surveys and experiments.	70·42 93·75	31,29,132	2·31 3·08	9,82,04,116	72·74 96·84
48·50		66,95,000	6·93	6,93,000	0·71	..	..	12,99,000	1·34	5,29,09,000	54·80	6,66,000	0·68	5,35,75,000	55·49
32·31		29,82,768	3·08	1,43,336	0·14	4,60,220	0·47	1,18,315	0·12	3,46,62,632	35·97	3,37,368	0·34	3,50,00,000	36·25

cludes Rs. 6,75,149 for extended channels from Rohilkhand.

TABLE 6.

Capital Costs of Various Projects.

I—Works																
rks	(2) Main Canal and Branches		(3) Distributaries		(4) Drainage & Protective Works		(5) Watercourses.		(6) Special Tools & Plant		(7) Losses on Stock		Total I. Works		II. Esta
ost per acre assessed.	Total cost to end of 1937-38.	Cost per acre assessed.	Total cost to end of 1937-38	Cost per acre assessed	Total cost to end of 1937-38.	Cost per acre assessed.	Total cost to end of 1937-38.	Cost per acre assesse.d	Total cost to end of 1937-38.	Cost per acre assessed.	Total cost to end of 1937-38	Cost per acre assessed.	Total cost to end of 1937-38	Cost per acre assessed.	Total cost to end of 1937-38.
5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Rs.	Rs-	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
0·92	1,14,27,340	9·09	41,58,405	3·31	1,33,368	0·10	6,823	0 .005	..	..	..	..	1,66,70,357	13·26	36,20,826
1·34	75,90,731	7·67	39,39,306	3·97	7,41,177	0·74	..	..	19, 24, 123 (on general works at end of 1864-65	1·94	..	..	1,55,19,402	15·67	40,68,121
0·92	1,22,99,045	9·98	41,43,819	3·36	5,93,310	0·48	..	..	27,505	0·01	315	..	1,82,00,310	14·77	49,10,321
4·62	1,57,73,523	6·69	75,47,712	3·20	20,26,528	0·85	1,30,131	0·05	66,858	0·02	2,792	0·001	3,64,60,707	15·46	81,36,544
5·42	65,40,496	7·73	47,63 503	5·63	5,02,791	0·59	..	..	..	..	..	..	1,64,06,837	19·39	33,44,927
7·38	5,63,09,205	28·08	1,28,43,594	6·40	29,78,726	1·48	15,60,863	0·77	68,861	0·03	6,859	0·003	8,85,81,640	44·17	1,55,43,951
15·83 16·14	2,94,06,132	19·88 20·28	1,65,87,333	11·22 11·44	3,28,978	0·22 0·22	39,51,611	2·67 2·72	31,31,230	2·11 2.15	4,03,832	0·27 0·27	7,72,14,743	52·24 53·26	1,31,97,643
6·73 8·96	4,40,88,706	32·65 43·47	1,65,32,210	12·24 16·30	29,16,659	2·16 2·87	18,68,565	1·38 1·84	40,77,592	3·02 4·02	1,19,351	0·08 0·11	7,93,73,422*	58·79 78·27	1,62,56,123
23·73	1,41,84,000	14·69	50,98,000	5·28	14,15,000	1·46	12,82,000	1·32	18,45,000	1·91	80,000	0·08	4,68,20,000	48·50	66,35,000
14·97	1,29,62,461	13·42	26,19,141	2·71	50,027	0·05	1,11,000	0·11	9,83,447	1·01	15,547	0·01	3,11,94,623	32·31	29,82,768

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ide page 8 of the Completion Report of Sarda Canal, 1931.

* Includes Rs. 6,75,149 for extende

) *per Acre Assessed.*

Gross Receipts.						Net profit per Acre	
irect Receipts		Indirect Receipts		Direct and Indirect Receipts		On Direct Receipts	On both Direct and Indirect Receipts
tal	per acre assessed	Total	per acre assessed	Total	per acre assessed		
2	13	14	15	16	17	18	19
.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
5,892	4·126	1,023,139	0·814	6,209,031	4·940	2·213	3·027
9,222	3·899	229,974	0·232	4,089,196	4·131	1·636	1·868
7,183	4·057	166,465	0·135	5,163,648	4·192	2·161	2·290
0,010	4·292	9,105,864	3·861	19,225,874	8·153	2·163	6·02
3,517	3·999	1,767,691	2·089	5,151,208	6·088	1·657	3·74
5,280	4·366	6,170,997	3·078	14,926,277	7·444	0·560	3·63
4,069	3·431	4,423,448	3·051	9,397,517	6·482	−0·928	2·12
4,708	1·720	482,833	1·868	927,541	3·588	0·894	2·70
1,606	1·523	320,098	1·864	581,704	3·387	−0·709	1·1
8,722	1·089	407,997	2·355	596,719	3·444	−3·003	−0·64
0,144	1·993	39,707	0·658	159,851	2·651	−1·280	−0·62
4,008	0·916	415,238	1·293	709,246	2·209	−0·741	+0·5
4,102	0·779	18,032	1·072	31,134	1·851	−2·326	−1·25

TABLE 26.

Financial Results of Punjab Canals based on Three Years' Average (1935-38

Name of Canal	Area assessed	Interest on Capital		Working Expenses						Total of Interest and Working Expenses per acre.	D: To
		Total	per acre assessed	Direct Charges. Total	Direct Charges. per acre assessed	Indirect Charges Total	Indirect Charges per acre assessed	Total Direct and Indirect Charges Total	Total Direct and Indirect Charges per acre assessed		
1	2	3	4	5	6	7	8	9	10	11	1
	acres	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
I—*Productive Works.* ..											
Upper Bari Doab ..	1,256,954	733,049	0·583	1,665,252	1·324	8,137	0·006	1,673,389	1·330	1·913	5,18
Western Jumna ..	989,840	642,390	0·648	1,589,823	1·606	9,014	0·009	1,598,837	1·615	2·263	3,85
Sirhind ..	1,231,589	879,235	0·713	1,452,066	1·179	5,034	0·004	1,457,100	1·183	1·896	4,99
Lower Chenab ..	2,357,921	1,639,805	0·695	3,367,865	1·428	14,952	0·006	3,382,817	1·434	2·129	10,12
Lower Jhelum ..	845,941	730,913	0·864	1,245,852	1·472	4,892	0·006	1,250,744	1·478	2·342	3,38
Triple Canals ..	2,005,139	3,703,387	1·846	3,912,199	1·951	17,899	0·009	3.930,098	1·960	3·806	8,75
Sutlej Valley Project ..	1,449,702	3,768,929	2·599	2,542,708	1·753	10,258	0·007	2,552,966	1·76	4·359	4,97
Sidhnai Canals ..	258,511	44,825	0·173	168,055	0·65	789	0·003	168,844	0·653	0·826	44
Chenab Inundation Canals	171,733	41,147	0·239	340,396	1·982	1,987	0·011	342,383	1·993	2·232	26
II—*Unproductive Works*											
Indus Inundation Canals	173,227	116,826	0·674	588,702	3·3984	3,388	0·0196	592,090	3·418	4·092	18
Shahpur Inundation Canal	60,288	7,592	0·126	189,019	3·135	723	0·012	189,742	3·147	3·273	12
Muzzaffargarh Inundation Canals. ..	321,025	74,275	0·231	455,122	1·417	2,799	0·009	457,921	1·426	1·657	2(
Ghaggar Canal ..	16,817	13,220	0·786	38,849	2·31	154	0·009	39,003	2·319	3·105	13

TABLE 6.

Capital Costs of Various Projects.

I—Works																
ı Canal and inches		(3) Distributaries		(4) Drainage & Protective Works		(5) Watercourses.		(6) Special Tools & Plant		(7) Losses on Stock		Total I. Works		II. Establishment.		III
Cost per acre assessed.		Total cost to end of 1937-38	Cost per acre assessed.	Total cost to end of 1937-38.	Cost per acre assessed.	Total cost to end of 1937-38.	Cost per acre assesse.d	Total cost to end of 1937-38.	Cost per acre assessed.	Total cost to end of 1937-38	Cost per acre assessed.	Total cost to end of 1937-38	Cost per acre assessed.	Total cost to end of 1937-38.	Cost per acre assessed.	Tota to e 193
7		8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Rs.		Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	
9·09		41,58,405	3·31	1,33,368	0·10	6,823	0 .005	..	..	..	...	1,66,70,357	13·26	36,20,826	2·87	7,3
7·67		39,39,306	3·97	7,41,177	0·74	..	..	19, 24, 122 (on general works at end of 1864-65	1·94	..	..	1,55,19,402	15·67	40,68,121	4·10	2,8
9·98		41,43,819	3·36	5,93,310	0·48	..	..	27,505	0·01	315	..	1,82,00,310	14·77	49,10,321	3·98	21,1
6·69		75,47,712	3·20	20,26,528	0·85	1,30,131	0·05	66,858	0·02	2,792	0·001	3,64,60,707	15·46	81,36,544	3·45	9,1
7·73		47,63,503	5·63	5,02,791	0·59	..	..	..	..	..	..	1,64,06,837	19·39	33,44,927	3·95	4,9
28·08		1,28,43,594	6·40	29,78,726	1·48	15,60,863	0·77	68,861	0·03	6,859	0·003	8,85,81,640	44·17	1,55,43,951	7·75	89,6
19·88 20·28		1,65,87,333	11·22 11·44	3,28,978	0·22 0·22	39,51,611	2·67 2·72	31,31,230	2·11 2.15	4,03,832	0·27 0·27	7,72,14,743	52·24 53·26	1,31,97,643	8·93 9·10	12,1
32·65 43·47		1,65,32,210	12·24 16·30	29,16,659	2·16 2·87	18,68,565	1·38 1·84	40,77,592	3·02 4·02	1,19,351	0·08 0·11	7,93,73,422*	58·79 78·27	1,62,56,123	12·04 16·03	15,4
14·69		50,98,000	5·28	14,15,000	1·46	12,82,000	1·32	18,45,000	1·91	80,000	0·08	4,68,20,000	48·50	66,95,000	6·93	6,9
13·42		26,19,141	2·71	50,027	0·05	1,11,000	0·11	9,83,447	1·01	15,547	0·01	3,11,94,623	32·31	29,82,768	3·08	1,4

ıpletion Report, 1935.
ıletion Report of Sarda Canal, 1931.

* Includes Rs. 6,75,149 for extended channels from Roh

ıl I. Works		II. Establishment.		III. Tools and plant		IV. Suspense.		V. Receipts on Capital Account.		Total Direct Charges.		Indirect Charges.		Total Direct and Indirect Charges.	
f	Cost per acre assessed.	Total cost to end of 1937-38.	Cost per acre assessed.	Total cost to end of 1937-38.	Cost per acre assessed.	Total cost to end of 1937-38.	Cost per acre assessed.	Total credit to end of 1937-38.	Credit per acre assessed.	Total cost to end of 1937-38.	Cost per acre assessed.	Total cost to end of 1937-38.	Cost per acre assessed.	Total cost to end of 1937-38.	Cost per acre assessed.
	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs	Rs.	Rs.	Rs.	Rs.
7	13·26	36,20,826	2·87	7,38,397	0·58	62,887	0·05	1,00,892	0·08	2,09,91,575	16·7	7,46,183	0·59	2,17,37,758	17·29
2	15·67	40,68,121	4·10	2,88,903	0·29	29,182	0·03	2,92,136	0·29	1,96,13,472	19·81	9,02,972	0·91	2,05,16,444	20·72
0	14·77	49,10,321	3·98	21,14,780	1·71	1,08,213	0·08	1,75,425	0·14	2,51,58,199	20·42	12,43,686	1·01	2,64,01,885	21·43
7	15·46	81,36,544	3·45	9,18,242	0·38	2,76,932	0·11	4,26,329	0·18	453,66,096	19·23	9,69,587	0·41	4,63,35,683	19·65
7	19·39	33,44,927	3·95	4,93,343	0·58	1,43,639	0·16	89,113	0·10	2,03,99,633	24·11	5,23,774	0·61	209,23,407	24·73
0	44·17	1,55,43,951	7·75	89,64,013	4·47	4,84,900	0·24	60,63,201	3·02	10,75,11,303	53·61	25,48,226	1·27	11,00,59,529	54·88
3	52·24 53·26	1,31,97,643	8·93 9·10	12,18,041	0·82 0·84	9,59,527	0·65 0·66	38,09,104	2·57 2·62	8,87,80,850	60·06 61·24	15,96,774	1·08 1·10	9,03,77,624	61·14 62·34
22*	58·79 78·27	1,62,56,123	12·04 16·03	15,46,831	1·14 1·52	9,13,264	0·67 0·90	33,00,000	2·44 3·25	9,50,74,984 including Rs. 2,85,344 for surveys and experiments.	70·42 93·75	31,29,132	2·31 3·08	9,82,04,116	72·74 96·84
00	48·50	66,95,000	6·93	6,93,000	0·71	..	..	12,99,000	1·34	5,29,09,000	54·80	6,66,000	0·68	5,35,75,000	55·49
23	32·31	29,82,768	3·08	1,43,336	0·14	4,60,220	0·47	1,18,315	0·12	3,46,62,632	35·97	3,37,368	0·34	3,50,00,000	36·25

udes Rs. 6,75,149 for extended channels from Rohilkhand.

Name of Headworks.	Year of Start / completion.	Design Data. Head across the Under-sluices.	Design Data. Head across the Weir.	Maximum Flood discharge.	Distance between abutments.	A. Preliminary.	B. Land.	C. Works.	D. Buildings.
1	2	3	4	5	6	7	8	9	10
		Feet.	Feet.	Cusecs.	Feet.	Rs.	Rs.	Rs.	
Madhopur (U.B.D.C.) ..	1869	11·0	..	2.00.000	....	..	466	10,68,827	8
Tajewala (W.J.C) ..	1869 / 1886	..	..	350,000	..	..	4,738	12,05,125	7
Sidhnai. ..	1884 / 1892	..	15·1	..	..	754	235	2,46,260	1
Rupar (S.C.) ..	1874 / 1882	14·5	14·5	233,000	2396	307·0	755	11,037	14,70,201	1,4
Khanki (Lower Chenab)	1889 / 1892	19·0	19·0	800,000	4414	5,710	54,105	104,69,436	1,5
Rasul (Lower Jhelum).	1898 / 1901	19·0	18·8	600,000	4400	12,619	31,772	42,92,885	2,0
Marala (Upper Chenab).	1905 / 1910	19·17	20·9	712,371	4469·5	8,284	94,615	83,59,383	2,2
Balloki (L.B.D.C.) ..	1907 / 1912	21·5	21·5	105,000	1645·5	14,355	2,27,918	47,91,521	2,1
Ganda Singhwala (Ferozepore S.V.P.)	1921 / 1927	19·0	19·0	450,000	1956	1,18,125	21,01,921	91,29,300	4,5
Sulaimanke (S.V.P.) ..	1921 / 1926	21·0	18·5	325,000	2223	84,517	7,06,348	1,37,45,879	4,7
Islam (S.V.P.) ..	1922 / 1927	18·25	18·0	225,000	1621	75,767	7,77,460	1,27,45,560	7,7
Panjnad (S.V.P.) ..	1926 / 1931	18·5	19·0	700,000	2150 Excluding Groyne.	33,426	6,97,761	1,30,11,468	6,0
Banbasa Head of Sarda Canal	1919 / 1930	17.0	15·0	600,000	1964	26,492	2,51,666	79,47,527	3,7
Lloyds Barrage of Sukkur	1926 / 1933	20·5	18·5	1500,000	4725	66,416	10,53,636	3,67,01,344	20,5
Emerson Barrage 1935 (Haveli Estimated).	1937 / 1942	19·0	19·0	650,000	4235	35,000	19,20,000	1,56,29,000	5,6
Emerson Barrage Total anticipated Actual expenditure ..	1937 / 1939	29·0	25·0	650,000	3026	50,000	19,00,000	1,09,24,000	4,0

STATEMENT SHOWING COSTS OF VARIOUS HEAD

Design Data.				I. Works											
				(1) Headworks.											
Head across the		Maximum Flood discharge.	Distance between abutments.	A. Preliminary.	B. Land.	C. Works.	K.— Buildings.	M.— Plantation.	O.— Miscellaneous.	P.— Maintenance.	R.— Railways	Losses on Nalagarh Quarry.	Total Headworks (Cols. 7 to 15).	(6) Special Tools and Plant.	(7) Losses on Stock.	To I. W (Col 16 t
Under-sluices.	Weir.															
3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Feet.	Feet.	Cusecs.	Feet.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	
				Expenditure to end of 1937-38 (including contribution figure).												
11·0	..	2.00.000		..	466	10,68,827	89,232	..	346	..	..	..	11,57,939	..	..	11,
..	..	350,000		..	4,738	12,05,125	75,824	..	13,539	24,839	..	..	13,24,065	..	..	13,
..	15·1	..		754	235	2,46,260	17,893	..	391	..	..	..	2,65,533	..	..	2,
14·5	14·5	233,000	2396	307·0	755	11,037	14,70,201	1,40,372	..	77,342	37,663	..	..	17,37,370	42,976	315	17,
19·0	19·0	800,000		4414	5,710	54,105	104,69,436	1,54,646	..	6,084	1,68,784	44,388	..	1,09,13,153	66,858	2,792	109,
19·0	18·8	600,000		4400	12,619	31,772	42,92,885	2,01,754	..	19,273	28,020	..	..	45,86,323	..	..	45,
19·17	20·9	712,371		4469·5	8,284	94,615	83,59,383	2,25,378	..	75,153	1,35,343	..	..	88,98,156	68,861	7,317	89,
21·5	21·5	105,000		1645·5	14,355	2,27,918	47,91,521	2,19,272	..	29,335	78,796	..	..	53,61,197	..	1,912	53
19·0	19·0	450,000		1956	1,18,125	21,01,921	91,29,300	4,58,328	7,120	3,24,339	1,19,971	7,03,434	12,44,628	1,42,07,186	12,30,723	49,508	1,54
21·0	18·5	325,000		2223	84,517	7,06,348	1,37,45,879	4,71,736	44,260	1,24,051	12,900	8,68,819	16,85,325	1,77,43,835	12,73,379	198,624	1,92
18·25	18·0	225,000		1621	75,767	7,77,460	1,27,45,560	7,78,153	(i) Service & Boundary Roads. 74,349 14,499	2,13,310	5,96,951	12,23,786	19,03,733	1,72,33,568	13,76,388	106,415	1,87
18·5	19·0	700,000		150 Excluding Breyne.	33,426	6,97,761	1,30,11,468	6,02,692	7,812	1,68,307	2,89,159	16,60,291	..	1,64,70,916	8,89,310	51,672	1,74
17.0	15·0	600,000		1964	26,492	2,51,666	79,47,527	3,71,387	7,902	3,18,703	1,71,513	..	..	90,95,190	..	..	† 90,
20·5	18·5	1500,000		4725	66,416	10,53,636	3,67,01,344	20,58,855	..	1,00,292	4,24,207	..	..	4,04,02,750	1,06,67,013	55,670	‡ 5,11
19·0	19·0	650,000		4235	35,000	19,20,000	1,56,29,000	5,63,000	10,000	1,85,000	1,76,000	11,49,000	..	1,96,67,000	10,76,000	50,000	2,07,
29·0	25·0	650,000		3026	50,000	19,00,000	1,09,24,000	4,00,000	4,000	1,10,000	1,65.000	9,00,000	..	1,44,53,000	9,27,000	11,000	1,53,

* Including Contribution figures.
† Taken from p. 119 of Completion Report of Sarda Canal, 1931.
‡ Taken from P. 118 of Completion Report of the Lloyds Barrage Vol. II.

OUS HEADWORKS.

) Losses n Stock.	Total I. Works (Columns) 16 to 18.	II. Establishment.	III Tools and plant.	IV. Suspense.	V. Receipts on Capital Account.	Total Direct Charges Cols. 19 to 23	Indirect charges.			Grand total Direct and Indirect (Cols. 24+27).	Cost per cusec of maximum flood discharge (on I. Works figures.)	Cost per foot of distance between abutments (on I. Works figures.(	Cost per cusec of maximum flood Discharge on direct and indirect charges.	Cost per foot of distance between abutments on direct and indirect charges.
							Capitalization of abatement of land revenue	Leave and pension and Audit and Accounts Charges.	Total Indirect Charges Cols. 25+26					
18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.		Rs.	Rs.	Rs.	Rs.
..	11,57,939										..	..	..	..
..	13,24 065	(Including contributi n figures).									..	..	..	..
..	2,65,533										..	..	..	..
315	17,80,661	(Including contribution figures).			Cost for Headworks under these Heads not available separately						..	..	..	..
2,792	109,82,803										7·64	658·28	..	..
..	45,86,323										13·72	2,488·17	..	..
7,317	89,74,334										7·64	1,042·34	..	..
1,912	53,63,109										12·59	2,007·95	..	..
49,508	1,54,87,417	14,10,318	2,29,879	1,22,769	5,00,715	1,67,49,668	81,648	263,960	3,45,608	*1,70,95,276	51·07	3,259·25	...	..
198,624	1,92,15,838	17,52,905	2,20,771	2,90,099	5,85,097	2,08,94,516	976	2,89,860	2,90,836	*2,11,85,352	34·41	7,917·90	37·98	8,739·91
106,415	1,87,16,371	23,65,306	2,88,664	3,33,271	4,23,450	2,12,80,162	..	2,90,271	2,90,271	*2,15,70,453	59·12	8,644·1	65·18	9,530·07
51,672	1,74,11,898	15,66,721	1,52,471	2,74,588	10,60,250	1,83,45,428	160	1,38,208	1,38,368	*1,84,83,796	84·3	11,546·18	97·16	13,306·86
..	† 90,95,190	Costs under these heads not available separately for 'Headworks.'									24·87	5,527·58	26·4	5,867·87
55,670	‡ 5,11,25,523										15·15	4,630 9	..	..
50,000	2,07,93,000	17,77,000	2,08,000	..	1,00,000	2,26,78,000	96,000	2,08,000	3,04,000	2,29,82,000	34·08	10,820·21	..	..
11,000	1,53,91,000	6,38,000	61,000	3,53,000	1,07,400	1,63,35,600	90,000	1,53,900	2,43,900	1,65,79,500	31·98	4,909·79	35·35	5,426·68
											23·67	5,087·93	25·50	5,480·82

Statement showing cost of Various

Name of Headworks.	C. Works.				
	(1) Training Works.	(*ii*) Weir and Undersluices.	(*iii*) Head Regulator.	(*iv*) Gates and Gearing.	(*v*) Pum
1	2	3	4	5	6
Sirsa Singhwala, S.V.P. (Ferozepore Weir.)	Rs. 10,63,391	Rs. 35,57,900	Rs. 11,03,726	Rs. 12,96,591	Rs 5,11
Sidhnanke S.V.P.	36,41,652	52,45,510	16,86,099	18,21,575	5,61
Islam S.V.P. ..	25,87,336	61,75,279	12,98,253	10,78,237	2,67
Rajnad S.V.P.	23,16,000	60,66,800	8,34,262	17,03,644	10,27
Emerson (1935) Estimated (Haveli Project.)	21,80,386	84,44,904	5,21,710	23,00,000	10,00
Emerson (1938) Actual anticipated on completion. .. (Haveli Project.)	12,52,600	63,75,000	2,81,400	17,65,000	5,50

GRAPH NO. 6
PAPER NO. 228

ADY RISE IN "DUTY" ON SOME OF THE PUNJAB CANALS

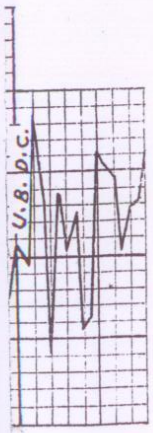
REFERENCES

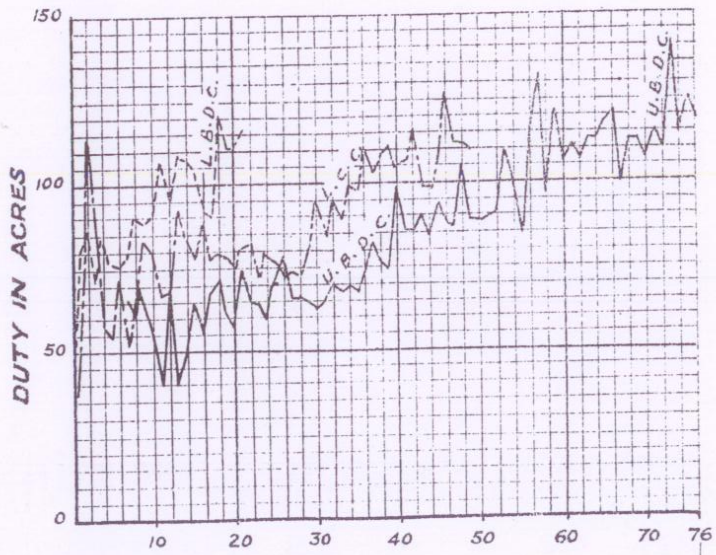
U. B. D. C. FROM 1960-61 ————

L. C. C. FROM 1887-88 —·—·—

L. B. D. C. FROM 1915-16 - - - - - -

KHARIF





50 70 76

F YEARS FROM DATE OF OPENING

PUNJAB ENGINEERING CONGRESS. 1939.

TABLE 8.

Headworks under 'C Works' by detailed sub-heads.

ig.	(vi) River Diversion.	(vii) Unforeseen.	(viii) Losses on Nalagarh Quarry.	Total.	Design Data. Head Across the: Under sluices.	Design Data. Head Across the: Weir.	Maximum flood Discharge.	Distance between abutments.
	7	8	9	10	11	12	13	14
06	Rs. 15,19,426	Rs. 77,160	Rs. 12,44 628	Rs. 1,03,73,928	feet. 19·0	feet. 19·0	cusecs. 4,50,000	feet. 1,956
91	7,89,252	..	16,85,325	1,54,31,204	21·0	18·5	3,25,000	2223
22	12,62,077	76,956	10,03,733	1,37,49,293	18·25	18·0	225,000	1,621
65	10,26,671	36,426	..	1,30,11,468	18·5	19·0	700,000	3,150 excluding Groyne.
00	5,50,000	6,32,000	..	1,56,29,000	19·0	19·0	6,50,000	4,235
00	6,00,000	1,00,000	..	1,09,24,000	29·0	25·0	6,50,000	3,026

TABLE 26.

Financial Results of Punjab Canals based on Three Years' Average (1935-38) per Acre Assessed.

Name of Canal	Area assessed	Interest on Capital		Working Expenses						Total of Interest and Working Expenses per acre.	Gross Re		
				Direct Charges.		Indirect Charges		Total Direct and Indirect Charges			Direct Receipts		Indirect R
		Total	per acre assessed	Total	per acre assessed	Total	per acre assessed	Total	per acre assessed		Total	per acre assessed	Total
1	2	3	4	5	6	7	8	9	10	11	12	13	14
	acres	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
I—*Productive Works.* ..													
Upper Bari Doab ..	1,256,954	733,049	0·583	1,665,252	1·324	8,137	0·006	1,673,389	1·330	1·913	5,185,892	4·126	1,023,139
Western Jumna ..	989,840	642,390	0·648	1,589,823	1·606	9,014	0·009	1,598,837	1·615	2·263	3,859,222	3·899	229,974
Sirhind ..	1,231,589	879,235	0·713	1,452,066	1·179	5,034	0·004	1,457,100	1·183	1·896	4,997,183	4·057	166,465
Lower Chenab ..	2,357,921	1,639,805	0·695	3,367,865	1·428	14,952	0·006	3,382,817	1·434	2·129	10,120,010	4·292	9,105,864
Lower Jhelum ..	845,941	730,913	0·864	1,245,852	1·472	4,892	0·006	1,250,744	1·478	2·342	3,383,517	3·999	1,767,691
Triple Canals ..	2,005,139	3,703,387	1·846	3,912,199	1·951	17,899	0·009	3.930,098	1·960	3·806	8,755,280	4·366	6,170,997
Sutlej Valley Project ..	1,449,702	3,768,929	2·599	2,542,708	1·753	10,258	0·007	2,552,966	1·76	4·359	4,974,069	3·431	4,423,448
Sidhnai Canals ..	258,511	44,825	0·173	168,055	0·65	789	0·003	168,844	0·653	0·826	444,708	1·720	482,833
Chenab Inundation Canals	171,733	41,147	0·239	340,396	1·982	1,987	0·011	342,383	1·993	2·232	261,606	1·523	320,098
II—*Unproductive Works*													
Indus Inundation Canals	173,227	116,826	0·674	588,702	3·3984	3,388	0·0196	592,090	3·418	4·092	188,722	1·089	407,997
Shahpur Inundation Canal	60,288	7,592	0·126	189,019	3·135	723	0·012	189,742	3·147	3·273	120,144	1·993	39,707
Muzzaffargarh Inundation Canals. ..	321,025	74,275	0·231	455,122	1·417	2,799	0·009	457,921	1·426	1·657	294,008	0·916	415,238
Ghaggar Canal ..	16,817	13,220	0·786	38,849	2·31	154	0·009	39,003	2·319	3·105	13,102	0·779	18,032

TABLE 26.

Financial Results of Punjab Canals based on Three Years' Average (1935-38) per Acre Assessed.

a ised	Interest on Capital		Working Expenses						Total of Interest and Working Expenses per acre.	Gross Receipts.						Net profit per Acre	
			Direct Charges.		Indirect Charges		Total Direct and Indirect Charges			Direct Receipts		Indirect Receipts		Direct and Indirect Receipts			
	Total	per acre assessed	Total	per acre assessed	Total	per acre assessed	Total	per acre assessed		Total	per acre assessed	Total	per acre assessed	Total	per acre assessed	On Direct Receipts	On both Direct and Indirect Receipts
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
es	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
6,954	733,049	0·583	1,665,252	1·324	8,137	0·006	1,673,389	1·330	1·913	5,185,892	4·126	1,023,139	0·814	6,209,031	4·940	2·213	3·027
9,840	642,390	0·648	1,589,823	1·606	9,014	0·009	1,598,837	1·615	2·263	3,859,222	3·899	229,974	0·232	4,089,196	4·131	1·636	1·868
1,589	879,235	0·713	1,452,066	1·179	5,034	0·004	1,457,100	1·183	1·896	4,997,183	4·057	166,465	0·135	5,163,648	4·192	2·161	2·290
7,921	1,639,805	0·695	3,367,865	1·428	14,952	0·006	3,382,817	1·434	2·129	10,120,010	4·292	9,105,864	3·861	19,225,874	8·153	2·163	6·024
5,941	730,913	0·864	1,245,852	1·472	4,892	0·006	1,250,744	1·478	2·342	3,383,517	3·999	1,767,691	2·089	5,151,208	6·088	1·657	3·746
5,139	3,703,387	1·846	3,912,199	1·951	17,899	0·009	3,930,098	1·960	3·806	8,755,280	4·366	6,170,997	3·078	14,926,277	7·444	0·560	3·63
9,702	3,768,929	2·599	2,542,708	1·753	10,258	0·007	2,552,966	1·76	4·359	4,974,069	3·431	4,423,448	3·051	9,397,517	6·482	−0·928	2·12
8,511	44,825	0·173	168,055	0·65	789	0·003	168,844	0·653	0·826	444,708	1·720	482,833	1·868	927,541	3·588	0·894	2·70
1,733	41,147	0·239	340,396	1·982	1,987	0·011	342,383	1·993	2·232	261,606	1·523	320,098	1·864	581,704	3·387	−0·709	1·14
3,227	116,826	0·674	588,702	3·3984	3,388	0·0196	592,090	3·418	4·092	188,722	1·089	407,997	2·355	596,719	3·444	−3·003	−0·64
0,288	7,592	0·126	189,019	3·135	723	0·012	189,742	3·147	3·273	120,144	1·993	39,707	0·658	159,851	2·651	−1·280	−0·62
1,025	74,275	0·231	455,122	1·417	2,799	0·009	457,921	1·426	1·657	294,008	0·916	415,238	1·293	709,246	2·209	−0·741	+0·51
6,817	13,220	0·786	38,849	2·31	154	0·009	39,003	2·319	3·105	13,102	0·779	18,032	1·072	31,134	1·851	−2·326	−1·254

It will be seen that gravity flow systems are the cheapest source of water supply in the intitial outlay.

Some of the readers may like to pursue the subject regarding the Punjab Canals. They may refer to Table 6. This table gives the outlay per acre under each of the administrative heads of accounts. Brief comments on each sub-head are given in the following paragraphs to emphasize on certain points, which are responsible for the disparity.

Headworks.

The most important single item of expenditure is the headworks in the river. Table 7 gives the costs of the more important headworks of the Punjab and those recently constructed in other provinces, under various heads. The cost of headworks is independent of the area irrigated and depends on the maximum flood discharge of the river, the width of the work required, head for which it is designed, the type and height of gates used and the nature of the river bed. It also depends on its distance from the source of supply of construction materials and the rates of labour prevalent at the time of construction. A strict comparison, therefore, between costs of various headworks is not possible. The costs have been worked out per cusec of the maximum flood capacity as well as per foot length between weir abutments. Rupar headworks has cost the least. Next comes Rasul, then come Khanki and Marala. Balloki's cost is very heavy. The more recent headworks on the Sutlej Valley Project, and Lloyd Barrage (Sukkur) have cost appreciably more. It will be interesting to compare the cost of the Emerson Barrage of the Haveli Project with the cost of the more recently constructed barrages. In comparing the costs with Banbasa and Lloyd Barrage one fact must be borne in mind, *i.e.*, that stone products were available near at hand at both these headworks. The stone quarry in the case of the Emerson Barrage is situated at a distance of about 80 miles.

The heaviest cost in the case of a headworks is under 'C-Works'. Table 8 compares the cost under various detailed sub-heads of 'C-Works for the recently constructed headworks in India.

At a time when older headworks were constructed, our knowledge regarding design of such structures was necessarily meagre. Costly repairs have therefore been necessary in subsequent years. The more recent headworks provide better facilities for regulation as they are provided with gates throughout, rather than shutters.

Storage Dams.

In view of the fact that all gravity flow projects with the exception of Thal have been built and storage schemes may be taken up in the near future it may not be out of place to state the cost of various dams in the world.

The cost of headworks of a storage dam would depend very much on its location, its height and its accessibility for Tools and Plant and materials required for construction. It may be stated that the cost per foot-acre of storage reduces appreciably as the storage capacity increases.

TABLE 9.

* *Comparative Statement of Cost per Foot-acre Capacity for Some of the World's Dams.*

Name of Dam.	Cost in lakhs of rupees.	Msonry contents, million cubic feet.	Net capacity in foot-acres.	Cost per foot-acre of capacity.	REMARKS.
	Rs.			Rs.	
Assuan (Egypt) ..	367·50	18·8	863,177	43	Pre-war.
Tansa (India) ..	30·80	11·0	15,863	194	Do.
Periyar (India) ..	50·00	5·0	213,499	23	Do.
New Croton (America) ..	212·12	23·1	117,539	180	Do.
Cross River (America).	38·30	4·3	40,404	95	Do.
Sennar (Africa) ..	847·00	14·8	517,906	164	Do.
Krishnarajasagara (Mysore-India)	250·00	29·9	1,008,586	25	Pre-war & after war.
Bundardhara(India)	84·00	12·0	231,542	36	Do.
Nizamsagar (Hyderabad-India) ..	365·70	30·1	584,160	63	
Lloyd Dam (India)	172·00	21·5	555,510	31	
Mettur (Dam) ..	†480·00	54·6	2,146,465	22	After-war (1928-34)

*Taken from Souvenir of the Inauguration of the Cauvery Mettur System.

† Inclusive of all overhead charges.

Main Canal and Branches.

The cost of the main canal and branches, per acre, is the least on the Lower Chenab Canal but may be taken to be practically the same for all the old perennial canals. It was very high on the Triple Canals and the Sarda Canal. The actual anticipated cost on the Haveli Project (1938) is only Rs. 13·4 against Rs. 19·9 on the Sutlej Valley Project (see Table 6) even though 43 miles of the Haveli main canal is lined with brick masonry at a cost of sixty lakhs of rupees.

The cost of the main canal and branches would depend on the distance of the irrigation boundary from the headworks, intensity of irrigation and the nature and size of cross drainages.

Distributaries.

The cost of construction of distributaries depends on the capacity per thousand acres of the area for which these channels are designed. The less the intensity of irrigation, the longer will be the channels to serve that area to achieve the same figure of irrigation and consequently greater will be the expense per unit of area irrigated. Again the higher the capacity factor, the less should naturally be the cost of first construction, *i.e.*, if the channel runs full supply throughout the year it will cost less per acre spread on the area irrigated by the water carried by the channel. As, however, there is a shortage of water during *rabi*, and on account of climatic conditions crops require less number of waterings in winter, it has been found more economical to construct the channels bigger to take greater discharge during summer months when greater supply is available from the river. Although this increases the unit capital cost of channels, it decreases the unit capital cost of headworks. This is the reason that the cost of distributaries in non-perennial areas is higher than in perennial areas.

In fixing the intensity of irrigation an important fact is that the canals in the Punjab are not constructed for earning the maximum profits for the State. The principle kept in mind in fixing the boundaries of irrigation has been the greatest good of the greatest number irrespective of territorial boundaries.

Table 10 will show how the cost of construction of distributaries on recently constructed canals has varied with their capacity per thousand acres of gross culturable commanded and irrigated areas.

TABLE 10.

Name of Canal.	Cost per acre of			Capacity at Distributary head per 1000 acres of		
	Gross area.	Culturable commanded area.	Area proposed to be irrigated.	Gross area.	Culturable commanded area.	Area proposed to be irrigated.
1	2	3	4	5	6	7
	Rs.	Rs.	Rs.	Cusecs.	Cusecs.	Cusecs.
Sutlej Valley Project.						
Pakpattan Canal	3·69	4·02	6·70	3·41	3·71	6·18
Eastern Non-perennial	5·78	6·37	10·61	5·45	5·99	9·99
Panjnad	3·15	4·19	4.50	5·34	7·11	7·63
Sarda Project (U. P.)						
Sarda Canal	2·00	4·02	10·71	1·15	2·31	6·15
Sukkur Barrage						
Rohri Canal	5·15	5·75	..	3·85	4·27	
Dadu Canal	4·29	5·14	6·03	4·74	5·69	6·67
North Western Canal	4·61	5·07	6·22	4·91	5·40	6·63

On the older canals intensity of irrigation was fixed after studying the depth of subsoil water level to avoid danger of waterlogging. These percentages ranged from 25 for proprietary land with ground water within 20 ft. of the surface, to 75 for Crown waste with ground water more than 40 feet from the surface. It has, however, been now admitted by the majority of the engineers that waterlogging is caused by percolation from the main canals and that intensity of irrigation has only a negligible effect, if at all, on the subsoil water-table.

Watercourses.

In the older projects watercourses were constructed by land proprietors themselves. In colony canals particularly it was considered necessary to construct the watercourses through the Government agency and recover the cost in instalments on an acreage basis. There are some bad debts which have had to be written off. Credit goes under 'Receipts on Capital Account.'

Actual cost of construction of watercourses for some of the more recent canals is given in Table. 11.

TABLE 11.

Name of Canal.	Cost per acre of		
	Gross area.	Culturable commanded area.	Area proposed to be irrigated.
1	2	3	4
Sutlej Valley Project.	Rs.	Rs.	Rs.
Pakpattan (perennial)	0·80	0·87	1·45
Eastern (Non-perennial)	1·52	1·67	2·79
Panjnad (Non-perennial)	0·49	0·65	0·70
Sukkur Barrage.			
Rohri Canal ..	1·04	1·16	- -
Dadu Canal ..	0·83	1·00	1·17
North Western Canal	1·24	1·36	1·67

Drainage and Protective Works.

In the earlier projects practically little or no provision was made for drainage in the original project. Some provision has been made in more recent projects. A view has been put forward that necessity of drainage works may exist quite apart from the introduction of irrigation and that protective works should in all fairness be excluded from the estimated capital cost of a project for the purpose of considering its financial prospects.*

* T.B. Tate, Chief Engineer (Punjab) in a note submitted to the Central Board of Irrigation in November, 1936.

Special Tools and Plant.

On the old projects all tools and plant was charged to "III Tools and Plant." On the recent projects there has been a tendency to introduce a lot of machinery. The cost of special tools and plant on the Sutlej Valley Project and Banbasa was Rs. 2·11 and 3·02 per acre respectively. On Lloyd Barrage it was very much higher. The provision made in the 1935 estimate of the Haveli Project comes to Rs. 1·9 per acre. When the time for actual construction came, maximum use was made of old plant available in India and little machinery was used which threw manual labour out of work. The result is that the actual cost of special tools and plant on the Haveli Project is not expected to be more than Re. 1 per acre.

Establishment and Ordinary Tools and Plant.

Cost of establishment entirely depends on the number of years taken to complete the work. The speedier the construction, the less the cost under this head. Even the cost of ordinary tools and plant is a factor of time taken in construction. The cost for recent projects under this head is summarized in Table 12.

TABLE 12.

Name of Canal.	Establishment cost per acre assessed.	Ordinary Tools & Plant cost per acre assessed.
	Rs.	Rs.
Triple Canals ..	7·75	4·47*
Sutlej Valley Project on actual area irrigated in 1937-38 ..	9·1	0·84
On area proposed to be irrigated on full development	8·93	0·82
Sarda Canal		
On Actual area irrigated in 1935-36	16·03	1·52
On area proposed to be irrigated on full development	12·04	1·14
Haveli Project (1935 Estimate) ..	6·93	0·71
Haveli Project (actual 1938) ..	3·08	0·14

The above Table shows the great economy effected on the Haveli Project due to speedy construction.

* This includes special tools and plant as well.

TABLE 13.

Percentage of ... to-date

TABLE 13.

Name of Project	Original estimated cost.	Cost as per revised estimate	Total Completion Report Cost	Percentage excess of Col. 4 on Col. 2	Total up-to-date capital cost 1937-38	Percentage excess of Col. 6 on Col. 4.
1	2	3	4	5	6	7
	Rs.	Rs.	Rs.	%	Rs.	%
Upper Bari Doab ..	1,57,98,600	..	1,64,06,476	3.84	2,17,37,758	32.49
Western Jumna ..					2,05,16,444	
Sidhani Canal ..	7,74,480	9,99,475	9,64,547	24.54	13,17,671	36.61
Sirhind Canal ..	2,85,74,138 (1874)	3,86,56,300 (1888)	3,70,89,326	29.79	4,08,23,671	10.06
*Lower Chenab Canal	*1,03,74,591 (1890)	2,65,15,966 (1892)	2,51,69,735	*142.69	4,63,35,683	84.09
Lower Jhelum Canal	1,25,26,676 (1888)	1,87,48,074	1,59,33,168	27.19	2,09,23,407	31.31
Triple Canals ..	7,82,38,925	10,36,81,985	10,58,14,375	35.24	11,00,59,529	4.01
Sutlej Valley Canals	14,59,90,433 (1920)	23,76,15,681	21,30,74,345	45.95	21,35,80,621 (1935-36)	.24
Sarda Canals ..	7,50,30,917	9,50,80,068	9,82,04,116	30.84	9,95,35,321	1.35
Lloyds Barrage ..	18,35,47 543	20,03,52,000	24,50,00,000	33.48	25,89,84,306	5.71
Haveli Project ..	5,35,75,000	3,50,00,000		—34.67 saving)		

* This represents the cost of the incomplete project as a complete Project Estimate for the whole canal was sanctioned for Rs. 2,65,15,966 (as per column 3).

Excesses on the Original Estimated Capital Costs.

That there has been in the past a tendency to under-estimate the costs of irrigation projects cannot be denied. Perhaps it will be more correct to say that under-estimating was due to lack of experience and to unforeseen difficulties and rise in wages in the interval. It will be seen from coulmn 5 of Table 13 that practically every project in the past exceeded heavily on its original sanctioned estimate. Haveli Project will be perhaps the only exception so far.

A reference to column 7 of Table 13 will show that even after completion of works heavy amounts have had to be spent, increasing the capital outlay by a large percentage. This expenditure was partly incurred in extending the irrigation system and partly in strengthening and improving the structures originally built. As knowledge increases through research and experience, the engineer continues his effort to bring the structures in his charge to perfection, even though sometimes this perfection is hardly commensurate with the expenditure involved or incurred.

Such heavy excesses on the original estimates must seriously jeopardize the financial success of a scheme. Fortunately the conditions in the Punjab were very favourable and in spite of the heavily increased capital costs as compared with the original estimates, the Punjab Canals are a financial success.

Interest Charges on Capital Outlay.

In the United States of America and Canada State irrigation schemes, the initial capital cost without interest is proposed to be covered in a certain number of years (the period fixed in United States of America is not more than 40 years), after which period the charges on account of capital cost cease. In India, however, the interest on capital cost is debited in perpetuity against the administrative accounts of a canal project. The capital outlay remains as a public debt to be wiped off gradually as the provincial budget permits. Irrespective of the actual amount of this debt a book debit against the various canals is raised every year on the capital cost of the canal up to the end of that year. For instance, the total outstanding public debt against the Punjab Government at the end of 1936-37 was Rs. 31,05,58,000 out of which Rs. 6,35,88,000 was for works other than irrigation, but the interest debited against canal projects was for a sum of Rs. 34,92,24,000 which represented the total capital expenditure on irrigation works up to the end of that year.

Before the introduction of the Reforms of 1921, the loans for the construction of irrigation works were raised by the Government of India and were treated as * advances to the Provincial Governments. Such advances were to carry interest at the rate of 3·3252 per cent in respect of the outlay to the end of the year 1916-17. For outlay after that year interest was charged on the average rate paid by the Governor-General in Council on loans raised in the open market from 1916-17 to the date on which the works in question were handed over to the management of the Provincial Governments. The amount of advance for the Punjab Canals on which† interest was charged at the rate of Rs. 3·3252 per cent. was fixed as Rs. 21,90,22,994.

On the introduction of provincial autonomy, the advance made by the Government of India to the Punjab Government was consolidated into a single advance of Rs. 16,95,70,000 with the exception of Rs. 10,00,00,000 relating to the pre-reform irrigation debt which was excluded from consolidation.

The interest charges on the unconsolidated debt are now payable at the rate of 3½ per cent. while the rate of interest chargeable on the consolidated debt is 4 per cent.

As regards capital raised by the Provincial Government, the rate of interest charged against each project is the actual rate at which a specific loan was raised. For capital charges met from the general revenues of the province, the rate of interest to be charged is fixed by the Finance Department from time to time.

Specific loans were raised for the Sutlej Valley Project at the rates of 5·75 and 6·25 per cent. For the Haveli Project a loan was raised only last year at a rate of interest of 3 per cent per annum.

For capital outlay financed otherwise than from borrowings, the rate of interest was 6 per cent. till 1st April, 1937, when it was reduced‡ to 4 per cent.

Cost of Administration and Annual Repairs.

In addition to the interest charges on the initial cost of construction there are costs of maintenance and working. It may be pointed out that

* Devolution Rules, Para 24.

† Meston Settlement Report.

‡ Letter No. 6232-B/37/ 40136, dated 24th November, 1937 from the Secretary to Government, Punjab, Finance Department, to the Accountant-General, Punjab.

working of irrigation channels is an important item of expenditure entirely distinct from maintenance. It is necessary to regulate and distribute the available discharge in the river amongst various canals and distributary systems. Water is to be delivered into the zamindari watercourse in accordance with the rights fixed for the various users. One system taking off from one headworks must be operated as a unit. As a result of the Triple Canal Project five canals are interlinked and the supplies available in the Jhelum and the Chenab have to be distributed between these canals as fairly as possible. The difficulty is increased by the variations in the available supply in the river from year to year and from month to month. On the Sutlej Valley Canals all the headworks are interlinked and the distribution of supply is not only a question of distribution between the various British Canals but between British Punjab, Bikaner and Bahawalpur States. Every partner naturally insists on sharing the available supply at the optimum time when the value of water is the maximum either in the sowing or the maturing period.

Thus, working and administration of canals involves the employment of considerable establishment. In addition to distribution of supplies a separate revenue staff has to be maintained in order to assess the areas from which water-rates are due.

A certain amount of maintenance is required in order to repair any damage that may have been done during the year. Earthen banks are liable to be worn out under the stress of rain and wind as well as on account of wear and tear due to the use of such banks by wheeled traffic and cattle. The floods in a river every year cause some damage to the headworks and the absence of repairs in time may easily lead to complete failure of such works. Silt is another factor which considerably adds to the cost of annual maintenance. Channels, particularly small ones, continuously silt up and to enable them to carry their designed discharge, they have frequently to be silt-cleared.

Besides ordinary maintenance there is occasional expenditure for improvement. It is not always possible to distinguish maintenance from improvements and replacements. In practice minor improvements are carried under annual maintenance but extensive improvements are charged to capital, thus adding to the initial capital cost of the Project (See Table 13).

The same staff which distributes the water available naturally looks after repairs and maintenance. In this way maintenance and working are so intermingled as to make any attempt to separate them more or less abortive. The cost of administration under each sub-head such as extensions and improvements, maintenance and repairs and establishment, audit and accounts, etc., for the various canals based on 3 years.

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	Extensions & Improvements.	Maintenance and Repairs.	Compensation.	Establishment.	Tools and Plant	Deduct recoveries on revenue account.	Total.	Capitalization of abatement of land revenue.	Leave and pension charges.	Audit and Accounts charges.	Total.	
1	2	3	4	5	6	7	8	9	10	11	12	13
	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
Western Jumna												
1898-1901 ..	·1278	·6678	·001	·6704	·0213	..	1·4883	·0015	·0938	..	·0953	1·58
1922-25 ..	·1682	·8684	..	1·0572	·0264	·0073	2·1130	..	·1287	·0102	·1390	2·25
1935-38 ..	·097	·583	..	·917	·008	..	1·606	·002	..	·007	·009	1·61
Sirhind												
1898-1901 ..	·0586	·4301	·0009	·4444	·0066	..	·9406	·0001	·0622	..	·0623	1·00
1922-25 ..	·101	·450	·00002	·816	·005	·009	1·365	·0001	·0999	·0055	·1056	1·47
1935-38 ..	·054	·355	..	·764	·006	..	1·179	..	..	·004	·004	1·18
Upper Bari Doab												
1898-1901 ..	·0918	.4610	·0009	·4391	·0127	..	1·005	·0004	·0515	..	·0619	1·07
1922-25 ..	.064	·507	..	·610	·008	·001	1·188	..	·073	·006	·079	1·27
1935-38 ..	.075	·528	..	·715	·007	..	1·325	·0004	..	·006	·0064	1·33
Lower Chenab												
1898-1901 ..	·0513	·2792	·002	·3726	·0093	..	·7144	·0001	·0521	..	·0522	·77
1922-25 ..	·075	·366	·001	·647	·024	·003	1·109	·0002	·0785	·0044	·083	1·19
1935-38 ..	·126	·507	..	·785	·0097	..	1·428	·000003	..	·00633	·00634	1·43
Lower Jhelum												
1922-25 ..	·1086	·3738	·0001	·735	·0083	·0219	1·204	..	·0888	·0048	·0935	1·30
1935-38 ..	·156	·421	..	·887	·008	..	1·473	·00001	..	·00577	·00578	1·48
Triple Canal Project												
1935-38 ..	·102	·791	..	1·045	·014	..	1·951	·000009	..	·008917	·008926	1·96
Sutlej Valley Project												
1935-38 ..	·113	·593	..	1·032	·016	..	1·754	..	..	·00708	·00708	1·76

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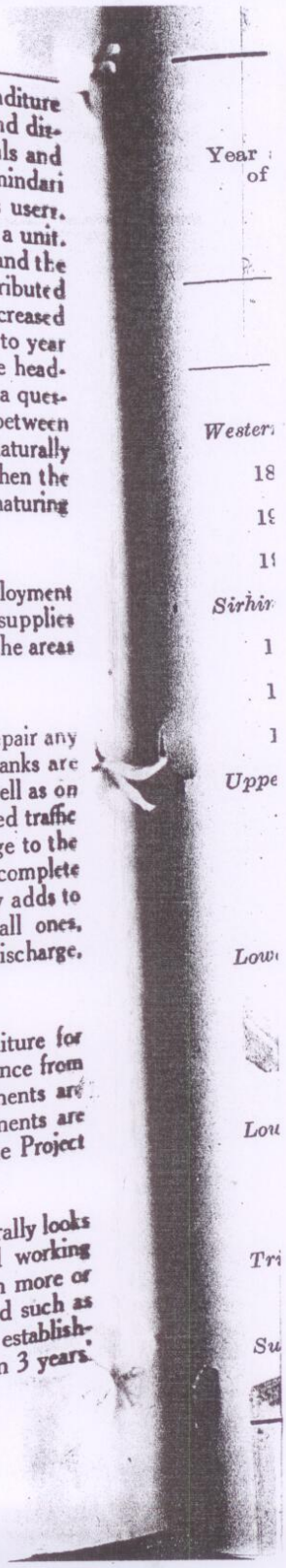

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1	2	3	4	5	6	7	8	9	10	11	12	13
	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
Western Jumna												
1898-1901 ..	·1278	·6678	·001	·6704	·0213	..	1·4883	·0015	·0938	..	·0953	1·58
1922-25 ..	·1682	·8684	..	1·0572	·0264	·0073	2·1130	..	·1287	·0102	·1390	2·25
1935-38 ..	·097	·583	..	·917	·008	..	1·606	·002	..	·007	·009	1·61
Sirhind												
1898-1901 ..	·0586	·4301	·0009	·4444	·0066	..	·9406	·0001	·0622	..	·0623	1·00
1922-25 ..	·101	·450	·00002	·816	·005	·009	1·365	·0001	·0999	·0055	·1056	1·47
1935-38 ..	·054	·355	..	·764	·006	..	1·179	..	..	·004	·004	1·18
Upper Bari Doab												
1898-1901 ..	·0918	.4610	·0009	·4391	·0127	..	1·005	·0004	·0515	..	·0619	1·07
1922-25 ..	.064	·507	..	·610	·008	·001	1·188	..	·073	·006	·079	1·27
1935-38 ..	.075	·528	..	·715	·007	..	1·325	·0004	..	·006	·0064	1·33
Lower Chenab												
1898-1901 ..	·0513	·2792	·002	·3726	·0093	..	·7144	·0001	·0521	..	·0522	·77
1922-25 ..	·075	·366	·001	·647	·024	·003	1·109	·0002	·0785	·0044	·083	1·19
1935-38 ..	·126	·507	..	·785	·0097	..	1·428	·000003	..	·00633	·00634	1·43
Lower Jhelum												
1922-25 ..	·1086	·3738	·0001	·735	·0083	·0219	1·204	..	·0888	·0048	·0935	1·30
1935-38 ..	·156	·421	..	·887	·008	..	1·473	·00001	..	·00577	·00578	1·48
Triple Canal Project												
1935-38 ..	·102	·791	..	1·045	·014	..	1·951	·000009	..	·008917	·008926	1·96
Sutlej Valley Project												
1935-38 ..	·113	·593	..	1·032	·016	..	1·754	..	..	·00708	·00708	1·76

averages for the years 1898-01, 1922-25 and 1935-38 are shown in Table 14. It will be seen that the cost of establishment and maintenance are almost equal.

For convenience in comparison the total working cost per acre irrigated for the major Punjab Canals are summed up in Table 15.

TABLE 15.

Name of Canal.	Working cost per acre irrigated (Average of 3 years).		
	1898-01.	1922-25.	1935-38.
	Rs.	Rs.	Rs.
Western Jumna Canal ..	1·58	2·25	1·61
Sirhind Canal ..	1·00	1·47	1·18
Upper Bari Doab Canal ..	1·07	1·27	1·33
Lower Chenab Canal ..	0·77	1·19	1·43
Lower Jhelum Canal ..	..	1·30	1·48
Triple Canals ..	..	..	1·96
Sutlej Valley Project ..	..	..	1·76

It will be seen that the Sirhind costs the least, in spite of its low intensity of irrigation. The Western Jumna Canal is high possibly on account of low intensity and high rainfall. The Triple Canals come out to be the most expensive on account of the cost of maintaining two feeder canals. The cost on Sutlej Valley Project is going down as the project develops.

Cost of working and maintenance as compared with earlier years has increased on account of a general increase in the pay of establishment and wages of labour and cost of materials.

Table 16 shows how the source of supply affects the working cost

TABLE 16.

Name of Canal	Working cost per acre assessed (1935-36).	Remarks.
	Rs.	
Inundation Canals, Punjab.		
Chenab Inundation Canals	2·0	
Indus Inundation Canals	3·46	
Shahpur Canals	3·19	
Ghaggar Canals	2·56	
Weir-controlled Canals (other provinces).		
Ganges Canal (U. P.)	1·5	
Sarda Canal (U. P.)	2·4	Expected to decrease on full development.
Lloyd Barrage Canals (Sind) ..	2·5	
Tubewell Schemes.		
Karol Bagh tube-well irrigation project (estimated)	9·0	Inclusive of electric and leave and pension charges.

It will be seen that annual costs in the case of inundation canals are higher and in the case of tubewell schemes several times more than the weir-controlled canals.

To get a still better comparison a reference may be made to American Projects. Table 17 is taken from Teele.*

* ' Economics of Land Reclamation,' by Teele - page 217.

TABLE 17.

Source of water supply.	Average annual cost per acre of operation and maintenance in United States of Ameica.	
	$	Rs. A. P.
Gravity supplies	1·25	3 7 0
Stored storm water	2·39	6 9 0
Streams pumped	6·52	17 15 0
Wells pumped	10·07	27 11 0

The above figures show that the average cost of operation and maintenance for wells pumped is about 8 times and that of working and maintenance for streams pumped is about 5 times as great as that for gravity supplies. The cost of operation and maintenance for pumping plant must always be high because it includes the cost of fuel or electric energy.

Total annual cost incurred.

It will be readily agreed that the initial capital cost of a project is not so important as the annual costs. The best combination obviously will be when the interest on the capital cost plus the annual charges for operation and maintenance are the least.

A comparison of the total annual charges for the various canals has been made in Table 18.

TABLE 18.

Name of Canal.	Annual Charges per acre assessed average of 3 years 1935-38.		
	Actual interest on capital.	Working expenses.	Total.
	Rs.	Rs.	Rs.
Weir-controlled.			
Upper Bari Doab ..	0·583	1·330	1·913
Western Jumna ..	0·648	1·615	2·263
Sirhind ..	0·713	1·183	1·896
Lower Chenab ..	0·695	1·434	2·129
Lower Jhelum ..	0·864	1·478	2·342
Triple Canals ..	1·846	1·960	3·806
Sutlej Valley Project ..	2·599	1·76	4·359
Inundation Canals.			
Chenab Inundation Canals	0·239	1·993	2·232
Indus Inundation Canals	0·674	3·418	4·092
Shahpur Inundation Canals	0·126	3·147	3·273
Muzaffargarh Inundation Canals ..	0·231	1·426	1·657
Ghaggar Inundation Canals	0·786	2·319	3·105
Tube Well.			
Karol Bagh ..	1·4	9·0	10·4
Other Provinces (1935-36) *per acre irrigated.* (From Triennial Report of Irrigation).			
Ganges Canal ..	1·2	1·4	2·6
Fuleli Canal ..	1·3	1·1	2·4
Sarda Canal ..	4·5	2·4	6·9
Lloyd Canals ..	5·1	2·5	7·6

The foregoing Table will dispel many wrong notions. In the case of some of the inundation canals the total annual charge is more than in the case of weir-controlled ones. The working expenses are even more important than the interest on the capital charge. The Sutlej

Valley Project is an exception, as the loan for this project was raised at a high rate of interest. This indicates the desirability of taking up new projects at a time when money is cheap. The total of interest and working expenses is the actual cost to the State of supplying irrigation water to each acre. When the water-rate for any crop is less than this amount, irrigation may be considered as subsidized by the State.

Total Annual Costs of Various Provinces Compared.

Table 19 compares the total annual costs of all the productive irrigation works taken as a whole in various provinces in India.

TABLE 19.

Name of Province.	Per acre irrigated (1935-36).		
	Interest on capital cost.	Working expenses.	Total annual cost per acre.
	Rs.	Rs.	Rs.
Madras ..	2·6	2·2	4·8
Bombay ..	3·7	2·2	5·9
Bengal ..	4·1	1·6	5·7
United Provinces ..	2·3	2·0	4·3
Punjab ..	1·0	1·5	2·5
Burma ..	1·4	2·3	3·7
Bihar and Orissa ..	1·4	1·6	3·0
N. W. F. P. ..	1·5	1·7	3·2

The above figures show that the Punjab can boast of the cheapest canal system in India both in first cost as well as working expenses.

Returns to the State.

In the Adminstrative Accounts of the Irrigation Department, revenue receipts are classified under two heads, Direct and Indirect.

Direct Receipts.

The Direct Receipts consist of occupiers' rates, sale of water, water supply to towns, receipts from plantations, receipts from other canal produce, water power, navigation receipts, rents, fines under the Canal Act, miscellaneous and other receipts.

Table 20 shows the percentage of revenue from different sources according to which these receipts are booked in the Administrative Accounts of each canal. It will be seen that under the Direct Receipts occupiers' rate or water-rates form the main source—being about 92·8 to 98·3 per cent. The table is based on three years' averages (1935-38).

TABLE 20.

Name of Canal.	Water-rate %	Sale of water %	Water supply to towns %	Receipts from plantations and receipts from other canal produce %	Water power and Navigation receipts %	Rents %	Fines %	Miscellaneous and recoveries of expenditure. %
1. *Productive Works.*								
Upper Bari Doab Canal ..	97·16	·213	·0064	·731	1·231	·36	·000038	·280
Western Jumna ..	95·06	·527	·14	·611	2·324	·38	·00011	·811
Sirhind ..	92·83	·879	·034	·620	1·911	·344	·00022	3·336
Lower Cehnab	98·32	·243	·204	·231	·134	·387	·00038	·469
Lower Jhelum	97·94	·285	·167	·492	·554	·448	·00066	·3341
Triple Canals	98·12	·305	·0066	·2018	·099	·567	·00017	·742
Sutlej Valley	96·48	·0487	.067	·125	..	·905	..	2·407

* Water-rates unlike the land revenue had never any scientific basis of assessment. They have been determind by rule-of-thumb, by what seemed to men of common-sense possible and expedient to take. The value of the crop raised and the volume of the water required to bring the crop to maturity served as rough guides. To start with, these rates were fixed deliberately very much below the commercial value of irrigation water, which must approximate to what it costs a cultivator to water his land from a well with bullocks.

The rise of average water rates on the major canals of the Province will be indicated by the following figures.†:—

	Rs.	
1900-01	.. 3·0 per acre ..	
1901-07	.. 3·3 per acre ..	The increase being due to the opening of Lower Jhelum Canal with a schedule of rates higher than that on Western Jumna and Upper Bari Doab Canals and to the enhancement of occupiers' rates on Sirhind Canal in 1904-05.
1907-10	.. 3·6 per acre ..	The increase being due to proportionately larger areas being sown under the higher rated crops of sugarcane, cotton and *rabi* oilseeds on Lower Chenab and Lower Jhelum Canals.
1910-16	.. 3·7 per acre ..	The increase being due to the introduction of a new schedule on the Western Jumna Canal in 1910-11 in which Owners' rate and cesses were added to the Occupiers' rate and the rate thus consolidated.
1916-24	.. 3·95 per acre ..	The increase being due to an increase in water-rates on Western Jumna Canal and also to the Triple Canals Scheme with a higher schedule than the older canals coming into action.
1924-26	.. 4·77 per acre ..	The increase being due to a new schedule on all canals.

* Resolution by the Governor in Council of the Punjab and its Dependencies No. 5539-Rev, dated 14-4-34.

† Mr. Waller, Abiana Committee Report, page 26 of Statements, Appendix III.

	Rs.	
1926-29	.. 4·5 per acre	.. The decrease is due to reduction of the fodder rates.
1929-30	.. 4·33 per acre	.. Due to further reduction of fodder rates by Re. 0-8-0 per acre and with Sutlej Valley Project coming into action with a slightly lower schedule.
1930-32	.. 3·87 per acre	.. On account of heavy general remissions.
1932-34	.. 4·29 per acre	.. Practically the same as for 1929-30.
1934-38	.. 4·0 per acre	.. On account of reduction of water-rates on sugarcane, rice, cotton, maize and wheat, as a result of the Abiana Committee of 1934.

It will be seen that there was a sudden jump in 1924.

After the Reforms of 1921 there was a widespread desire for extension in many directions, especially beneficent departments. In the absence of alternative sources of revenue, both the Government and the Legislative Council considered the canals as the most important source of financing the requirements of the Province irrespective of all theoretical considerations. Another point emphasized in the Government Resolution in 1934 was that the waters in the Punjab rivers are the property of the State, *i.e.*, of the whole body of citizens, while the users of canal water are not the whole body of the citizens of the Province but a fortunate section comprising only about 34 p.c. of the total population. The physical conditions prevent everyone being benefited directly. The majority have thus a claim against those who benefit and this can best be met by fixing the water-rates high enough to derive a share for those who cannot receive the water. In this connection it must be remembered that the liability for the debt raised for construction has to be borne by everyone whether he holds irrigated land or not. In order to make clear the sources of revenue receipts in the Punjab, Table 23 is abstracted from figures in the Statistical Abstract of British India for 1931-32.

TABLE 23.

Province	Expenditure charged to revenue per head.	Excise income per head.	Land revenue per head.	Col. 2 less Cols. 3 & 4 (Miscellaneous including irrigation receipts.)
1	2	3	4	5
	Rs.	Rs.	Rs.	Rs.
Madras ..	2·7	·9	1·14	0·66
Bombay Presidency	6·1	1·5	2·27	2·33
Bengal ..	1·9	·3	0·6	1·0
United Provinces	2·2	·22	1·4	0·58
Punjab ..	3·7	·4	1·3	2·0
Bihar & Orissa	1·2	·3	0·45	0·45
Central Provinces	3·1	·4	1·5	1·2

This Table shows that the Punjab is enjoying more expensive State provision than any other province except Bombay. It will also be clear that income per head from land revenue and excise is less, and that a greater proportion of the amenities that the Punjab enjoys is due to its income from irrigation receipts both Direct and Indirect. Irrigation receipts constitute more than 40 per cent of the total revenue of the Punjab. The dependence of the provincial budget on the irrigation receipts makes it fully justifiable that the pitch of water-rates should be as high as is consistent with farm economics. The basis of fixing these rates is further discussed in Part IV of this Paper.

It has been suggested several times in the past that the method of charging on the crop-acre basis leads to wastage of water and that a better method would be to charge for water actually taken on the volumetric basis. Objections to this method are several.

Firstly, it involves an appreciable initial cost in the shape of meters. Secondly, it will require a large additional staff to measure the water and record the amount taken by cultivators, thus increasing the working cost. Thirdly, the method is open to a lot of corruption. Fourthly, the volume of water sold would vary considerably from year to year, owing to climatic variations, causing much more fluctuation of revenue than at present. Fifthly, from the cultivators' point of view, the values of different crops may not be in proportion to the amount of water required to mature them.*

* Note by T. M. Lyle, Chief Engineer, U. P., presented to Central Board of Irrigation in November, 1936.

Indirect Receipts.

The indirect receipts are made up of four items :—

(*a*) Share of the enhanced land revenue collected by the Civil Department.

(*b*) Interest on sale proceeds of Crown waste land.

(*c*) Rents from temporary cultivation of Crown waste lands.

(*d*) *Malikana* from Crown waste lands.

Table 24 gives the percentages of Indirect Receipts from the above sources for major canals of the Province.

TABLE 24.

Percentage of Indirect Receipts from Major Punjab Canals under each Head based on three years' averages (1935-38).

Name of Canal.	Share of land revenue.	Interest on sale-proceeds.	Rent from temporary cultivation.	Malikana from Abadkars.
1	2	3	4	5
	%	%	%	%
Upper Bari Doab	85·71	14·29	..	..
Western Jumna	99·62	·38	..	..
Sirhind ..	100·00	..	..	..
Lower Chenab	74·74	25·26	..	..
Lower Jhelum ..	88·47	11·53	..	..
Triple Canal ..	71·37	28·63	..	..
Sutlej Valley Project ..	50·72	11·09	29·65	8·54

On the introduction of irrigation, the net assets of the cultivator increase and correspondingly the Government claims a share in the increase in these net assets. As the increase is due to irrigation, it is credited to the administrative accounts of the canal responsible for irrigation. The exact details for each canal are contained in Para. 41 of Financial Commissioners' Standing Order No. 61. A return is made by the Financial Commissioner to the Chief Engineer, Irrigation Works every half year showing the amount of land revenue which the Canal Department is entitled to take credit for in its accounts.

From the actual enhanced land revenue, the additional cost of civil administration is subtracted before credit is given.

There were large tracts of land which were subject to no rights of ownership as they could not be brought under cultivation on account of lack of moisture, the rain fall being insufficient. No land revenue was being yielded by these lands. On the introduction of canals these lands were either sold or given on temporary cultivation. The land revenue and the *malikana* from these lands is credited to the canals.

Even more important than the receipts from an increase in the land revenue are the receipts from sale proceeds of Crown waste lands. The importance of this source of revenue would be realized from the fact that including the Sutlej Valley Project, out of an area of about 21 million acres within the irrigation limits of Government canals, more than 8 million acres was or is Crown waste. Even if the price of the Crown waste land is taken at an average figure of Rs. 100 per acre the total value of the Crown waste lands comes to Rs. 80 crores against the total capital outlay of about Rs. 34 crores incurred so far by the Government on the productive irrigation works in the British Punjab. The Haveli and the Lesser Thal Projects will cover 219,546 and 510,000 acres of Crown waste area respectively. There is no Crown waste area on the Bhakra Dam Project.

The actual sale proceeds from Crown waste lands are treated as extraordinary receipts in the provincial budget and interest on the amounts of such receipts is credited to the canal project from which the particular Crown waste areas receive irrigation. Interest was calculated at the rate of 4 per cent. from all sale proceeds realized before the end of the financial year 1920-21. From the 1st of April, 1921, credit was given annually to the project concerned at the same rate as actually paid by the Local Government in respect of expenditure incurred on the work during the year in question.

A portion of the Crown waste land is disposed of to the highest bidders by public auction. In the process of colonizing large areas it was not always practicable to synchronize the introduction of settlers,

with the completion by the Canal Department of the watercourses of some particular section of the scheme. In such cases the lands commanded by the completed watercourse system could profitably be given out on what is known as 'temporary cultivation', *i.e.*, cultivation by tenants-at-will for one or more harvests, only to utilize water which would otherwise run to waste. This system of giving out lands on temporary cultivation has been extensively and methodically used in the Nili Bar Colony where large areas of Crown waste land could not be disposed of sufficiently fast at a reasonable price. The system also afforded employment to nomads and riverain landlords in the locality.

Rents from temporary cultivation vary according to the quality of the soil and the quantity of water available. In the preparation of the revenue estimate of the Haveli Project, credit was taken at Rs. 3 and Rs. 8 per acre allotted on the non-perennial and perennial areas respectively. Experience in the Nili Bar Colony has, however, shown that the system is fraught with dangerous evils even though it looks financially profitable to the state.

A certain proportion is allotted as grants to peasants on very libera concession rates. The object of giving these liberal grants was to encourage the right type of peasantry to settle in the colony. The importance of this in the earlier history of colonization was very great. In fact, the successful colonization of waste lands depended to a large extent on the selection of suitable cultivators. Government has been granting land on peasant terms for military and other services also.

When land is given out on peasant terms Government charges for the first 11 years a very moderate charge per acre called *malikana*. This rate is much below the cash rental value of the land, which a landowner would charge from the cultivator in recognition of his proprietary right. This rate is sometimes called "seigniorage" but in reality the payment of *malikana* acknowledges a more real right of proprietorship in the land. Government's claim to land revenue is based on its seigniorial rights over all land, but the payment of *malikana*, which is not paid by proprietors, is charged in virtue of the definite ownership by the State of Crown waste. Theoretically it should be 4 per cent of the market value of the land in its waste condition, or a sum which shall not be less than half the land revenue.*

Rates of *malikana* taken in the Haveli Project were Re. 1 and Rs. 2 per acre allotted for the non-perennial and perennial respectively.

From the 11th year onwards an additional amount is charged so as to allow the peasant occupier to purchase the land in a period of 30 years or so, for a very moderate yearly payment, which he can defray from the produce of the land.

*Punjab Colony Manual (1934), Paragraph 387.

Justification for crediting 'Indirect Receipts' to the Canal Projects.

It has always been a vexed question whether income from the enhancement of land revenue and from sale proceeds of Crown waste lands is correctly creditable to the canal projects or not. In 1879, Sir George Campbell, the ex-Lietutenant Governor of Bengal in his evidence before the Select Committee on Indian Public Works contended that it would be impossible to express in figures the exact increase which may be due to canals, as there may be many other causes operating at the same time. According to him it was quite impossible to distinguish between the amount of additional revenue or rent which was due to canals and the amount which was due to other causes, notably, due to means of communication. This view, however, was not taken by the House of Commons and Lord Hartington in his financial statement in the House of Commons on the 17th of August, 1880 recognized the justice of crediting the amount on account of enhancement of land revenue to irrigation works.* Previous to 1877-78 all enhancement of land revenue due to irrigation works was treated as 'ordinary' revenue, and it was only in that year that a portion of it was credited for the first time to irrigation works. It was then conceded that the revenue on account of the so-called Indirect Receipts owes its very existence to the introduction of canal irrigation, and is the direct offspring of the canals. This source of revenue was born with the canals, and would disappear with the extinction of these canals if that deplorable event ever took place.†

So far as the credit of these receipts in testing the productivity of a particular project is concerned, the procedure followed is perfectly logical and reasonable. In deciding whether heavy expenditure on a new project should be incurred the Government must take the widest possible view as to the effect of the project on the State revenues. In considering the financial aspect of a new project, therefore, the extra revenue which would accrue to the provincial exchequer on the completion of that particular project may legitimately be treated as a credit to the accounts of that project.

It will be seen from Table 25 that Indirect Receipts form a fairly high percentage of the gross revenue of the Punjab Canals.

*The Irrigation Works of India by R. B. Buckley (1880).

†Abiana Committee Report (1934).

TABLE 25.

Name of Canal.	Three years' average (1935-38).		
	Gross Receipts.	Indirect Receipts.	Percentage of Indirect Receipts to Gross Receipts.
1	2	3	4
	Rs.	Rs.	%
Upper Bari Doab ..	62,09,031	10,23,139	16
Western Jumna ..	40,89,196	2,29,974	5
Sirhind ..	51,63,648	1,66,465	3
Lower Chenab ..	1,92,25,874	91,05,864	47
Lower Jhelum ..	51,51,208	17,67,691	34
Triple Canals ..	1,49,26,277	61,70,997	41
Sutlej Valley Project ..	93,97,157	44,23,448	47

These Indirect Receipts should not, however, be considered forming a part of the profits of canal irrigation. It would be obvious wrong to demand a reduction in the water-rates on the plea that the Government has been making huge profits from canal projects.

Supposing for the sake of argument that irrigation projects in the Punjab were financed by private companies instead of Government agency, the only income to such a promoting company would be from the Direct Receipts alone. Like all other owners of land, Government would benefit as regards the Crown waste land receiving benefit irrigation from such lands. Also according to the Land Revenue Act in force Government would in addition be legitimately entitled to increase in the land revenue consequent on an increase in the net asset of the land.

Actual Financial Results of the Punjab Canals.

Table 26 gives complete details of the costs and returns to the State from the Punjab Canals based on three years' averages. The years taken are 1935-36, 1936-37 and 1937-38. The details are presented in a form easily digested, though the form adopted is not in accordance with forms contained in the Departmental Administration Reports. Net profit or loss to the State per acre has been worked out both for the Direct Receipts as well as combined Direct and Indirect Receipts. A careful perusal of this statement will amply repay the little labour required to study it.

TABLE 26.

Financial Results of Punjab Canals based on Three Years' Average (1935-38) 1

Name of Canal	Area assessed	Interest on Capital		Working Expenses						Total of Interest and Working Expenses per acre.	Direc
		Total	per acre assessed	Direct Charges.		Indirect Charges		Total Direct and Indirect Charges			Total
				Total	per acre assessed	Total	per acre assessed	Total	per acre assessed		
1	2	3	4	5	6	7	8	9	10	11	12
	acres	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
I—*Productive Works.* ..											
Upper Bari Doab ..	1,256,954	733,049	0·583	1,665,252	1·324	8,137	0·006	1,673,389	1·330	1·913	5,185,8
Western Jumna ..	989,840	642,390	0·648	1,589,823	1·606	9,014	0·009	1,598,837	1·615	2·263	3,859,2
Sirhind ..	1,231,589	879,235	0·713	1,452,066	1·179	5,034	0·004	1,457,100	1·183	1·896	4,997,1
Lower Chenab ..	2,357,921	1,639,805	0·695	3,367,865	1·428	14,952	0·006	3,382,817	1·434	2·129	10,120,0
Lower Jhelum ..	845,941	730,913	0·864	1,245,852	1·472	4,892	0·006	1,250,744	1·478	2·342	3,383,5
Triple Canals ..	2,005,139	3,703,387	1·846	3,912,199	1·951	17,899	0·009	3,930,098	1·960	3·806	8,755,2
Sutlej Valley Project ..	1,449,702	3,768,929	2·599	2,542,708	1·753	10,258	0·007	2,552,966	1·76	4·359	4,974,0
Sidhnai Canals ..	258,511	44,825	0·173	168,055	0·65	789	0·003	168,844	0·653	0·826	444,7
Chenab Inundation Canals	171,733	41,147	0·239	340,396	1·982	1,987	0·011	342,383	1·993	2·232	261,6
II—*Unproductive Works*											
Indus Inundation Canals	173,227	116,826	0·674	588,702	3·3984	3,388	0·0196	592,090	3·418	4·092	188,7
Shahpur Inundation Canal	60,288	7,592	0·126	189,019	3·135	723	0·012	189,742	3·147	3·273	120,1
Muzzaffargarh Inundation Canals. ..	321,025	74,275	0·231	455,122	1·417	2,799	0·009	457,921	1·426	1·657	294,0
Ghaggar Canal ..	16,817	13,220	0·786	38,849	2·31	154	0·009	39,003	2·319	3·105	13,10

TABLE 26.

Financial Results of Punjab Canals based on Three Years' Average (1935-38) per ...essed.

	Interest on Capital		Working Expenses						Total of Interest and Working Expenses per acre.	Gross Receipts.					Net profit per Acre	
			Direct Charges.		Indirect Charges		Total Direct and Indirect Charges			Direct Rec	Indirect	Receipts	Direct and Indirect Receipts		On Direct Receipts	On both Direct and Indirect Receipts
	Total	per acre assessed	Total	per acre assessed	Total	per acre assessed	Total	per acre assessed		Total	p... a... Total	per acre assessed	Total	per acre assessed		
	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18	19
	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
54	733,049	0·583	1,665,252	1·324	8,137	0·006	1,673,389	1·330	1·913	5,185,892	1,023,139	0·814	6,209,031	4·940	2·213	3·027
10	642,390	0·648	1,589,823	1·606	9,014	0·009	1,598,837	1·615	2·263	3,859,222	229,974	0·232	4,089,196	4·131	1·636	1·865
39	879,235	0·713	1,452,066	1·179	5,034	0·004	1,457,100	1·183	1·896	4,997,183	166,465	0·135	5,163,648	4·192	2·161	2·290
21	1,639,805	0·695	3,367,865	1·428	14,952	0·006	3,382,817	1·434	2·129	10,120,010	9,105,864	3·861	19,225,874	8·153	2·163	6·02
41	730,913	0·864	1,245,852	1·472	4,892	0·006	1,250,744	1·478	2·342	3,383,517	1,767,691	2·089	5,151,208	6·088	1·657	3·74
39	3,703,387	1·846	3,912,199	1·951	17,899	0·009	3.930,098	1·960	3·806	8,755,280	6,170,997	3·078	14,926,277	7·444	0·560	3·63
02	3,768,929	2·599	2,542,708	1·753	10,258	0·007	2,552,966	1·76	4·359	4,974,069	4,423,448	3·051	9,397,517	6·482	−0·928	2·12
11	44,825	0·173	168,055	0·65	789	0·003	168,844	0·653	0·826	444,708	482,833	1·868	927,541	3·588	0·894	2·70
33	41,147	0·239	340,396	1·982	1,987	0·011	342,383	1·993	2·232	261,606	320,098	1·864	581,704	3·387	−0·709	1·1
27	116,826	0·674	588,702	3·3984	3,388	0·0196	592,090	3·418	4·092	188,722	407,997	2·355	596,719	3·444	−3·003	−0·64
38	7,592	0·126	189,019	3·135	723	0·012	189,742	3·147	3·273	120,144	39,707	0·658	159,851	2·651	−1·280	−0·62
25	74,275	0·231	455,122	1·417	2,799	0·009	457,921	1·426	1·657	294,008	415,238	1·293	709,246	2·209	−0·741	+0·5
17	13,220	0·786	38,849	2·31	154	0·009	39,003	2·319	3·105	13,102	18,032	1·072	31,134	1·851	−2·326	−1·25

Let us now consider the Punjab Canals as a whole, both Productive and Unproductive. The following figures are for the year 1937-38:

Capital Outlay to end of the year (excluding Haveli Project) ..	.. Rs. 35,22,28,724
Gross Receipts Direct	.. Rs. 4,36,78,445
Indirect	.. Rs. 2,49,65,790
Working Expenses	.. Rs. 1,66,94,016
Interest on Capital Outlay	Rs. 1,31,47,225
Area Irrigated	.. 12,252,513 acres.
Gross Receipts per acre both Direct and Indirect	.. Rs. 5·6
Gross Receipts per acre Direct only	.. Rs. 3·6
Working Expenses per acre 1·3 Interest on Capital Outlay 1·1	.. Rs. 2·4

If direct receipts only are taken into consideration the net profit to the State from the canal system is Rs. 1·2. per acre assessed.

It may be emphasized that these results have been obtained after some of the canals have been working for over thirty years. This point will be discussed in detail in part V of this Paper.

The Punjab Compared with Other Provinces.

It will not be devoid of interest to compare the financial results of other provinces with those of the Punjab. Table 27 has been abstracted from the 'Triennial Review of Irrigation in India for 1933-36' by simple arithmetical process, for Productive Works only.

TABLE 27.

PRODUCTIVE WORKS.

Name of Province.	PER ACRE IRRIGATED (1935-36)		
	Gross Receipts both Direct and Indirect.	Total annual cost (working expenses plus interest).	Net profit (+) or loss (—)
	Rs.	Rs.	
Madras ..	6·9	4·8	+2·1
Bombay ..	3·5	5·9	—2·4
Bengal ..	3·5	5·7	—2·2
United Provinces ..	5·8	4·3	+1·5
Punjab ..	5·9	2·5	+3·4
Burma ..	4·3	3·7	+0·6
Bihar & Orissa ..	4·4	3·0	+1·4
N. W. F. Province ..	5·5	3·2	+2·3

The above table shows that gross receipts per acre are the highest for Madras; United Provinces and Punjab are bracketed second; and North West Frontier Province is a close third. Other provinces perhaps suffer from permanent settlements. As the proportion of Indirect Receipts is comparatively high in the Punjab, the average water-rates must be lower than some of the other provinces.

IV. COST AND RETURNS TO THE CULTIVATOR

Initial cost.

Cost of Watercourse system.—The charges for water realized by the State cover the cost of bringing the water to the head of the cultivator's watercourse, but no further. The system of watercourses on the farm itself has to be put in by the cultivator at his own expense. As a rule, the cost of construction of a watercourse system should vary to a certain extent from farm to farm depending on the topography of the land, the character of the soil and the number of culverts, etc., required for road crossings. It had, however, been a practice in the Punjab to construct the watercourse system at Government expense in the first instance and then spread the cost over the total area covered by the project and recover such cost by levy of a flat acreage rate charged for a number of years on the opening of the canal. This acreage rate includes the cost of field surveys, demarcation and construction of watercourses. The exact procedure of recoveries has varied in the various colonies. On the Sutlej Valley Project the entire colony was treated as a whole and the charge was distributed over holdings by the Colonization Officer who maintained the necessary accounts in his office. The sum eventually fixed was Rs. 3 per acre if paid in a lump sum or Rs. 4-4-0 per acre if spread over 8 half yearly instalments. The same rates as in the Nili Bar Colony were also sanctioned for the Pir Mahal, Khikha and Burala Branch of the Lower Chenab Canal. A certain amount of difficulty has been experienced in the Nili Bar Colony in levying the acreage charge on proprietary lands, as, strictly speaking, no provision of law exists under which it can be applied to such lands until the owners have themselves made an application under Section 16 of the Northern India Canal and Drainage Act. The announcement of this levy in the proprietary land caused a good deal of discontent particularly among owners of non-perennial land who saw at first no advantage in the change to a new canal system and untried watercourses.

After prolonged consideration, it was decided, that in the case of non-perennial proprietary lands, culverts should not be constructed by Government, and that the construction rate could be reduced on that account to Re. 1-10-0 per acre of gross culturable area if paid in a lump sum, or Rs. 1-12-0 if paid in eight half yearly instalments.

TABLE 28.

Item.	Per acre.		Percentage to the total.	
	Unirrigated.	Irrigated Colony Dists.	Unirrigated.	Irrigated.
	Rs. A. P.	Rs. A. P.		
Upkeep of bullocks.	4 7 11	5 13 8	53	32
Labour ..	0 10 11	1 11 0	8	9
Seeds ..	0 13 1	0 15 6	10	5
Implements ..	0 8 2	1 6 0	6	8
Irrigation ..	..	4 7 8	..	25
Land revenue ..	1 14 11	3 14 9	23	21
Miscellaneous ..	0 0 9	..	..	..
Total ..	8 7 9	18 4 7	100	100

The above figures do not include the wages of the farmer's family in both cases.

Returns to the Cultivator from Irrigation.

The returns to the cultivator from irrigation may be of two kinds:—
(*a*) increased land values,
(*b*) additional income from farm products.

Increased land value. Irrigation enables a higher percentage of land being brought under cultivation and also a higher percentage to be sown, every year. The price of land already cultivated with the help of rain has gone up in the past up to 5 or 6 times on the introduction of irrigation. In the case of a greater portion of the colonies the rainfall was so scanty that practically no crops could be grown on the land. The cost of sinking a well per acre would come to about Rs. 50. The income received from grazing of sheep and goats was almost negligible. In such cases it may be said that without irrigation the land had very small value, not more than Rs. 10 to Rs. 20 per acre. On the introduction of irrigation the price of such land suddenly goes up to Rs. 200 to Rs. 400. It will be irrational to claim a credit to irrigation for the entire increase in the value of the land, as the farmer has to incur some

expenditure before he can bring it under irrigation. There is, however, little doubt that the owner of the land has substantial benefit from this increase in the value of the land on account of introduction of the canal, towards the construction of which he has had to contribute nothing. It has been suggested off and on that methods should be devised so that a part of this increase in the value of the land should be credited to the canal project responsible for the increase. This may be a very important factor in making projects of the future, 'Productive.'

Additional Income from Farm Products.

This may be grouped as under:—

(*a*) Due to higher percentage of matured to sown area.
(*b*) Due to more valuable cropping.
(*c*) Due to higher yield per acre.

(*a*) *Higher percentage of maturity.* A failure of sown crops represents a heavy dead loss to the cultivator. In 1922, the Director of Land Records* found that in the province as a whole the normal rate of crop failure mainly due to deficient or unseasonable rainfall was 21 per cent. In bad years, in districts entirely dependent on rainfall, it may be as high as 65 per cent or still higher as is the case during the current year in the Hissar District. In canal irrigated portions of the same district, the percentage of matured crop to sown area will be found to be as high as ninety per cent. Even if the land revenue is remitted by the Government, every acre of unirrigated land sown, but not matured, represents a loss of more than Rs. 6 in the waste of his seed and upkeep of bullocks, leaving alone his own wages and those of his family working on the farm.

Calvert puts this figure for the province at a cautious estimate of round about eight to ten crores.†

(*b*) *More valuable cropping.*

As canal water is available at critical times of the season, when water is required for sowing and maturing more valuable crops like surgarcane, cotton and wheat, more area is brought under cultivation under these crops in preference to cheaper crops grown on *barani* lands. In the Punjab cotton and sugarcane will be practically impossible without irrigation. These have to be sown before the monsoon rains start and require at least one watering after the monsoon rains have finished.

(*c*) *Higher yield.*

According to the Director of Land Records the yield per acre in Amritsar is 5 maunds more on irrigated than on unirrigated land, although the mean annual rainfall in that District is over 24 inches. For Lyallpur the same authority puts this difference as nine maunds.‡

*Calvert, Page 122 Wealth & Welfare of the Punjab.
†Page 123 Wealth & Welfare of the Punjab.
‡Page 126 Wealth & Welfare of the Punjab.

Table 29 compares the out-turn and value of crops per acre of unirrigated and irrigated land.

*TABLE 29.

Serial No.	Crop.	Outturn per acre in lbs.			Value of outturn per acre in Rs.		
		Unirrigated.	Irrigated.	Percentage increase of 4 over 3.	Unirrigated.	Irrigated.	Percentage increase of 7 over 6.
1	2	3	4	5	6	7	8
1.	Wheat ..	403	810	101	25	50	100
2.	Barley ..	640	1120	75	20	35	75
3.	Rice ..	1120	1493	33	26	60	131
4.	Maize ..	448	1120	150	26	49	89
5.	Gram ..	420	747	78	19	29	53
6.	Oilseeds ..	320	320	..	17	44	159
7.	Sugar (raw)	2240	2240	..	114	163	43
8.	Cotton (*Desi*)	747	815	9	40	80	100
9.	Fodder ..	..	..	..	20	30	50

The above table combines the results of better quality of crop as well as higher yields per acre.

In the United States of America also the average excess of yield† for irrigated land in 1919 was 42·4 p.c. and the average excess of value of crop per acre was 45·6 p.c. as compared to unirrigated land.

Economic Value of Canal Water to the Farmer

(*a*) *As compared to Open Wells.* In the western parts of the Punjab where rainfall is too scanty for *barani* cultivation, the economic value of canal water can be judged only by a comparison of the cost of canal water with the cost of obtaining water from other sources such as wells.

* From Season and Crops Report of the Punjab for the year 1924-25 page 4.

† Teele, pages 233 and 234 tables 33 and 34 of Economics of Land Reclamation.

Costs of well irrigation in the Punjab have been worked out in the Farm Accounts. The following information* is taken for the year 1934-35.

TABLE 30.

Lift.	Per acre matured.			Total cost per acre matured.	
	Overhead Charges.†	Cost of motive power.	Manual labour.	Including manual labour.	Excluding manual Labour.
	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.
Electrically driven pump	8 4 10	17 12 5	5 8 7	31 9 10	26 1 3
Electrically driven Persian wheel ..	5 1 2	7 9 8	6 5 6	19 0 4	12 10 10
Bullock driven Persian wheel	1 8 1	9 3 4	5 14 11	16 10 4	10 11 5

The above table gives the cost of irrigation per acre matured by electrically worked pump. electrically worked Persian wheel and bullock driven Persian wheel, excluding cost of well and transmission lines. Cost of electric current delivered at site was taken as 0-1-6 per K. W. H. For other details, a reference may be made to Publication No. 53 of Board of Economic Inquiry. The cost for the electrically-driven pump is higher than for bullock-driven Persian wheel by Rs. 14-15-6. Since the pumps in the experiments were installed the price of machinery has come down considerably and the cost may now be less.

Against the above figures, the average water-rates are only Rs. 4 per acre.

(*b*) *As compared to Tube Wells.* The cost of water-supply for watering one acre from a tube-well can be best taken from the estimated figures of Karol Bagh Tube-well Irrigation Scheme now in hand.‡

*Bøard of Economic Inquiry Publication No. 53, page 284.

†Over-head charges include interest and depreciation on Persian wheel and cost of repairs. The rate of interest taken is 8 per cent and the rate of depreciation on the Persian wheel on an average is about 14 per cent. Interest and depreciation on wells are not included.

‡Figures were kindly supplied by Mr. A. M. R. Montagu, Officer on Special Duty, Tube-well Investigation.

The average cost to the cultivator of watering one acre on this Project is estimated to be Rs. 17·2 and Rs. 7·0 during *kharif* and *rabi* respectively.

The above rates are based on the following assumptions :—

(*a*) Depth of one watering, 4″.

(*b*) Cost of electric energy delivered at site, 11 pies per unit.

(*c*) 5000 hours of running per annum.

(*d*) Duty per cusec capacity of pump.

Kharif	116 acres.
Rabi	189 acres.

(*e*) That the charges on Karol Scheme will be the same as levied at present on the cultivator in the United Provinces and sanctioned for Qadian, *i.e.*,

Rs. 3-3-0 per watering in *kharif*.

Rs. 2-2-0 per watering in *rabi*.

According to these rates there is a loss to Government during the *rabi*. On the whole the Project may just pay the interest on the capital spent.

The average annual charge per acre for the Karol Project comes to Rs. 10·87 against the average water-rate of Rs. 4 per acre on the canals.

It is conceded that more valuable crops can be grown on tube-wells, partly setting off the extra cost. Actual reliable figures are not available. It may be, however, safe to state that unless the charges of current are reduced appreciably, even the electric tube wells have little chance of comparing favourably with gravity flow irrigation from canals.

(*c*) *As compared to Unirrigated Areas.* It has been previously mentioned that the cost of production per acre is appreciably more in irrigated than unirrigated areas. Does the additional income leave a margin after paying off the extra costs?

The income and expenditure per acre for irrigated and unirrigated areas, given in Table 31, are taken from *Farm Accounts for 1934-35.

* Board of Economic Inquiry Publication No. 53 Pages 7 to 8.

TABLE 31.

Particulars.	Per acre		
	Gross income	Expenditure	Net income
	Rs. A. P.	Rs. A. P.	Rs. A. P.
Unirrigated area ..	16 11 7	8 7 9	8 3 10
Irrigated area (colony districts) ..	40 4 2	18 4 7	21 15 7

The above figures of gross income include both the landlord and the cultivator's share and are based on the prices of agricultural products prevailing in 1934-35. These were :—

Wheat	..	Rs. 2 4 0	per maund.
Gram	..	Rs. 1 15 0	per maund.
Rape-seed	..	Rs. 4 6 0	per maund.
Desi Cotton	..	Rs. 5 1 0	per maund.
American cotton	..	Rs. 8 2 0	per maund.

Variation in prices of crops.

The net increase to the farmer in any year must naturally depend on the prevalent prices and it is this variation which hits him hard in years of depression.

Graph No. 1 shows the variation in the price of five principal agricultural commodities in irrigated areas, prevailing at Lyallpur from 1905-06 onwards.

On the same graph are shown the average gross value of crop per acre irrigated and the incidence of average water-rate. The percentage ratio of the average water-rate to the average gross value of crop per acre have also been plotted.

Besides the water-rates, his other expenses too do not vary to the same extent as does the gross income. The result is that the variation in his net income is exaggerated out of proportion with the variation of prices of crops.

Graph No. 2 is prepared from the figures given in Farm Accounts published by the Board of Economic Inquiry. It gives for certain canal irrigated plots, the gross income and the expenditure per acre from 1926-27 to 1934-35. The intercepts between the two lines indicate the net income from the farm per acre. In the figures of expenditure the wages of the family members working on the farm are not included. This graph makes it perfectly clear that the cultivator was hit hard during 1931-32, but his position since then has been steadily improving.

Causes of Variation in Crop Prices.

As in all spheres of economics the prices of agricultural products are governed by supply and demand. Wheat may be taken as a typical instance. Since 1925, the average increase per year in the world's output of wheat comes to 18 per cent, while the world population increased by 14·4 per cent only. That was not all. World consumption of wheat per head decreased particularly in the New World, where a rise in the standard of living, involving a change over from grain to meat, vegetables, fruits and dairy products was probably responsible for the tendency. In spite of an increase of 14·4 per cent in the world population, the total world consumption of wheat increased only 8·4 per cent*. The synchronization of these two factors caused an unprecedented fall in the price of wheat. The large increase in wheat production has been brought about by most of the countries of the world increasing their output in an attempt to make them self-sufficient and it may not be very long before the rising curve of population may cross the rising curve of outturn of food products. Once that happens the prices will go up again.

Why Does the Cultivator not Adjust Production to the Changing Prices ?

It will be noted from graph No. 1 that prices do not vary gradually in the same direction, nor do the prices of all products rise or fall to the same extent. Why does the cultivator not take up articles which fetch better prices?

Good prices do tend to an increase in production, the tendency being in fact always towards over-production, in the industrial as well as the agricultural field. It is this tendency, which causes the cyclical and secular fluctuations which have become almost a normal economic phenomena both in agriculture and in industry.†

While industry can be adjusted to the changing demands of time, agriculture is from its inherent characteristics unable to do so.

* S. A. Husain, Agricultural Marketing in Northern India (1937), page 24.

† Economics of Agriculture by Van Der Post (1937), page 524.

Agriculture is dependent upon the vicissitudes of nature and the seasons. The agriculturist can, for example, never plan production in the same way as the industrialist, because he cannot foretell the behaviour of the weather months in advance. He cannot, therefore, at will change production in order to counteract a fall in the prices. Secondly, the length of the agricultural productive process makes the turnover in agriculture much slower than in industry. Most crops require several months to mature. Thirdly, money invested and labour employed in agriculture are not as readily transferable as in industry. Fourthly, change from one crop to another, from one branch of agriculture to another, is usually difficult because natural conditions in any particular area render it suitable to some form of specialization or another. Marketing conditions may not be favourable to the substitute crop. Fifthly, agricultural production is the sum total effect of the efforts of a large number of scattered individual producers, each of whom exercises a negligible influence on the market. It is the total production, not the contribution of the individual producer, that influences the market. The agriculturist can, therefore, not influence the price of his product as can the manufacturer who may have developed a special brand and a special market for the product of his factory. Sixthly, agriculture's dependence upon seasonal and natural conditions makes the supply of agricultural products subject to great variations and this in turn similarly affects price. A subnormal crop tends to raise prices out of proportion to the fall in production and appears at least in the case of some commodities to cause a greater deviation in price than a surplus.

Fluctuations in the produce due to seasonal variations would to a certain extent be smoothed out under a system of international free trade, because variations in some countries or in one hemisphere tend to counterbalance variations in the opposite direction occurring in other countries or in the other hemisphere. Unfortunately the nations of the world have found it necessary to adopt protective measures in the interest of home production and have thereby to a large extent negatived the stabilizing effect which a comparatively stable world agricultural production would tend to have on agricultural prices.

Because of the above characteristics of agriculture the farmer finds it most difficult to adopt his productive programme to the dictates of changing conditions. He consequently feels the effects of depression and of adverse conditions generally in an extreme degree.

The above indicates that the necessary control and guidance in agriculture must come from the State. It is further indicated that methods to vary the cost of the farmer in accordance with the rise or fall of crop prices are called for. It may be possible to find a way of fixing water-rates on a sliding scale.

A Sliding Schedule of Water-rates.

A reference is again invited to Graph No. 1. The percentage ratio of the average water-rate to the average value of the produce per acre on the Punjab Canals has varied from 6·0 per cent. in 1918-19 to 15·2 per cent. in 1930-31. The variation in the case of certain areas and of particular crops may have been even greater. If the water-rates are to depend on the paying capacity of the cultivator, as hitherto assumed, they should obviously bear a more or less constant ratio to his net profits from irrigation.

What this ratio should be, is too difficult and complex a question to be discussed in this Paper.

In America, the ratio of water-rate to value of crop raised per acre varies from 16 to 20 per cent., while in Egypt the ratio is about 14 per cent.*

V. THE FUTURE.

Is there Over-production in India?

The drop in the price of agricultural products may lead one to think that there is over-production of wheat and other cereals in the Punjab and that it is time to cry halt to further expansion of irrigation for a decade or so. The subject is of such a great economic importance to the province that it deserves a detailed examination.

According to 1930-31 figures, the area under cultivation in India per head was 0·86 acres out of which only 0·14 acres was irrigated. Even an elementary knowledge of agriculture is enough to show that this area is entirely inadequate for a predominantly agricultural country like India.

Let us compare the Punjab figures with those of the Western Part of the United States of America, comprising of Wyoming, Colorado, New Mexico and far Western States, which are, like the Punjab, mainly dependent on irrigated agriculture.

* T. M. Lyle, C.I.E., Chief Engineer, U.P., in a note presented to Central Board of Irrigation in November, 1936.

TABLE 32.

Year.	Irrigated area per capita.		Cultivated area per capita in Punjab.
	Western States of* of U. S. A.	Punjab.†	
	Acres.	Acres.	Acres.
1890-91 ..	1·14	..	1·39
1900-01 ..	1·76	·44	1·40
1910-11 ..	1·94	·52	1·45
1920-21 ..	1·94	·63	1·41
1930-31 ..	(not available)	·63	1·3

The recent agricultural depression in India was primarily due to reduction in its export of wheat, due to large areas in U. S. S. R., U. S. A., Canada and Australia being brought under cultivation. The up-setting of the equilibrium of such an important commodity was bound to have reactions on other agricultural products.

The drop in the price of wheat cannot, however, be regarded as evidence of over-production. Tables 33 and 34 compare the area under wheat per capita and the out-turn per acre in the world's premier wheat growing countries:—

‡TABLE 33.

Area Under Wheat per Capita.

Couuntry.	Population in 1935.	Area under wheat in acres (1935).	
		Total.	per capita.
U. S. S. R. ..	173,000,000	91,529,000	·529
Canada ..	10,949,000	14,105,000	2·202
U. S. A. ..	127,172,000	51,208,000	·403
India ..	368,278,000§	33,617,000	·091
Punjab (British only) ..	24,587,463§	9,300,000¶	·378

* Taken from Henny's paper No. 1666 of American Society of Civil Engineers (Table 1).

† Population taken from table XI. and area irrigated is taken from Table VI of Agricultural Statistics and includes all sources.

‡ Figures taken from International Year Book of Agricultural Statistics for the year 1935-36

(1) hectare =2.47 acres.

(2) quintal =100 lb.

§ 1931 census figures with 4·4 % increase for 4 years.

¶ Agricultural Statistics of India.

*TABLE 34.

OUTTURN OF WHEAT PER ACRE.

Country.	Area under wheat in acres.	Out-turn in quintals.	Outturn per acre in lb.
U. S. S. R. ..	91,529,000	308,298,000	336·8
Canada ..	24,105,000	76,731,000	318·3
U. S. A. ..	51,208,000	170,466,000	332·9
India ..	33,617,000	98,851,000	294·1

The above tables show that the produce of wheat per capita, taking India as a whole, is appreciably less as compared with other agricultural countries of the world. The problem of Indian agriculture at present is not over-production but the large diminution in the export of cereals. And though the likelihood of substantial export of wheat in the near future cannot be visualized, this does not involve any cause of anxiety. Countries like Australia, Canada, Southern Rhodesia, Argentina and South Africa, with a comparatively small population, and a wide expanse may incur the risk of over-production with its attendant problems. But the home market in India is so vast that for a long time there could be no danger of the accummulation of surpluses. What is required is a careful organization and study of the details of changes in the demand of the public and adjusting the supply according to this demand.

The diet of the people, especially of the masses, leaves much room for improvement; a permanent state of under-nourishment is to be found everywhere. Table 35 compares the consumption of wheat per head in India with other countries.

TABLE 35.

Countries.	Consumption of wheat† per head kilograms (1925-26 to 1929-30).
Europe	128·7
U. S. A.	124·6
Argentina	149·1
Australia	146·0
India	23·7

*Figures taken from International Year Book of Agricultural Statistics for the year 1935-36.

† The Agricultural Crisis (League of Nations) 1931, Vol. 1, pp. 25-27.

The food eaten by the ordinary villager is inadequate in quantity and inferior in quality. Wheat, vegetables, fruits and dairy and live stock products, should find place in their menus. Wheat is consumed by a small section of the total population. As it is a superior food and contains higher nutrition it should be eaten by all; hence there is an immense scope for promoting the consumption of wheat*. Coarse grain could then be used for feeding cattle, thus bettering their physique. And land, under crops which are no longer required for human consumption, may advantageously be given over to the cultivation of fodder and rotation crops.

Growth in Population.

The population of India is increasing constantly. During the period 1921-31 the increase was 10·6 p. c. Since 1931, India has remained comparatively free from violent outbreaks of epidemic diseases and the annual balance of births over deaths has been consistently favourable to progressive increase of population. Between the census of 1931 and June 1936 the actual increase has been 6·1 p.c. Assuming the same rate of growth during the next five years, the increase in population during the decennium 1931-41 is likely to be something over 11 p.c.† How is this increase in population going to find employment?

If an increase in population is not compensated for by a corresponding increase in the cultivated area, then the people must either produce more from the same area, by improving their methods of cultivation or they must reduce their standard of living, unless they can send their surplus numbers to industries or out to other countries.

Can Industries Absorb a Portion of the Growing Population?

The 1931 Census Report showed that there were less workers in 1931 on industries than in 1921. There was also a fall of 0·35 p.c. among workers in trade. These losses were explained as balanced in part and largely met by the increase under "Insufficiently Described Occupations." This might be a way of explianing away the losses under one head as gains under another, but it cannot be interpreted to mean that the position of industry remains the same. While the industries of India are growing so far as capital invested, total output, and the field of activity are concerned, they do not employ a larger percentage of the population.‡

From statistics regarding cotton and paper mill industries it can be proved that while there has been expansion in production, the increase

* S. A. Husain, Agricultural Marketing in Northern India, (1937) Pages 309-310.

† Indian Information Series, September, 1, 1938.

‡ S. A. Husain, Agricultural Marketing in Northern India, (1937) Pages 42 and 43.

in the number of persons employed on these industries has been comparatively small. The more the working capital, the greater is the use of specialized machinery and labour-saving devices. Besides, the more the organized industries are set up, the larger is the number of unorganized workers and craftsmen driven out of their work. Their manufactures—hand-made and on a small scale—cannot compete with machine-made goods, with the result that the artisans, particularly in the rural areas, give up their original industry and join the ranks of the agriculturist.

The natural conclusion from the above fact is that industrialization has not relieved the burden on the soil, and in spite of the new industrial ventures, India still remains essentially an agricultural country. The sooner it is recognized that the setting up of large-scale industries cannot solve the population problem for a long time to come, and that it is through the organization and development of agriculture alone that the conditions of the masses can be improved, the more would it be in the interest of the country. The protagonists of the policy of industrializing India seem to regard it as a panacea for all the economic ills of the land. Without questioning the need for starting new industries for manufacturing articles of our daily requirements, it may be pointed out that, at the present rate, industries cannot provide employment for a large percentage of the population.

As the agricultural classes form an overwhelming majority of the population and unless their income increases, consumption must be meagre and the home market will remain undeveloped as long as the standard of living among the agriculturists is not raised. Thus the development of India's agriculture will be directly in the interests of her industries as well. In fact, the interdependence among agriculture, industry and commerce is so close that it is impossible for one to enjoy lasting prosperity regardless of the others. This point has been stressed at a great length in America where there is an over-increasing demand for industrial population being spread on to agricultural lands in a very organized manner.*

Can Emigration Help ?

There is barely any possibility of the hardships of over-population being removed or even decreased through migration. Emigration, when India is taken as a whole, influences the population very little. Due to greater restrictions imposed upon them, the few Indians who migrated to places like the British colonies in South America and Africa, are actually returning to their home country.

* Transactions of American Society of Civil Engineers for 1938 Paper No. 1984.

Birth Control.

The last Census Report referred to the possibility of limiting population by birth control. It will be outside the scope of this Paper to discuss the merits or demerits of this aspect of the question, particularly when in countries like Germany and Italy there is a definite State policy for encouraging the growth of population. The density of population* for the Punjab Province is 208 per sq. mile, that for Japan being 439, United Kingdom 489, Germany 358 and Belgium 699.

Irrigation—The Best Cottage Industry.

As mentioned previously the total population of India in 1941 is expected to reach 400,000,000 ; out of this the agricultural population may be taken as about 300,000,000.† With the present rate of wealth production it has been estimated that the average income per head of this agricultural population will be approximately Rs. 50 per year. This clearly shows that the average Indian is ill-fed, lives in a half-starved condition and has low vitality. Nobody can doubt the statement that with the present economic organization and present production India cannot support its growing population. The only way open to India to meet its growing population is rapid expansion of irrigation, as irrigation is not only a means of increasing production but it affords a considerable scope for the employment of a large number of men not only during the period of construction of works but later in the operation of cultivation. Irrigation in this sense is the best cottage industry for an agricultural country.

Relationship of Area Cultivated and Irrigated with Population in the Punjab.

The problem from the point of view of the British Punjab may be considered in still greater detail.

Graph 3 shows how the growing population was supported by a constant rise in the area brought under cultivation mainly by Government canals.

To meet the anticipated increase of 11 per cent. from 1931 to 1941, the additional area required to keep the same average standard of living is about 3 million acres.

The Haveli Project which is nearing completion will bring an additional area of about 400,000 acres under irrigation. An increase of about 250,000 acres may be counted on Sutlej Valley Project Canals from 1931 to 1941.

* Atta Ullah, The Co-operative Movement in the Punjab (1937) Page 27.

† P. A. Wadia. Population Problem of India.

canals respectively. Taking the expenditure of the cultivator as Rs. 10 per acre, the area remitted represents an annual loss of Rs. 36 lakhs and this alone would justify a capital expenditure of nine crores of rupees.

Sources of Future Water Supply.

The natural winter supplies of the Punjab rivers have already been used up fully, except the Indus. A bar was placed by the Government of India after the sanction of the Sukkur Barrage Project preventing the Punjab from withdrawing any water from the Indus. This bar has only recently been relaxed and the Punjab has been allowed to withdraw 6000 cusecs in summer and about 3600 cusecs in winter, for the Thal area.

Where are then the additional supplies to come from? There are three likely sources:—

(*a*) Savings from absorptions of large canals by masonry lining.

(*b*) Storages on the rivers in foot hills.

(*c*) From subsoil by tube wells.

Absorption losses from the main canals of the Punjab excluding the Sutlej Valley Project Canals come to about 1800 cusecs. If the main canals of the Sutlej Valley project are also included, the figures of water lost by absorption go up to about 4200 cusecs. By lining the main canals alone a saving of at least 3000 cusecs in summer and 1700 cusecs in winter can be effected.

Possibilities of storage in the hills are vast. Table 38 shows the percentages of run-off actually utilized and those still available for storage. It also shows that suitable sites exist on practically all the Punjab rivers for storing large volumes of summer supplies now going to waste.

As regards tube-wells, the subject has been examined in great detail by a very senior and capable officer placed on special duty. It is hoped that he will enlighten members of the Congress with his views. Conditions in the Punjab are so different from those in the United Provinces, particularly with reference to rainfall, that the chances of financial success of tube-well schemes on a large scale in the Punjab are at the best very doubtful both to the State as well as to the farmer. So many factors are uncertain that the Punjab will be well advised to advance with tube-well schemes with the utmost caution.

The future of the development of the Punjab, in the opinion of the Author, lies in its storage schemes.

TABLE 38
(Condensed from Wiley Committee Report, Page 26)

River	Based on average of 5 years 1922-23 to 1926-27.					Storage capacity available in foot hills as contemplated in Wiley Committee* Report.
	Mean annual run-off	Water utilized by existing Canals.		Balance available for storage.		
	Cusecs per day.	cusecs per day	%of column (2)	Cusecs per day	%of column (2)	Cusecs per day.
1	2	3	4	5	6	7
Sutlej	19,528	5,601	29	13,927	71	14,585†
Beas	17,467	12,282	70	5,185	30	34,412†
Ravi	8, 694	4,170	48	4,524	52	12,240†
Chenab	29,557	8,456	29	21,101	71	7,148‡
Jhelum	32,256	6,619	21	25,637	79	Not investigated

* A Committee consisting of Messrs. Wiley, an American Expert, two Indian Geologists and Mr. Nicholson was appointed by the Punjab Government in 1927.

† On Sutlej, Beas and Ravi ample capacity is available so that when the first reservoirs start depleting due to silting, storage at other sites can be taken up.

‡ This capacity is on one tributary, i.e., Eastern Tawi only, but there are other sites not examined by the Committee.

This subject would be incomplete without the mention of one important geographical feature of the province. Most of the storage sites are situated outside the boundaries of the British Punjab. Thus the Punjab has a very special interest in the Indian States in which the upper reaches of the Punjab rivers are situated. As the States concerned have no direct relations with the Punjab Government, the latter is not in a position to press their point with these States and must rely upon the good offices of the Government of India. The future prosperity of the Punjab obviously holds difficulties in store. The Government of India Act of 1935 does not contain, so far as the Author is aware of, any clear provision to safeguard these potential interests of the Punjab. Section 127 authorises the Federation to acquire any land situate in a Province for any purpose connected with a matter, with respect to which the Federal Legislature has power to make laws. Such land is to be transferred to the Federation on such terms as may be agreed or in default of agreement as may be determined by an arbitrator appointed by the Chief Justice of India. The interests of the Punjab require that this Section should be applicable, when land situated in and belonging to one province or Federated State is required by another province or State.

Need for a Change in the Financial Policy.

It has been shown that there is need for expansion of irrigation in the Punjab. It was but natural that the less costly and more profitable sources of supply were tapped in the beginning. The projects were undertaken only after they satisfied the test of productivity laid down* by the Government of India. The test consisted of the Project being able to show a certain percentage return on the sum at charge in the 10th year of the opening of the canal. The sum at charge is taken as the capital cost plus the arrears of interest up to that year.

For works sanctioned before the 1st April, 1919, the test of productivity was 4 %. For works sanctioned between 1st April, 1919 and 1st August 1921 it was 5 p. c. and for all works sanctioned after that date the prescribed test is 6 per cent.

Although the rate of interest in the open market has fallen to 3 p.c. the Punjab and Madras provinces have not yet lowered the test of productivity. It is argued that the capital charge of irrigation works is a perpetual sum and consequently the test of productivity should be based on the Government's effective borrowing rate for a long term. It has also been suggested by financial experts that a small percentage should be added to cover the risk of having to pay a higher rate of conversion and the risks inherent in any estimate.

* Public Works Account Code, Appendix 4, page 216.

Thus on the one hand the projects of the future must by the nature of things be less paying; on the other hand the financial ex are in favour of stiffening up the test of productivity.

Unless there is a change in the financial outlook, future dev ment of the Punjab may be seriously jeopardized.

Irrigation schemes represent a comparatively long time in ment. The test of productivity takes the results in the tenth ye the opening of the canal. This time limit has been entirely arbitra

Graph No. 4 shows the percentage return of the net revenue, direct and indirect, on the capital outlay on the Punjab weir-contr canals from their date of opening. Some of our best canals, *viz* Upper Bari Doab and the Sirhind did not start paying a return of cent up to the 10th year. If only direct receipts be taken into cons ation even the Lower Chenab and the Triple Canal Project below the present-day test of productivity (see graph No. 5).

Both the graphs show that there has been a very steady increa the return on all the Punjab canals. This increase is only partiall to an increase in *abiana* rates. The greater share of increase go a steady rise in the "duty," on water. This is borne out by graph N

In order to make the point clearer another graph (No. 7) has plotted showing the culturable commanded area, area irrigated *rabi* mean discharge utilized. *Kharif* discharges have been left o water has generally been available up to the demand, the quantity ally utilized varying to a certain extent with the precipitation of Leaving out fluctuations from year to year, an increase in the *rabi* discharge would indicate extension on the system. It will be seen even though the mean *rabi* discharge has not increased, there has b steady increase in the area irrigated on each system, even after the year of the opening.

Some good projects in California have taken as long as 30 yea bring them to a point at which income fully covered all expens operation.*

There is another point to which attention has not so far been in India. Even the indirect receipts credited to canal projects d represent the actual wealth created by the project. In Germany France it has been estimated that on navigation canal schemes, 45 47 p.c. respectively of the capital cost is directly returned to Govern in the form of taxes, duties, etc. They estimated in Germany th per cent of even the operation charges are likewise returned to Go

* Grunskey, C. E., Transactions of the American Society of Engineers (1928) Volume 92, page 561.

ment. There can be no reason to doubt that vast revenues are derived by the Central and Provincial Governments in India as a result of development of irrigation, besides the direct and indirect receipts.* Actual figures are, however, not available. It was for this reason that the Central Board of Irrigation resolved†:—

"*That an economic survey should be carried out with a view to estimating the direct and indirect financial benefits accruing to the Central and Local Governments from irrigation projects. If it is ascertained that the indirect revenue accruing to the Central Government is appreciable, the Government should see its way to contribute towards the cost of future irrigation projects in order to encourage provincial Governments to extend irrigation facilities, which, without such a subsidy, would otherwise not be undertaken.*

The Board is also of the opinion that when irrigation projects benefit proprietary lands, and therefore, enhance their value, some means should be devised of recovering a portion of that enhancement for credit to the cost of the projects."

The above resolution will be a mile-stone in the history of development of irrigation policy, if it does not remain buried in the records of the Board. For the present the Government of India has decided to take no action on this resolution.

There is yet another point which is of particular importance to those parts of the Punjab which are still waiting for irrigation facilities to be extended to them. Accumulated net profit to Government from its canals up to the end of 1937-38 comes to Rs. 89·2 crores, after paying all operation, maintenance and interest charges, against a total capital outlay, both direct and indirect, of Rs. 34·5 crores. Thus the Punjab Government could have put up a reserve fund of Rs. 54·7 crores from the income earned by its canals in order to construct canals in those parts of the Punjab, which are physically less fortunate. It can be argued that all these profits were utilized in building up beneficent departments. Even the share of benefit from these departments derived by the inhabitants of the unirrigated areas has been much less than that derived by their otherwise more fortunate brethren in the irrigated areas. Time has perhaps come for a more equitable distribution of the natural wealth of the Province. This can be done by taking up the Irrigation Projects in the areas so far relegated to the background, irrespective of their financial results. Their capital cost may be considered as merged into the capital cost of projects already executed and then applying the test of productivity to the canal system as a whole.

* T. B. Tate. Introductory note on 'The Policy of Irrigation in India' submitted to the Central Board of Irrigation in November, 1936.

† Item 11(d) of the Agenda (Technical) of the 7th Annual Meeting of the Central Board of Irrigation held in November, 1936.

As pointed out in Part II of this Paper, the irrigation policy in U. S. A. underwent a radical change in 1902. A standing Land Reclamation Fund was created. An advance of $ 20,000,000 was made to the fund from the General Treasury in 1910, which is supposed to be paid back at the rate of $ 1,000,000 per annum. Additional sums were later made available from royalties and rentals from oil and potassium leases of public lands, from federal water-power licences and special appropriations from the General Treasury. An idea of these accretions to the Reclamation Fund may be formed from the following figures showing the state up to the end of 1926 :—

	$
Receipts from sale of public londs	108,486,000
Receipts from oil royalties	29,001,500
Receipts from potassium royalties	31,000
Receipts from Federal power licences	18,500
Total ..	$ 137,537,000

In other countries also irrigation schemes are mostly subsidized by Government. Colonel, the Hon'ble Deneys Reitz at one time Minister of Lands and Agriculture and Forestry and Irrigation* declared on several occasions that the South African Government had never regarded irrigation as a proposition that would pay directly any more than the dykes of Holland were expected to pay directly.

Conclusions.

It has been shown that there is no over-production in India. The growing population demands an increase in the cultivated area, which can be achieved only by development of irrigation. Industries can absorb only a microscopic fraction of the increasing population. Irrigation schemes provide a vast scope for the employment of unskilled labour during the construction period as well as in the actual operation of cultivation. In this sense irrigation is the best cottage industry for a predominantly agricultural country.

Waterlogging and malaria, as the direct results of irrigation, have been over-emphasized by certain critics. The area actually affected by *sem* is only 0·25 per cent. of the total area irrigated. The best remedy to combat malaria is to improve the economic condition of general masses. This can be achieved by extending facilities of growing more and better crops through further development of irrigation.

It has been further shown that both cultivable land and water are available in abundance in the Punjab for expansion of irrigation. The

* Van Der Post, Economics of Agriculture (1937) page 269.

only difficulty is that future schemes are not likely to pay as good a return on the capital spent as the ones constructed so far have done. It was but natural that easier and more profitable schemes were taken up first.

A plea has been put forward to change the financial outlook as regards future irrigation projects. The standard of basing the test of productivity on the results of the tenth year after opening is arbitrary. Irrigation is a long-time investment. Some of the best canals in the Punjab and in other countries failed to come up to this test. Full development of an irrigation scheme may take as many as 30 years.

Both the Provincial as well as the Central Governments derive so large sums of revenue, besides the Direct and Indirect Irrigation Receipts, as a result of development of irrigation, that there are sufficient grounds to lower the financial test of such schemes. In other countries irrigation has been invariably subsidized by the State. It is suggested that the cost of storage schemes for supplementing the existing winter supplies should be pooled with the costs on the original projects for the purposes of financial tests. The best test for undertaking a new irrigation project is whether there is a further demand for the agricultural wealth that the project will produce. In considering this it should be remembered that at least fifteen years are required for a reasonable development of the irrigated area after construction has been started.

The financial requirements of the province demand that the water-rates should be fixed at a pitch that the cultivator can reasonably afford to pay. The returns to the State from irrigation works already built are no criterion for fixing water-rates. Certain parts of the province are physically less fortunate and schemes for extending irrigation facilities into these parts may not be as remunerative. These schemes should be pooled with the rest of the irrigation works so that water, the natural wealth of the province, is as equitably distributed as possible.

Irrigation is of such an economic importance to the province that a better understanding of the problems connected with it is imperative from the electorate and its representatives.

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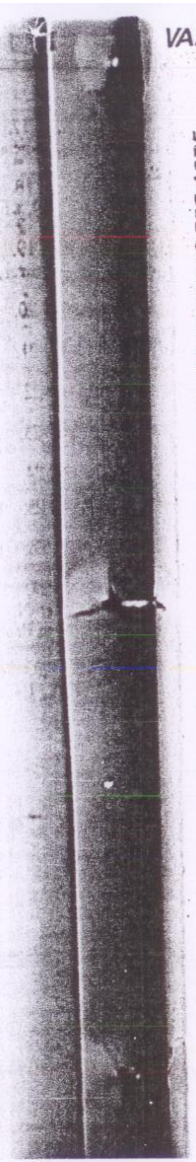
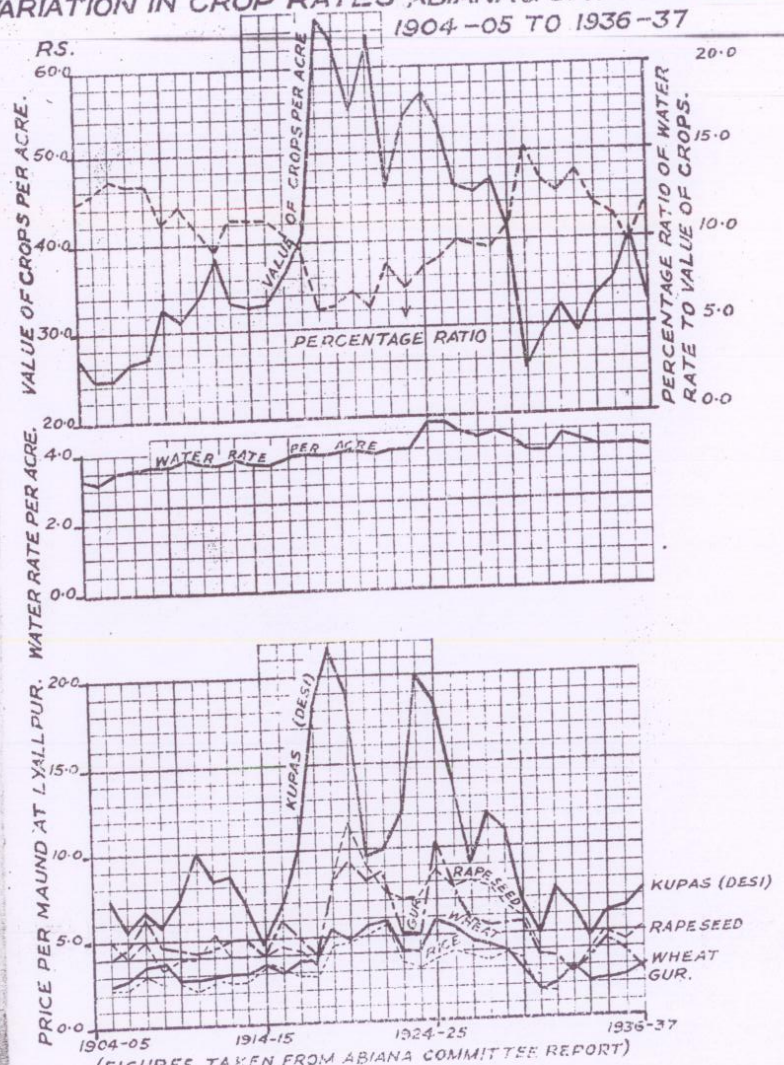


VARIATION IN CROP RATES ABIANA & GROSS PRODUCE PER ACRE
1904-05 TO 1936-37

GRAPH No. 1
PAPER No. 228

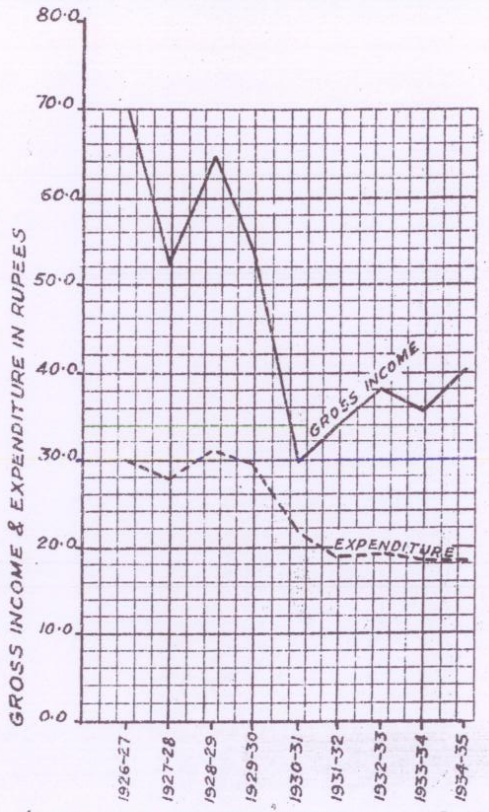


(FIGURES TAKEN FROM ABIANA COMMITTEE REPORT)

PUNJAB ENGINEERING CONGRESS
1939.

GRAPH NO. 2
PAPER NO. 228

GROSS INCOME AND EXPENDITURE OF CERTAIN CANAL IRRIGATED HOLDINGS IN THE PUNJAB.



(FIGURES TAKEN FROM FARM ACCOUNTS 1934-35, PAGE 5)

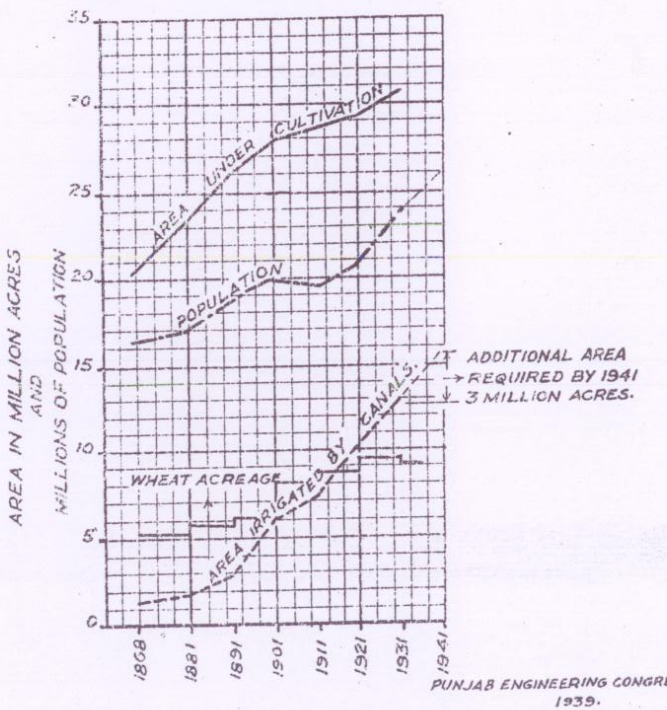
PUNJAB ENGINEERING CONGRESS.
1939.

GRAPH NO.3

PAPER NO. 228

RELATIONSHIP BETWEEN POPULATION & AREA CULTIVATED & IRRIGATED IN THE BRITISH PUNJAB.

(FIGURES TAKEN FROM AGRICULTURAL STATISTICS OF THE PUNJAB, PAGE 16 AND FROM FACTORS AFFECTING PRICE OF WHEAT).



PUNJAB ENGINEERING CONGRESS 1939.

PAPER NO. 228

DIAGRAM SHOWING PERCENTAGE OF NET REVENUE (BOTH DIRECT & INDIRECT) ON CAPITAL OUTLAY OF THE PUNJAB WEIR CONTROLLED CANALS.

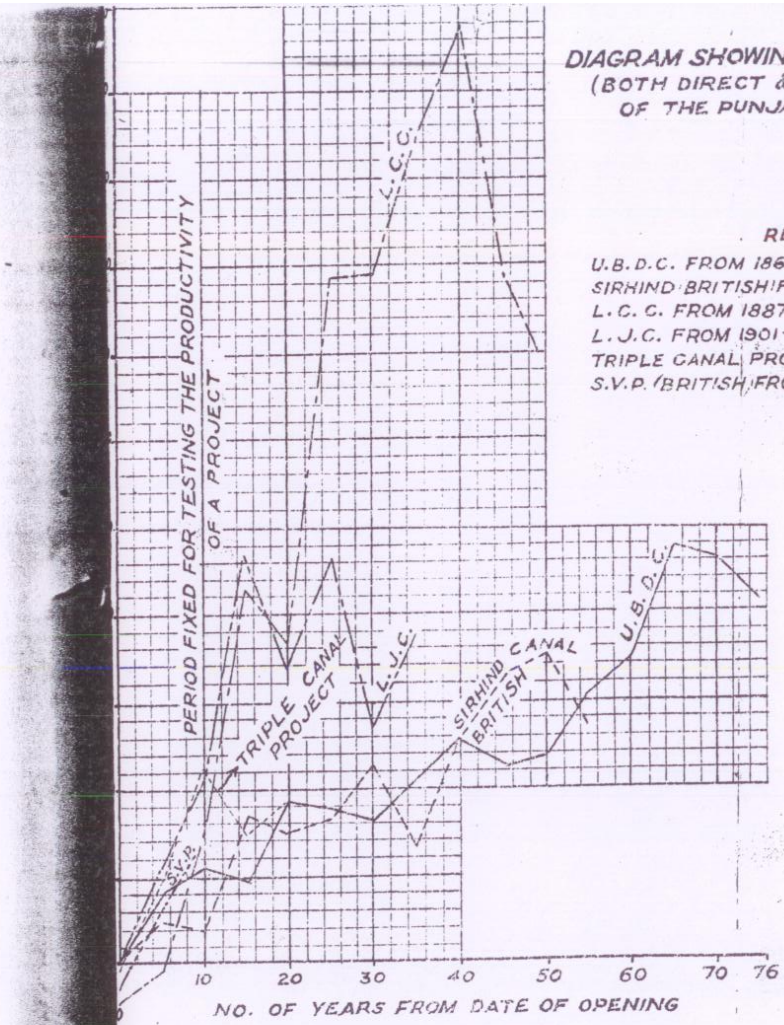


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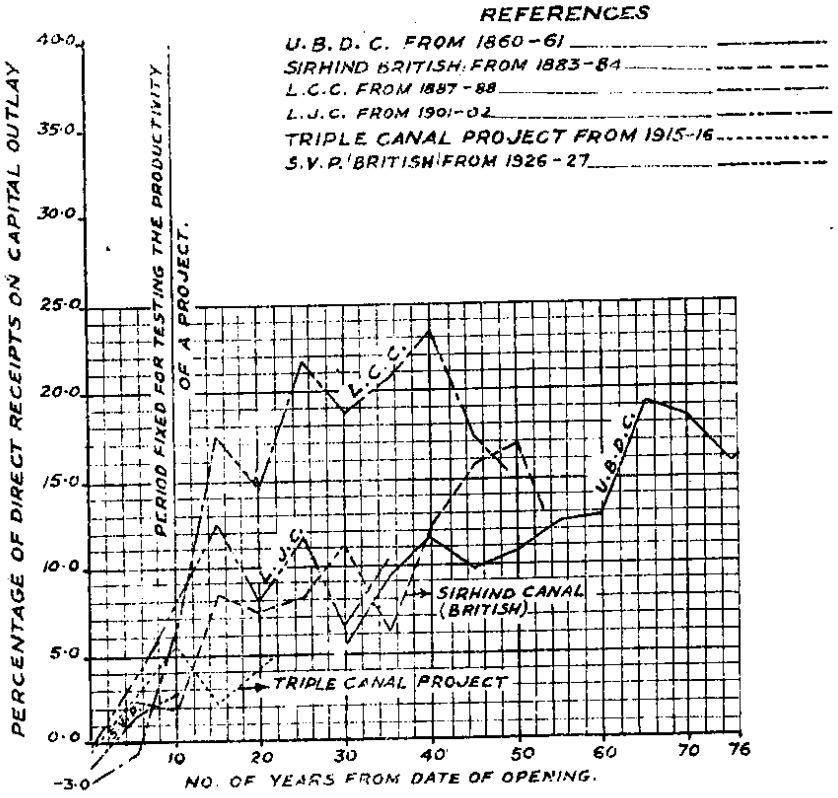
DIAGRAM SHOWING PERCENTAGE OF DIRECT REVENUE ON CAPITAL OUTLAY OF THE PUNJAB WEIR CONTROLLED CANALS



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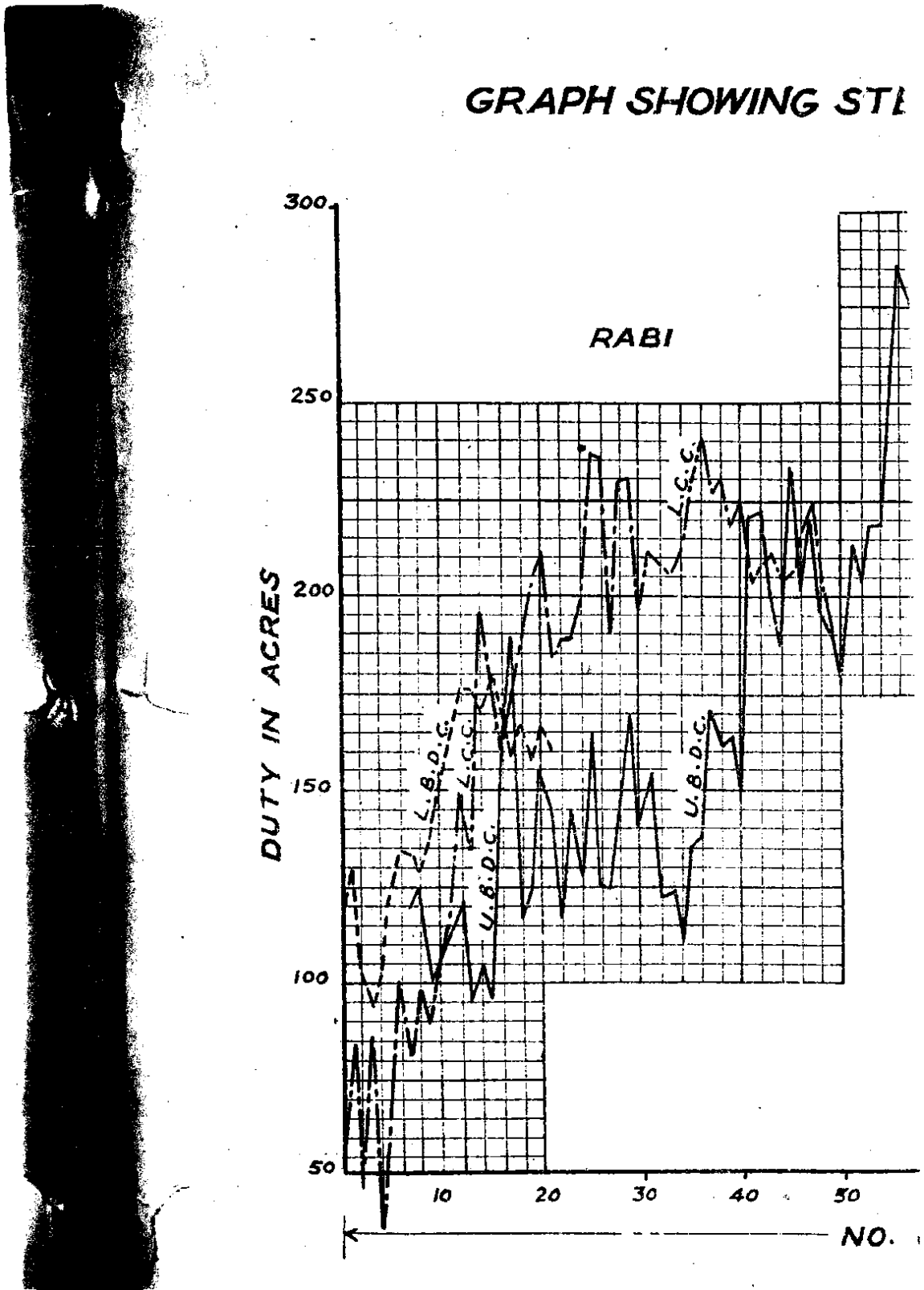
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ADY RISE IN "DUTY" ON SOME OF THE PUNJAB CANALS

GRAPH NO. 6
PAPER NO. 228

REFERENCES

U. B. D. C. FROM 1860-61 ————
L. C. C. FROM 1887-88 —·—·—
L. B. D. C. FROM 1915-16 - - - - -

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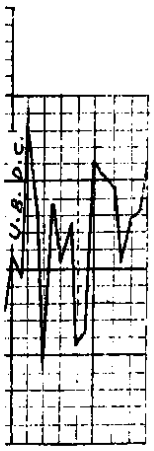

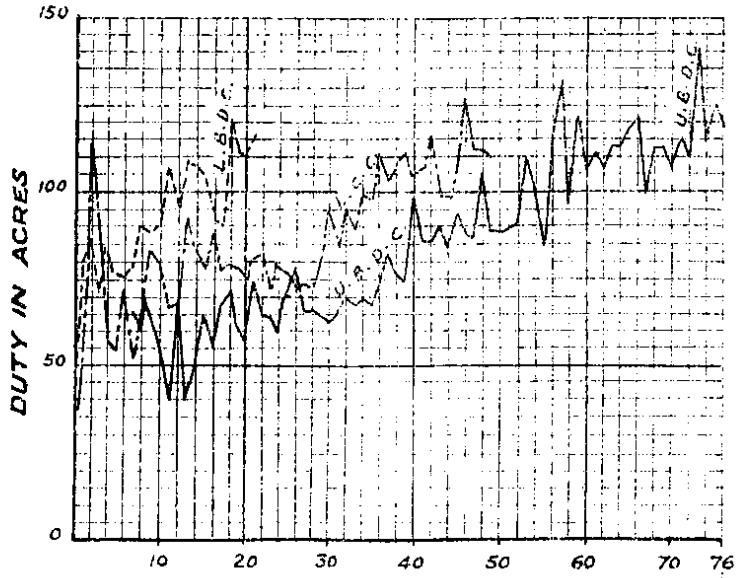

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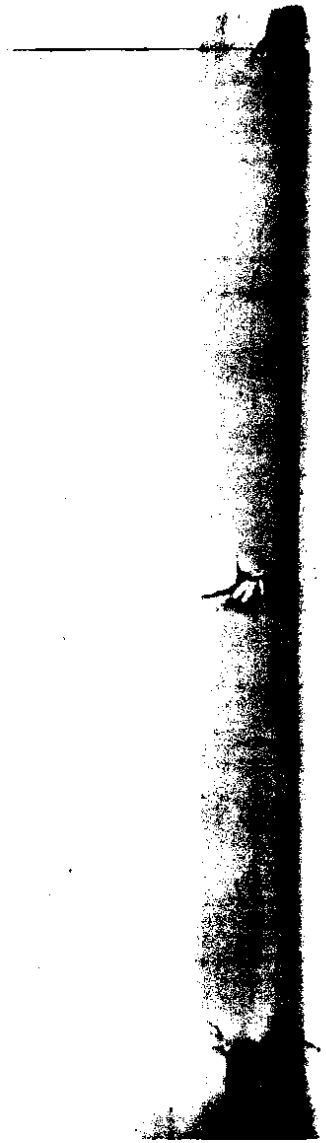

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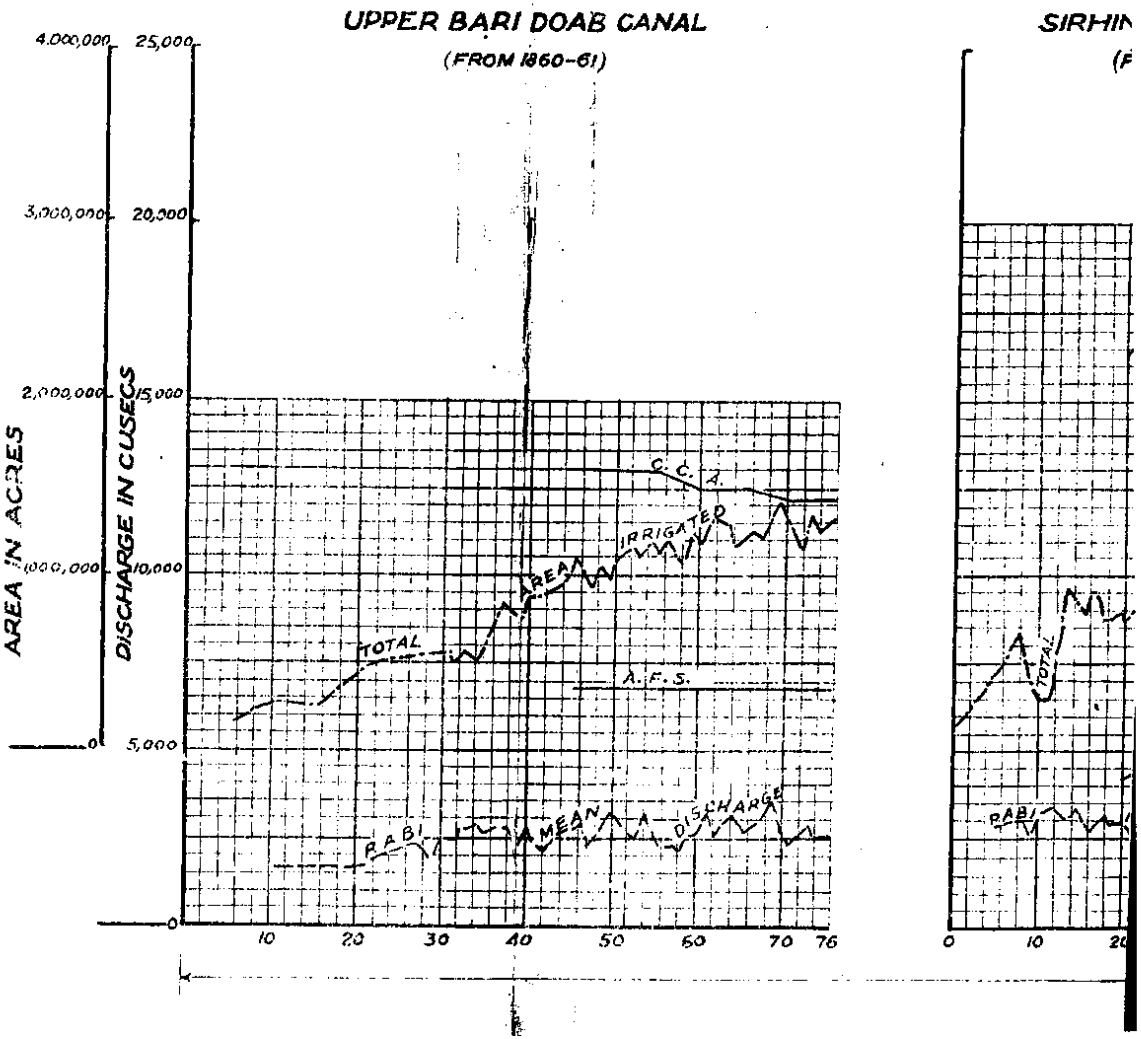
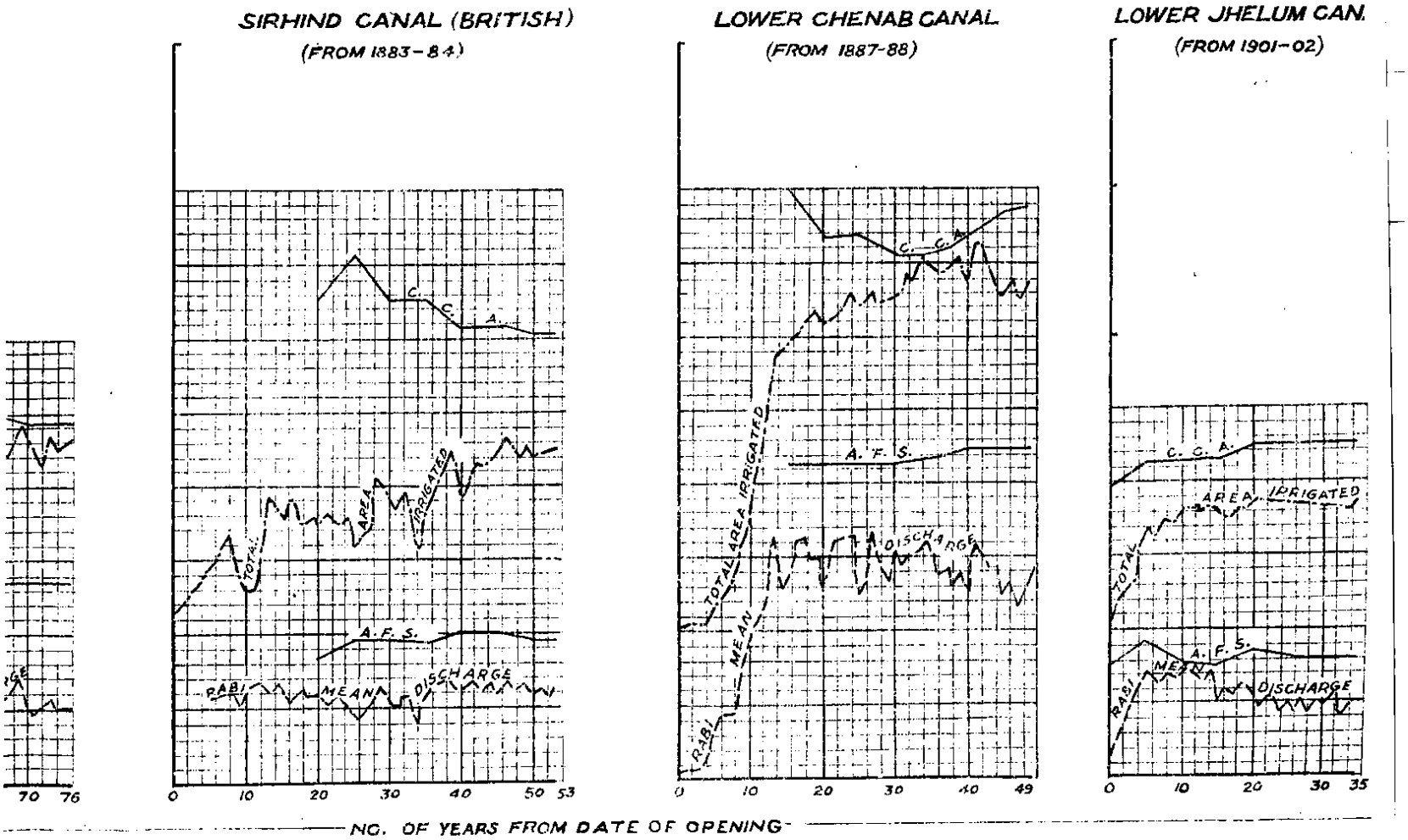


GRAPH SHOWING DEVELOPMENT OF IRRIGATED AREA ON THE PUNJAB WEIR CONTROLLED CAN

(C.C.A. & A.F.S. PLOTTED FOR EVERY FIFTH YEAR ONLY)



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(FROM 1887-88)

(FROM 1901-02)

TRIPLE CANAL PROJECT

(FROM 1915-16)

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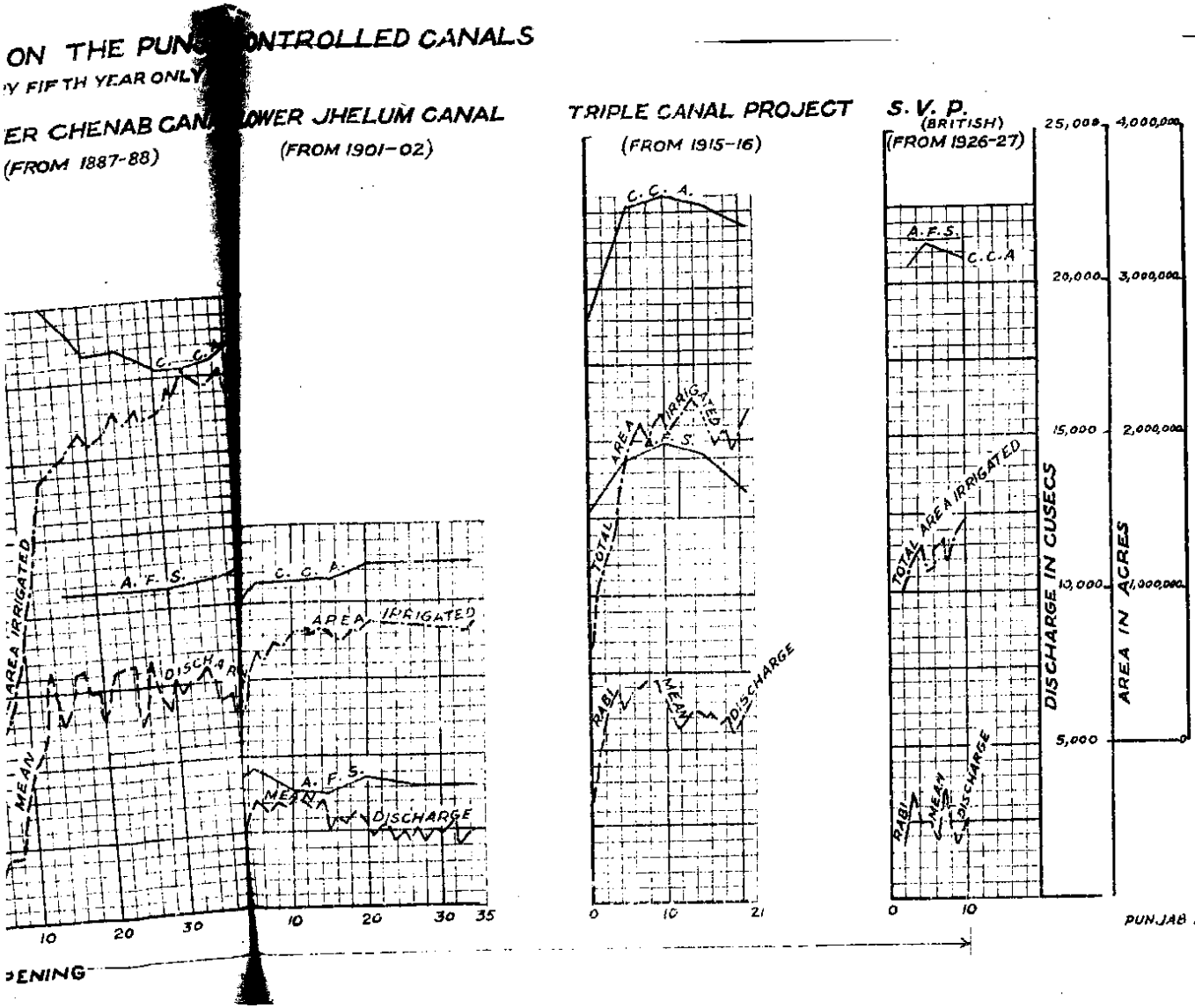

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PUNJAB ENGINEERING CONGRESS. 1939.

DISCUSSION

Mr. **Kanwar Sain** opened the discussion with a quotation from Mr. E.R. Foy, a former Chief Engineer of the Punjab*.

He said that an eminent member of the U.S. Reclamation Service once made a short tour through the Punjab. In the course of conversation with the Governor of the Province the visitor said " keep irrigation out of politics". Coming as this did from a democratic citizen of a democratic country like America, the Governor was rather surprised. The visitor then went on to explain that some rather good and financially sound irrigation projects in America had been either wrecked or quite severely hampered by candidates for election to Congress who secured the settlers' vote by promising either cancellation of the unpaid balance or postponement of payment if elected.

The speaker continued that this state of affairs was corroborated by J.B. Lippincott, but that the state had since adopted a more rigid attitude towards those who failed to pay.

He added that at a time when the abiana rates prevalent in the Province were the subject of serious discussion in the legislature, it was of paramount importance that the financial and economic aspects of irrigation projects should be clear not only to the irrigation engineers and the civil administrators on the one hand and the members of Opposition in the Legislature on the other, but to every man in the Province who had the welfare of the Province at his heart. There was a time when the finances of the Government of India, as one Finance Member claimed,—nay the whole annual outlook of the great majority of its people were based upon a gamble in the monsoon. It was by a persistent broad administrative policy that a greater portion of the Punjab had been placed outside the reach of this gamble. In fact, to the greater part of the Punjab a failure of monsoons might now mean not a disaster but wealth. That was achieved not from the mere fact that the Punjab possessed great assets in its climate, its soil and its people; these alone remained untapped for centuries till a great benevolent administration came forward to utilize these resources. The speaker referred to the push and the initiative which the Government of India had taken in the past in furthering the ends of irrigation projects all over India. If the Punjab had a difficulty or was met with an obstacle, the Government of India sought a remedy with the single desire to secure benefit to the Province. If the difficulty or obstacle had arisen from another province or State, the Central Government had acted as a friendly arbitrator, using its good offices to bring about settlement in the best interests of both parties. In such cases it was sufficient for the parties to state their position in order to ensure a

*From discussions on Mr. Lindley's paper on Government Reclamation Policy in British India, presented to the American Society of Civil Engineers in 1930.

thoroughly complete and impartial consideration by the Government of India. With almost negligible exceptions it might be stated that there was no question of canvassing disinterested provinces or states or striving to win not by the rightness of the cause but by haggling for votes.

No one could say, continued the speaker, how the new Federal Government was going to react to the Provincial irrigation policies. The distribution of the waters of the Punjab rivers between the British Punjab and the States on the one hand and the Sind Province on the other had already become a very complicated question. This was not all. The Punjab canals were dependent upon the continued careful conservation of catchment areas of the Punjab rivers beyond its own boundaries. The entire catchment areas lay in States which had no direct relations with the Punjab Government. The Punjab therefore was not in a position to press these States either in matters of conservation of forests or in persuading the States to agree to the construction of dams in their territory for the further development of the Province. As put down by Mr. Calvert, the threat to Punjab prosperity would always be real and the future obviously held difficulties in store. If to the above difficulties, said the speaker, the provincial legislature added criticism of a destructive nature without the full knowledge of relevant facts, not only would the further development of irrigation in the province but the working of those which had already been built might present difficulties which at first might not be fully realized.

The speaker opined that the Punjab tax-payer and farmer would prevent a repetition of the history of Federal Reclamation Development in America. That had been briefly summed up in a discussion by E.H. Newel (Henny's paper in the American Society of Civil Engineers). The first chapter, Mr. Newel said, was that of eager importunity on the part of local land owners and their representatives for the expenditure of federal funds. This was accompanied by a statement that no matter what reclamation cost, the reform was worth it and the owners would cheerfully pay the costs.

The second chapter was of popular enthusiasm and praise of the engineer and his operations, accompanied by urgent appeals to Washington that the works under construction should be built in the most permanent manner regardless of cost; that the canals must be made larger and the ditches built to every farm.

The third chapter opened with practical completion of the works, the turning of the waters on to the fields and the beginning of the time of repayment. That was the opportunity for the Opposition Members to make a political capital out of their practical knowledge of human nature. Facts were obscured and in the effort, the poor engineer was made the scapegoat. This began the long and heart-breaking campaign of attack which resulted in driving from the public service many able and conscientious

engineers. The engineer of to-day and all the more of to-morrow, said the speaker, must study the moods of the public with the same degree of care and personal attention as problems of floods or adequacy of water supply or seepage flow under a barrage in a sandy river bed, factors which were known to have caused failures of engineers' works. Equal or perhaps greater destruction could come to the reputation and organization of the engineer through changes of public sentiment.

Nothing would help to clear the position more than to make a clean breast of all the facts backed by actual figures, so that the issues were not confused by a clever juggling of words. The speaker mentioned, in passing, that the Haveli Project had already passed through the first two chapters. The speaker hoped that the third chapter of the Federal Reclamation of the history of United States of America would not be repeated in the Punjab by putting up unreasonable demands regarding Abiana rates on the Project. That, however, was a matter which entirely concerned the future policy of the Government. The Engineer would have done his duty if with honesty and clearness he put forward his facts, and it is with this desire, said the author, that the paper under discussion had been written.

The speaker asked for indulgence for slight inaccuracies in figures that might have inadvertently crept in.

R.B. **A.N. Khosla** stated that the Author had presented an excellent paper which would serve not only as ready reference for those who were engaged on preparing new irrigation projects, but as a useful guide for Irrigation Engineers in general. He had treated the subject in a very comprehensive manner and had clearly brought out the relative importance of various factors involved in an irrigation under-taking. He had rightly put forward a plea for a change in the financial policy. This needed serious consideration, for irrigation projects of the future were going to be constructed under more unfavourable conditions and would therefore be relatively more expensive. If the financial test was not suitably modified in respect of new projects, the development of future irrigation was likely to be hampered.

The Author had given comparative statements of costs and other data for the various Headworks. For a correct comparison, various governing factors should be taken to account. The main factors were:

(1) Head across the Weir $=H$
(2) Length of crest between abutments $=L$
(3) The discharge per foot run $=q$

The Head governed the length of floor, the position and depth of sheet piles and thickness of the floor from point to point. It governed the exit gradient and thus determined the factor of safety. The length

between the abutments was a direct measure of the cost of the work and its magnitude. The discharge per foot run determined the length of the floor and in the region of the standing wave its thickness. It further determined the depth of maximum scour at each section, and therefore the quantity of loose protection at these sections. The magnitude of the work could be correctly and completely measured by the following equation.

$$\text{Magnitude} = H \times L \times \sqrt{q}$$

If the Emerson Barrage as constructed were taken as unity in magnitude, then the Lloyd Barrage at Sukkur would be 1·26, Panjnad 0·07, Ferozepore 0·44, Sulemanke 0·38 and Islam 0·30.

Mr. **G.R. Sawhny** said that the author deserved to be congratulated on the result of his efforts and on his being able to present the Congress with a really good digest of very useful information, the various aspects described in this paper being undoubtedly very instructive.

He pointed out that the word rate should not follow 'Abiana' it should be either occupier's rate or 'Abiana'.

The speaker disagreed with the remarks that levelling was not necessary for barani cultivation; as a matter of fact it was ever so more necessary to level barani fields so that the run off of water from them during the drains should be reduced to the very minimum.

Mr. Sawhny said that the remarks 'increase in cost is due to increasing difficulties in construction' needs to be amplified as he did not see why our difficulties with all our experience and clever officers should instead of being decreased be increasing every day.

In finding out outlay per acre assessed, the speaker asked what areas had been taken into consideration for Haveli figures. If old and new areas had been taken into consideration then had the calculations been made on the same basis as for other projects which brought mostly new areas under irrigation or on some different basis?

The speaker agreed with the author that a strict comparison of cost of various Head Works was not possible. He added that same would apply to various projects which were carried out at different times and under different circumstances. All that was possible to do was that estimates and accounts for each project were thoroughly examined both before starting and after completion by an independent committee who should report whether such a project had been estimated and carried out economically or not and if not what and how savings could have been made. Comparison so long afterwards in the form of a Table, in the opinion of the speaker did not in all cases give a correct idea.

Mr. Sawhny asked how it had been found more economical to construct channels to take higher discharge during summer. He thought such a design would be much more troublesome and also expensive. He expressed the opinion that the Distributaries should be designed to their full supply requirements and run full supply continuously during summer and by rotational closures during the winter as is being done on the Lower Bari Doab Canal.

The speaker agreed that making use of old plant available in the country was no doubt the very correct thing to do but said that all such plant had to be purchased by some one before for it to be available to be made use of now, secondly there being no big works going on any where else at the time more labour was available for the works to be carried out in less time on the Haveli Project. Mr. Sawhny however did not by any means wish to convey that he did not appreciate that the works on the Haveli Project had been carried out with a really good *bandobast* very economically and in a very, very quick time.

In considering the very important question of growth in population Mr. Sawhny thought it best to consider the all Punjab aspect of it only, without basing his ideas on compensating the increase in population by a corresponding increase in cultivated areas. The colonization in the Punjab had definitely shown that the increase in population had gone up much more quickly already and was still in the up growth, while there were little more areas left to be brought under cultivation ; otherwise instead of solving this important problem, a great menace would be created to the province. Mr. Sawhny was of the opinion that in the statement under birth control, the author should have given similar figures for Africa, South America and other countries which had extreme climate like India. The countries quoted by the author could well afford to live peacefully because of their industrial and climatic conditions. The speaker thought that overpopulation was already a very serious cause of our troubles.

Irrigation was no doubt a cottage industry but it was already overdone. Mr. Sawhny suggested that India's problem of over population could be solved by introducing other cottage industries which may go hand in hand with the irrigation.

He pointed out that Table giving the comparative rates for a cusec of water charged in various countries where irrigation is being done, would have added to the comprehensiveness of the paper. Referring to a quotation of Sir William Robert's views in the paper, Mr. Sawhny asked Sir William Roberts to name any of his farms on the L.B.D.C. where he had been able to achieve 200 per cent intensity.

Talking about the increase in intensity of irrigation Mr. Sawhny said that in his opinion unless and until better methods of cultivation

arithmetic. The point to be emphasized was that in making these calculations not only were the prices that prevailed at harvest time taken into account, but also the areas under the different crops and the estimated actual outturns.

In the Lower Bari Doab Colony, in the Lyallpur District and in certain parts of the Sheikhupura District, land revenue was now being assessed on a sliding scale and this had prominently brought to notice the question of assessing water rates in a similar manner. This was not the place to describe the system of assessing land revenue on a sliding scale, but it was necessary to give a few details in order to understand fully the subject under discussion. The unit for fixing the land revenue rates was what is known as the assessment circle, which was a group of estates sufficiently homogeneous to admit of a common set of rates being fixed. The assessment circle was generally a Tehsil or a part of a Tehsil. One of the most important items which determined the assessment of land revenue was the value of agricultural produce. The Settlement Officer took a number of factors and it was on this estimate that his land revenue rates were based, in accordance with the standard of one-quarter net assets. These factors were:—

(*i*) the percentage of the total matured area under each important crop,

(*ii*) the average yield per acre of each of those crops,

and (*iii*) the commutation price assumed for each of those crops.

By multiplying these figures together, an index figure was obtained. The percentage of remission to be given in any harvest was determined only on the basis of the market prices as compared with assumed commutation prices, no regard being paid, unless there were exceptional reasons to the contrary, the variations in the percentage of crops and the average yield per acre. The market prices of one year determined the remissions to be given the next year.

It would be seen that there was a definite standard, viz., one quarter net assets which determined the pitch of the land revenue rates, also that in determining the remissions to be granted, only one factor, namely, that of prices was taken into account. All this made for simplicity in working the system, although in the opinion of many experienced Revenue officers, the procedure which makes the remissions to be given during a year dependent on the prices prevailing in the pre ceding year is defective, as it assumed that the average cultivators had a certain power of "carry over" from year to year which he had not. At the same time it had to be admitted that it is impracticable to work out the scale of remissions on the prices prevailing for the current year, because instalments of land revenue were realized before the marketing of the crops was complete.

Mr. Kanwar Sain's idea of framing a sliding scale for assessment of water rates appeared to be by a reversal of the process, according to which the percentage ratio of water rate to value of crops was determined at present. Before such a scale could be framed the following points would have to be decided :—

(1) What was to be considered as a fair value for the ratio of water rate to value of crops in the assessment of land revenue a definite criterion, namely, one quarter net assets had been laid down. But, as stated by Mr. Kanwar Sain himself on page 223 of his paper, water rates had no such basis and were determined more or less by rule of thumb. Was this ratio to be the same value over the whole of the area irrigated by the major canals of the province? Or was the unit to be a canal, a civil district, an assessment circle, or a holding. Was the ratio to be a percentage of the gross value of the produce of the cultivator's net profit.

(2) Having fixed a value for this ratio the next step would be to ascertain the value of crops per acre. The unit of calculation having been decided as above, it would then be for consideration whether all the three factors which influence the value of the produce should be taken into account or only that of prices.

(3) With the ratio and the value of crops determined, the average water rate per acre assessed could be found over the area taken as a unit. Would this flat rate be applied to the whole assessable area in the unit or would it be split up into different rates according to the class of crops grown. If so, how?

(4) What would be the final effect of sliding scale in case it was possible to evolve one.

The idea of regulating the demand for water rates in accordance with the paying capacity of the cultivator was very attractive and deserved to be explored. As stated before, with the introduction of a sliding scale of land revenue assessment in certain parts of the Province, the question had assumed added importance, although, unlike land revenue, water rate was a payment made by the cultivator for value received.

During the course of the enquiry that a committee, appointed by Government to go into the working of the Canal Act and other kindred matters, had been conducting, a demand had been made at more than one place visited by it that, like land revenue, water rates should also be assessed on a sliding scale. The matter, however, bristled with

difficulties and in the foregoing remarks the speaker had tried to bring out some of those which would have to be faced before a satisfactory solution could be found.

Mr. **B.K. Kapur** said that the interest of the paper under discussion extended far beyond the sphere of the Engineering profession as it dealt with a subject of such vital importance not only to the public of the Punjab, but to the whole of India.

The author had collected highly valuable data, but the speaker was afraid that within the time available to most of the members, it had not been possible to do justice to the subject matter. It dealt with highly abstruse problems which had formed the subject of investigation of scientists and philosophers of so many countries and ages.

So, inspite of the fact that we were liable to get lost in the intricacies of the problems discussed, the author was to be congratulated on his boldness in making a departure in presenting a paper to the Punjab Engineering Congress, which was not purely of Engineering interest.

The speaker thought that the author's connection with the various projects had confirmed him in the belief that nothing but the extension of irrigaton would solve the problem of increasing population of the province. Mr. Kapur observed that in discussing the subject, the author had taken a partial view in pressing forward the importance of extending irrigation to the exclusion of all other factors which go to make a prosperous country.

He quoted from a budget speech of the late Lord Curzon, delivered in 1901.

" In every country that is so largely dependent upon agriculture, there comes a time and it must come to India, when the average agricultural income per head ceases to expand for two reasons : first that the population goes on increasing, second that the area of fresh ground available for cultivation does not increase pari passu, but is taken up and thereby exhausted. When this point is reached it is no good to attack the Government for its inability to fight the laws of nature. What a prudent Government endeavours to do is to increase its non-agricultural sources of income".

That great man, continued the speaker, saw with prophetic vision, that without the help of non-agricultural income, the extension of irrigation would not lead to increased prosperity of the people. Since then we had seen, one great colony after another come into existence and made rapid progress, so that we might now say that nearly half the wealth of the Province came from the Canal irrigated area. But unfortunately the condition of the people even of the Canal irrigated tracts was no better in 1939 then it was when Lord Curzon uttered his prophetic words.

Thus the author would see that his plea for the further extension of irrigation in the Province would not solve the problem of poverty of the people. After the bright vision of first few years of bumper crops and increasing prosperity, people would again settle down to their miserable condition.

There was a universal tendency for population to outrun the means of subsistence and the extension of irrigation was only a palliative like emigration, because in new colonies population was known to double in 20 years or less and continued to multiply, while under the most favourable circumstances, the means of subsistence could only add up. Population invariably increased when the means of subsistence increased, so the author's proposal for the extension of irrigation would only hasten the further increase of population without in the long run improving their lot. The Census Superintendent thus summed up his conclusions regarding the pressure of population on the agricultural resources of the Province :—

" Density varies everywhere in accordance with agricultural resources to the exclusion of all other factors, it is so directly proportionate that the conclusion that there is pressure on these resources is irresistible. Yet this same direct proportion also indicates that other factors have not yet been brought into play and hence that the pressure on resources is not yet extreme, for in that case industrialization would have been forced into existence and would have led to variations of density independent of agriculture."

In any country where agriculture predominated, the condition of the people was subject to almost every degree of variation. If, as in India, a considerable part of the manufactured commodities be purchased by the export of its raw produce, the relative value of its raw produce would be lower and therefore the value of the food which a labourer earns above what he and his family consume, would go but a very little way in the purchase of clothing, lodging and other conveniences and the consequence was that his condition in these respects was very miserable ; at the same time, his means of subsistence, such as they were, might be comparatively abundant.

Quoting from Malthus, the speaker said, that in an agricultural country, the development of manufactures and commerce could alone liberate the mass of the people from slavery and give the necessary stimulus to industry and accumulation.

It was only if industries flourished, that the produce of the soil would find a ready market at home as visualized by the author on page 244.

In an industrial country, even when the effective demand for labour begins to slacken, and the wages in food to be reduced, still the high

relative value of food keeps up comparatively the condition of the labouring classes, and they could never be reduced to the miserable condition of the people in a purely agricultural country, where, at the same time that the demand of labour was stationary or was actually less, the value of food, compared with manufactures and foreign commodities was extremely low.

Any efforts to improve the methods of cultivation and to add to the irrigated area deserved all praise, but it was unreasonable to expect the agricultural income to increase rapidly and keep pace with the growth of population. According to Mr. Kapur remedy lay in the development of non-agricultural sources of income, because excessive dependence on agriculture must in the end impoverish the country.

Sir **William Roberts** said that when he first read the paper under discussion he thought what a useful purpose it would serve, if some one with the ability and knowledge of the author of the paper could write on the prevailing position, with regard to waterlogging and experience in ameliorating the same.

It was very difficult for a layman to know what had been done, particularly by way of drains and by way of observation of the rise in the water-table and its causes. Before referring further to the paper Sir William referred to a point raised in Mr. Duncan's paper, as it had a bearing on certain matters discussed by Mr. Kanwar Sain.

Mr. Duncan valued the cusec at Rs. 1000 per annum and thus calculated that the saving from lining in the Haveli Project would be Rs. 3·3 lakhs or sufficient to pay for the cost of lining in 16 years. Sir William's opinion was that we should look at the cusec from a broader aspect than its annual earning. Without water the land was useless. The value of the cusec in land appreciation alone on the basis of duty of 250 acres per cusec was about Rs. 50,000. The real value therefore of the 300 odd cusecs saved on the land on the Haveli Project would be Rs. 150 lakhs, if we valued land at Rs. 200 only per acre.

It was important to have an agreed understanding on this question of valuation of a cusec, because that would have a very important effect when discussing lining as compared to other methods of solving the water-logging problem. As long as we were tied to the out of date ideas about land revenue and land as having any value apart from water, we could not make any real progress.

There was one other aspect, which would appear to be somewhat contradictory, but which the speaker wished to put forward. This was that the present charge for abiana was felt heavily in view of the very low prices of agricultural produce. When water rates were raised in 1924, the prices of cotton and wheat were in some cases three times what

they were in 1939. Sir William felt strongly that water rates should be graduated to some extent according to the prices of the crop that the farmer was growing.

Messrs. J. D. H. Bedford, S. H. Bigsby and A. M. R. Montagu also took part in the discussion.

Correspondence.

Sir **Bernard Darley** wrote from London that Mr. Sain had written a most interesting paper, and he was to be congratulated on the manner in which he had put forward so many useful facts and figures.

It was only in Section III " Costs and Returns to the State" that some of his statements were misleading. Throughout this section Mr. Sain compared capital cost and working expenses per acre assessed without considering the varying conditions which prevailed on many of the canals mentioned. The conclusion come to on page 219, therefor viz that the Punjab can boast of the cheapest canal system in India, though true in one sense would make it appear that other provinces were not so economical.

In actual fact conditions in the Punjab were ideal for economical irrigation. Rainfall was light and it was therefore possible to irrigate in many parts as much as 75 to 80 per cent. of the culturable commanded area. Sir Bernard compared this with the United Provinces. There the rainfall was so high that canal systems only irrigated 25 to 35 per cent. of their culturable commanded area. That meant that in the United Provinces, to irrigate the same area, it was necessary to have over twice the mileage of canals as that required in the Punjab. Thus the capital cost and the working expenses must be higher. There was the added expense of extensive drainage systems, as shown in Table No. 39. Such large drainage systems were not required in the Punjab.

Table No. 39 had been prepared from the Triennial Report for the years 1930-1933 (the latest return available). It compared the cost of maintenance per mile of canal for some of the principal canals of the Punjab and the United Provinces. Possibly the later Triennial Report from which Mr. Sain quotes might alter the costs slightly.

There were obvious reasons why the cost of maintenance in the Punjab must be more expensive than in the United Provinces and this no doubt was the chief reason for the marked differences shown. It was a fact, however, that the margin of profit in the United Provinces was so small that the utmost economy must be practised. For instance, motor roads, which cost so much to maintain in the Punjab, had to be cut down to a minimum in the United Provinces, inspections being done for the most part on horse back.

Such statements as those given in Mr. Sain's paper and that in Table No. 39 only show that such comparisons were often very misleading.

TABLE NO. 39.

Statement showing the cost of maintenance per mile of Canal for the principal Canals of the Punjab and of the United Provinces.

(Figures taken from the Triennial Report for the years 1930-33)

Canal System.	Mileage of Canal			Working Expenses Direct & Indirect.	Cost of Maintenance per mile of Canal.	Mileage of Drainage Channels.
	Main Canal and Branches.	Distributaries.	Total.			
1	2	3	4	5	6	7
	Miles.	Miles.	Miles.	Rs.	Rs.	Miles.
			PUNJAB CANALS.			
Upper Bari Doab.	332	1513	1845	13,79,347	748	Not known.
Western Jumna.	306	1747	2053	18,76,563	914	
Lower Chenab.	453	2477	2930	34,51,610	1178	
Upper Chenab.	172	1245	1417	15,75,613	1112	
Lower Bari Doab.	132	1317	1449	16,40,103	1132	
Lower Jhelum.	181	1011	1192	14,70,139	1233	
Sutlej Valley Project.	Mileage in British India not shown separately in the Triennial Report.			27,34,928		
			UNITED PROVINCES CANALS.			
Ganges Canal.	568	3320	3888	16,89,303	435	1957
Lower Ganges.	662	3165	3827	14,18,064	371	1182
Eastern Jumna	129	795	924	5,39,631	584	483
Agra Canal.	100	902	1002	4,42,721	442	312
Sarda Canal.	912	3265	4177	19,67,583	471	1679

Note. The cost of maintaining Drainage Channels col. 7 is included under Working Expenses col. 5. Thus the actual cost per mile of canal is less than shown in col. 6.

There was a mistake in Table 13 where the capital cost of the Sarda Canal was shown to have exceeded the estimate by 30·84. The Sarda Canal was sanctioned in two parts:—

(1)	The Sarda-Kichha Canal.	Rs. 2,00,56,666 including head works.
(2)	The Sarda-Oudh Canal.	Rs. 7,50,30,917 works.
	Total	Rs. 9,50,80,068.

Mr. Sain had only shown item (2). The excess was actually only 3·4% based on the cost shown in the Completion Report.

Mr. Sain's paper must have entailed much study and he was to be congratulated on the result.

Mr. **M. T. Gibling, I.S.E.** communicated in writing that Mr. Kanwar Sain had presented a very useful collection of information from a large number of sources, and he had compiled it in a very interesting and lucid manner. He hoped it would be brought to the notice of all the finance and economics experts, not only in the Punjab, but also in the Government of India and the other Provinces.

The main object of the Paper was to put forward a plea to revise the financial tests at present applied to irrigation works before they were undertaken, and the speaker thought that the author had made out a very good case. They were one or two points, however, which Mr. Gibling wished to emphasize. The Punjab was ideally suited for irrigation, and it was obvious from the figures which Mr. Kanwar Sain had presented that revenue from irrigation works was the main support of the Province. It was fortunate moreover that the Punjab had been able to introduce its irrigation without resorting to expensive storage schemes or schemes which drew upon the sub-soil water table. Other less fortunate provinces had to undertake works, sometimes famine protective works, which not only could not be classed as productive works, but which were constantly losing money. No one would say, however, that the country would be better off without those works, as the indirect benefits far outweighed the returns which were shown in the annual accounts. In considering future projects in the Punjab an attempt should be made, as Mr. Kanwar Sain had rightly suggested, to consider all the irrigation projects in the Province as one large scheme and to lump together the costs, and consider the returns from them as a whole. This principle had in fact been accepted by adopting uniform water rates throughout the Province. The revenue figures given in the paper only presented half the picture and the complete picture of the benefits to the Province from irrigation could only be obtained from the figures showing the value of crops grown under irrigation. It would be seen that against a total capital cost of Rs. 35½ crores for irrigation works carried out in the Punjab, the value of crops

grown was about 40 crores of rupees per annum. If there were no irrigation, certain crops would no doubt be grown, but from the figures given in Table 29 showing the outturn and value of crops grown on irrigated and unirrigated land, an idea could be obtained of the value of irrigation. Enormous wealth was being produced in the Province which was greatly in excess of the revenues accruing to Government. Mr. Gibling thought that economists would say that provided the money was circulating, every anna of it was of economic benefit to the Province, and a large portion of it went to the Provincial Government through devious channels. In this connection the author has referred to a resolution by the Central Board of Irrigation recommending an economic survey of irrigation projects, and he had mentioned that the Government of India had decided to take no action on the resolution. There was no doubt that such a survey would show that the Central Government were deriving considerable indirect benefits from irrigation projects financed by the Provinces and the Central Government had nothing to gain from any such exposure, and everything to lose. Nothing would be done unless it was done by the Provinces, and it was up to the Punjab, which had gained more from irrigation than any other Province in India, to assist in carrying out this proposed survey. Even if nothing came of it in the form of subsidies from the Government of India, it would be an extremely valuable investigation for students of economics in the Punjab, and it would at least enable the Punjab Government to draw a line betwen economic and uneconomic projects. The author had suggested that the Punjab Government should take up projects in areas so far relegated to the background, irrespective of their financial results. Mr. Gibling expressed his fear that the financiers would not look kindly upon such a proposal, but he thought that the author meant that what might be called the book value of a project should not be the deciding factor. It was only by such a survey as had been suggested by the Central Board of Irrigation that it would be possible to define a dividing line between projects which would be of economic benefit to the Province in the broad sense, and those which would not.

The author has stated in the paper that in his opinion the future of the development of the Punjab lay in storage schemes, and that suitable sites existed on practically all the Punjab rivers for storing large volumes of summer supplies now going to waste. In Table 38 on page 252 there was a remark to the effect that when the first reservoirs start depleting due to silting, storage at other sites could be taken up. In Mr. Gibling's opinion this was rather a defeatist attitude. There was a lot of talk these days about erosion and deforestation and the Punjab was one of the few Provinces in which something was being done. He suggested that having decided upon a catchment for the storage of water and outlined a project which was likely to be acceptable to the financiers, the erosion experts should then be called upon to prepare a scheme for preservation of the catchment, and the prevention of silt deposit in the basin. This would of course have to be taken up some time before the actual project

was commenced. The cost of any such desilting works would most probably put the project outside the limit of what might be considered "paying projects" unless the suggestions made by the author in this paper were accepted. But soil erosion measures were of interest to the Province as a whole and were necessary quite apart from the question of storage reservoirs. They should therefore be excluded from the cost of the project when considering its financial prospects. It would be inadvisable to continue silting up natural reservoirs and eventually lose what would have become established irrigation due to the lack of a new reservoir site.

There was another point which the author had mentioned and which Mr. Gibling wished to emphasize, and that was that there was much less risk of failure of works these days, owing to the considerable advance made in their design, and it was not necessary therefore to provide anything like such a large margin for possible failures or heavy expense in remodelling. At the same time it would be advisable to proceed cautiously in this direction. A large number of projects had now been undertaken in the Punjab and the speaker felt certain that when each of those projects was completed, the engineers responsible for them had just as much confidence in their design and workmanship as the engineers of to-day, but their optimism had always been justified. Fortunately, the engineers of to-day had considerably more theoretical and practical knowledge which had mostly been acquired from the mistakes of those who constructed similar works before them, but nature had an uncanny way of turning up a trump card at the most unexpected place and moment.

At the bottom of page 208 the author had stated that it had been now admitted by the majority of engineers that waterlogging was caused by percolation from the main canals and that intensity of irrigation had only a negligible effect, if at all, on the sub-soil water table. No mention was made of rainfall, or the combined effect of rainfall and irrigation. However, the speaker was not in a position to prove or disprove the author's statement, and although his own opinion might agree with that of the majority, it could be only a mere surmise. If this statement of the author went unchallenged, then a very important step forward would be made. The author had stated that the area affected by waterlogging or rise of salts was only very small compared with the total area under irrigation. This might be so, but he understood that the area was increasing at an alarming rate, and he could not believe that the Punjab engineers were prepared to let the matter rest at that and in fact there seemed to be no necessity to do so if they had now found the main cause of the rise in the water-table.

Mr. Kanwar Sain had mentioned on page 230 that if the canals were owned by companies they would only receive the Direct Receipts, and similarly, Government should only consider such Direct Receipts, but the speaker ventured to suggest that if the canals were owned by

Mr. Post was of the opinion that the author had made out a strong case for further irrigation development in India and for the state being the sponsor. Although on a purely population basis, India should primarily be an industrial country, it was for historical and cultural reasons still predominantly an agricultural—in fact peasant-country. The author's conclusion, therefore, that irrigation was the best cottage industry would in the circumstances appear fully justified despite the decidedly economic disadvantages that attach to peasant and cottage farming. The author has done the writer the honour of referring to his book, "*Economics of Agriculture*", and in that work he had made a strong plea for—in fact, a strong case in favour of the large sized agricultural unit and had criticized a small holdings policy because it encouraged a peasant type of farming and thus resulted in poor farmers. In principle the same criticism would appear to apply even in the case of Indian irrigation projects. A principle, however, applied under a particular set of circumstances must be judged in the light of those circumstances. Indian circumstances, therefore, demanded that the principle stated above be qualified when applied to Indian irrigation projects. With the average Indian ill-fed, half-starved, of low vitality and low purchasing power, industrialization to the extent demanded by density of population was not yet—or in the near future—possible. The only alternative, therefore, was "cottage industry". In the author's words, (page 246), industrialization had not relieved and, Mr. Post added, would not soon relieve, because of low purchasing power of the masses—the burden on the soil and despite the new industrial ventures India still remained—and Mr. Post added, would for long remain—essentially an agricultural country.

With an enormous and ever growing population of comparatively small demands pressing on her soil India was bound to increase the yield of that soil and, with her abundant supplies of water, she had, it would appear, no alternative but to use irrigation as a means of maximum economic exploitation of the soil.

Mr. **Kanwar Sain** inreplying to the discussion thanked all members who had taken part in the discussion. He was particularly grateful to Sir William Roberts, and Messrs. A.M.R. Montagu and A.N. Khosla for kind references.

Referring to Mr. Khosla the Author said that he had no quarrel with his contention in regard to the cost of the Trimmu Headwork with other headworks. He naturally chose to be modest. He was, however, of opinion that a strict comparison between the costs of various headworks was not possible.

In reply to Mr. G. R. Sawhny the Author said that comparatively very little levelling was required for barani cultivation. Regarding the remarks "Increase in cost is due to increasing difficulties in construction" the Author explained that the easier projects had already been taken up

and the projects left over for the future were naturally more expensive. They involved construction of feeder canals or of dams.

The only basis on which a comparison of costs of various projects could be made was to take such costs per acre irrigated. Such costs took all factors into consideration. Commenting on Mr. Sawhny's suggestions that each project should be thoroughly examined before starting and after completion by an independent committee, the Author said that a Board or a committee generally resulted in a dilatory proceeding. It was commonly said that when the Head of a Department shirked to take responsibility he appointed a committee, as in the case of a committee such responsibility was divided.

The author said that he did not follow Mr. Sawhn'ys remarks regarding distributaries. On the Haveli Project the distributaries were designed to take full supply discharge during the summer and were meant to run by rotational closures during the winter. Regarding the growth of population the Author said that he did not question the necessity of control of population, but he was dealing with the facts and not with what should be? Similarly the Author said that he did not express any opinion against the necessity of establishing cottage industries. Regarding the increase in intensity of irrigation the Author said that Mr. Sawhny had been replied to by Sir William Roberts and there was nothing for him to add.

Mr. Kanwar Sain thanked Mr. Ajit Singh Kalha for his support in advocating the construction of dams. The Author was convinced that the future prosperity of the Punjab was bound up with the construction of dams.

Commenting on Mr. Isher Dass's remarks, the Author said that he did not know of any actual experiments which corroborated the assumption that the absorption losses in watercourses were about 40 per cent. The Author was of the opinion that so far as the Government was concerned they could take up lining of bigger channels with more advantage. He, however, agreed with Mr. Isher Dass that the land owners should be encouraged to line their watercourses. If some system of giving the cultivators loans from Co-operative Banks could be worked up, it would go a great way to give impetus in this direction.

Referring to Mr. Ganpat Rai's query regarding sliding scale for water-rates the Author said that in his opinion the demand for water rates should bear a certain ratio of the net profits of the cultivator. The Author stated that he fully appreciated the difficulties in fixing the wates rates on a sliding scale basis. This, however, did not mean that the difficulties could not be overcome. What the Author contended was that the facts, which he had brought forward, indicated clearly that the present condition did call for a change and reform. He admitted that the

problem was complex but asked was there any problem which given due consideration by the best brains of the Province could not be solved? The Author suggested that a workable solution would be to take a block of say five years in fixing the rates. The idea would be just to smooth out glaring inequalities from year to year. If water rates were treated purely as a payment by the Cultivator for value received then, in the opinion of the Author, all scales of water rates should be on a volumetric basis. The very policy of the Provincial Government to fix the water rates in an arbitrary manner was to fix the rates in accordance with the paying capacity of the cultivator, and if the latter assumption was correct then, in the opinion of the Author, the idea of fixing the demand for water rates on a sliding scale basis deserved exploration. The Author, however, felt that he was hardly competent to deal with the difficulties that have been pointed out by R.B. Ganpat Rai in changing the water rates to a sliding scale system.

Replying to Mr. B.K. Kapur the Author asked in what directions did Mr. Kapur wish to increase the non-agricultural resousces of the province. Extension of irrigation in the Punjab had definitely increased the prosperity of the people in the Province. It could be proved from facts and figures that average standard of living in the Punjab was higher than in other Provinces. Mr. Kapur had stated that the extension of irrigation would only hasten further increase of population without in the long run improving their lot. He had quoted the Census superintendent's remarks that density varied everywhere in accordance with the agricultural resources to the exclusion of all other factors. The Author stated that was exactly his contention.

Against the quotation from Malthus the Author gave a counter quotation from P.A. Wadia. In his book, 'The Population Problem of India, Professor Wadia had stated that industrialization, and above all rapid industrialization, might increase the burden on the soil by throwing out of employment a large proportion of the 35,000,000 who were at present dependent on the handicrafts. Moreover, with currency and credit control lying beyond popular supervision in the interest of India, rapid industrialization was outside the bounds of probability.

There was of course, the possibility of limiting the population by birth control. The last census report referred to it as the only way out of the difficulty, but the problem seemed to offer no solution even along these lines, when one remembered the socio-religious out-loock of the people and the tradition of centuries embedded in the social mind. The fact remained that the population of India was increasing and something had to be done to provide bread for the increased mouths. The Author hoped that with the rapid changes that were taking place in the country, the social mind of India might realize the crime of multiplication and might break through the bounds of the past. Even that, however, should not be used as a counter argument for developing the natural

resources of the province. If the population could be controlled, as is advocated by our expert economists, the increase of production by harnessing agricultural facilities available in the province would mean raising the standard of living of the masses.

The Author referred Mr. Kapur to the comments of Mr. A.P. Vander Post, Assistant Chief of the Division of Economics and Markets in South Africa. The Author was in no way against increasing industries. In fact, he pleaded that irrigation in a way was a suitable cottage industry in the present circumstances of India. Agriculture and industry, in the opinion of the Author, must go hand in hand. Construction of dams, as advocated by the Author, would give an impetus to industries by the production of cheap hydro-electric power which would be generated as a bye-product from the high dams constructed primarily for irrigation purposes.

Referring to Sir William Robert's remarks the Author felt flattered and was very grateful to Sir William for the kind remarks he had made in reference to the paper. There was no doubt that in the Punjab land was useless without water, and that a part of the enhanced value of the land should be credited to irrigation projects. An attempt was being made to realize a part of this enhanced value in the Thal Project area in order to make that project a financial success.

The Author was grateful to Messrs. J.D.H. Bedford, S.H. Bigsby and A.M.R. Montagu for their part in the discussion.

With regard to the criticims of Sir Bernard Darley, received by correspondence, the Author reiterated that the only basis in which the economic aspects of various projects in various provinces and countries could be compared was to take the capital cost and working expenses per acre assessed. This took care of all the factors natural and artificial. Nothing was farther from Author's intention than to state that other provinces were not so economical. Natural circumstances combined however, to give the place of pride to the Punjab. Vast areas of Crown Waste Land that were available in the Punjab went a great way in making irrigation projects in the Punjab financially most successful. The very fact that the value of a cusec was much more in the Punjab than it was in the United Provinces meant that the administration and maintenance of canals in the Punjab must receive much more attention and consequently cost more per mile.

The figures of the capital cost of the Sarda Canal were taken from page 6 of the Sarda Completion Report, and the Author regretted that an error had crept in due to Author's ignorance in this respect.

Referring to Mr. M.T. Gibling's contribution the Author was grateful for Mr. Gibling's emphasis on the necessity of revising the financial

tests at present applied to irrigation works. The Author agreed with Mr. Gibling that the Central Government had nothing to gain from any survey which would show that the Central Government was deriving considerable indirect benefits from irrigation projects which were financed by the Provinces. The Author agreed that such a survey could best be taken up by the provinces and in the Punjab a survey of this kind could easily be taken up by the Board of Economic Enquiries. Mr. Gibling had made a very valuable suggestion in regard to the possible remedy against the silting up of reservoirs. He had suggested that the erosion experts should be called upon to prepare a scheme for preservation of the catchment and the prevention of silt deposit in the basin. This work, of course, had to be taken sometime before the actual project was to commence. The Author agreed with Mr. Gibling that the cost of such soil preservation measures be excluded from the cost of the Project when considering its financial prospects.

There was, however, a way out of the difficulty if a new reservoir site was not available after the first reservoir had silted up. In the first place, silting up of a large reservoir is a matter of a couple of hundred years. The silted reservoir would afford great facilities for the generation of very cheap hydro-power and this cheap power could be used in an extensive tube well scheme to draw water from the sub-soil.

The Author agreed that the problem of waterlogging could not be left alone. What he had tried to emphasize was that the undertaking of future projects should not be discouraged on account of the bogey of waterlogging Of course, the problem required a careful investigation to find a suitable remedy even for a small percentage of the area that had actually been affected by waterlogging.

The Author entirely agreed with Mr. Gibling that agriculture and industry must advance side by side.

The Author wished to convey thanks to Mr. Vander Post for his written contribution on the paper. Irrigation in the Punjab was profitable both to the State as well as to the cultivator. The Author had already shown in the paper that about 40% of the annual income of the Province came from irrigation. The cultivator would be able to grow nothing from the land if he did not receive irrigation water.

The Author agreed with Mr. Vander Post that small size holdings encouraged uneconomic type of farming. The curse of small holdings was a serious handicap in the way of profitable farming. Average cultivated area in the Punjab was only from 7 to 8 acres per owner and in some of the districts average holdings seldom exceeded 4 acres. But the factor which was much more responsible for the stagnation of agriculture than the smallness of the holdings was its excessive fragmentation. The principle of succession to have equal division among the male-heirs, which had been enforced for centuries in India, had resulted in small holdings

Every co-sharer claiming a separate share from every quality of land had caused a wide fragmentation of such holdings. The Co-operative Bank in the Punjab had introduced the scheme of consolidation of holdings to combat the latter part of the evil. It would be a long time before Indian Legislature would rise equal to the occasion and legislate laws preventing further fragmentation of holdings.

The Author agreed as he had already stated in replying to Messrs. Kapur and Gibling that agriculture and industry must advance hand in hand. This, however, was no argument to stand in the way of improving the agricultural facilities that were obviously within an easy reach in the Punjab.

the all important sand were clever and well thought out examples of ingenuity, nevertheless when dealing with rivers and headworks, the results so apparently convicingly obtained from such model experiments rarely came up to expectations and when translated into practice or when attempts were made to force rivers to obey directions, whether for the purpose of regulating their lines of flow or their actions up or downstream of weirs the limitations of such experiments soon came to be realized.

With the sub-grade of sand not being proportional, their resulting momentum was also not proportional and it was due to this that well thought out lines of attack on the rivers seem to result in failure sooner or later. The speaker maintained that this fault lay in basing hopes on experimental data founded on incorrectly subdivided grades of sand. He said that the Authors had quite rightly pointed out the two all important requirements at canal headworks but it would be still more useful if they could give a real solution which would fulfil these requirements. The fixation of scale ratios and the determination of the time scale as made in this case went to prove that too much was taken for granted in fixing any ratio or time scale that might just fit in with an odd observation, as the basis for giving advice, and in the opinion of the speaker, before such ratios or scales should be fixed, it should be conclusively proved that they were really correct and not merely assume them to be so.

He observed that these experimental results were compared with previous surveys of river conditions, often the result of an overseer or mistri having unwillingly carried out an unpalatable job, which may have not been checked, and suggested that before starting, to make model experiments, local conditions should be studied much more thoroughly than at present and the necessary data collected with greater pains. He observed that it would be useful if a well thought out paper was presented on the best means of collecting such data, laying down directions for the guidance of persons responsible for the field work in the river bed and at the headworks.

He said that past experience of diversion cuts in the Punjab had not been too happy and proposals which appeared suitable in the first instance, subsequently turned out to be the reverse in actual practice failed to achieve the results originally anticipated.

In order to get river approaches to conform with requirements they should be canalized. Their working should be carefully watched from season to season ; their beds should be dredged and belas side eroded from year to year to suit requirements and the stream forced to follow the desired course by opening particular gates or undersluices. He hoped that the faithfulness shown by the model would not only go as far as to inspire hope but would be substantiated by actual results.

Engineers were students all their lives. A model experiment was

the nature of a kindergarten method of teaching which was both interesting and instructive. They should not be disappointed if experiments proved futile now and again, but should persist in experimenting until the object was achieved.

The whole hearted manner in which the Punjab Research Institute was working had taught engineers a great deal already and the speaker felt sure that shortly it would be in a better position to help in actually solving the problems referring to rivers and headworks.

Mr. **R. K. Khanna** said that in one of his pamphlets he pointed out that small scale model experiments in hydraulics had only a limited application for detemining flow over weirs, etc, and that these could not be used for investigating the laws of flow of water in earthen channels because the sizes of sand particles could not be reduced to the same scale as the horizontal and vertical distances. Dr. Bose had by some mathematical miracle found out that for a horizontal scale of 1/200 and vertical scale of 1/34, exact river conditions would be reproduced by the action of flow on the sand particles as were found at Khanki. As however, the sand particles used on the model weir were coarser than those present at Khanki, the vertical scale had been slightly increased to 1/30. He did not know how the Lacey theory had been helpful to Dr. Bose in finding out the relationship between the horizontal and vertical scales and the particles of sand, but it would have been much better if some indication had been given in the paper how exactly this discovery had been made.

The main theme of the paper was that with low supply running in a channel, belas and islands were formed and when the discharge was increased the section of the channel developed. This was no more than saying that in a silt laden channel the quantity of flow of water determined the sectional are a silting and scouring recurring according as the supply went down or up respectively. This discovery of the authors of the paper reminded the speaker of a Pickwickian find during a certain scientific excursion. Those gentlemen discovered a piece of stone with some mutilated characters graven on it, and thinking that this might lead to some important archæological discovery, long discussions were held by them as to the exact meanings of the characters on the stone. Many suggestions were made but ultimately it appeared that the stone represented nothing more than a piece of slab knocked off from a grave stone. Similarly, all the manipulations with the model experiment at Malikpur appeared to have led to no better discovery than the well known fact that discharge determined the sectional area of earthen channels. Item No. 2 of the summary and conclusions appeared to be wrong because as long as the canal of 10 or 12 thousands of cusecs was fed from the channel on the left, there was no possibility of that channel getting choked up, whatever be the extent of heading up at the weir. Indeed the greater the heading up and flatter the slope of flow of

the feeding channel the deeper and clearer would it be. Similarly, the conclusion that the most suitable discharge in the left arm for optimum silt entry in the canal was about 40,000 cusecs also appeared to be wrong. The most suitable discharge in the left arm for optimum silt entry in the canal would be exactly the discharge required for feeding the canal and no more. Again, the slope of 1/4000 for optimum silt entry in the canal was also wrong, because from plate 3 of the paper it was seen that the flatter the slope of the feeding channel the less must be the entry of silt into the canal. The conclusion of the Authors that by feeding the canal from the right, more silt entered the canal was refuted by actual experience of Marala where, in spite of presence of heavy grades of silt in the river, there was no silt trouble in the canal simply because the canal was fed from the right side. Thus it appeared that the model experiments at Malikpur had not given any real guidance regarding the methods of regulation and control at Khanki.

Mr. **M. T. Gibling** observed that the experiments described in the paper were of considerable interest even to engineers who were not fortunate enough to have seen Khanki Headworks or the river, and they must be of considerably more value to those who were acquainted with the local conditions, and particularly those responsible for the works.

A very large number of similar experiments had been, and were being carried out in many parts of the world, and they undoubtedly provided engineers with very useful guides in designing original works or improvements, but he had found that very few engineers had more than a very little faith in the proposals arising out of these experiments. This was to be expected, as this type of model work was at present only in its infancy, and an engineer was not inclined to spend money and risk his reputation on something in which he has not complete confidence. He thought this lack of confidence could be overcome to a large extent if there were more information available as to the results of works carried out in the field which had been designed from experimental information. An endeavour had been made a short time ago to collect information regarding model experiments for the purpose of comparing the functioning of models and their prototypes, but the information available was almost negligible.

In most cases, it was the practice to reproduce on the model the known conditions of previous years, as was done in the investigation described in this paper, but generally those conditions did not involve any great changes compared with those which the experiments showed to be necessary, and if the river was at all sensitive, any small change in the conditions might have very extensive results. In any case, it was always easier to solve a problem when one knew the answer.

He considered it very important therefore to place on record the actual results in the field when works were undertaken after investigating the problem on models of this type.

If the proposals put forward by the investigators were not accepted and carried out in exact detail, then the final proposals should be introduced in the model and a careful record kept of the effect of those proposals. Later, when the works had been carried out in the prototypes, their effect should be compared with the model results.

He suggested therefore that at the Punjab Engineering Congress of 1940 or 1941, the authors of this paper, or the engineers in the field, should present a paper giving details of the works carried out at Khanki and how they had functioned in comparison with the model.

By this method alone would the engineers gain confidence in this type of investigation, and make extensive use of the results in practical application.

Mr. **J. M. J. Drane** said that though not an Irrigation Engineer, perhaps he might be allowed to make a few observations on this interesting subject of Model Experiments.

Since his student days, when he saw Professor Abel's naval architectural tanks and his wind tunnels for model experiments, it was a subject of which he would have liked to have known more.

Some years ago, when he spent some little time on the works of the Mersey Dock and Harbour Board, he had the opportunity of noting the working of a tidal Model then in use for predicting changes in the regime of the Mersey Estuary, and he remembered wondering how it would be possible to obtain accurate results as the grains of sand used in that comparatively small model were so obviously out of proportion to its other features.

He was therefore, now, particularly interested to learn from this paper that completely accurate results could not be obtained in the course of the careful experiments carried out by the authors on the comparatively very large model which they employed for this inaccuracy confirmed the conjecture which he casually made years ago. As other sources of error could not have been present in these careful experiments described by the authors, it undoubtedly pointed to the disproportionate size of sand grains used in the model having been responsible for the inaccuracy obtaining in this case.

Though a previous speaker doubted the utility of such model experiments, he pointed out that the inaccuracies described did not vitiate the value of Law of Proportionality. In the case of ship model experiments for naval architectural design and in that of wind tunnel experiments for aeronautical design, their utility was unquestioned and the results obtained obviously invaluable.

He suggested, therefore, that there was a useful field for research with regard to the allowances which should be made in applying this law to riverain flows, for the factors of size, specific gravity, viscocity, possibly mass effect and certainly under estuarine conditions, for electrostatic reactions, in the case of fine solids suspended in moving fluids.

In conclusion, the speaker congratulated the authors of this paper not so much on their excellent paper, as on the spirit of enterprise and progress, which gave rise to the experiments and on the actual great work which they did in carrying out those experiments on which their valuable paper is based. While, sometimes, in this country, one despaired of real engineering progress being possible, this paper was a happy indication that Irrigation Engineering, in this Province of the Punjab, was abreast of the times to-day and might well be in the van to-morrow.

Mr. **S. A. Bunting** observed that the co-ordination of the different scales of magnitude and time in hydraulic models to make them represent what occurred in nature had always been the main problem in model work but it had been solved elsewhere and could be solved here.

The missing line appeared to be the size and quality of bed particles to use.

Probably the best example of model research on flow of a river was carried on on the model of a reach of the Rhine in the hydraulic laboratory at Karlsruhe. This model was installed and maintained by an International Technical Commission, (Switzerland, Germany and Holland) under the presidency of Dr. Th. Rehbock, interested in making the Rhine navigable, and one Assistant Engineer from each country was employed on making the necessary observations.

The main object was to make the river scour out a channel all the way of ample depth and width to pass the standard 1500-ton barges with as little velocity to oppose when going upstream, as possible. Measures to this end had been taken continuously over more than a century and records of the effects of these measures were fairly complete.

This investigation by means of a model about 150 feet long of the reach above Mannheim where the scour was now needed was facilitated from the outset by a mass of data not usually available to investigators of river conditions.

Nevertheless, when the model investigation commenced there was considerable difficulty in achieving correct results on the model which was finally tracked down to the quality of the bed material used. The Rhine bed near Mannheim was a small gravel, about pea size, and all sizes from this down to a fine sand, and various changes of longitudinal slope and relation of vertical to horizontal scale were tried without

hitting on the correct solution, the bed would not move in the model in the same way as it did in nature. Finally brown coal or lignite was tried in the bed, which combined a rougher surface with a smaller specific gravity, and it was not long before definite relations between the model and nature began to be established.

Since then these relations had become absolute certainties.

The time scale evolved had allowed of reproducing on the model all the effects recorded in the last hundred years and now the prognostication of the future was as certain as the records of the past. When last the speaker visited it, the state of the river in 1944 was being established. This knowledge had allowed training works, spurs, etc., to be limited to the minimum necessary and the budgetting for funds for this work could be correlated to the needs of the increasing water transport.

Dr. Rehbock had proved by a large number of experiments that the stable final shape of a river bed downsteram of a weir for instance was within wide limits much the same with different sizes of bed material; and if anything, scour might be rather deeper with coarse material than with fine sand. But the time taken to attain this final shape was certainly longer with the coarser material, and when steady quiet flow was being investigated, a material more readily moved than the river sand might become necessary in the model if the experiments were to yield practical results in any reasonable period of time.

In the case of scour below weirs, Dr. Rehbock would limit the reduction of size of sand in the model to half a millimetre, anything sensibly smaller failing to reproduce in the model the actual results in nature. That again had to be a matter of velocity less binding in the case of steady flow.

The speaker believes there was a lignite at Dandot in the Salt Range which might answer the purpose for this model also at no impossible cost.

It certainly seemed that further experiment with different bed material would clear up discrepancies and give satisfactory results.

The **Authors** in replying to the criticism said that further experiments had also been made on reduced lengths of the spurs as suggested by the Chief Engineer. The effectiveness of a spur in between the two was also examined. It was found out that in order to develop the creek to Bay 4, it was necessary to construct a spur 400 ft. long at Palkhu. The length of the second spur could however be reduced to 300 ft. The construction of a 3rd spur in between the two spurs was not found to be of any advantage.

In reply to Mr. Kapoor the authors pointed cut that the Merala conditions could not be stimulated on the model of Khanki Headworks. The approach of the river at Merala was quite different from that existing at Khanki. Apart from that, there were no long groynes at Merala as they existed at Khanki. It was, therefore, wrong to compare the conditions of Merala with those of Khanki even if the canal was fed from the right. A test was made in the presence of Mr. Kapoor for determining the quantity of silt entering the canal when it was fed from the right channel and the results were compared with those made under the existing conditions for similar discharges. The method of regulation was entirely left to him. When the canal was fed from the right, he adopted several closures (as many as 6) for washing off the silt in a short period of 4 hours and also opened bays 2 and 3 any number of times he liked. But in spite of that, at the end of the run it was found that the quantity of silt which entered the canal was much more than that entering the canal when it was fed from the left channel. At Rasul, the quantity of silt entering the canal was much less as compared with that passing into the Upper Chenab Canal at Merala. The canal at Rasul was fed from the left channel. Regarding the passage of floods, the figures given by Mr Kapoor for a flood of 2,64,504 cusecs were incorrect. According to the prototype figures a level of R. L. 733·1 was attained in the right undersluices, with gates of the undersluices partially opened and the d/s level of R. L. 731·7. Again the model figures quoted by him were wrong. It was stated that for a discharge of 300,000 cusecs the gauge on the right would be R. L. 732·8 with all the gates opened. The corresponding d/s level was R. L. 730·2.

It was considered improbable for the river to go on the right when once it had developed a definite channel to Bay 4 in the presence of the spurs in the left channel. In reply to Mr. Sawhney it was stated that one of the reasons why distortion was necessary, was to give extra slope to the bed in order to effect movement of sand. It was therefore not necessary to subdivide the sand and reduce it in the ratio of the scales. In this connection, the speaker was referred to the experiments carried out by Vernon Harcourt, Fargue Reynold and Gibson. These investigators tested sand, powdered stone, coal dust, powdered sulphur and lignite and found that sand was the most suitable material for reproducing the river bed in the model. Regarding the grade of sand for the model, Reynold's test showed that no material difference was obtained in the bed configuration of the model even by using the same sand and exaggerating the vertical scales over ten times.

In reply to Mr. R. K. Khanna, the authors said that the replies to his relevant criticism had already been given while answering the criticism of the other speakers.

The model might have some drawbacks in not reproducing strictly quantitatively certain conditions of the prototype; but it had to be said

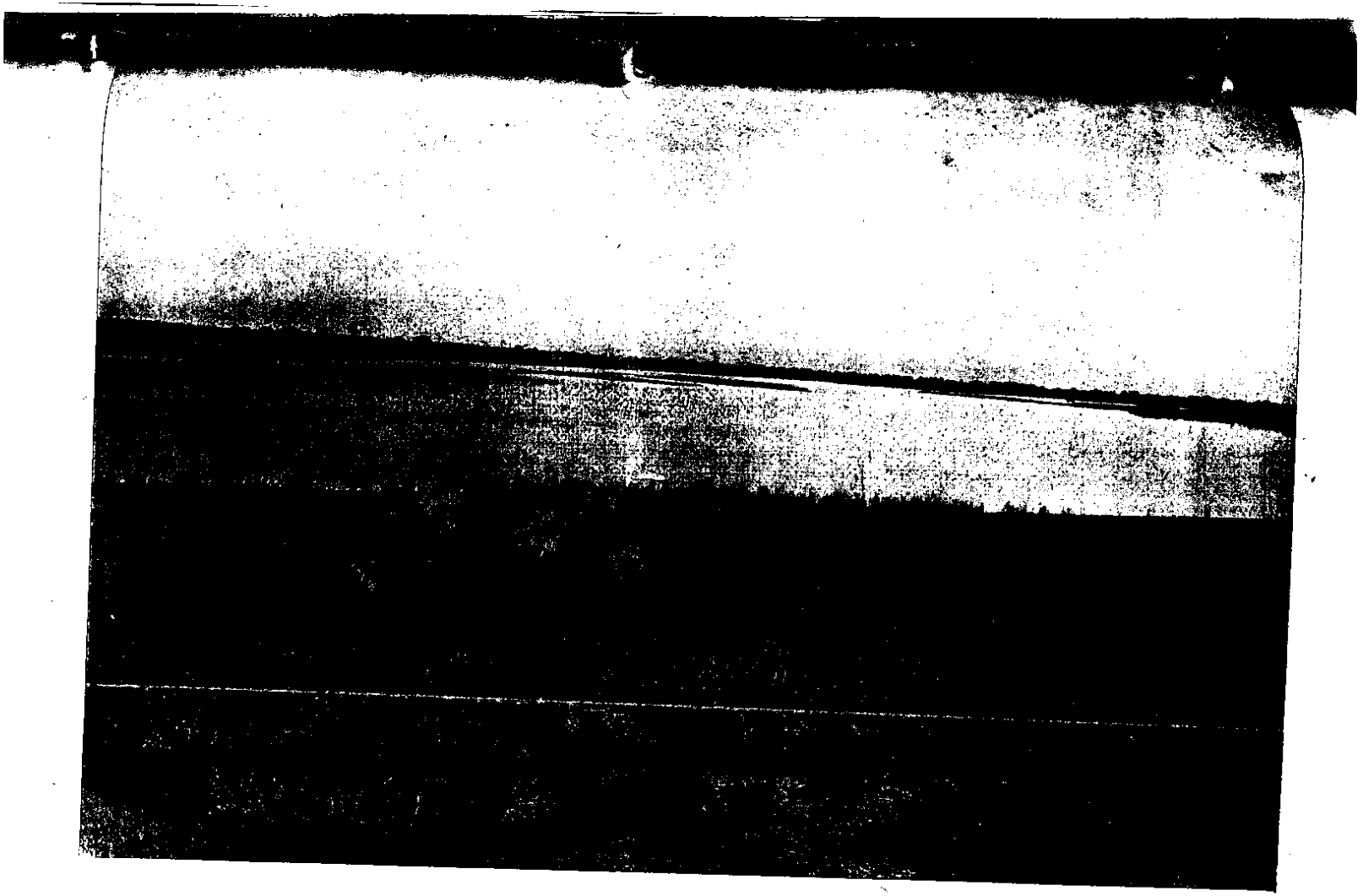


Photo No 16—Veiw taken from spur E. Showing the formation of Belas in the left arm and at the nose of the main R.L

that an honest attempt had been made to find out the capabilities of the model and having found out that the model reproduced faithfully the prototype conditions, a solution of the difficulties experienced at Khanki was sought.

The object of reading this paper in the Congress was to get the advice of experts on the most satisfactory solution of the difficulties now faced at Khanki.

It might be said that some of the speakers who contributed to the discussion ignored the main object of the paper and expressed only their lack of faith in the model. Time did not permit here to discuss in detail the remarkable agreement which had already been achieved between the model and the prototype in other parts of the world.

The first true river model was made by Fargue, a French Engineer in the year 1875. The investigation was started with a view to settle a controversy which had arisen in the city of Bordeaux. One group favoured dredging for improving the channel of the Garonne River and the other party stood for regulation combined with dredging. Fargue's results, which were obtained after two years' tests settled the controversy.

After Fargue, work was carried out by Osborne Reynolds and Sir William Vernon Harcourt on similar lines. Very interesting experiments on models of rivers and estuaries were made. Although no time scale was used for model test in those days, still the results which were obtained from those small models went a long way to create confidence in the Engineers of those days.

With the dawn of the 20th century, started a study in the science of river research. The works of Prof. Hubert Engels, Thiery, Ludin and Krey were monumental. They based their studies on the laws of hydraulic similitude and showed that a carefully made model reproduced most of the conditions of the prototype.

The faith created by model tests in other parts of the world was such that no scheme was taken in hand unless it was first tested on the models. In the Punjab, this study was of recent origin, but whatever little had been done definitely showed that the model gave a correct indication of the prototype conditions. From the model tests, a forecast was made of the probable conditions of flow to be experienced at Khanki in 1939.

(Ref. to Page 177—Paper No. 227).

Test I (3) "The main stream bifurcated at a point higher up than the nose of the central bela." This implied that fresh belas developed at the nose of the central bela which obstructed the flow at that point. Photo No. 16 taken from Spur 'E' at Khanki in October 1939, shows the development of belas similar to those forecasted from the model study.

(5) "The creek close to the main bela which used to flow to Bay 4 from the left channel became choked. The whole of the water flowed in the left channel to the undersluices; then parallel to the weir to Bay 4. An examination of the river at Khanki at the end of October 1939 showed that there was a definite bela in extension of the main bela in the left channel. Besides that, belas had also developed in the left channel. the flow in this channel took place along the left bank and to the left under-sluices. The development of the belas on the model was shown in Photos No. 3 and 4. A photograph of the prototype taken at Palkhu spur was given in Photo No. 17 which showed a number of belas developing in the left channel.

Photo No. 18 showed the condition of Bay 4 at Khanki. The approach had been completely masked by the existence of a large number of belas in front of it.

Photo No. 19 showed the condition of the right arm at Khanki. It would be seen from the photograph that the channel was clear of belas.

A forecast* was also made in the year 1937 from a study of the model of the River Sutlej at Palla Headworks that :—

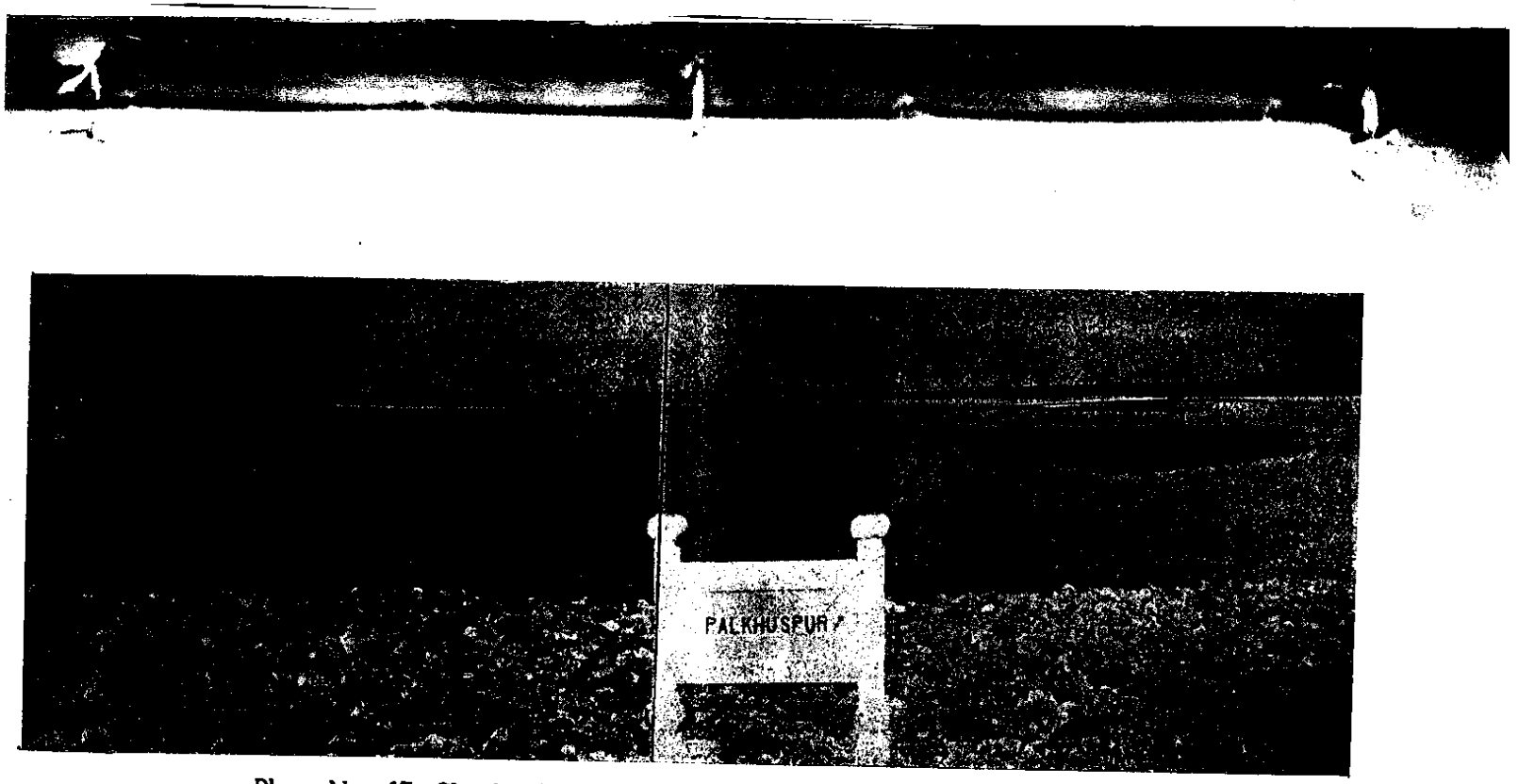
(1) With the construction of a new spur upstream of Murphy spur, the main course of the river between the new spur and the old "T" head spur would shift from the left to the right as shown in Photo 20.

(2) The major portion of the flow would take place at the old "T" head spur. The flow from the old "T" spur would take place straight towards the weir up to the nose of the guide bank and then would deflect towards the left guide as shown in Photo 20. Observations taken on River Sutlej after construction of the new spur in 1939 showed that the findings of the model had all been reproduced on the prototype. The direction of flow observed on the prototype and given in Plate No. IV compared very well with those observed on the model in 1937.

The water levels at various gauges as predicted on the model in 1937 and those obtained on the prototype in 1939 were compared in the table below :—

Discharge in cusecs		W. S. R. L.	W.S.R.L.
model	Prototype	Prototype in 1939.	model 1937.
80000	80254		
Position of gauge.			
L. G. B.		453·5	453·5
'T' head spur		454·8	454·0
Murphy nose		455·0	455·0
New 'T' spur	U/S	455·3	455·5
" "	D/S	455·1	455·1

* An investigation of a model of river Sutlej above Pallah Headworks by Harbans Lal Uppal and Mushtaq Ahmed.



Photo, No. 17—Showing formation of Belas in the left arm in front of Palkhuspur.

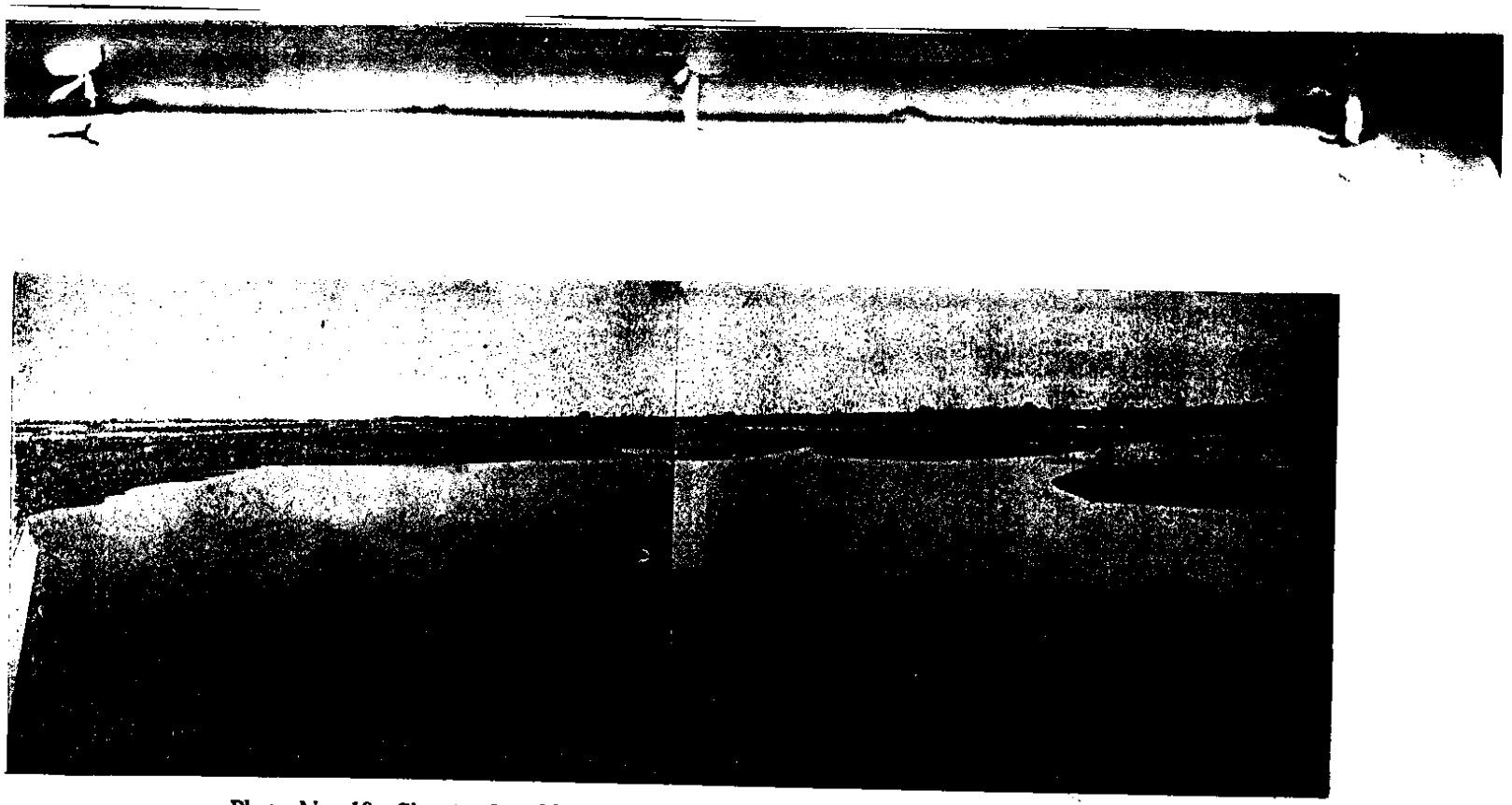


Photo No. 18—Showing bay No. 4 of Khanki weir completely masked by Belas.

GLOSSARY OF TERMS USED IN THE PAPER.

Vernacular—		*English*—
Abadis	..	Hamlets.
Abiana rate	..	Charge for irrigation water.
Abadkars	..	Settlers.
Acre	..	One acre is equal to 4840 square yards.
Barani	..	Dependent on rainfall.
Chak	..	The smallest sub-division of area which has a separate outlet on the irrigating channel.
Foot-acre	..	One foot-acre is equal to 43560 c. ft.
Kharif	..	The Autumn harvest.
Malikana	..	Dues on account of ownership.
Rabi	..	The Spring harvest.
Rupee	..	One rupee is equivalent to 1s. 6d.
Som	..	Deterioration of land due to water-table being too close to the surface.
Thur	..	Deterioration of land due to accumulation of salts on the surface.

ERRATA.

Page 206 line 1 table 9 *read* Assuun *for* Assuan

Page 217 line 3 table 17 *read* 6·50 *for* 6·52

Page 228 line 18 *read* liberal *for* libera

Page 230 line 7 *read* companies *for* company and *delete* a *after* such

Page 230 line 10 *read* projects *for* lands

Page 232 line 15 (new para) *read* colony *for* olony

Page 236 line 3 *read* wetter *for* better

Page 238 footnote *read* 6 to 8 *for* 7 to 8

Page 243 line 1 of table 33 *read* country *for* couuntry

Page 243 line 2 total column of table 33 *read* 24,105,000 *for* 14,105,000

Page 250 line last 2nd column of table 37 *read* 20,552 *for* 20,522