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Silting Tanks on the Western Jumna Canal

BY

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INTRODUCTORY

Almost every canal has its silt problems. Silt problems of the Western Jumna Canal are both urgent and complicated.

It may be stated without fear of exaggeration that one of the most important problems confronting the irrigation engineer is the control of silt in his canals.

A great deal of research work both theoretical and in field has been done in this connection all over the world by eminent scientists and engineers, and it is still being carried on.

It will be needless to reiterate the harmful effects of an overdose of silt in a canal. An underdose can also be attended with distressing symptoms, and the canal engineer has constantly to combat the evils resulting from an overcharge or undercharge of silt in his canals.

This research can be divided into two main parts :—

(*a*) Design of irrigation channels so that they will neither silt up nor scour.

The problem becomes complicated on account of varying silt charges, and discharges in summer and in winter seasons.

(*b*) Measures adopted to exclude harmful silt from entering the canal, or to eject it after it has entered the canal.

It is apparent that silting tanks fall under category (*b*) above.

An account of the various types of silting tanks as employed in the Punjab Irrigation Branch appears as Chapter 15 in the Manual of Irrigation Practice, published by the Punjab Government for the benefit of the Irrigation Branch Engineers.

This paper describes very briefly the silting tanks which are at present functioning on the Western Jumna Canal.

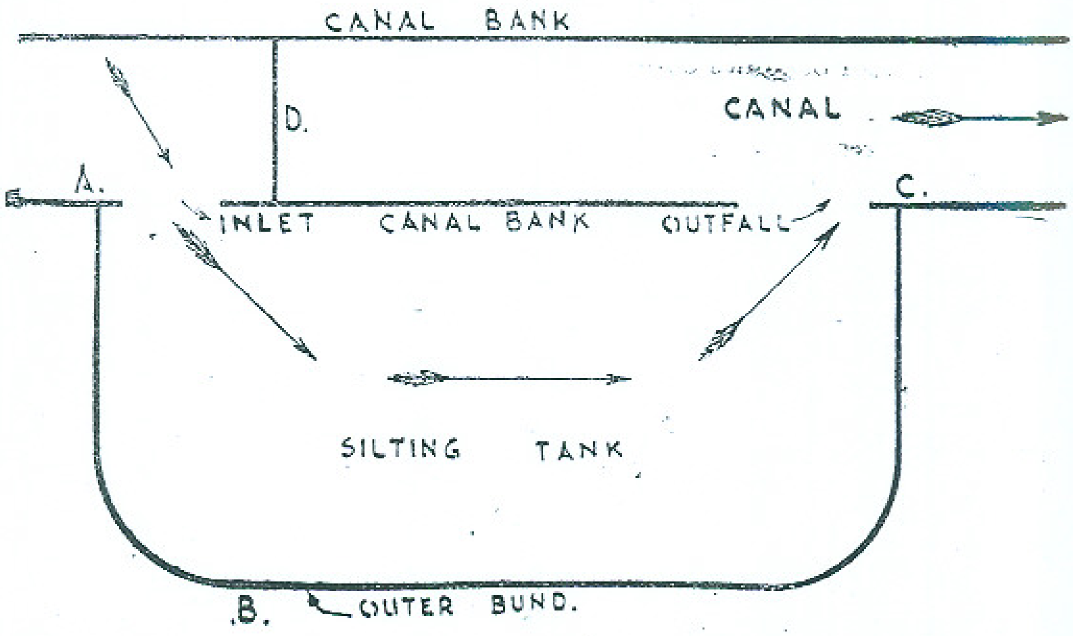
A discussion of the merits of alternative methods of silt ejection compared with silting tanks is outside the scope of this paper.

The Western Jumna Canal takes off at Tajewala from the sub-mountainous reach of the river Jumna. Very large quantities of shingle and coarse silt have been entering the canal ever since it started functioning. The canal head regulator is unfavourably situated from the point of view of shingle and silt induction from the river. Until recently (1940) it consisted of a large number of small arch spans fitted with undershot gates. This head regulator was remodelled in 1939-40, and although its design is modern enough, it is hardly an improvement over the old head regulator, so far as shingle and silt entry into the canal is concerned. Shingle begins to move when the river discharge exceeds about 9,000 cusecs, and the debris entering the canal varies from boulders up to 1½ feet long, down to fine silt.

In order to keep the Western Jumna Canal System functioning, it is essential to "desilt" its waters. To achieve this end, not only is a really efficient device for excluding or ejecting boulders and shingle required at or near the canal head, but coarse silt must also be removed from the canal before it finds its way into, and chokes the branch canals and distributaries. To prevent shingle entering the Western Jumna Canal a shingle excluder was built at its head in 1942-43, and several large silting tanks have also been constructed along the canal to act as traps for coarse silt.

2. DEFINITIONS

*(*a*) "A silting tank is an artificial basin constructed alongside an irrigation channel (figure 1) through which a part or whole of the canal supply is passed at a low velocity, during periods when the silt content of canal water is comparatively high, so that most of the silt charge is deposited inside the tank. Thus a silting tank utilizes the simple process of decantation at low velocities in order to deprive the silt laden canel water, of most of its silt charge."



*As in Chapter 15 of Manual of Irrigation Practice.

(*b*) **Inlet.*—" An inlet of a silting tank is a gap in the canal bank near the upstream end of the silting tank through which silt laden canal water enters the silting tank."

(*c*) **Outfall.*—" An outfall of a silting tank is a gap in the canal bank near the downstream end of the silting tank, through which silt free water from the silting tank flows back into the canal."

(*d*) *"*Performance*" of a silting tank is the average quantity of silt measured in cubic feet which is deposited by passing one cusec day (86,400 cft. of water) through the silting tank. A distinction should be drawn between the "performance" and the "efficiency" of a silting tank. Whilst the "performance" of a silting tank is measured in terms of the quantity of silt deposited in the silting tank per cusec day, without reference to the silt charge entering or leaving the silting tank, its "efficiency" is measured in terms of the percentage of the silt charge entering the silting tank, which is intercepted by the tank. For all practical purposes, it is necessary only to determine the performance of a silting tank.

(*e*) "*Silting season*" is the period of the year during which the silt content of river water is high. It is generally taken from the first of June to end of September.

3. GENERAL

The first silting tanks on the Western Jumna Canal were constructed in or about the year 1892. Their purpose was not to deal with the silt problem of the canal, but to strengthen the banks of the Main Line Lower in certain reaches, and also to reclaim some water-logged area situated alongside the canal; and for these two purposes exclusively were silting tanks employed, until the year 1904. It was in 1904 that Mr. R. G. Kennedy for the first time utilized silting tanks for the express purpose of "relieving the branch canals from excessive silt which was being steadily deposited on their beds," in addition to the reclamation of water-logged areas and strengthening of the canal banks.

In those days and until very recently (upto 1939) silting tanks were crude affairs, so to say, because their inlets and outfalls were merely open gaps in the canal bank, without any means of controlling supplies to be let into the silting tanks. For large scale silting operations, the whole of the canal discharge used to be forced through a silting tank by cutting a *kacha* inlet and a *kacha* outfall through the canal bank, and throwing a *bund* across the canal just downstream of the inlet, while a second *bund* was also generally placed across the canal just upstream of the outfall. The inlet in such cases remained fairly stable, but the *kacha* outfall not only proceeded to scour in all sorts of directions at the exit, but helped in the development of well defined relatively deep channels inside the silting tank area. Once such deep channels are established, they carry a major part of the discharge let into the silting tank, and relatively little silt is deposited inside the tank, while the cost and trouble in connection with the maintenance of these *kacha* outfalls increases with each successive season.

*As in Chapter 15 of Manual of Irrigation Practice.

Thus although the importance of silting tanks as a means of keeping the Western Jumna Canal functioning, was recognized as early as 1904, the working of silting tanks was essentially a haphazard process. It was left to Mr. A. M. R. Montagu, in his capacity as Superintending Engineer, Western Jumna Canal Circle (from November 1939 to February 1943) to develop the silting tanks of the Western Jumna Canal on scientific lines, and to achieve an ample measure of success in running them efficiently. The greatest single improvement in silting tank practice was the introduction of a *pacca* outfall in the design of silting tanks. In April 1941, the Superintending Engineer, Western Jumna Canal, wrote that "we have learnt from the operations of the past few years that it is an absolute essential to provide a *pacca* outfall for silting tanks large or small, whether fed by partial discharge or the full volume of the canal supply." Since then, silting tanks on the Western Jumna Canal have been progressively provided with *pacca* outfalls with remarkable success in every case. These *pacca* outfalls are high crested weirs of suitable design, such that the full supply depth on top of the crest does not exceed 2.5 to 3.0 feet, as greater depths of water over the crest tend to induce the formation of well defined deep channels in the silting tank area.

The other major improvement in the design of silting tanks was to replace the *kacha* open inlet by a *pacca* inlet combined with a regulator across the canal. The advantages of such an arrangement are obvious, and may briefly be stated as follows :—

(*a*) The head necessary to force the required supplies into the silting tank is assured at all stages of the silting up process, and under all conditions of supply in the canal.

(*b*) Supplies let into the silting tank can be promptly shut off in case of an emergency.

(*c*) The extent of desilting of canal water can be controlled, by means of regulated supplies let into the silting tank.

(*d*) Silting tanks provided with *pacca* inlets can be closed off during winter, without having to incur repeated expenditure in the construction and removal of earthen *bunds* required for closing a *kacha* inlet every winter, and without having recourse to a canal closure which is usually required for carrying out the earthwork of these *bunds*. It is a well-known fact that a canal closure is very undersirable in the beginning of a *rabi* season, and should be avoided at all costs in the interest of crops. It is necessary to close silting tanks in winter,

(*i*) in order to avoid absorption and evaporation losses when water supply is already scarce,

(*ii*) to grow *rabi* crops in the reclaimed silted up areas, and

(*iii*) to keep down the growth of water weeds which flourish in silting tanks.

That the expense involved in the construction of *pacca* outfalls and inlets for silting tanks is justified has been amply demonstrated on the Western Jumna Canal during the last five years or so. The performance of silting tanks provided with *pacca* works has improved beyond recognition, while the resulting effect on the channels concerned has also been equally remarkable.

Probably the best opportunity for studying the performance of a silting tank before and after its being provided with a *pacca* outfall was afforded by the functioning of the Chaulandi silting tank during 1941 and 1942.

In the 1941 silting season before the introduction of a *pacca* outfall, the Chaulandi silting tank actually registered a *scouring out* of 8.6 millions of cubic feet of silt from the tank area, whereas during the 1942 silting season after the construction of the *pacca* outfall, the quantity of silt entrapped in the silting tank was 50.3 millions cubic feet. The result was achieved in spite of the fact that the total volume of water passed through the silting tank was very much in defect of the normal, both during 1941 and 1942 silting seasons. Further comment is needless.

4. DESCRIPTIVE

It will not be possible nor is it necessary to describe every silting tank which has been constructed so far on the Western Jumna Canal system, as their number is considerable and is still increasing. It is therefore proposed to give a description of only the following silting tanks which are at present functioning on the Western Jumna Canal system. Small silting tanks of no special importance have been omitted.

(*a*) The Habibpur Silting tank.
(*b*) The Chaulandi Silting tank.
(*c*) The Indri Silting tank.
(*d*) The Munak Silting tank.
(*e*) The Hansi Branch Silting tank.

Necessary plates showing the details of these silting tanks and their *pacca* works are appended.

(*a*) **The Habibpur silting tank.** This silting tank is situated on the left side of the Main Line Lower and extends from R.D. 62,300 to R.D. 70,000. The total area under this tank is 340 acres, and the total calculated silt capacity of the tank is 33.5 million cubic feet. The silting tank was constructed as a famine relief work in summer 1940 with the object of relieving the Main Line Lower of as much of its coarse silt charge as possible, and of reclaiming the low water-logged area lying alongside the Main Line Lower from R.D. 62,000 to R.D. 70,000. The silting tank was put into operation during the monsoon season of 1940, with an inlet at R.D. 63,000 Main Line Lower. The inlet, 250 feet in width was meant to take the whole of the discharge of the canal, viz about 6,500 cusecs, and consequently an earthen *bund* was thrown across the canal just downstream of the inlet. Both the inlet and the *bund* were protected against outflanking and scour by means of brushwood crates filled with stone. The outfall of the silting tank, 700 feet in width was also a *kacha* open cut in the canal bank, from R.D. 68,000 to R.D. 68,700 Main Line Lower. The *kacha* outfall promptly proceeded to scour out a deep hole at the exit. The scouring action gradually developed backwards into the silting tank and formed a well defined deep channel throughout the length of the silting tank. This deep channel eventually carried most of the discharge, and hence a major proportion of the silt charge was carried back into the canal, with the result that after reaching a certain level, practically no further silt was deposited in the silting tank. A *pacca* outfall was proposed to be built at R.D. 69,500 Main Line Lower, but the scheme has not materialized so far, due to stringency of funds, and the silting tank has therefore not been operated after the silting season of 1941.

The performance of this silting tank is shown in the table given below :—

Silting season.	Type of Outfall	Volume of water passed through the silting tank in cusec days	Quantity of silt deposited in the tank cft.	Performance of the silting tank Col : 4 / Col. 3 :
1	2	3	4	5
1940	Kacha Open cut	764,261	14,350,000	18.8
1941	,,	645,928	3,550,000	5.49

The performance of the silting tank measured in cubic feet of silt deposited per cusec day passed through the silting tank was low on account of its defective outfall.

The total cost of operating the silting tank in 1940 and 1941, including first the cost of earthwork of the *bund* placed across the canal to divert supplies into the silting tank was Rs. 22,540 or Rs. 1-4 per % cft of silt deposited in the silting tank.

Nearly 120 acres area under the silting tank has been relieved of water-logging, and crops are now grown regularly in the silted up area.

(*b*) **Chaulandi silting tank.** This is the largest silting tank on the Western Jumna Canal. It covers an area of 1,728 acres, and has a silt capacity of 308 million cft. It has a history of its own.

The area covered by the silting tank was a big swamp situated between the canal and the *dhaya* of river Jumna, and it was in order to reclaim a part of the swamp and also to strengthen the right bank of the Main Line Lower that silting operations were first started in 1893 by making small compartments and working them on the "in" and "out" system, *i.e.*, diverting a small supply into one compartment at a time through a *kacha* inlet and out through a *kacha* outfall. This swamp was fed from Rakhashi *Nala*, and during floods, surplus water was drained out into the canal by cutting the canal bank during the monsoon season. This process of working the Chaulandi tank on the "in and out" system continued up to 1898 when it was abandoned because the results achieved were not considered to be satisfactory or commensurate with the expenditure involved.

In 1899 it was decided to divert the whole of the canal discharge into the swamp through a *kacha* inlet situated just downstream of Dhanaura regulator at R.D. 145,000 Main Line Lower. The outfall which was also *kacha* was situated at R.D. 156,000. This process continued up to 1903 at an average annual cost of about Rs. 6,000. During this period a large quantity of silt was deposited in the upper reaches of the swamp, but during the silting season of 1904, it was found that no further deposition of silt in the silting tank area was taking place as the *kacha* outfall had considerably scoured out and deep channels had formed in the silting tank area. To counteract this tendency, an attempt was made to construct a temporary weir consisting of wire crates full of boulders at the outfall. The crest level of the weir was kept only 0.5 ft. lower than the full supply water level of the tank at the outfall. The work was completed in July 1904 and water was let into the tank on the 1st of August. The crate weir failed the very next day and the silting tank was consequently closed off in September 1904.

The tank remained closed for full 24 years and the old practice of escaping surplus water into the canal was resumed. In 1921 a complete survey of the swamp area was made and it was proposed to re-start the silting operations or alternatively to drain off the swamp to the left side of the canal into the river Jumna by means of a syphon under the canal. After a prolonged discussion a decision was taken in 1925 that silting operations should be re-started. The zamindars of the area were in the first instance not willing to place their lands at the disposal of the canal authorities for silting operations, but they were given favourable terms and eventually they were persuaded to come to an agreement.

The swamp area was divided into nine big compartments. Each compartment was in fact a silting tank in itself. The earthwork of the compartments was completed before the monsoon season of 1928, and water was first let into the Chaulandi silting tanks on the 11th of June, 1928 through an inlet situated upstream of the Dhanaura regulator. This system of operating the Chaulandi silting tank with partial supplies let through *kacha* inlets continued till 1935 when a review of the results achieved showed that the amount of silt which had been deposited in the silting tanks from 1928-1935 was not appreciable. During all this period of seven years the outfall continued to be a *kacha* cut in the canal bank.

In 1935 the whole area was again surveyed in detail and a scheme was drawn up for diverting the whole supply of the canal through tanks

Nos. 1 to 4 by throwing a *bund* across the Main Line Lower at R.D. 139,000. The necessary earthwork could not be completed till the beginning of 1937, and the silting tanks Nos. 1, 2, 3 and 4 were opened in the beginning of 1937 monsoon season. The result achieved was very satisfactory as it was found that compartments Nos. 1, 2 and 3 had almost silted up solid. In 1938 tanks Nos. 2, 3 and 4 were closed off and the supply was diverted into tanks Nos. 5, 6, 7, 8 and 9, and again the result was very satisfactory. While only 11 millions of cubic feet of silt was deposited from the year 1928 to 1936, 25.3 million and 23.7 million cubic feet were found to have been deposited during 1937 and 1938 respectively when the whole of the canal supply was diverted into the silting tanks.

After this preliminary silting up in the upper reaches of the silting tank, it was found that the quantity of silt deposited in subsequent years fell off rapidly due to an unsatisfactory outfall, so much so that after the silting season of 1941, it was found that there was actually a scouring action inside the silting tank ; the quantity of silt that had been scoured out being 8.6 million cubic feet, although the total volume of water passed through the silting tank was only about 40 per cent of the normal.

It was, therefore, decided to construct a *pacca* high crested outfall for the silting tank at R.D. 158,000 Main Line Lower, and the work was completed before the silting season of 1942. During 1942, the whole of the canal supply was diverted into the silting tank. The result was very satisfactory because the quantity of silt deposited during the 1942 season was 50.26 million cubic feet, and this was achieved in spite of the fact that on account of a heavy monsoon the average canal supply was about one half of the normal full supply discharge of the canal. A plan of the *pacca* outfall of the Chaulandi silting tank appears at Plate VII.

The *pacca* outfall suffered from some damage during the 1942 season on account of scour in the canal bed caused by the silt free water which emerged from the outfall. Necessary repairs were carried out during the winter of 1942-43.

As the silting operations progress the crest of the outfall is to be raised gradually. The final crest level will depend upon the final full supply conditions at the outfall. The crest of the outfall was raised by one foot in 1942-43 and again by 0.9 foot in 1944-45.

Water emerging from the Chaulandi silting tank over the *pacca* outfall is practically silt free, and in 1942 it resulted in deep scour in the bed of the Main Line Lower. This scour assumed dangerous proportions and threatened the safety of the Badarpur bridge situated just downstream of the *pacca* outfall, and steps had to be taken to protect the bridge.

A fall was built in the winter of 1943-44 just downstream of the Badarpur bridge in pursuance of the general scheme of regrading and remodelling of the Main Line Lower.

The following table shows the data regarding quantities of silt deposited in the Chalaundi silting tank from 1929 to 1943, and the expenditure incurred in each year, and the performance of the silting tank from 1938 to 1943, the period for which the relevant figures of discharges etc., are available :—

Year	Type of outfall.	Volume of water passed through the silting tank in cusec days.	Quantity of silt deposited million cft.	Expenditure incurred during the year.	Performance measured in cft of silt deposited per cusec day.	Cost of silt deposited per %o cft.	Remarks.
1929	Kacha	Not available	11·97	19,064	...	1 10 0	
1930	,,	,,	2·40	3,729	...	1 10 0	
1931	,,	,,	4·56	2,436	...	...	
1932	,,	,,	...	...	...	...	
1933	,,	,,	7·09	8,055	..	1 11 0	
1934	,,	,,	7·55	3,785	...	...	
1935	,,	,,	1·72	4,903	...	2 13 8	
1936	,,	,,	...	...	...	...	
1937	,,	,,	25·28	12,889	...	0 8 2	
1938	,,	589,312	23·69	14,901	40·2	0 10 1	
1939	,,	714,715	54·20	3,182	76·0	0 0 11	
1940	,,	748,161	39·64	17,403	53·0	0 7 0	
1941	,,	Not available	8·60	15,408	...	...	Scour *Includes
1942	Pacca	493,902	50·25	30,100*	144·3	0 9 7	one-tenth
1943	,,	813,600	37·10	32,724*	45·5	0 14 0	cost of the
1944	,,	778,557	16·30	27,700*	20·9	1 11 2	outfall.

It will be seen that the performance of the silting tank recorded in 1942 was the highest, and is directly attributable to the *pacca* outfall.

Generally it may be stated that the Chaulandi silting tank is of fundamental importance to the proper functioning of the Western Jumna Canal. The Main Branch of the Western Jumna Canal taking off at Indri (R D. 190,000 tail Main Line Lower) has been steadily receiving large quantities of coarse silt, and its bed silted up from 3.0 to 5.0 feet in the head reach. Its slope steepened to 0.26 per thousand against 0.13 required, and its full supply levels at head rose to such an extent that it was a difficult matter to run the branch even with its perennial full supply discharge of 4,840 cusecs. The authorised full supply discharge of the branch was however, raised by 800 cusecs in 1941 to feed the new Extensions channels, and it was, therefore, essential to control the full supply level at head of the Main Branch to enable it to take this extra discharge. This could only be achieved by preventing coarse grades of silt from entering the Main Branch, and the splendid performance of the Chaulandi silting tank saved the situation. There was an appreciable scouring action in the head reach of the Main Branch in 1942 which has since been maintained, and which enables the Main Branch to run to its new increased capacity.

About 1,000 acres area out of 1,726 acres covered by the existing tank which was previously an impassable swamp, has so far been reclaimed.

It is anticipated that the Chaulandi silting tank will last for another five or six years. During this period it is necessary to provide other means of preventing coarse silt from reaching Indri, if the canals taking off at Indri are to continue to function. The Indri silting tank which was constructed just upstream of the Indri regulator, in 1942, will carry the bulk of the silt burden for the next 15 to 20 years, and during this period some other means will be provided to tackle the silt problem.

(*e*) **The Indri silting tank.** The Indri silting tank R.D. 175,760 to 189,185 of the Main Line Lower is the most modern of all the silting tanks on the Western Jumna Canal. It is provided with *pacca* inlet designed for a partial discharge 2,500 cusecs, at R.D. 175,760. The *pacca* inlet is combined with a regulator across the Main Line Lower, so that there is complete control of supplies at the inlet. The silting tank covers 1,327 acres area and has a capacity of 500 million cubic feet of silt. It is estimated that the silting tank will function for a period of 15 to 20 years. This silting tank like the Chaulandi silting tank has a history of its own.

In 1904 a series of tanks were proposed by Mr. R.G. Kennedy, Chief Engineer, Punjab Irrigation, between R.D. 170,000 and 190,000 left of Main Line Lower through which it was proposed to divert the whole of the canal. The objects in view were :—

(*a*) to render safe the insecure left bank of the Main Line Lower from R.D. 170,000 to R.D. 190,000.

(*b*) to render culturable the area adjoining the left bank which had been converted into a swamp by seepage from the canal, and

(*c*) to relieve the Sirsa and Hansi branches of their excessive silt load.

It was the first time that the idea of relieving the branch canals of excessive silt load by means of a silting tank was considered and given a practical shape.

The work of constructing the silting tank was taken in hand in 1905 and was completed in 1907 after it had gone through several vicissitudes. The final cost of work was in the neighbourhood of Rs. 90,000. The cost had swelled on account of long leads of earthwork involved, which had to be carried by means of trollies, over soft and marshy ground. The average height of the main *bund* of the silting tank was not more than 7.0 feet above the N.S. level.

At the inner toe of the main outer *bund* of the silting tank a smaller *bund* was placed parallel to the outer *bund* in order to consolidate the outer *bund* so as to avoid the possibility of a breach in it. It was however, found that although the width of the tank was not more than 1,200 feet at any point, severe wave action in high winds seriously threatened the safety of the outer *bund* which called for heavy protection at a cost of about Rs. 10,000. Eventually L shaped spurs, 100 feet in length were provided which resulted in the formation of a wide berm along the *bund* making it safe against breaches. This tank functioned up to 1911. No information is available as to the expenditure incurred on operating the silting tank or the results achieved. It is, however, recorded that deep channels were formed inside the silting tank and although several attempts were made to silt them up, the deep channels remained. The development of the deep channels was of course due to there being no proper outfall provided for the silting tank. No further silting operations at this site were carried out till the construction of the New Indri silting tank in 1940-42.

As already mentioned, the Chaulandi silting tank entrapped large quantities of silt during the period 1937 to 1940 and it was considered that this silting tank could not last longer than four or five years and therefore fresh low areas had to be explored to take up the enormous load of silt in the canal. This was particularly necessary in order to prevent the Main Branch silting up, and further reducing its already low working head to an extent that it would not run with its full supply discharge, which had been stepped up from 4,840 to 5,640 cusecs in 1939.

No other large swamps situated between the right bank of the canal and the river *Dhaya* were available for the purpose, and therefore, the Indri swamp situated on the left side of the canal, where silting operations had been carried out in the past as mentioned above, was selected as the most suitable site for another large silting tank.

The Indri swamp slopes away from the canal towards the river Jumna unlike the Chaulandi silting tank area which slopes towards the canal. This necessitated a heavy limiting embankment for the Indri silting tank. In the case of all the previous silting tanks on the Western Jumna Canal, including the Chaulandi silting tank, the height of the limiting embankment was negligible, because of favourable ground contours, the general slope being upwards from the canal to the boundaries of the silting tank.

In the case of the Indri silting tank, although the embankment has been aligned long the highest contours available, the height of the outer bank varies from 11 to 16 feet. The danger of breaches through such an embankment is serious, and the consequences of a breach would be really disastrous. Apart from the mere volume of water contained in the silting tank, the entire discharge of the canal would continue to issue from the breach until the canal could be closed at Dadupur. It would take a fairly long time to close such a breach and the consequences of interruption of irrigation during a period of keen demand amounting to as much as 10 to 15 days would be dangerous. It was therefore considered necessary to provide the Indri silting tank with a *pacca* inlet, in addition to a *pacca* outfall.

The outfall is 200 feet wide, and is shown in detail at Plate No. IX. The inlet consists of 8 spans of 9 feet each, and there is a regulating fall across the canal situated just downstream of the inlet. For details of the inlet see Plate No. VIII. These works were constructed in 1940-41. The outer *bund* of the silting tank was started in 1940 as a famine relief work but it was completed in 1942, as the large quantity of earthwork involved was not only of a difficult nature due to marshy soil, but the work had to be executed most carefully to minimize risk of breaches. The staunching of the enormous embankment was a big job by itself. It was started in the first week of July 1942 and the inner slope of the *bund* was gradually puddled in layers 5 feet wide and 6 inches deep, by labour employed departmentally. The pond level in the silting tank was also raised slowly up to the maximum. During these operations very strict and intensive watch was kept for any cracks in, or leakages through the *bund*. The embankment was strained to the utmost during the very first monsoon season (1942) which proved to be exceptionally heavy. Great care had to be exercised to protect the inner slope of the embankment against wave action which assumed dangerous proportions in high winds on account of the large size of the tank. Earthen breakwaters or spurs had been provided before the tank was opened, and they proved extremely useful in keeping down the wave action. Rolls of *pathera* grass were first of all tried as protection for earthwork against wave action, but as grass rots away rather quickly, the rolls were later substituted by a layer of brick bats 1½ feet in thickness. This latter form of protection proved efficacious, and as large quantities of brickbats were available in the Indri village situated close to the bank, the cost of brickbat protection was about Rs. 150 per chain length of the embankment.

The total cost of constructing the silting tank including the connected *pacca* works, and compensation paid to zamindars is Rs. 2,72,664.

The following table shows the performance and cost of maintenance of the silting tank :—

Year	Volume of water passed through the silting tank in cusec days	Quantity of silt deposited in millions cft.	Performance measured in cft. of silt deposited per cusec day	Expenditure on maintenance of silting tank	Remarks
July 1942 to end of 1943	650,755	30·36	47	12,347	The total expenditure on the silting tank up to end of 1944 is Rs. 2,91,261. The total quantity of silted deposited to end of 1944 is 47.49 million cubic feet. There fore cost per ‰ cft. of silt deposited i Rs. 6/2/-.
1944	172,810	17.13	99	6,250	

(*d*) **The Munak silting tank.** This is a small silting tank and is situated on the left side of the Main Branch from R. D. 148,600 to R. D. 154,800 (*vide* Plate V). The tank is long and relatively narrow, and covers an area of 42.5 acres only. This area, before the silting operations started, was water-logged, and the owners of the area readily agreed to let the Government use the area for silting operations. The estimated silt capacity of this tank is 7.3 million cubic feet.

The earthwork of the outer *bund* of the tank and *kacha* inlet and *kacha* outfall were completed in 1937. The tank was opened in 1938 with three *kacha* inlets at R. Ds. 148,000, 149,000 and 150,300 with a single outfall at R. D. 154,400. Silt deposits during the first two years of its functioning were encouraging; the quantities being 306,400 during 1938 and 309,300 during 1939, total 615,700 cft.

In 1940, however, it was observed that some of the silt which had deposited in the lower reach of the tank in 1939, had scoured during the summer of 1940, and thus instead of a further deposit of silt, scour had been going on. The reach from R. D. 148,000 to 151,000 which had silted up in 1938 and 1939 was separated from the rest of the silting tank by means of an earthen *bund*, and the area upstream of the *bund* was handed over to cultivators for cultivation.

A small *pacca* outfall 72 feet in width was built at R. D. 154,400 in 1940-41 with its crest level 1.5 feet below the designed full supply level in the silting tank. The *pacca* outfall justified its construction because during the 1941 silting season, 700,000 cft. of silt was deposited out of a total remaining capacity of about 11 lacs cubic feet.

In 1942, the silting operations were resumed and the silting tank was found to have silted up practically to its full capacity. The functioning of this small silting tank is another illustration of the usefulness of a *pacca* outfall for carrying out silting operations successfully.

(*e*) **The Hansi Branch silting tank.** This silting tank covers an area of 426 acres and is therefore relatively small, but it is large when compared with the discharge of Hansi branch viz., *2,300* cusecs, the whole of which is diverted through the silting tank by placing a *bund* across the Hansi branch just downstream of the *kacha* inlet at R. D. 1,800 R. Hansi branch. This cross *bund* is removed during the winter season and as Hansi branch has periodical closures all through the low river supply season, the necessary work connected with the placing and removal of the *bund* across Hansi branch is carried out during rotational closures without any interruption of supplies.

This silting tank was the first on the Western Jumna Canal to be provided with a *pacca* outfall and the results achieved fully justify its construction in 1939. Silt is deposited evenly in the tank in a fan shaped area starting from the inlet and it goes on gradually increasing in extent as the silting tank is operated. It was after an inspection of the silt deposits in this silting tank that the necessity of *pacca* outfalls for silting tanks was finallv accepted by the Chief Engineer.

To keep down the cost of the outfall to as low a figure as possible, the design of the outfall was made unduly light. It consisted of kankar blocks cement grouted and was not deeply founded. The outfall was seriously damaged in 1942, and was then replaced by a more substantial structure at a cost of nearly Rs. 8,000 *vide* Plate XI.

The silting tank was opened in June 1940 and its operation has been satisfactory from the very beginning.

The following table shows data regarding quantities of silt deposited in the silting tank and its performance from 1940 to 1944 :—

Year	Type of outfall	Volume of water passed through the silting tank in cusec days	Quantity of silt deposited cft.	Performance measured in cft. of silt deposited per cusec day	Remarks
1940	Pacca	68,655	3,437,750	51	Total expenditure to end of 1944 is Rs. 48358. Total quantity of silt deposited is 51.77 million cft. Cost per ‰ cft. -/15/-.
1941	,,	237,500	20,689,250	87	
1942	,,	142,090	10,526,675	74	
1943	,,	312,500	10,570,000	34	
1944	,,	255,662	6,548,000	26	

The effect of all this silt extraction on the regime of Hansi branch has been very appreciable. At Majra fall at R. D. 22,500 of Hansi branch, the downstream gauge at the fully supply discharge of 2,171 cusecs used to be 9.8 feet before the silting tank was opened in 1940. At the end of the silting season of 1941, *i.e.*, in October 1941, this gauge had fallen to 8.8 for the same discharge which meant a general bed scour of 1.0 foot. Below Anta fall at R. D. 60,000 Hansi branch also the gauge similarly fell from 9.2 feet to 8.8 feet indicating a general scour of 6.4 feet. Below Muana fall at R. D. 106,000 the corresponding drop in gauges was 0.25 foot. This indicated that the effect of silt extraction had travelled down to Muana fall, *i.e.* 21 miles downstream of the silting tank, within the first two years of its opening.

At the end of the 1943 silting season, it was observed that the Majra gauge had fallen by another one foot, bringing the total fall in this gauge to 2.0 feet. Below Anta fall R. D. 60,000, the gauge dropped by another 0.5 feet. The effect of exclusion of silt from Hansi branch has made itself felt in the Butana branch also, which takes off above Anta fall.

Hansi branch was silting up progressively from year to year, and as it runs in heavy filling for a considerable part of its length, the successive raising of banks was proving not only costly but troublesome to maintain. The silting tank therefore proved a great boon for the Hansi branch.

This silting tank is not only helping Hansi branch but is now taking the silt burden of Delhi branch also, because most of the silt which reaches Munak (from where Hansi branch and Delhi branch take off) is diverted into Hansi branch by means of silt vanes built in front of the Hansi branch head in 1942. These silt vanes exclude most of the coarse silt from Delhi branch and divert it into Hansi branch where it is entrapped in the silting tank.

The area under the silting tank was badly water-logged, but most of it is now reclaimed and bears good crops.

5. CONCLUSION

In conclusion it may be said that siltings tanks with properly designed intakes and outfalls are an efficient means of keeping silt out of harm's way. In fact silting tanks can be too efficient and therefore it is essential carefully to watch the effect of silting tanks on the regime of channels concerned, and to call a halt to or regulate the operation of silting tanks, should they become over-effective. On the Western Jumna Canal, gauges have been erected along the branch canals at one mile intervals to keep a record of the discharges and corresponding slopes in order to watch any undesirable regime changes. So far, the silting tanks on the Western Jumna Canal have proved to be very efficacious in keeping this, the oldest of the Punjab Canals, alive, and it is hoped that the Engineers to come will continue devising means to keep the Western Jumna Canal system running to its full capacity.

PLATE 1
PAPER 277

WESTERN JUMNA CANAL
PART INDEX PLAN SHOWING SILTING TANKS

SCALE:- 1" = 16 MILES

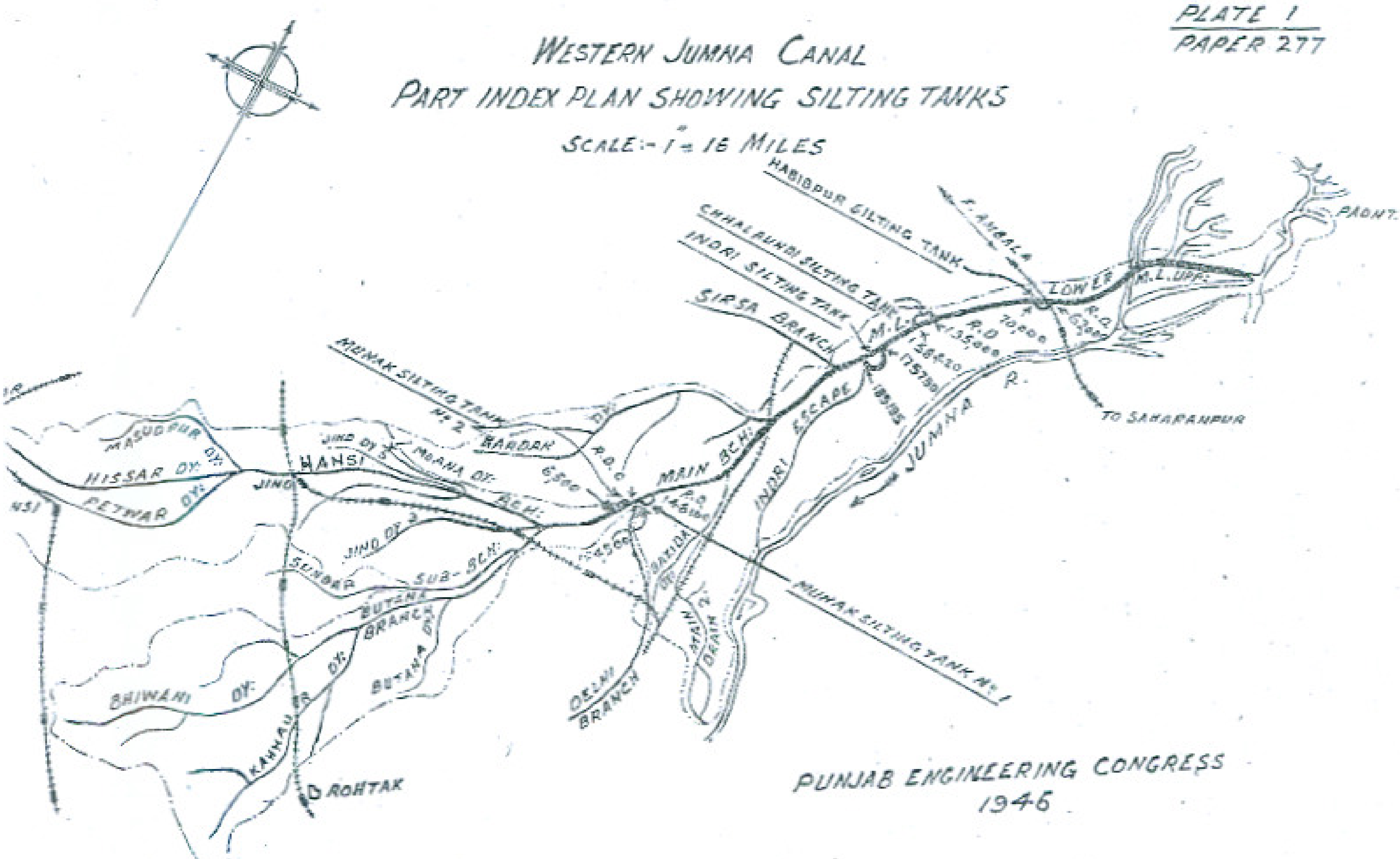


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PLATE III
PAPER 277

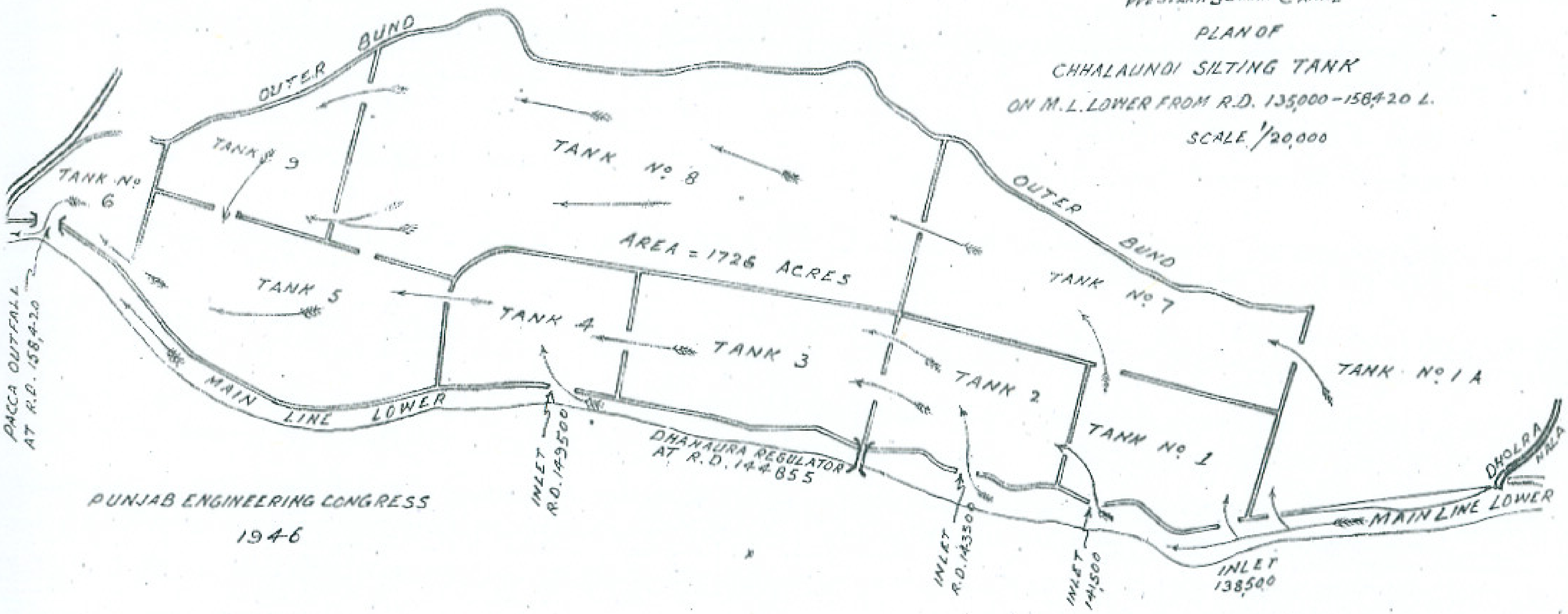
WESTERN JUMNA CANAL

PLAN OF

CHHALAUNDI SILTING TANK

ON M.L. LOWER FROM R.D. 135,000–158,420 L.

SCALE 1/20,000



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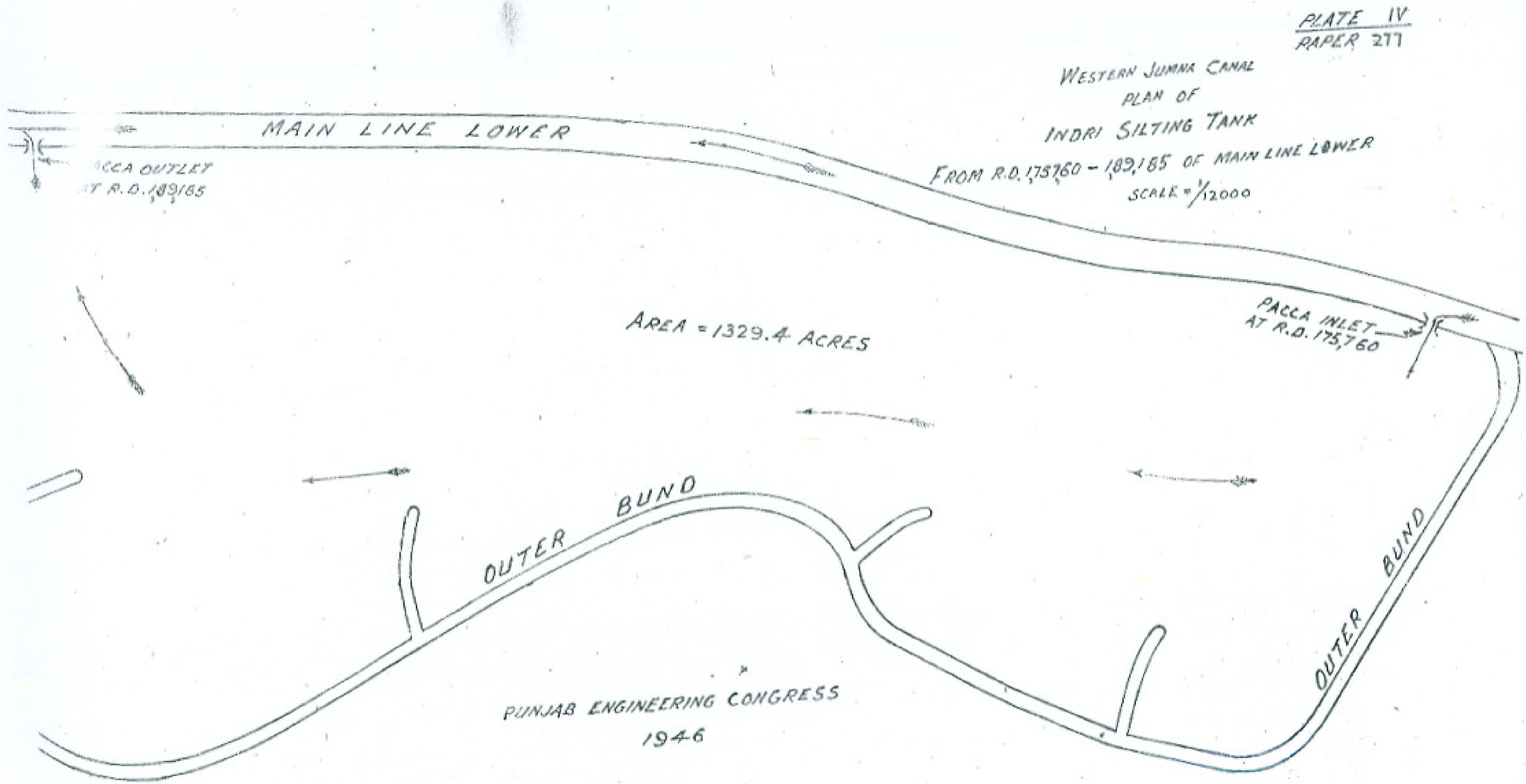
PLATE IV
PAPER 277
WESTERN JUMNA CANAL
PLAN OF
INDRI SILTING TANK
FROM R.D. 175,760 – 189,185 OF MAIN LINE LOWER
SCALE = 1/12000
MAIN LINE LOWER
ACCA OUTLET
AT R.D. 189,185
PACCA INLET
AT R.D. 175,760
AREA = 1329.4 ACRES
OUTER BUND
OUTER BUND
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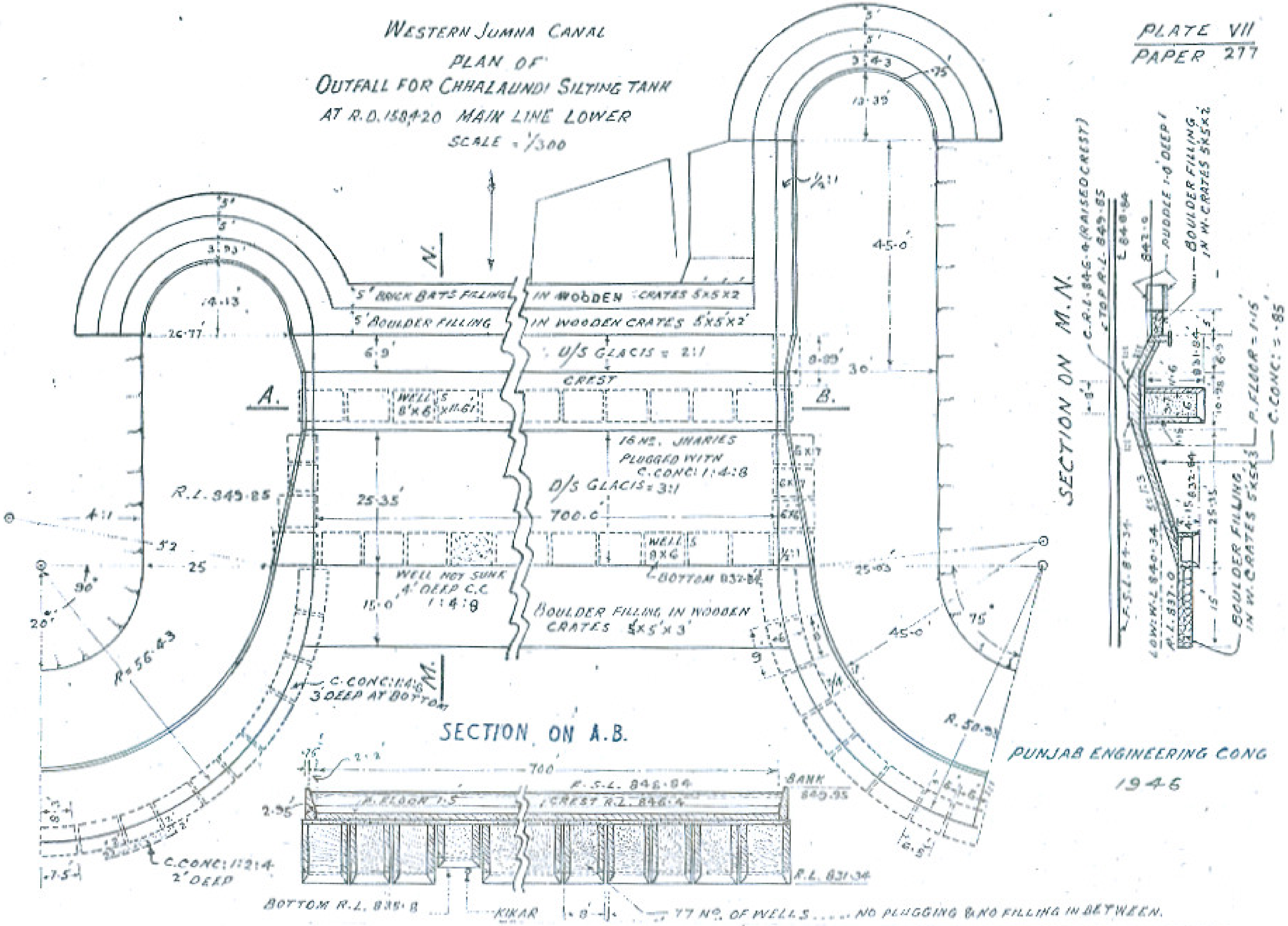
WESTERN JUMNA CANAL
PLAN OF
OUTFALL FOR CHHALAUNDI SILTING TANK
AT R.D. 158,420 MAIN LINE LOWER
SCALE = 1/300
PLATE VII
PAPER 277
5' BRICK BATS FILLING IN WOODEN CRATES 5x5x2
5' BOULDER FILLING IN WOODEN CRATES 5'x5'x2'
U/S GLACIS = 2:1
CREST
WELLS 8'x6' x11.61
16 No. JHARIES PLUGGED WITH C.CONC: 1:4:8
D/S GLACIS = 3:1
700.0
25.35
R.L. 849.85
WELLS 8x6
BOTTOM 832.84
WELL NOT SUNK 4' DEEP C.C 1:4:8
15.0
BOULDER FILLING IN WOODEN CRATES 5'x5'x3'
C.CONC: 1:4:8 3' DEEP AT BOTTOM
C.CONC: 1:2:4 2' DEEP
R=56.43
R. 50.93
45.0
SECTION ON A.B.
F.S.L. 846.84
CREST R.L. 846.4
P.FLOOR 1:5
BANK 849.95
R.L. 831.34
BOTTOM R.L. 835.8
KIKAR
77 No. OF WELLS ..... NO PLUGGING & NO FILLING IN BETWEEN.
SECTION ON M.N.
C.R.L. 846.4 (RAISED CREST)
TOP R.L. 849.85
PUDDLE 1-0 DEEP
BOULDER FILLING IN W.CRATES 5x5x2
F.S.L. 84.34
LOW W.L. 840.34
R.L. 837.0
BOULDER FILLING IN W.CRATES 5x5x3
P.FLOOR = 1:15
C.CONC: = .85
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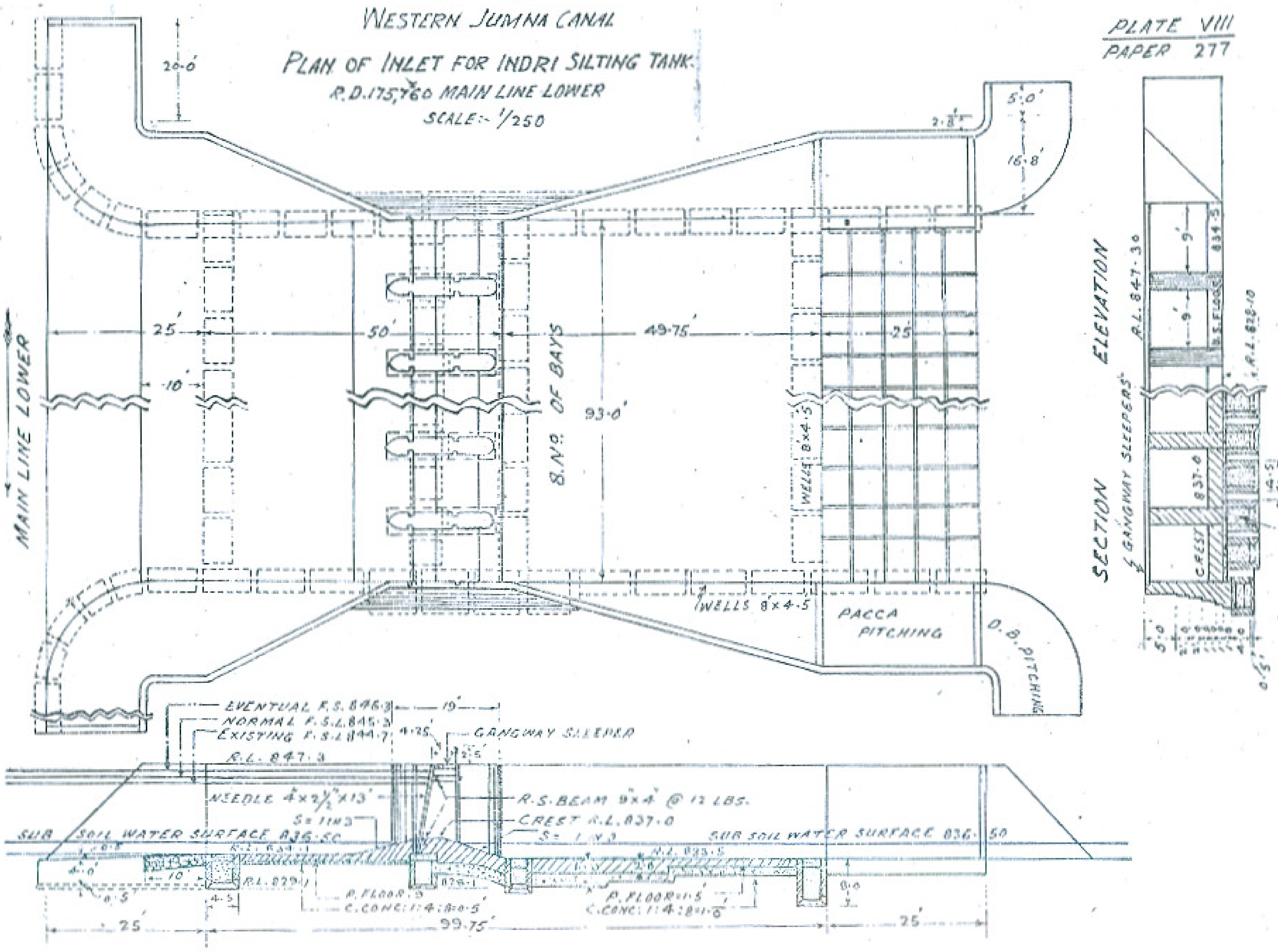
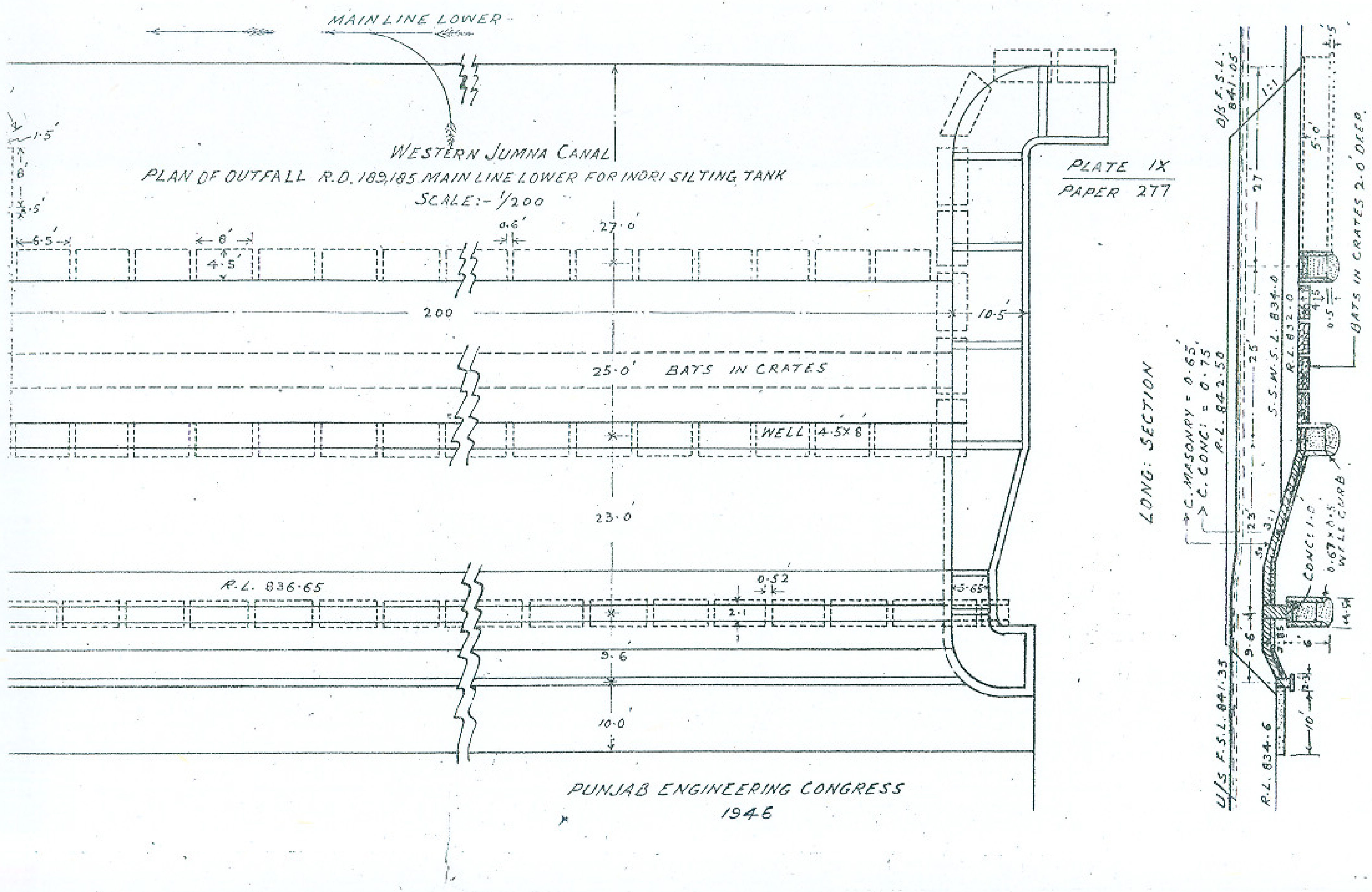
PLATE VIII
PAPER 277




MAIN LINE LOWER
WESTERN JUMNA CANAL
PLAN OF OUTFALL R.D. 189,185 MAIN LINE LOWER FOR INDRI SILTING TANK
SCALE:- 1/200
PLATE IX
PAPER 277
27·0'
25·0' BATS IN CRATES
23·0
9·6
10·0'
200
10·5'
WELL 4·5×8
R.L. 836·65
0·52
2·1
6·5'
6'
4·5'
0·6'
LONG: SECTION
C. MASONRY = 0·65'
C. CONC: = 0·75'
R.L. 842·50
S.S.W.S.L. 834·0
R.L. 832·0
BATS IN CRATES 2.0' DEEP
D/S F.S.L. 841·05
U/S F.S.L. 841·33
R.L. 834·6
CONC: 1:0
0·67×0·5 WELL CURB
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G EQUIPMENT

D BY

ie Machine.	Method of Operation.
icket or Load.	1. Number of Units in Operation.
equired.	2. Method of Transporting Excavated material.
— ping.	3. Skill and Experience of Operators and of Supervisors.
	4. Layout of Cuts, Ramps and Roads.
of Machine ottom Condi-	5. Deposition of Material (Loading or Spot Dumping).
Performance.	6. Size of Receiving Units.
achine and	
id Reliability	

, Pump and	1. Depth of Cut.
rge Line.	2. Type of Power used.
on Pump.	3. Method of Carrying Discharge Pipe.
re.	4. Deposition of Material Fill or Waste).
iead.	5. Skill and experience of Operators and Supervisors.
Machine and	6. Layout of Cut.
ind Reliability	7. Location of Booster Pumps.
e Line.	8. Method of Feeding Dredge (Underwater Digging or Sluice Feed).