PAPER No. 399

MARALA BARRAGE
INVESTIGATIONS FOR HIGH UPLIFT PRESSURES UNDER THE DOWNSTREAM FLOOR

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1. GENERAL

Contract for the construction of Marala Barrage was let out to Messrs E. D. Zueblin, A. G., a German Firm on 31-1-1965. Design of the Barrage and supervision of its construction was done by M/s Coode & Partners of London. Although the Contractor had a set-back of two months due to September 1965 war, but he managed to complete the Barrage by 30-9-68 *i.e.* three months ahead of the scheduled date of completion.

Before the work on entire barrage had finished, heading up of river supplies in a partially completed portion of the Barrage commenced in April, 1968 and both U.C.C. and M. R. Link were fed through the new regulators. Arrangements for observing piezometric levels were provided in piers No. 11, 12, 35, 47 and 60. These observations were started on Piers No. 23 and 35 in May, 1968, on Pier 47 in July 1968 and on Pier 60 in August 1968. Up to November 1968, Coode & Partners were responsible for these observations and after this WAPDA assumed the responsibility.

High Uplift Pressures

The Barrage has been designed for the following effective head of water against uplift pressures;

Undersluices:

U.S.W.L.	..	+812.0	Normal Pond Level.
D.S.W.L.	..	+787.0	Top of D/S Rubble Apron.
	H ..	25.0 ft.	

Normal Openings:

U.S.W.L.	..	+812.0	Normal Pond Level.
D.S.W.L.	..	+790.5	Top of Lip wall at D/S end of floor.
	H ..	21.5 ft.	

**Deputy Project Director, Marala.*

The actual effective head of water ranged between a maximum of 16.0 to a minimum of 8.0 ft. up to December 1968. Piezometric levels indicated that for Piers 11, 23, 47 and 60, the Phi values for all piers and along the Sections of the Barrage were about within the designed values. However, for Pier 35, these values were higher than the designed for all points downstream of Pile F-3. A section of the Barrage at Pier 35 is shown in Exhibit-I. A statement of observed values up to December 1968 for Pier 35 is at Appendix 'I'. The Phi values at the critical point No. 9 generally ranged between 23.0 and 40 against the designed value of 21.00. There were 5 readings below 21.00 and appear to be erratic. This position was brought to the notice of Consulting Engineers who after studying the problem reported as below in January, 1969:

1. Considering the margin of safety prescribed in the design of the Barrage, the downstream and middle parts of the floor where pressures are high, are safe for the following critical case :

U.S.W.L.	..812.00 Pond level.
D.S.W.L.	..790.50 Top of Lip wall.
Head	.. 21.50

2. Actual conditions observed on site till recently are also safe for the floor uplift.
3. Frictional resistance of the sheet piling cut offs which have not been accounted for in the design calculations will contribute to the stability of the floor.

Phi values shot up beyond 40 during the month of February, 1969 and continued in the range 41 to 49. During May, 1969, increase in the Phi value beyond 51 was registered. This naturally alerted everybody. So far the Barrage had been operated without any head across limitations. It was considered that such an operation would jeopardise the safety of the downstream floor. The problem was again studied by the Consultants in the light of the high values of Phi, registered for points No. 4 to 10 for Pier 35. In their report of July, 1969 they concluded as follows:

(*i*) The uplift pressures on the downstream floor opposite Pier 35 are high and it is not safe to operate the Barrage without any limitation of head across the floor.

(*ii*) The Barrage should be operated in such a manner that the factor of safety does not go below 1.05.

(*iii*) The cause of build-up of excessive pressures under the downstream floor is probably due to some restriction between the toe of the last pile line F_1 and the top of the clay beneath it.

(*iv*) Remedial measures should be carried out if the Barrage is to be operated for the designed effective head.

(*v*) Relief wells drilled through the bed of the downstream floor at about 4 ft. centres may serve the purpose.

In actual practice the limitation of the factor of safety as 1.05 resulted in a maximum head across of 13.0 ft. In winter when river discharges were low, we had to escape some valuable water downstream so that the head across of 13.00 was not exceeded. It was not possible to shut all the gates of the Barrage to pass the entire flow of the river into U.C.C.

The problem was again jointly studied by Harza and Coode & Partners and they came forward with the following conclusions in their report of September, 1969:

(*i*) The cause of the high uplift pressures under the downstream floor is not known and can be only determined through adequate investigations.

(*ii*) That the number of bays actually affected by high uplift pressures can only be established by investigations carried out by drilling through the downstream concrete floor.

(*iii*) That the drilling through this floor can be safely done during the low flow season.

2. CONTRACT FOR INVESTIGATIONS

In the light of the above report of Consultants, decision was taken to carry out investigations for the high pressures.

Quotations from the following three Firms were invited on 26th September, 1969 for carrying out sub-surface investigations through the downstream floor of Marala Barrage for the three schemes discussed below :

(*i*) M/s. Harold T. Smith.

(*ii*) M/s. Johan Kellers.

(*iii*) M/s. Indus Valley Construction Company.

The three schemes were :

Scheme 'A'

Drilling with continuous sampling of 5 No. bore holes through the downstream block apron opposite Piers Nos. 31, 33, 35, 37 & 39 down to and 5 ft. into clay strata at about 755 level.

Scheme 'B'

(*a*) As in Scheme 'A' above followed by (*b*) drilling under pressure with continuous sampling of 17 No. bore holes through the downstream floor down and 5 ft. into clay stratum between Piers 27 to 45.

Scheme 'C'

(*a*) 17 bore holes as per (*b*) of Scheme 'B' only.

(*b*) The idea of three schemes was as below :

(*i*) In certain quarters there were great apprehensions about the puncturing of a pressurised floor of a Barrage. It was feared that sand might blow out of the punctured hole and lead to catastrophic collapse of the floor.

(*ii*) After getting confidence and experience of boring in the block apron, it might be possible to drill a number of holes, through the concrete floor to determine the confines of the high pressure zone.

(*iii*) If the arrangement for drilling appear foolproof, direct drilling through the downstream floor may be resorted to.

In view of satisfactory arrangements for drilling through the floor, Scheme 'C' was considered suitable for investigation. Although the above mentioned three Firms were invited to quote, but two Firms *i.e.* M/s John Kellers & Indus Valley Construction Company submitted their quotations. A comparison of the quotations for Scheme 'C' for the various items of B.O.Q. is at Appendix 'II'. The quotation of Indus Valley Construction Company for a sum of Rs. 52,3374 was the lowest.

After some correspondence Indus Valley Construction Company was informed on 13th January, 1970 that their tender was accepted.

One of the conditions of the contract was that the contractor shall insure in the joint names of Employer and the Contractor against all loss or damage to existing Barrage and Ancillary works for a sum not exceeding Rs. 35,000,000. As compared to the total cost of work of Rs. 5,23,374 the insurance of Rs. 3.5 million appeared very high. This raised certain doubts in the minds of Insurers. However, at the interference of WAPDA the Insurance Company agreed to provide insurance cover for Rs. 3.5 million. The Contractor started work at site on 21st January, 1970 after mobilising his equipment and staff.

3. ARRANGEMENT FOR DRILLING THROUGH THE FLOOR

For drilling through the concrete floor the following works had to be carried out :

(*i*) Cutting a Chase in the Concrete Floor

Due to head across limitation, some water had to be released downstream. However, for cutting a chase in the concrete floor, it had to be dried up. This object was achieved by placing a double walled steel caisson in position between the D/S rows of deflector blocks. This caisson which is shown in Exhibit 'II' was so designed that it would float on water when empty and would sink and sit on the floor when annular space was filled with water. The water tightness of this caisson was achieved by means of rubberoid 2″×1½″ rings fixed in circular channels at its bottom. The bottom of caisson is shown in Photo I. For sinking the caisson two 3″ dia valves were provided at its bottom. After placing the caisson in position, the water inside was pumped out and concrete floor was dried up. A 15″ deep chase 16″ square at top and 22″ at bottom was cut in the concrete floor by pneumatic tools. This size was increased where the exposed bars of the floor interfered with placing of Starter pipe. A section of chase is also shown in Exhibit 'II'.

(*ii*) Fixing Starter Pipe

An 18″ long and 8″ internal dia mild steel pipe called "STARTER PIPE" was placed and grouted in the chase in such a way that 12″ was buried in the concrete and 6″ remained above the concrete floor. A photo of Starter pipe is at Photograph No. II. The grout mix consisted of 1 : 1½ : 3 cement concrete containing about 1% of Calcium Chloride for quick setting. In addition aluminium powder was also added for increasing the strength of the mix. A number of lugs were welded to the Starter Pipe for providing a good bond in the grout. Some of the lugs which were touching the reinforcement were welded to it to increase the bond.

(*iii*) Fixing a Reducing Pipe:

On the top of Starter pipe a reducing pipe 9″ long was bolted to reduce the internal dia from 8″ to 6″. Rubber packing was provided to make the joint leak-proof.

(*iv*) Extension Pipe

An extension pipe about 15 ft. long in four pieces was bolted on the top of reducer pipe in such a way that it projected about 2.0 ft. above the drilling platform. A six inch sluice valve was also fitted in the extension pipe so that in the event of any danger of sub-soil foundation material, piping up the bore hole could be closed. An assembly of Starter pipe, reducer and extension pipe is shown in Exhibit 'III'.

(v) Drilling Platform

A specially manufactured drilling platform was placed over the point of drilling. A drawing of this platform is shown in Exhibit 'III'. The height of the drilling platform was kept such as to provide a free-board of 2.0 ft. during the normal floods occurring in the months of February and March. For easy movement of this platform four flanged wheels were fitted on its vertical legs. There are two rows of deflector blocks 6.0 ft. apart on the downstream end of the floor. Rails were laid on the top of these deflector blocks. The spacing between the legs of the drilling platform was kept such as the wheels would fit into the rails. This arrangement provided easy movement of the platform from one location to another. Besides this arrangement also saved a lot of time as otherwise the platform would have been dismantled after drilling at one location and reassembled at the next bore hole.

(vi) Drilling Technique

As the pressurised floor was to be punctured, the method of drilling should have been such as would ensure that there was no danger of foundation materials blowing out of the holes. This object was achieved by maintaining water level in the stand pipe almost equal to the upstream pond level.

(vii) Important Precautions

Having completed the above-mentioned arrangements, drilling rig was mounted on the top of the platform. Tripod was also erected on the platform. Before commencing drilling operations it was most important to see that there was absolutely no leakage of water from any of the joints of the stand pipe. From three joints above the water level leakage of water could be visible. However, there were two joints submerged in water and it was most important to ensure that these joints were also leak-proof. If steel caisson had been kept in position there would not have been any difficulty in testing their leak tightness but these were removed after fitting one piece of extension pipe for use at other holes. Therefore for testing the leak tightness under water the stand pipe was filled with water almost to its top level. Readings of the water level in the stand pipe at 10 minutes' interval were taken. If the water level remained stable for about an hour it was a sure test of leak tightness of all the joints of the stand pipe.

4. DRILLING OPERATIONS

Having completed the above-mentioned arrangements and after checking the leak tightness of the stand pipe, drilling operations were commened. Drilling rods fitted with a double tube core barrel and one 116 m.m. diamond drilling bit were lowered into the stand pipe. Drilling was done at a slow rate so as to

have a good core recovery. As the diamond drilling bit neared the bottom of the concrete floor, drilling pressure was further reduced so that bottom portion of the floor does not break in a chunk under the drilling pressure and the weight of the drilling rods. If 3 inches of the blinding concrete core was also recovered, it ensured that no chunk of concrete had been dislodged at the bottom of the floor. Drilling work in operation is shown in Photo No. III.

(*i*) **Piezometric reading after puncturing the Floor**

As soon as the concrete floor had been punctured core barrels and drilling rods were taken out and water in the stand pipe was allowed to stabilize. In the first hole it took 14 hours for the water level to become constant. It was found later that fine concrete grindings had settled at the bottom of the concrete floor forming an impervious layer. This resulted in very slow falling of water level in the stand pipe. For the remaining holes the following precautions were taken. Drilling was stopped about 2'' above the bottom of the concrete floor and the bore hole was thoroughly flushed with clean water. When the clean water was noticed, dropping out of the stand pipe further drilling was commenced. This considerably reduced the fine concrete grindings and therefore the water table in the stand pipe stabilized quickly after puncturing of the floor.

When the water level in the stand pipe stabilized, its reading was taken with a steel tap at the lower end of which a bell sounder had been attached. R. L. of the top of the stand pipe was observed with a level and thus the R. L. of the water level inside the stand pipe was determined. Water levels upstream and downstream of the Barrage were simultaneously observed and from this data value of Phi was calculated. At Pier No. 35 piezometric reading in the stand pipe was compared with the reading of point No. 9 of the pressure pipes. There was very close agreement between the two reading and this dispelled any doubt about the erratic functioning of the pressure pipes.

(*ii*) **Percussion Drilling**

Drilling below the concrete floor into the Sub-soil Strata was done by lowering 116 mm OD, 113 mm OD and 98 mm OD casing through the stand pipe and using a boiler of suitable diameter for taking out the soil samples. The size of casing pipes was reduced as the hole progressed to reduce frictional force in lowering and pulling out of casing pipes. Sampling of soil strata was done by means of split spoon sampler. The samples were properly logged, packed in polythene bags and placed in the sample boxes.

5. PIEZOMETRIC READINGS

The most important piezometric reading was the one which was taken just after puncturing the floor. Besides piezo readings were also taken at the

following points as the percussion drilling progressed :

1. At R. L. 760.00 *i.e.* the level of the bottom of the last sheet pile line.
2. Just above the first clay strata.
3. On the top of second clay strata.
4. Just below the concrete floor on back filling of the bore hole with river sand.

From these readings Phi values were worked out and are tabulated in Appendix 'III' for all the 14 holes.

Phi values for different locations of the same hole are generally in agreement. Minor variations can be attributed to the variations in Pond and D/S levels of the river.

6. PERMEABILITY TESTS

A number of field permeability tests were carried out at specified depth along the holes during drilling operations by constant head method. A constant head was maintained by keeping the stand pipe filled with water up to the top. Water was poured into the pipe by gallon measures if the rate of fall was slow or a fiexible rubber pipe from a drum filled with clean water. In case the quantity of water required to maintain the constant head was very large direct pumping of clear water was done. The water from the pumps passed through venturimeter so that the quantity of water pumped could be measured. For each test following observations were recorded on the field logs :

(*i*) R. L. of the constant water level in the stand pipe.

(*ii*) Piezometric water level.

(*iii*) Quantity of water poured or pumped into the hole.

(*iv*) Duration of test.

From these readings permeability was worked out with the help of the following formula :

$$K = \frac{q}{5.5\,rh}$$

when q = rate of flow of water into stand pipe.
r = inner radious of pipe.
h = constant head applied.

Permeability as worked out for various points of bore holes are shown on Exhibit VII along the bore hole logs.

7. BACK FILLING OF HOLES

All holes were back filled with river sand up to the underside of the concrete floor when drilling up to 10 ft. into clay had been completed and all other tests and observations had been made. While back filling the casing pipe was gradually withdrawn.

8. INSTALLATION OF TEMPORARY PIEZOMETERS

In eleven holes *i.e.* hole Nos. 29, 31, 32, 33, 35, 36, 37, 39, 40, 41 & 43 temporary piezometers were installed just above the bottom of concrete floor. This was done after back filling, the hole with river sand as mentioned above. The piezometric assembly is shown in Exhibit IV. It is also shown in Photo IV. The two important items of this assembly were as below :

(*i*) **Sintered Bronze Filter**

This a metallic filter which consists of compressed granules of broze. It is porous and hard. Its performance is considered to be better than the usual wire mesh filters.

(*ii*) **Rubber Plug**

It is a cylindrical piece of rubber about 4.25'' outer dia and 3.25'' long. It is fitted between two notched plates. The upper plate can be screwed down so that the rubber plug bulges out and its sides press against the hole in the concrete. This makes the hole leak tight and thus its grouting can be done easily.

9. PLUGGING OF HOLES AND GROUTING

All the concrete holes were plugged by means of an assembly with or without a filter. The holes which have been fitted with a sintered bronze filters can be used for piezometric readings when required. As mentioned above, a rubber plug was expanded to seal the hole in the concrete floor. The leak tightness of the rubber plug was tested by filling the stand pipe with water. If any leakage was noticed, the plug was further expanded by tightening the top plate. Then the upper part of stand pipe was completely removed and steel caisson was placed on the hole. The water inside the caisson was pumped out. The reducer and last short piece of stand pipe was removed. The hole in the concrete floor was grouted with a cement concrete mix 1 : $1\frac{1}{2}$: 3 containing 1% by weight of calcium chloride for quick setting. The upper end of 1/2'' dia pipe from the piezometric assembly was closed by a stop-cock. A perforated or blind flange was bolted on the top of the stand pipe, so that piezometric readings could be taken when required.

10. BORE HOLE LOCATIONS

Bore hole locations of the 14 holes are shown in Exhibit 'V'.

11. DRILLING PROGRESS

The following table shows the time taken in completing the various bore holes by means of two drilling machines :

B. Hole	Commencement		Completion		Time taken in Hours.
	Date	Time	Date	Time	
43	12-2-70	14.30	24-2-70	20.45	294
35	20-2-70	12.30	25-2-70	24.00	132
39	4-4-70	01.45	7-3-70	19.30	90
33	4-3-70	21.00	10-3-70	01.45	125
41	9-3-70	13.30	11-3-70	17.00	52
31	11-3-70	10.45	16-3-70	07.30	117
37	19-3-70	16.30	22-3-70	16.00	72
29	20-3-70	14-00	24-3-70	01.00	83
32	25-3-70	18.45	29-3-70	22.30	100
40	26-3-70	09.30	30-3-70	18.15	105
26	2-4-70	13.00	5-4-70	22.00	81
36	3-4-70	17.30	6-4-70	13.00	68
39 A	10-4-70	15.30	13-4-70	11.30	68
34	11-4-70	19.10	19-4-70	09.15	182

This time includes the time taken in various tests and in one or two cases idle time also. The work on all the 14 bore holes was completed in 65 days. Drilling progress of various holes is also shown graphically in Exhibit VI. Each machine drilled 7 holes 43, 41, 39, 37, 40, 32, 39A and 35, 33, 31, 29, 32, 26 & 34.

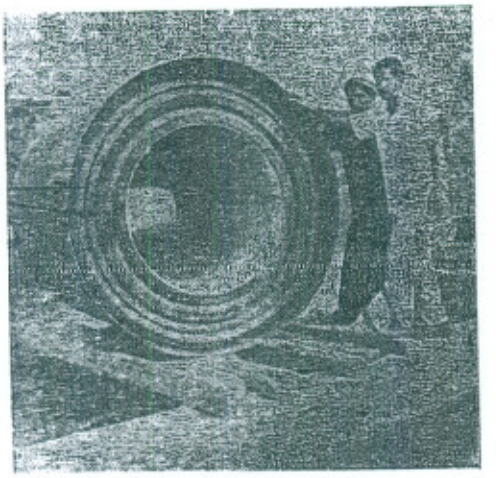
12. BORE HOLE LOGS

Bore hole logs of 14 holes are shown in Exhibit VIII. The following information is also given on this Exhibit :

(*i*) The various type of strata encountered in the bore holes has been shown by different markings indicated in the legend.

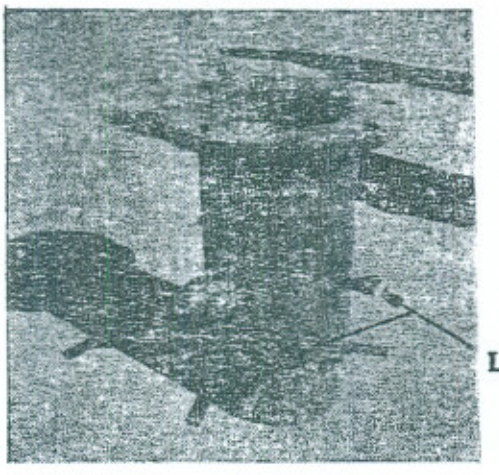
I

Rubberoid Rings



Double-walled Steel Caisson 4′ inner dia.

II



Lugs

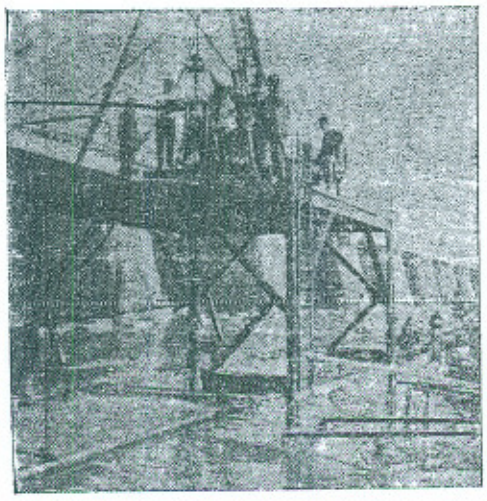
Starter Pipe 18″ Long and 8″ Inner Dia with Welded Steel Lugs.

III

Drilling Rig

Stand Pipe

Rails laid on deflector blocks

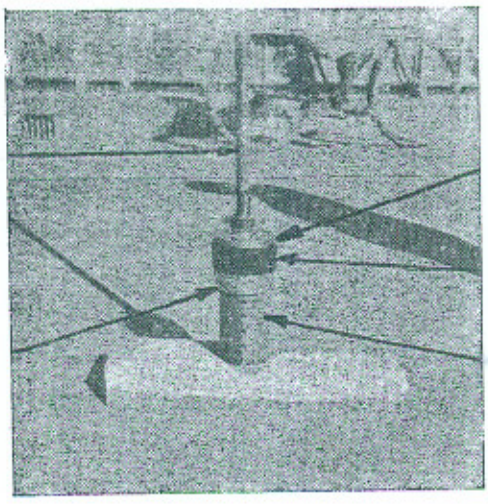


Drilling Platform Mounted on Rails

IV

1/2" dia G. I. Pipe

Low Fixed Plate



Upper Moveable platform expanding rubber rings

Rubber ring for sealing

Perforated 3" dia steel pipe inside which there is sintered bronze filter.

Plezometer Assembly

(*ii*) A line indicating the bottom of last pile line F-1, at R. L. 760.50 is also marked on the bore hole logs to indicate the clearance between the bottom of the pipe line and the clay strata.

(*iii*) A graph showing the actual observed Phi values for the 14 bore holes has been plotted, just above the bore hole logs.

(*iv*) A graph showing the theoretical Phi values used for design as calculated at the points of bore holes have also been marked on this drawing.

(*v*) Values of permeability as actually observed at various points of bore holes are written in figures along the logs of bore holes.

(*vi*) Top of clay as assumed in original and as found by investigations is shown by thick hatched lines.

13. UNUSUAL PHENOMENA

Some unusual phenomena were observed during investigations on bore holes 40 & 41. On both these holes there was heavy loss of water just after puncturing the floor and some confined pressure was encountered after drilling through the first clay layer. Drilling was first done on B. H. 41. A detailed description of both the phenomena is given below :—

(*i*) High Rate of Loss of Water

When the concrete floor on B. H. 41 was punctured, water level in the stand pipe fell suddenly to elevation 794.98. Pond level at that time was 806.19 and Tail Water level 793.31. Water was put into the hole at the rate of 15 g.p.m. to flush it but the level of water in the Stand Pipe could not be raised even by one inch. Finding it difficult to raise water level casing pipes were lowered for percussion boring. Efforts were made to take permeability tests at depths of one foot and two feet below the bottom of the concrete floor but this was not possible until a depth of 3 ft. was reached. At this point an inflow rate of 12.5 g.p.m. gave a head of 8.05 ft. in the Stand Pipe. For this data the permeability worked out to be 139020 ft./year which is equivalent to $0.133 \times$ cm/sec. This indicated highly pervious material.

The behaviour of B. H. 40 was exactly similar. After puncturing the floor, the water rushed down to elevation 795.5. After the experience of B. H. 41, arrangements for a higher inflow rate had been made. Initially water at the rate of 30-35 g.p.m. was discharged into the stand pipe but in vain. Ultimately clear water from the river was pumped into the stand pipe directly at the rate of 155 g.p.m. to build up a head of 9.76 ft. This gave a permeability

of 1428322 ft./year *i.e.* 1.38 cm./Sec. However, this permeability decreased very rapidly as shown below :—

Depth below the bottom of concrete	Rate of flow in G.P.M.	Head of water	Permeability Cm/Sec.
0	155.13	9.76	1.38
1	13.33	1.59	0.728
2	0.125	12.5	0.00087
3.	1.82	12.5	.013

It was suspected that there was some sub-soil runnel which caused this heavy loss of water just after puncturing the floor. For tracing out this rapid flow of water, florecene dye about 1/2 lbs. in weight was added at about 01-00 hours at night. Downstream surface of water was scanned with a special florecene lamp for about one mile D/S for five hours but no trace of dye was detected. These efforts were given up in the morning. However the possibility of any runnel was ruled out because when the hole was back filled with river sand, the quantity of going into the hole was only 14 cft.

(*ii*) **Confined pressure:**

On puncturing first clay strata the piezometeric readings in both the holes were higher than the readings taken at the time of puncturing the floor. There was no appreciable difference in the pond level. A comparison is given below :

Bore Hole	On Puncturing the Floor		On Puncturing	First Clay Strata
	Pond	Piezo. Readings	Pond	Piezo. Readings
40	806.96	795.5	806.75	800.01
41	805.69	794.58	806.19	798.62

These observations show that there was some confined pressure below the first clay strata in these two bore holes.

14. CONCLUSION

(*i*) Doubts about the erratic behaviour of pressure pipes of pier 35 have been dispelled.

(*ii*) **Area of High Uplift Pressures Lies between Pier Nos. 31 & 40**

In Exhibit VII the actual observed Phi values at the various bore hole. and calculated theoretical Phi values have been shown graphically. The

intersection points of these two graphs show the area of high pressures (above the design) along the length of the Barrage. This area lies between Piers 31 to 40. The highest value is opposite Pier 35 and the high pressures go on decreasing towards Pier 31 & 40.

The high pressures also go on falling towards upstream of the Barrage. Based on the following assumptions *high pressure equipotential lines* are marked on a plan between Pier 31 to 40 and are shown in Exhibit VIII.

Assumption II.—Phi values between Pier 23 & 35 decrease uniformly between points of pressure pipes for which observations are made.

Assumption II.—High pressures also decrease uniformly between Pier 23 & 35.

Assumption III.—The high pressures between Pier 35 & 47 also decrease uniformly for the various points of observations.

(*iii*) **Cause for High Uplift Pressures is higher elevation of clay and low permeability of soil**

(*a*) The area of high pressures lies between Pier 31 and Pier 41. The geologic sections prepared for the various bore holes shows a layer of impermeable material consisting of clay or silty sand. The elevation of uppe r surface of this layer is as below opposite various piers :

Pier No.	Pop Elevation of impermeable material.
31	752
32	747
33	755
34	757
35	758
36	758
37	754
39	759
39 A	758
40	758

From the above data it is evident that there is not enough space between the toe of sheet Pile F-1 at Elevation 760.50 and the type of impermeable material for drainage and release of pressures.

(*a*) The foundation under the downstream floor was densified by vibroflotation method up to Elevation 764.00. These treatments seem to have reduced permeability of the foundation materials. The low permeability is indicated by the results of permeability tests values which are written on the bore hole logs. It is rather strange that for the same type of materials the permeability values are very different. However, there is no doubt that the low permeability of the foundation material is another cause of the built up of high pressures.

15. SUGGESTED REMEDIAL MEASURES

The following remedial measures were considered :

(*i*) A deep upstream cut-off.
(*ii*) Relief wells in the downstream block apron.
(*iii*) Drainage wells in the concrete floor.
(*iv*) Weighting of the concrete floor with mass concrete or dummy piers.
(*v*) A combination of III & IV.

These measures are discussed below :

(*i*) A Deep Upstream Cut-off

This scheme was ruled out for the following reasons :

(*a*) Such a scheme would be very costly and fraught with lot of construction difficulties.
(*b*) The location of the cut-off would be remote from the downstream floor and it would be doubtful whether it would provide effective relief at the downstream end of the floor.

(*ii*) Relief Wells in the Downstream Block Aprons

This scheme was also rejected on the following considerations :

(*a*) The investigations carried out indicate that the cause of high pressures is due to the combined effect of low permeability of foundation strata and restriction of drainage under the downstream sheet piling. There is no drainage restriction under the apron block. As such relief wells in the downstream apron blocks would not be effective in reducing the pressures under the floor.

(*iii*) Drainage Wells in the Concrete Floor :

As the cause of high pressures is low permeability of foundation material and obstruction of drainage under the downstream sheet pile line F-1, drainage through the downstream floor would be really effective.

(*iv*) **Weighting of the Concrete Floor with Mass Concrete or Dummy Piers:**

From the investigations carried out, the magnitude of uplift pressure is known. For counter-acting the high pressures either mass concrete may be laid on the concrete floor with a thickness of 3 ft. to 4 ft. or Dummy Piers may be constructed on the floor with such spacings that the nominal reinforcement in the concrete floor can take up the tensile stresses in the concrete.

16. FINAL APPROVED REMEDIAL MEASURES

The above mentioned remedial measures were discussed at length between the representatives of WAPDA, Irrigation Department and Central Government, Harza Engineering International, Coode & Partners and World Bank Consultants. The finally approved measures are a combination of drainage wells and Dummy Piers. Briefly the scheme is as below :

(*i*) Ten Dummy Piers should be constructed by extending piers from 31 to 40. Eighteen Dummy Piers should be constructed on the downstream floor between the extended piers 22.5′ centres. The thickness of the Dummy Piers would be 7.25'. Provision for future raising of these piers would be made.

(*ii*) The existing lip wall should be raised by 2 ft. between piers 31 to 40 to provide a permanent depth of 3 ft. of water on the floor.

(*iii*) Installing 54 relief wells, six opposite each bay from Pier 31 to 40. The location of the relief wells would be between the last row of deflector blocks.

(*iv*) Extension of the present stone apron from 73′ to 110 ft.

17. EQUIPMENT USED FOR INVESTIGATIONS

The equipment used by the Contractor for carrying out investigations is listed in Appendix 'IV'.

Appendix—I

MARALA BARRAGE

PRESSURE RECORDING PIER—35

Date	Pressure Point No.			1	2	3	4	5	6	7	8	9	10
	Designed Unit Pressure			..	87	81	65	62	51	48	32	21	..
	U/S	D/S	H	Observed Unit Pressure:									
18-5-68 ..	809.18	798.8	10.34	62.8	52.7	48.3	48.3	48.5	41.1	37.0	31.3	23.3	4.0
8-7-68 ..	811.46	802.4	9.04	86.6	80.6	78.8	68.1	64.5	59.0	52.5	42.4	34.1	..
1-8-68 ..	811.50	801.16	8.17	91.0	86.7	85.7	73.4	74.4	65.2	61.2	47.9	39.2	3.1
7-8-68 ..	810.92	802.7	10.34	88.7	83.1	80.7	72.5	72.5	64.5	62.7	48.4	38.7	5.7
7-9-68 ..	811.08	798.17	12.91	95.0	86.9	81.0	64.9	61.9	49.8	48.0	31.9	20.9	5.0
8-9-68 ..	811.08	798.42	12.66	95.0	87.1	80.9	64.9	62.0	57.0	47.9	31.9	21.0	4.9
9-9-68 ..	812.12	798.25	13.87	88.1	80.6	75.1	60.3	57.5	47.2	44.5	29.7	19.5	4.6
10-9-68 ..	811.17	797.83	13.34	94.9	87.0	81.0	64.9	61.9	50.9	47.9	32.0	20.9	5.0
11-9-68 ..	811.08	796.46	14.62	95.0	87.0	80.9	64.9	62.0	51.0	48.0	32.0	20.9	5.0
12-9-68 ..	811.00	797.79	13.21	95.0	86.8	81.0	65.0	61.9	51.0	47.9	32.0	20.9	5.0
13-9-68 ..	811.00	797.75	13.25	97.0	87.0	80.9	65.0	62.0	51.0	48.1	32.0	21.0	4.9
14-9-68 ..	810.71	797.25	13.46	83.8	80.9	76.3	68.2	67.0	59.4	54.8	44.9	37.2	3.1
15-9-68 ..	810.42	798.42	12.00	84.7	81.3	76.7	68.4	67.0	56.6	54.8	45.1	37.1	2.1
16-9-68 ..	810.58	797.82	11.75	91.5	88.0	82.8	74.8	73.9	64.6	63.4	48.9	40.4	2.9
17-9-68 ..	810.17	797.95	12.42	84.0	80.8	76.4	68.8	67.4	59.7	55.3	44.9	37.2	2.3
18-9-68 ..	810.21	797.50	12.71	80.2	77.6	73.2	65.6	64.3	57.4	53.0	42.9	36.0	2.5

19-9-68	..	810.08	797.17	12.91	82.9	80.3	75.8	68.7	67.3	59.8	54.8	37.1	29.4	1.5
20-9-68	..	810.00	797.83	12.17	82.4	79.7	73.6	66.8	65.7	58.2	53.7	43.4	35.6	1.7
21-9-68	..	810.08	797.42	12.66	82.5	79.9	75.3	67.7	66.7	58.8	54.5	44.3	36.8	1.5
22-9-68	..	809.67	796.92	12.75	82.3	79.0	75.1	67.2	66.6	58.4	54.1	44.3	36.8	2.5
23-9-68	..	809.67	797.42	12.25	82.2	79.5	74.7	66.9	66.9	58.4	54.3	44.8	37.0	2.4
24-9-68	..	809.21	797.33	11.88	81.7	79.2	75.0	67.3	66.6	58.2	54.3	44.1	36.5	2.1
25-9-68	..	809.12	797.33	11.79	81.6	79.2	74.9	67.5	66.4	58.6	54.4	44.5	37.1	2.1
26-9-68	..	809.17	796.75	12.42	81.1	79.4	74.4	67.3	66.4	58.3	54.3	44.6	36.8	2.6
27-9-68	..	809.04	796.11	12.93	77.6	76.6	70.8	63.4	62.1	62.7	51.1	41.8	34.1	1.6
28-9-68	..	809.12	796.08	13.04	85.0	97.1	75.4	66.7	66.4	58.5	53.9	44.0	36.1	0.6
29-9-68	..	809.12	795.17	14.95	79.3	91.3	70.5	63.2	62.4	54.8	50.7	41.4	34.5	2.2
30-9-68	..	809.21	795.08	14.13	85.5	97.5	75.5	67.8	66.9	59.0	54.5	44.8	37.1	2.6
12-10-68	..	808.33	792.58	15.75	88.4	94.2	74.6	67.2	66.1	58.7	55.0	45.6	37.6	2.7
13-10-68	..	808.12	792.58	15.54	90.6	100.3	75.6	67.5	66.5	59.1	54.7	45.6	37.5	2.7
14-10-68	..	808.08	792.58	15.50	89.8	99.3	75.3	67.5	66.7	59.1	54.8	45.1	37.6	2.6
12-11-68	..	806.67	792.42	14.25	93.8	99.0	73.5	66.6	66.0	58.1	54.8	45.5	38.2	2.8
13-11-68	..	806.50	792.33	14.47	94.4	99.7	73.7	66.4	66.4	59.1	55.3	45.8	38.5	2.9
14-11-68	..	806.42	792.33	14.09	94.6	100.0	74.8	67.4	66.2	59.2	55.0	42.5	38.4	2.7
25-12-68	..	805.33	795.67	9.66	96.6	99.2	71.5	63.8	62.1	56.9	53.4	45.7	37.9	2.6
26-12-68	..	805.25	795.32	9.93	96.6	99.2	69.8	61.4	60.5	56.4	52.9	44.6	38.0	3.5
27-12-68	..	805.08	795.67	9.41	99.2	100.0	71.7	62.6	61.1	56.7	52.2	45.7	37.2	0.9

Appendix II

MARALA BARRAGE

DOWNSTREAM SUB-SOIL INVESTIGATION COMPARISON OF QUOTATIONS SCHEME

Item No.	Description	Unit	Approx : Qty:	I. V. C. C.		Kellers	
				Rate Rs.	Approx: Cost Rs.	Rate	Approx: Cost Rs.
1.	Mobilisation charges including bringing plant and equipment to site, access, temporary works, staging and utilities.	Sum	..	..	312,000		2,45,000
2.	Boring in downstream floor concrete including concrete grouting of boreholes.	Lin. ft. of depth	98	128	*12,544	310	30,380
3.	Boaring in sub-soil including all necessary casing; continuous sampling, moving rig from one location to another; back-filling; and provision of preliminary reports.	do.	633	75	47,475	150	94,950
4.	Undisturbed sample, if required	each	Rate only	58	Rate only	Not quoted	
5.	Constant head permeability	each	110	116	12,760	280	30,800
6.	Piezomatic water level recordings	each	110	53	5,830	260	28,600
7.	Particle size analysis	each	110	24	2,640	60	6,600
8.	Final reports	each	12	375	4,500	800	9,600
9.	Clearing of site and removal of plant and equipment.	Sum	..	...	50,625	..	51,000
10.	Provision and installation of Piezometer	Prov. sum	..	..	75,000	..	75,000
		Total approx. cost Rs.			5,23,374		5,71,930

*Corrected

MARALA BARRAGE

DATA OF SITE INVESTIGATIONS 1970

Bore Hole	Drilling Started		Puncturing of Floor		Observed Phi values for various bore holes at different points														
					Piezomentric Lievel														
					Below Floor				At R. L. 760				First Clay Lense				On Top 2nd Clay		
	Date	Time	Date	Time	R. L.	U/S W. L.	D/S W. L.	ϕ	R. L.	U/S W. L.	D/S W. L.	ϕ	R. L.	U/S W. L.	D/S W. L.	ϕ	R. L.	U/S/ W. L.	D
43	12-2-70	14-30	14-2-70	16-25	796.00	805.43	792.71	18.1	795.00	805.54	792.67	18.1	795.47	806.67	792.75	20.0	796.83	805.58	79
35	20-2-70	12-30	20-2-70	18-15	799.62	805.25	792.67	55.2	799.84	805.67	792.75	54.9	799.84	805.67	792.75	54.9	799.60	805.46	79
39	4-3-70	01-45	4-3-70	09-20	798.04	806.00	793.08	38.4	797.88	805.96	792.88	38.4	797.88	805.96	792.88	38.2	797.63	805.85	79
33	4-3-70	21-00	5-3-70	10-00	798.83	806.00	793.08	44.5	798.86	805.96	792.95	45.4	798.94	805.85	792.98	46.3	798.17	805.69	79
41	9-3-70	13-30	9-3-70	19-10	794.58	805.69	792.96	12.7	795.65	805.71	792.82	22.0	795.64	805.83	792.92	21.1	798.62	806.19	79
31	11-3-70	10-45	11-3-70	14-15	796.07	806.20	792.94	22.7	796.20	806.30	793.40	21.8	Not	Observed			799.53	807.85	79
37	19-3-70	16-30	20-3-70	08-45	800.22	806.50	793.60	51.3	800.21	806.45	793.46	52.0	Not	Encountered			801.19	806.63	79
29	20-3-70	14-00	20-3-70	18-00	795.71	806.63	793.62	16.0	795.59	806.63	793.62	15.1	Not	Encountered			796.09	806.63	79
32	25-3-70	18-45	25-3-70	09-30	798.24	806.69	794.25	32.1	798.54	806.70	794.95	30.5	Not	Observed			797.39	806.54	79
40	26-3-70	09-30	26-3-70	11-00	795.50	806.83	793.75	13.4	797.84	806.83	794.67	26.1	Not	Observed			800.01	806.63	79
26	2-4-70	13-00	2-4-70	18-45	795.75	806.48	793.83	15.0	795.84	806.79	794.00	14.0	Not	Encounte;ed			796.25	807.33	79
36	3-4-70	17-30	4-4-70	09-50	800.75	806.63	793.77	54.0	801.02	806.92	794.04	54.0	Not	Observed			801.56	807.04	79
39A	10-4-70	15-30	11-4-70	11-45	799.57	808.00	795.42	33.0	799.52	808.04	795.92	29.7	801.21	808.00	796.00	43.4	Not	Apploached	
34	11-4-70	19-10	12-4-70	09-40	801.60	807.90	794.92	51.0	801.93	808.25	795.75	49.0	801.27	808.17	795.58	45.0	801.09	807.95	79

Observed Phi values for various bore holes at different points

Floor		Piezomentric Lievel																First Clay Lense		2nd Clay lense		Drilling Completed		TH: ϕ
		At R. L. 760				First Clay Lense				On Top 2nd Clay Lense				On Back Filling				Top R. L.	Bot. R. L.	Top R. L.	Bot. R. L.	Date	Time	
L. D/S W. L.	ϕ	R. L.	U/S W. L.	D/S W. L.	ϕ	R. L.	U/S W. L.	D/S W. L.	ϕ	R. L.	U/S/ W. L.	D/S W.L.	ϕ	R. L.	U/S W. L.	D/S W. L.	ϕ							
792.71	18.1	795.00	805.54	792.67	18.1	795.47	806.67	792.75	20.0	796.83	805.58	792.85	31.2	Not	Observed			762.43	753.93	748.00	738.00	24-2-70	20-45	24.0
792.67	55.2	799.84	805.67	792.75	54.9	799.84	805.67	792.75	54.9	799.60	805.46	792.83	53.6	799.70	705.48	792.75	54.6	756.06	754.25	742.06	732.05	25-2-70	24-00	24.0
793.08	38.4	797.88	805.96	792.88	38.4	797.88	805.96	792.88	38.2	797.63	805.85	792.98	36.1	Not	Observed			760.00	755.17	748.25	738.00	7-3-70	19-30	24.0
793.08	44.5	798.86	805.96	792.95	45.4	798.94	805.85	792.98	46.3	798.17	805.69	792.96	41.0	Not	Observed			758.25	754.75	734.57	724.57	10-3-70	01-45	25.0
792.96	12.7	795.65	805.71	792.82	22.0	795.64	805.83	792.92	21.1	798.62	806.19	793.31	41.2	794.78	806.20	793.30	11.5	759.08	754.00	748.71	738.71	11-3-70	17-00	24.0
792.94	22.7	796.20	806.30	793.40	21.8	Not	Observed			799.53	807.85	796.25	28.2	799.26	807.69	795.42	31.3	751.84	751.76	746.58	736.58	16-3-70	07-30	26.0
793.60	51.3	800.21	806.45	793.46	52.0	Not	Encountered			801.19	806.63	793.62	58.2	Not	Observed			Not Encountered		747.92	737.92	22-3-70	16-00	24.0
793.62	16.0	795.59	806.63	793.62	15.1	Not	Encountered			796.09	806.63	793.65	18.8	Not	Observed			Not Encountered		745.79	735.80	24-3-70	01-10	26.0
794.25	32.1	798.54	806.70	794.95	30.5	Not	Observed			797.39	806.54	793.53	29.6	Not	Observed			746.43	745.78	744.96	734.95	29-3-70	22-30	26.0
793.75	13.4	797.84	806.83	794.67	26.1	Not	Observed			800.01	806.63	795.08	42.7	795.24	806.60	793.60	11.8	758.00	754.58	731.75	721.75	30-3-70	18-15	24.0
793.83	15.0	795.84	806.79	794.00	14.0	Not	Encountered			796.25	807.33	794.27	17.0	Not	Observed			Not Encountered		747.29	737.29	5-4-70	22-00	27.0
793.77	54.0	801.02	806.92	794.04	54.0	Not	Observed			801.56	807.04	794.25	57.0	Not	Observed			757.79	753.79	744.29	734.96	6-4-70	13-00	24.0
795.42	33.0	799.52	808.04	795.92	29.7	801.21	808.00	796.00	43.4	Not	Apploached			Not	Observed			758.94	754.77	Not Approached		13-4-70	11-30	24.0
794.92	51.0	801.93	808.25	795.75	49.0	801.27	808.17	795.58	45.0	801.09	807.95	794.94	47.3	Not	Observed			756.64	755.30	734.22	723.80	19-4-70	09-15	24.5

Appendix IV.

EQUIPMENT USED

The following equipment was used by I.V.C.C. for carrying out drilling work under contract 326.

1.	Cralius Rotary Drill XCH-90 (with accessories like slip, chain wrenches etc.)	.. One No.
2.	Cralius Rotary Drill AB-50G (with accessories like slip, chain wrenches etc.)	.. One No.
3.	Drilling platform (locally manufactured)	.. Two No
4.	Cralius water pump (Suction 2" Delivery 1½") 15 g.p.m.	One No.
5.	Boyle's water pump (Diesel Engine-driven) 12 g.p.m.	.. One No.
6.	Beco Centrifugal pump (Suction 4" Delivery 3") 350gmp	One No.
7.	Duplex pump (Worthington Simpson) 12 g.p.m.	.. Two No.
8.	Consolidated Pneumatic Sump Pump (Centrifugal Delivery 2½").	.. Two No.
9.	Consolidated Pneumatic Sump (Delivery 2½")	.. One No.
10.	Air Compressor (G. M. 600 c. f.m.)	.. One No.
11.	Derricks (Cralius, accessory with drill rig)	.. Two No.
12.	Caissons (Size 5'-7½" dia, 6' high locally manufactured	Two No.
13.	Extension pieces for Caissons (3 feet high locally made)	Two No.
14.	Extra weight pieces for Caissons (6'-7½" dia, 2½ feet high.)	.. Two No.
15.	Standard Penetration Test apparatus complete locally made).	.. Two No.
16.	Core barrels with (116 m.m. 98 mm & 86 mm) diamond bits.	.. Two No.
17.	(*a*) Drill rods—(50 m.m. size in 10', 5' and 2½' lengths	250 Feet.
	(*b*) Casing pipes—114, 96 m.m. sizes	.. 250 Feet.
18.	Split Spoon samplers 2" and 3" size	.. 12 No.
19.	Boilers (2¾" & 3½" size)	.. Two of each size.
20.	Chisels (2¾" & 3½" size)	.. Two of each size.
21.	Pipe Triphod (for lifting caissons)	.. Two No.
22.	Pneumatic chipping hammer	.. Six No.
23.	Steel Picks (Chisels and points)	.. Five Dozen.

24.	Welding set with accessories (Diesel driven) 400 Amps		One No.
25.	Transformer with accessories (for welding set) 400 Amps. 220/440.	..	One No.
26.	Floodlights (complete with cables and stands etc.)	..	7 No.
27.	(Oxyacetylene) Cylinders & accessories	..	One No.
28.	Electric lighting set (Generator) 3.5 KV.	..	One set.
29.	Water tanks capacity varying from 40-200 gallons (with steel staging).	..	15 No.
30.	Water Meters	..	3 No.
31.	Gallon measures (1, $\frac{1}{2}$, $7\frac{1}{4}$ gallon : capacity, for permeability tests).	..	12 No.
32.	Steel rails complete with ties, fish plates, wooden blocks etc.	..	24 No.
33.	(*a*) G.I. Pipes 2″ size for pipe scaffolding for gangway		3500 ft.
	(*b*) G.I. pipes (for compressed air feed lines)	..	1500 feet.
34.	Flexible hoses (for compressed air lines)	..	1000 feet.
35.	Ladders (*a*) of Rope	..	2 No.
	(*b*) of Bamboo and wood	..	6 No.
	(*c*) of Steel	..	6 No.
36.	Manila Rope	..	1000 feet.
37.	Boats with crew (*a*) Large	..	3 No.
	(*b*) Small	..	2 No.
38.	Measuring tapes (*a*) Steel (with bell sounding attachment) for checking water level.	..	2 No.
	(*b*) Metallic	..	2 No.
	(*c*) Small 8′ & 6′ sizes	..	12 No.
39.	Stop-watches for permeability tests	..	2 No.
40.	Torches ordinary	..	2 No.
41.	Violet light torch (for detecting flourescene colour	..	One No.
40.	Torches ordinary	..	2 No.

(SUPPLIED BY HARZA INTERNATIONAL)

42.	Vehicles (*a*) Jeepster, (*b*) Land Rover } of Contractor only)	..	One No.
43.	Chain Pulley blocks	..	One No.
44.	Misc. workshop tools for field job	..	Two
45.	Wooden Planks for gangway	..	

CROSS SECTION OF BARRAGE—STANDARD OPENING

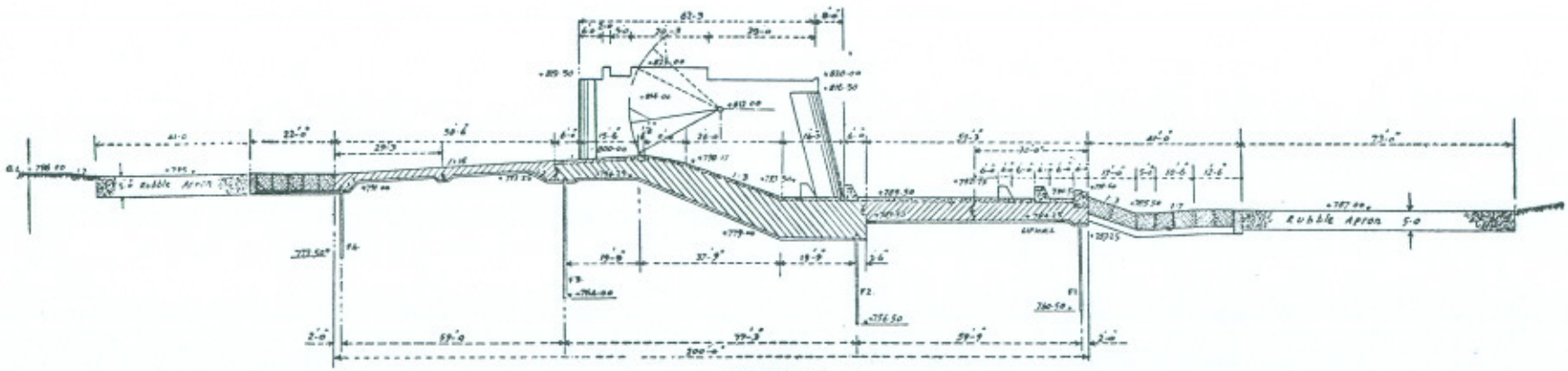
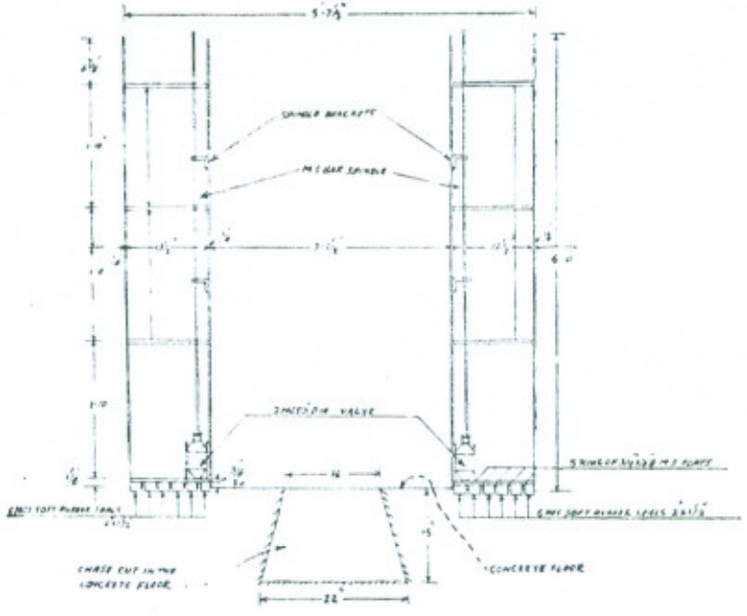


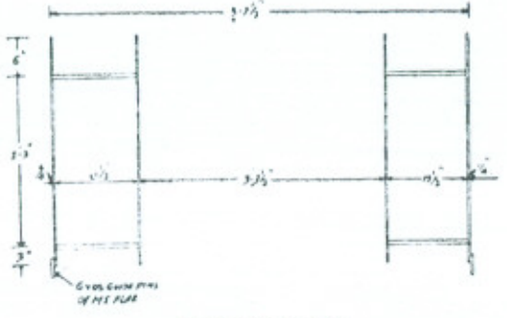
EXHIBIT (I)

MARALA BARRAGE UP-LIFT PRESSURE INVESTIGATIONS DOWNSTREAM FLOOR SKETCH SHOWING THE PROPOSED CAISSON

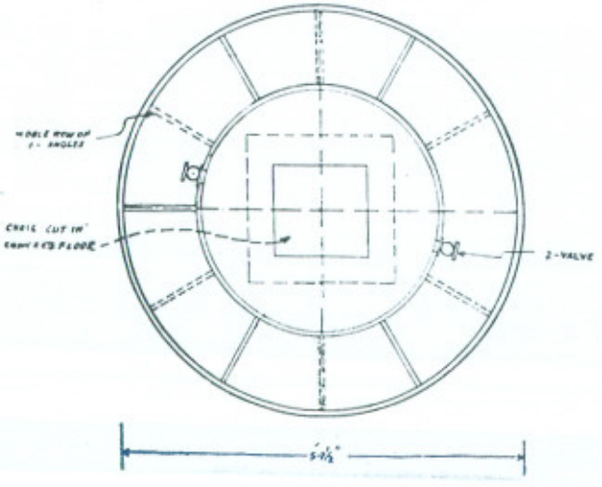
(Scale 1"=1')



SECTION



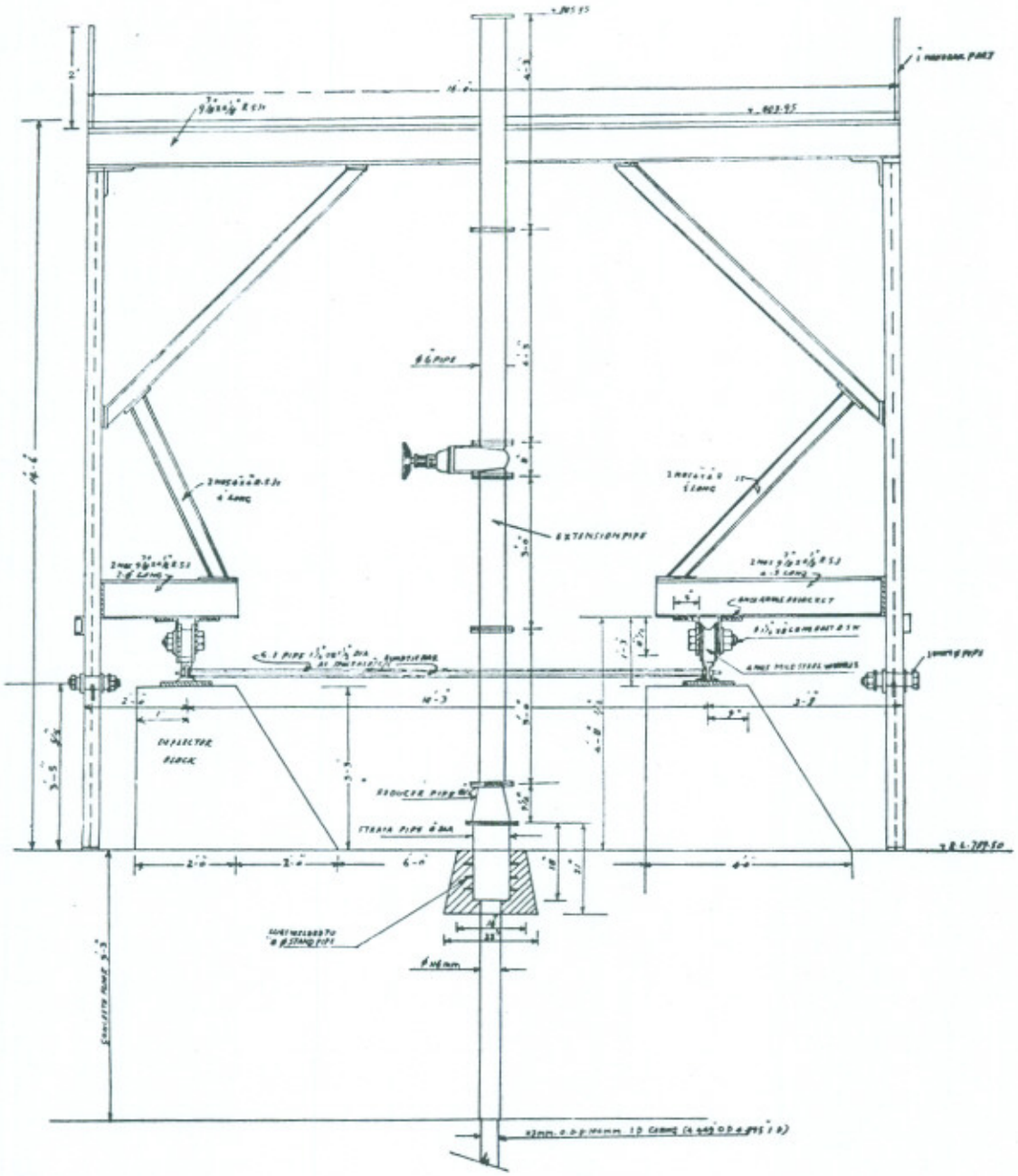
EXTENSION PIECE



	PARTICULARS	0 FEET HIGH	3 FEET HIGH	WEIGHT BUT
1	WEIGHT OF CAISSON LBS	3308		571
2	DISPLACEMENT PER FOOT			
	i) WHEN NOT IN USE L B S	1027.25		-
	ii) WHEN IN USE LB S	1553		-
3	WEIGHT OF WATER PER F			
	IN ANNULAR SPACE L B S	368.38		1602

MARALA BARRAGE UP-LIFT PRESSURE INVESTIGATIONS DOWNSTREAM FLOOR SKETCH SHOWING THE DRILLING PLATFROM

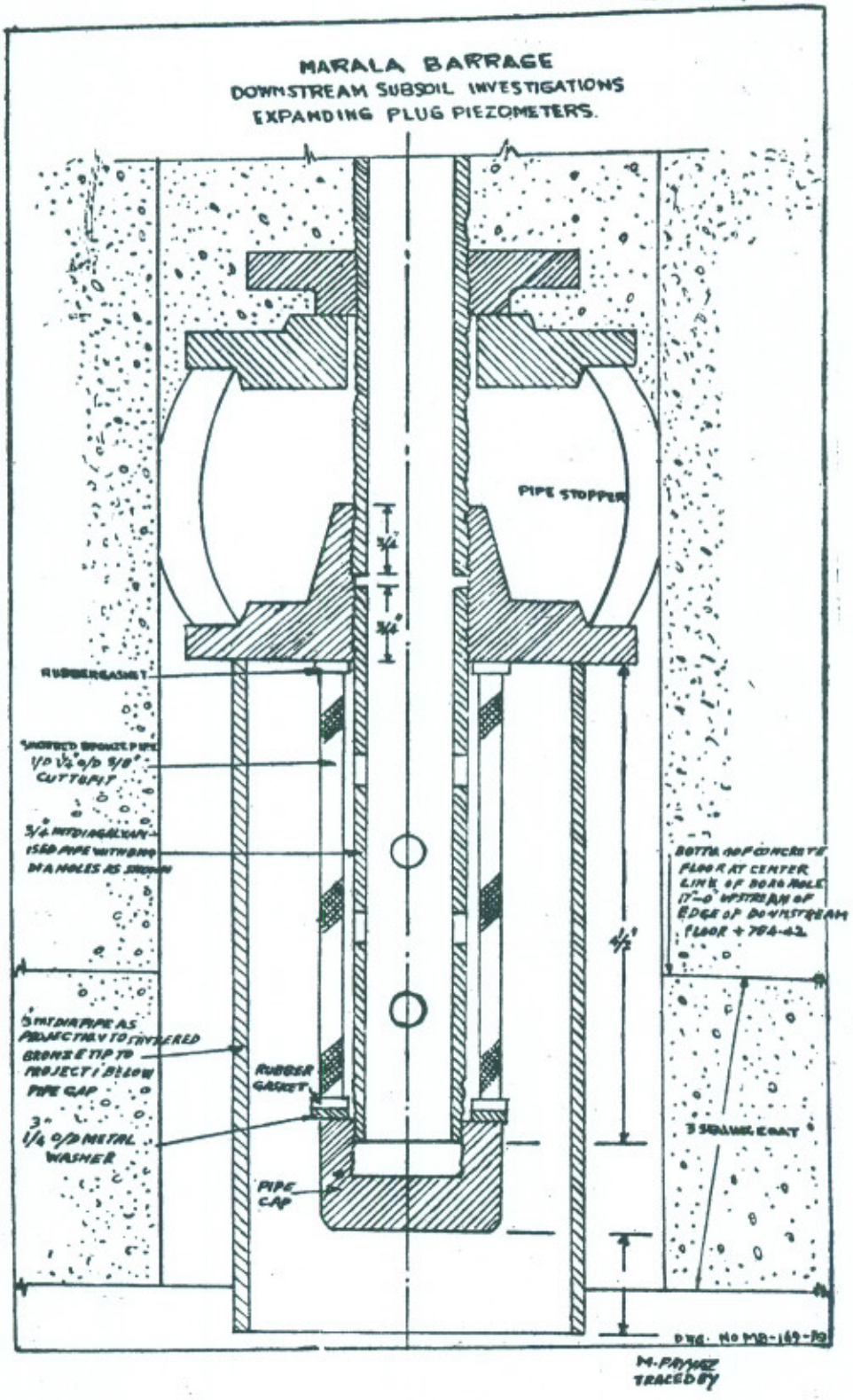
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SIDE ELEVATION

EXHIBIT (II)

EXHIBIT (IV)


MARALA BARRAGE
DOWNSTREAM SUBSOIL INVESTIGATIONS
EXPANDING PLUG PIEZOMETERS.
PIPE STOPPER
¾"
¾"
RUBBER GASKET
WELDED BRONZE PIPE
1/D ½" o/D 5/8"
CUTTO FIT
¾" DIA GALVANIZED
I.S.O. PIPE WITH 8MM
DIA HOLES AS SHOWN
BOTTOM OF CONCRETE
FLOOR AT CENTER
LINE OF DAM ABOUT
17'-0" UPSTREAM OF
EDGE OF DOWNSTREAM
FLOOR + 784-42
4½'
3" DIA PIPE AS
ABOVE CUT TO TAPERED
BRONZE TIP TO
PROJECT 1" BELOW
PIPE CAP
3"
¼" O/D METAL
WASHER
RUBBER
GASKET
PIPE
CAP
DWG. NO MR-169-P9
M. PAYNE
TRACED BY

MARALA BARRAGE DOWNSTREAM SUB-SOIL INVESTIGATIONS

EXHIBIT X

LOCATION PLAN OF BOREHOLES

FIG 1 - PART PLAN OF BARRAGE SHOWING LOCATION OF BORE HOLES

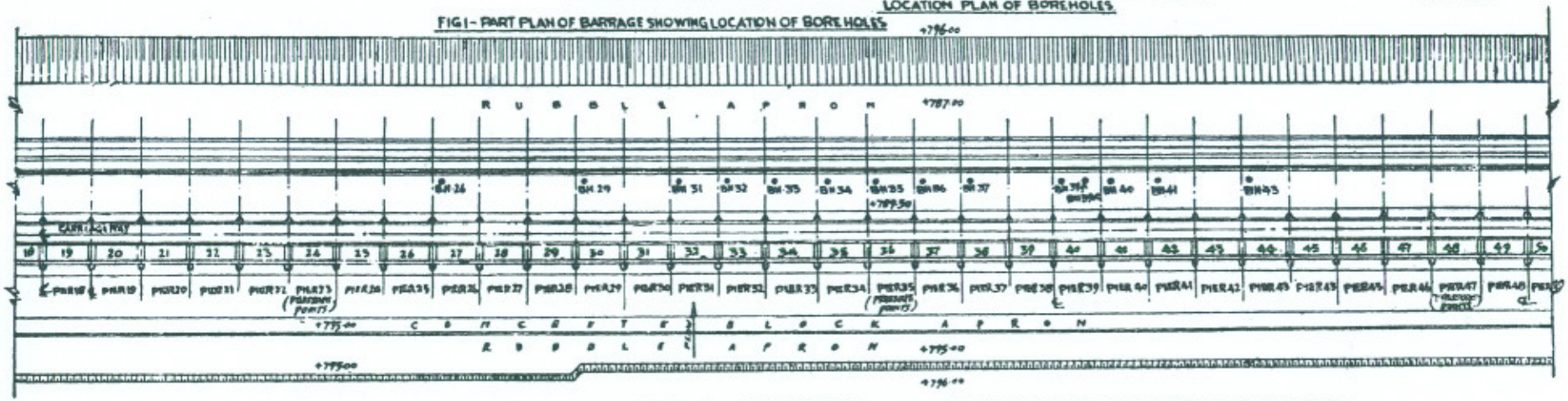


FIG 2 - PLAN OF A BARRAGE BAY SHOWING LOCATION OF BOREHOLE

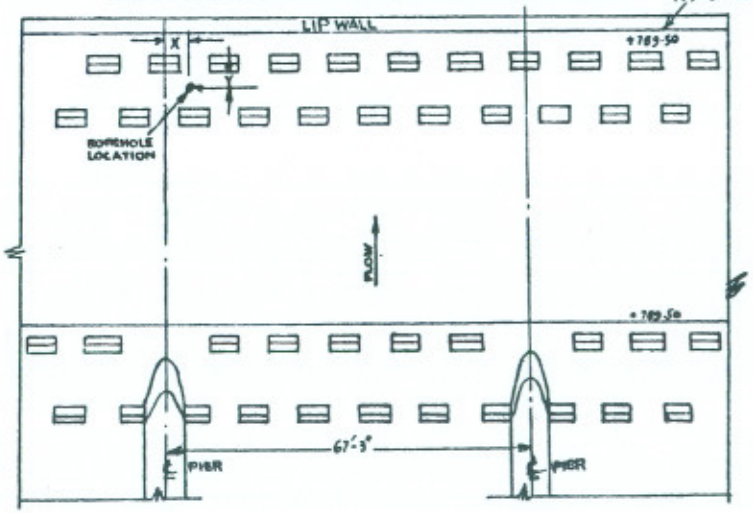
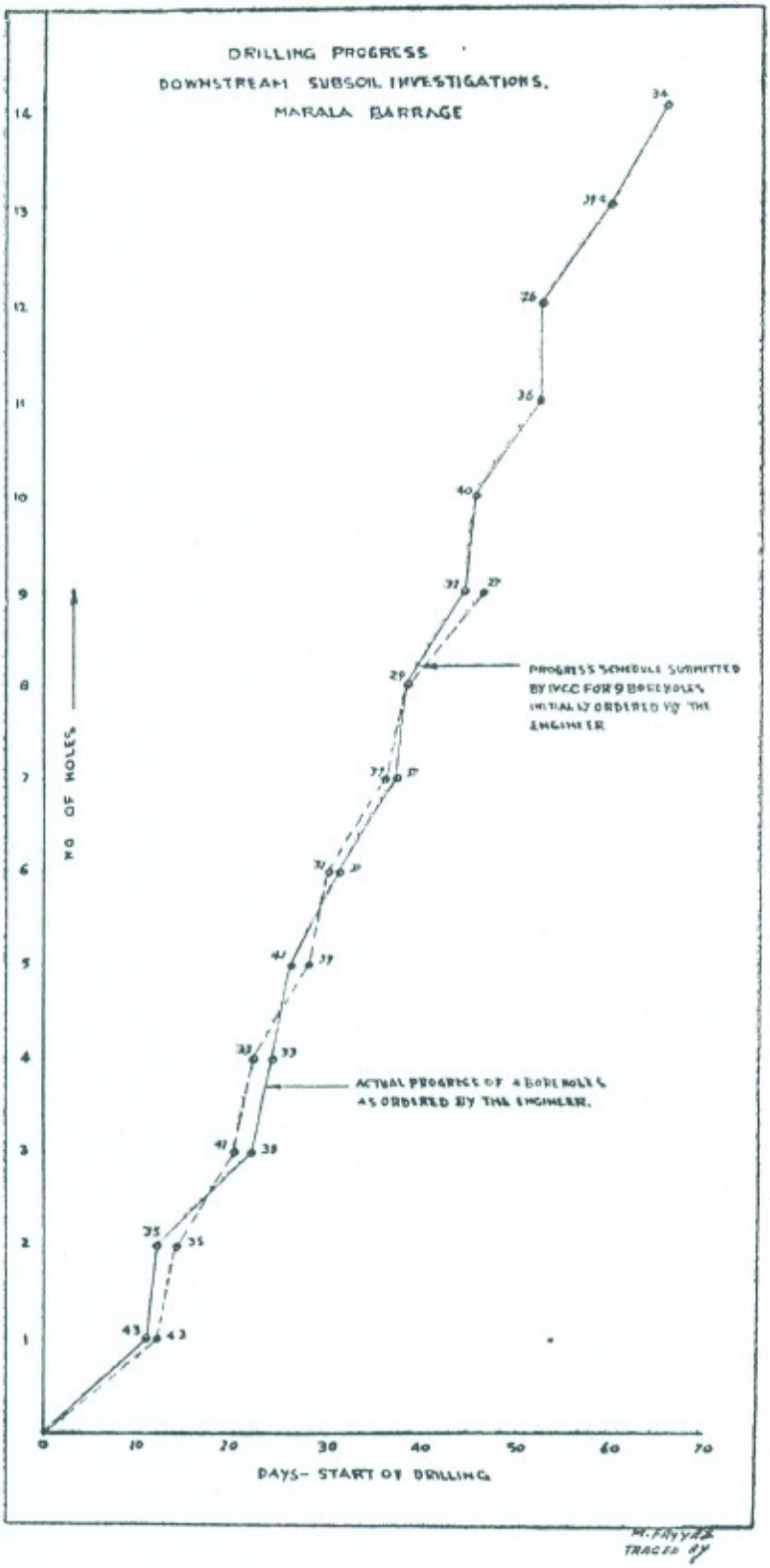


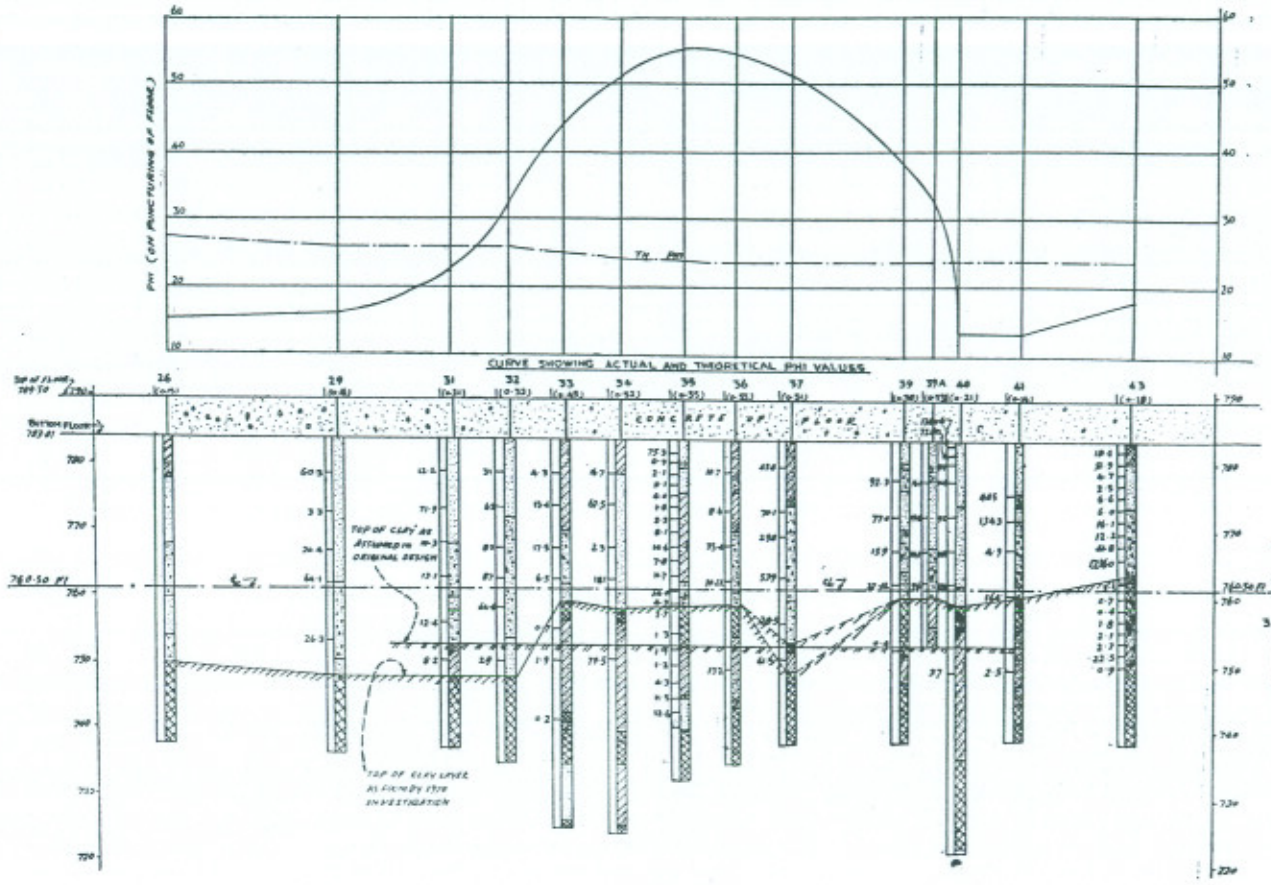
FIG 3 - TABLE OF X AND Y DIMENSIONS IN RELATION TO FIG 2

BORE HOLE NO	DISTANCE X FROM ℄ OF PIER	DISTANCE Y FROM S/S EDGE OF S/S BLOCK
BH 43	4'-7"	2'-6"
BH 41	4'-6"	2'-10½"
BH 40	4'-2"	1'-11½"
BH 39A	38'-7½"	3'-2"
BH 39	4'-11"	2'-9½"
BH 37	3'-0"	2'-7"
BH 36	5'-6"	1'-10"
BH 35	10'-4"	3'-1½"
BH 34	4'-3"	3'-0"
BH 33	4'-9"	2'-11½"
BH 32	4'-10"	2'-7¼"
BH 31	4'-11"	2'-0"
BH 29	4'-4"	3'-½"
BH 26	5'-1"	2'-9¼"

EXHIBIT VI


DRILLING PROGRESS
DOWNSTREAM SUBSOIL INVESTIGATIONS.
MARALA BARRAGE
NO OF HOLES
DAYS- START OF DRILLING
PROGRESS SCHEDULE SUBMITTED BY IWCC FOR 9 BOREHOLES INITIALLY ORDERED BY THE ENGINEER
ACTUAL PROGRESS OF 9 BOREHOLES AS ORDERED BY THE ENGINEER.
TRACED BY

MARRLA BARRAGE SOIL PROFILE BORE HOLE LOGS



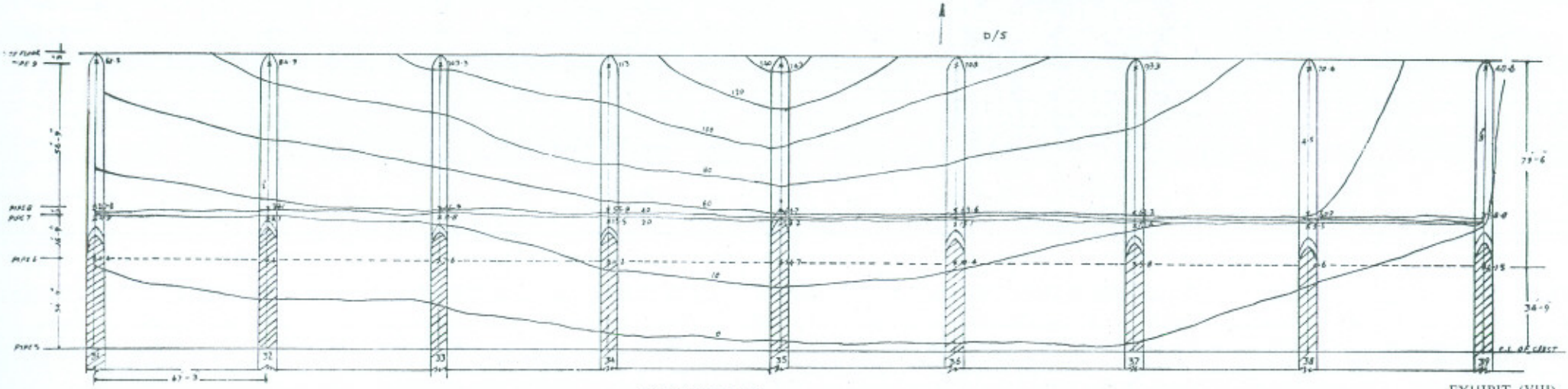
SOIL PROFILE

Scale: H=1"–80'
V=1"–20'

EXHIBIT (VII)

MARALA BARRAGE CIRCLE PROPOSAL FOR WEIGHTING D/S FLOOR TO RESIST UP LIFT PRESSURES

Scale 1/20=1



STANDARD BAYS

EXHIBIT (VIII)