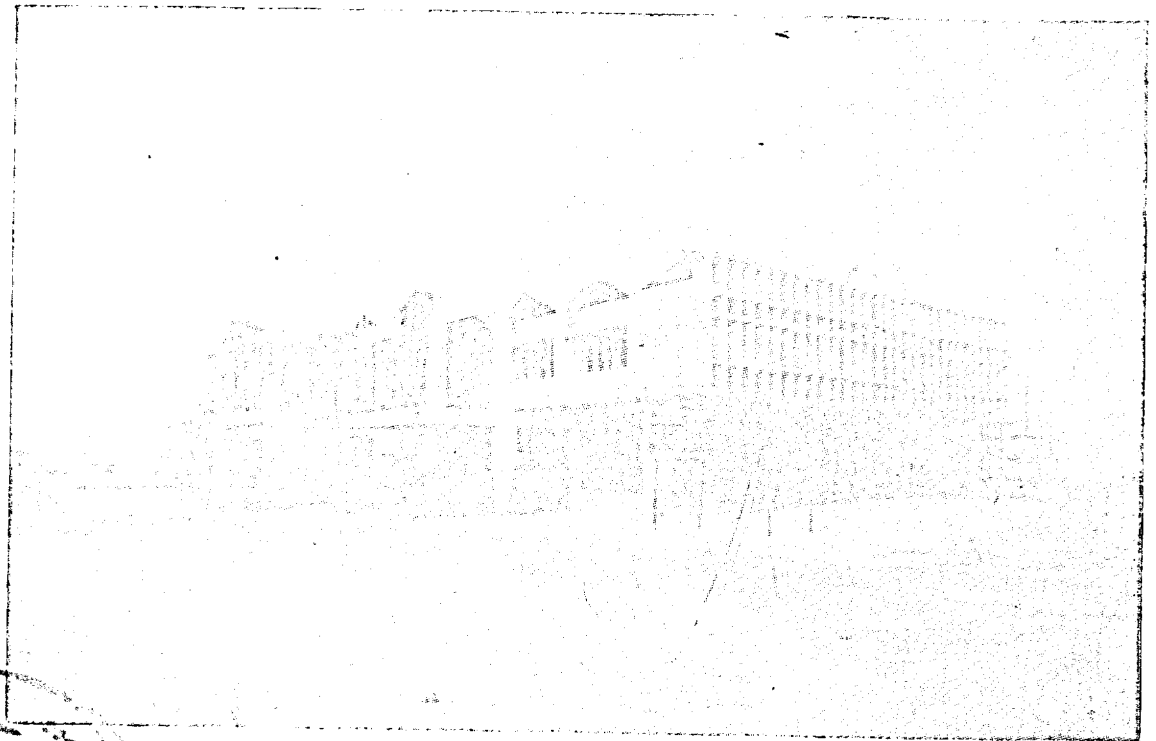
The NEW IRRIGATION ERA

VOLUME XII AUGUST 1971 ISSUE 2

COOUM IMPROVEMENTS SCHEME—R. C. C. JETTY WORK IN PROGRESS.



Cooum Improvements Scheme—Boat House Under Construction.

Cooum Improvements Scheme—R.C.C. JETTY. at Cooum Mouth
Reinforcement Being Tied for Monolith Well No. 2.

THE NEW IRRIGATION ERA

Published by the Irrigation Branch of the Public Works Department, Madras-5, South India.

(For departmental circulation only)

Vol. XII | AUGUST 1971 | No. 2

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ROLE OF CEMENT CONCRETE IN THE CONSTRUCTION OF HIGH MASONRY DAM—

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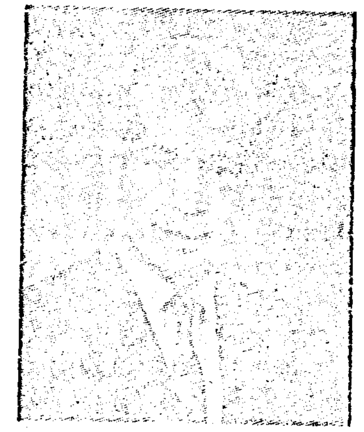
Irrigation Chief Retires.

Thiru. J. E. Vaz had his early education at St. Aloysius College, Mangalore and later at the College of Engineering Guindy, graduating in Mechanical Engineering in 1938. After practical training in the Golden Rock workshops at Tiruchy, he worked for some time in Coimbatore District Board. In 1940 he was directly recruited as Assistant Engineer in the Public Works Department. During the Second World War, he opted for military service as a Commissioned Officer in the corps of Engineers. He was in active service including a year of overseas service spent in Burma. After the close of the War, Thiru J. E. Vaz rejoined the P.W.D. as Executive Engineer. He was deputed to the United States of America for inspection of important Irrigation and Power projects with a view to get specialised knowledge in the use of construction plant and machinery. He was responsible for the design and execution of the Malampuzha canal system, and various appurtenent works in that system. In 1954 he headed the Public Works Workshop and Stores as Superintending Engineer. During this period he was responsible for the design and manufacture of high head gates and different types of crest gates which in the previous years were imported from abroad. From 1958 to 1961 Thiru Vaz on deputation to the Central Water and Power Commission, New Delhi as Director of Plant and Machinery. On his return to Madras, for a short while he worked as Superintending Engineer, Parambikulam-Aliyar Project canals system; then he joined the Tamil Nadu State Transport Department as head of the Engineering Branch. During his stay in the Transport Department, rapid strides were made in the field of body building as well as creation of maintenance workshops and terminal stations. In February 1967 Thiru J. E. Vaz took over as Chief Engineer for Irrigation. He was also in charge of the General portfolio from June 1970 till 31st December 1970, the date of retirement. As Chief Engineer for Irrigation, he was mainly responsible for strengthening the Grand Anicut Canal and for the successful implementation of the double cropping programme in Thanjavur delta. During his tenure of office, a large number of investigation Divisions were created with a view to give relief to the unemployed technical personnel. During his long service of over thirty years, Thiru Vaz had wide and varied practical experience covering all sections of Civil and Mechanical works. He was an engineer with sound practical knowledge and could handle with ease and confidence any river valley project. Above all he was simple, direct and practical in his approach and that is how he has stolen the love and respect of other engineers.



THIRU. J. E. VAZ B.E., M.I.E.,

With such a distinguished record of service for the last 30 years, he retired in December 1970 at the age of 55. We wish him long life and happiness in his retirement.

Role of Cement Concrete in The Construction of High Masonry Dam.

BY

Sri Bh. SURYANARAYANA RAJU,* B.E., M.E., A.M.I.E. (I).,

(SYNOPSIS :—In this paper, the versatality and the value of cement concrete in construction of a high masonry dam like Nagarjunasagar Dam are brought out. Though 124.7 metres, (409 feet) high dam was decided to be constructed in stone masonry, plain and reinforced cement concrete was used inevitably at important locations. The importance and necessity of using concrete at those locations has been brought forth in this paper. It cannot be gainsaid that cement concrete has its pride of place as a modern construction material and it cannot be replaced very easily. [The paper is suitably illustrated.]

1.0. Nagarjunasagar Dam is a straight gravity, stone masonry dam of 124.7 metres (409 feet) maximum height. In the construction of this dam 11.38 lakh tonnes (11.2 lakh of tons) of cement was used to build 4.89 million cubic metres (172.7 million cft.) of masonry and 0.76 million cubic metres (27 million cft.) of concrete. Though concrete forms about 13.5 per cent of cubic contents of the dam, it has to be realised that plain and reinforced concrete has been used in all important locations, mainly :

1. Foundations,
2. Contraction joints.
3. Around openings in the body of the dam (i.e., around sluices, galleries, etc.).
4. Trash rack structures,
5. Spillway crest, its rear-face and bucket,
6. Spillway piers and bridge, and for
7. Architectural features (parapets, lamp posts, entrances to galleries, etc.). This is to quote a few.

2.0. The importance of cement concrete cannot be stressed too strongly. It is a construction material which comes in handy to the Civil Engineer, where difficult problems are to be dealt, with success and confidence. Foundations of Nagarjunasagar Dam are very good in general but there were a few locations which proved difficult and needed special treatment. 1449 metres (4,756 feet) long main dam was divided into 79 blocks of varying lengths ranging from 9.14 m. to 21.34 m. (30 feet to 70 feet).

2.1. Treatment of foundations :—Concrete plain and reinforced came in handy for treatment of foundations. Due to steep abutments, foundations of blocks 6 and 70 are having steep slopes of about 5 vertical to 1 horizontal on the sides adjacent to blocks 5 and 70 A respectively. It was necessary to provide cement concrete 1.52 m (5 feet) thick covering the sloping foundations effecting good bond and bearing with the rock surface and also to improve water tightness. Cement concrete 1:5.62 (1 cement and 5.62 combined aggregate) mix with 38 mm (1½ inches) maximum size aggregate with a 28 days compressive strength of 210.9 kgs/sq. cm (3000 lbs/sq. inch) was used .38 mm (1½ inches) dia. dowels at 1.52 m (5 feet) centre to centre (staggered) were provided for the exposed sloping foundation to develop bond. Further the contact planes between concrete and the sloping rock face and the upstream excavated face were grouted.

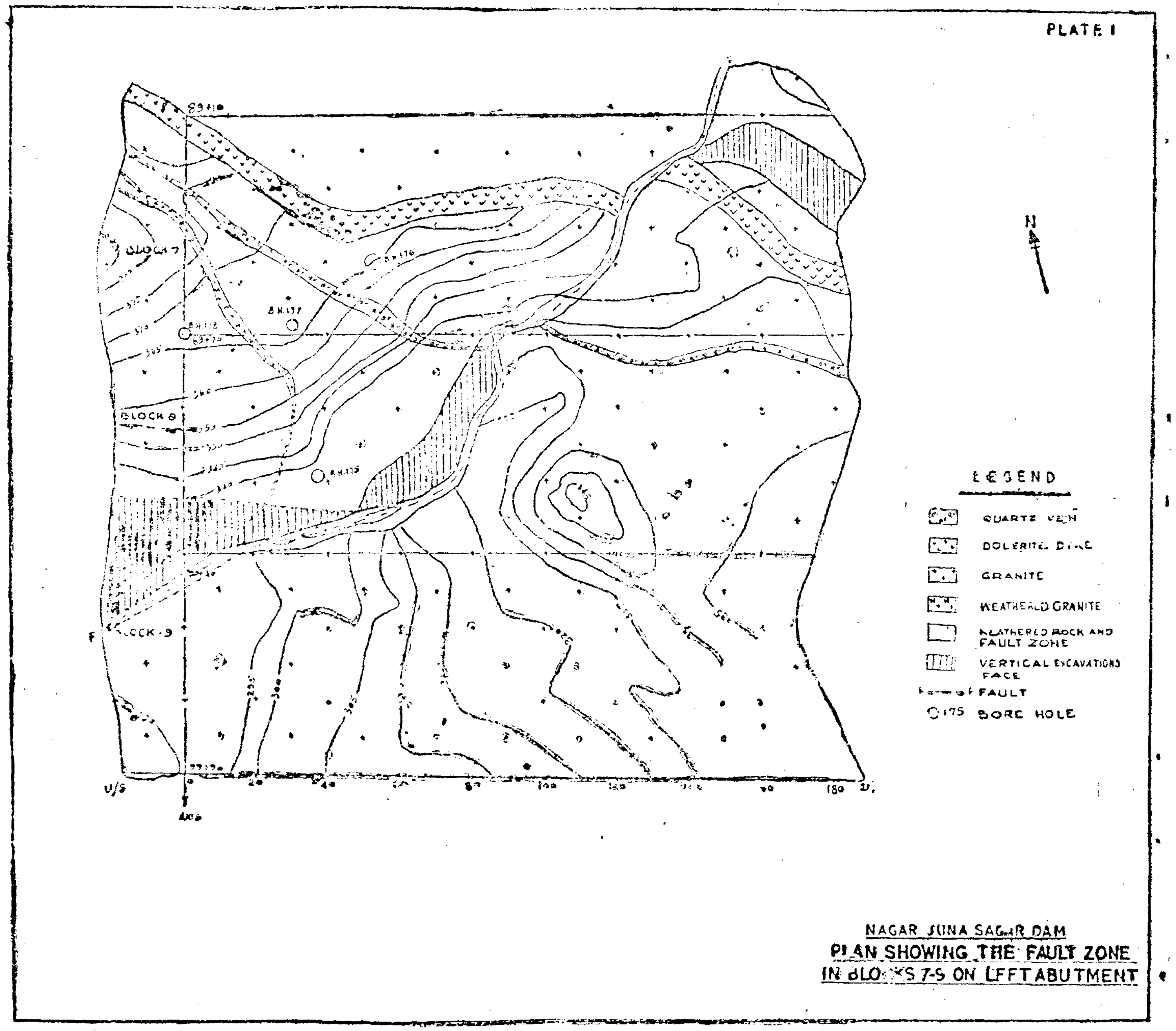
2.2. Fault zone in blocks 7, 8 and 9 :—Please refer plate 1. This was detected during final excavation as a wide soft zone dipping towards the upstream below a mound of fresh granite. This was established after extensive borings were drilled. This consisted of highly weathered and crushed granite varying in thickness from 1.22 m to 4.88 m (4 feet to 16 feet). For treating this area, in order to make it fit to take the enormous load transmitted by the dam it was filled with concrete. The method consisted of the following :

(1) The fault zone was excavated inside by removing weathered and soft material. The zone below was thoroughly grouted.

(2) The excavated trench was back filled with cement concrete 1:4.99 mix with 19 mm maximum size (¾") aggregate and strength of 210.9 kgs/sq. cm (3000 p.s.i.).

2.3. Dolorite dyke in blocks 18 to 23 :—This fault zone cuts across the dam foundations from the upstream end of block 18 to downstream end of block 23. The width of this dyke zone at the axis of the dam was 0.91 m to 1.22 m (3 ft. to 4 ft.) which attained a width of 1.83 m to 2.44 m (6 ft. to 8 ft.) near the downstream toe of

* Deputy Chief Engineer, Technical and Designs, Nagarjunasagar Dam Unit.



blocks 22 and 23. Here again the foundation was suitably treated and made fit to receive the high bearing pressures of the dam. Treatment with concrete as detailed below was found necessary.

1. Excavation was taken deeper along the fault zone and all the weathered and loose material was removed.

2. A vertical shaft 9.14 m (30 ft.) deep and 9.14 m x 6.1 m (30 ft. x 20 ft.) in size was provided at the upstream end of the dyke zone.

3. Bottom of the trench and the shaft were extensively grouted.

4. They were back filled with cement concrete 1: 5.62 mix with 38 mm maximum (1½") size aggregate and 210.9 kgs/sq. cm (3000 lbs/sq. inch) strength.

5. At the top of the shaft a R.C.C. raft was provided to span over it with 10.4 kgs/metre (20 lbs/yard) rails at 0.61 m (2 ft.) spacing both ways.

2.4. Crushed zone in block 55:—A crushed zone 0.61 m to 1.22 m (2 ft. to 4 ft.) width extended at right angle to the axis of the dam from the upstream to downstream edge of excavation in block 55. Along the crushed zone, highly fractured rock was met with. The treatment given was similar to that in the blocks 18 to 23, described above.

3.0. Contraction joints are formed between masonry blocks of dam. Side face of one of the blocks is plastered smooth, while the adjacent block is built butting the smoothly plastered face of the other block. This leaves a contraction joint from the upstream face of the dam to the downstream face. Naturally, this is to be made water-tight against the standing head of water upstream of the dam. Therefore the materials that go to form the contraction joint should be strong, water-tight and durable ensuring good bond with masonry. Details of the joint are given in plate No. 2. From the above it may be seen that 0.52:1:4.62 mix concrete of 210.9 kgs/sq. cm (3000 P.S.I.) strength at 28 days is used.

4.0. Openings in the body of the dam can mainly be classified as (1) Gallery system and (2) Sluices.

4.1. Functions of gallery system in the body of a dam are many and varied. Gallery system can be compared to the arteries in a human body. The galleries at various elevations in the dam are inter-connected by means of adits, stair wells, elevator shafts, vertically formed seepage water drains, ventilating shafts, etc. Plate No. 3 enclosed gives details of the gallery system in non-spillway and spillway sections of dam. It may be noted that one longitudinal gallery is provided for about 30.48 m (100 ft.) height of dam. One will be able to appreciate better if he examines in detail the purpose served by each of the galleries. The foundation gallery of 2.29 m x 1.52 m (7½' x 5') with semi-circular roof which is more or less a standard type is situated about 3.05 m (10 ft.) from the foundation of the dam and generally follows the foundation profile from end to end of the main dam. The porous shaft 0.203 m (8") dia. at 3.05 m (10 ft.) centre to centre, formed in no fines concrete collects water that seeps from the front impervious face of 2.74 m (9 ft.) thick masonry of dam and leads it to foundation gallery. This impervious vertical barrier is constructed in rich mortar 1: 3 mix. This water collected in the drain of the gallery is in turn led away to suitable sump wells, from where the water is pumped out. We have one well in block 15 on the left side and another in block 52 on the right side. These arrangements are for intercepting the seepage water that will otherwise travel to the rear face eventually leaching away all important lime content of cement mortar which means weakening of the structure. For effecting an effective curtain underneath the dam foundation all along its length, high pressure grouting is done from foundation gallery by drilling holes from the gallery at 3.05 m (10 ft.) intervals. Drainage holes drilled from the gallery floor bring out water in the foundations of the dam and reduce the uplift pressure. Such reduction in uplift pressure brings in lot of economy and reduction in section of the dam. Toe gallery is provided for grouting and strengthening the portion of the dam where the stresses are high. Lead wires of various instruments embedded in the dam are connected upto the panels in the galleries for facility of taking periodical readings and analysing how the dam is behaving from time to time under various operating conditions. These studies help correlating the design assumptions with the proto-type behaviour.

413

Toe gallery at El. 79.86 m (El. 262.0) :—

This gallery of size 1.52 m x 2.29 m (5 ft. x 7'-6") is located at a distance of 51.05 m (167'-6") downstream of dam axis and about 6.71 m (22 ft.) high up the foundation level. It was mainly intended for grouting the contact plane of concrete in toe portion and the masonry adjacent to it. Other important functions of this gallery include facilitating inspection and maintenance of the toe of the dam and recording observations of instruments like thermometers, stress meters, strain meters, joint meters, etc. embedded in the toe area. Gallery at El. 106.68 m (El. 350.0) : Located at a distance of 8.38 m (27'-6") downstream of the axis, this gallery is 1.52 m x 2.29 m (5 ft. x 7'6") in size. This serves (1) Collecting the

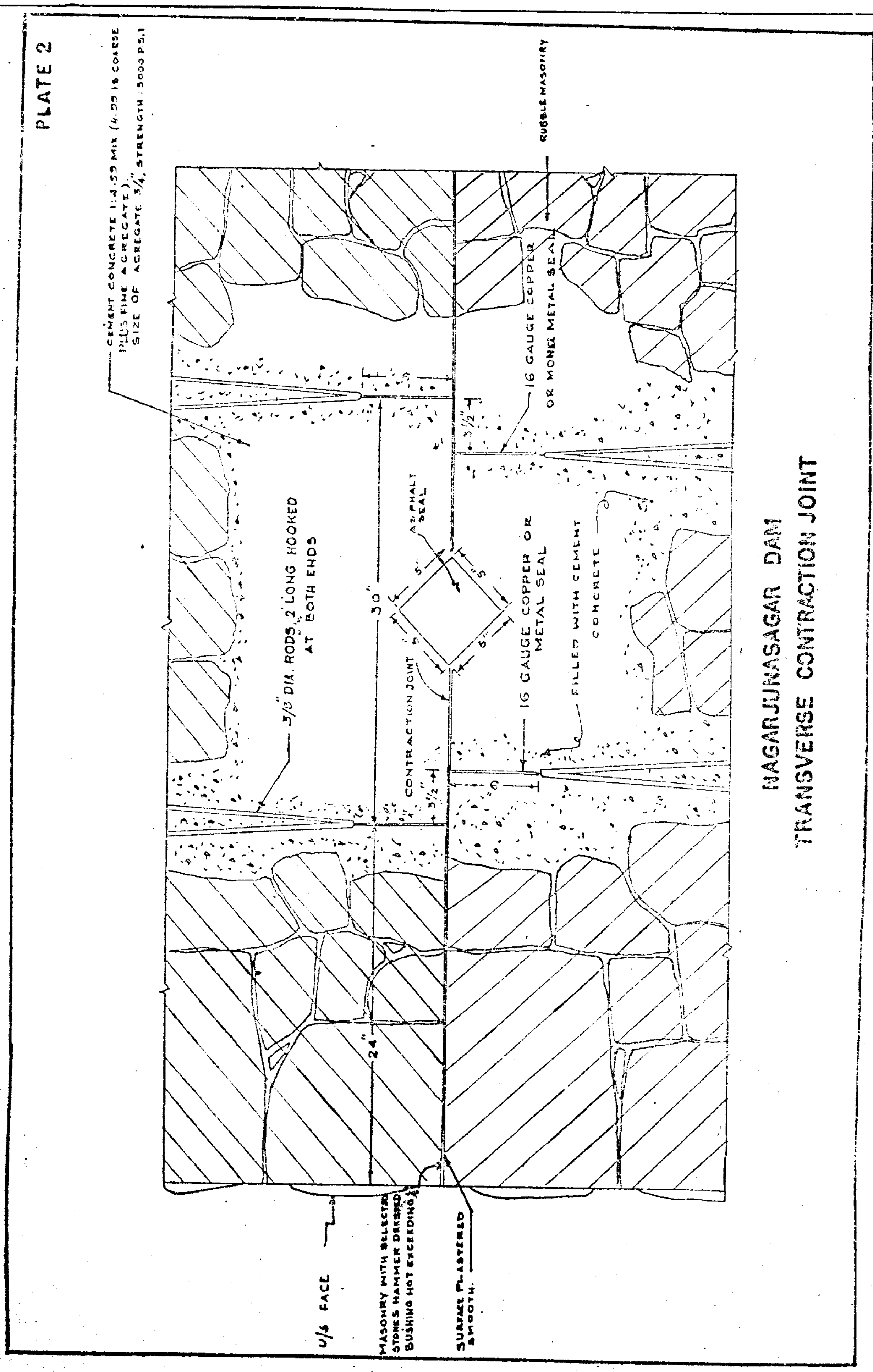


PLATE 2

NAGARJUNASAGAR DAM
TRANSVERSE CONTRACTION JOINT

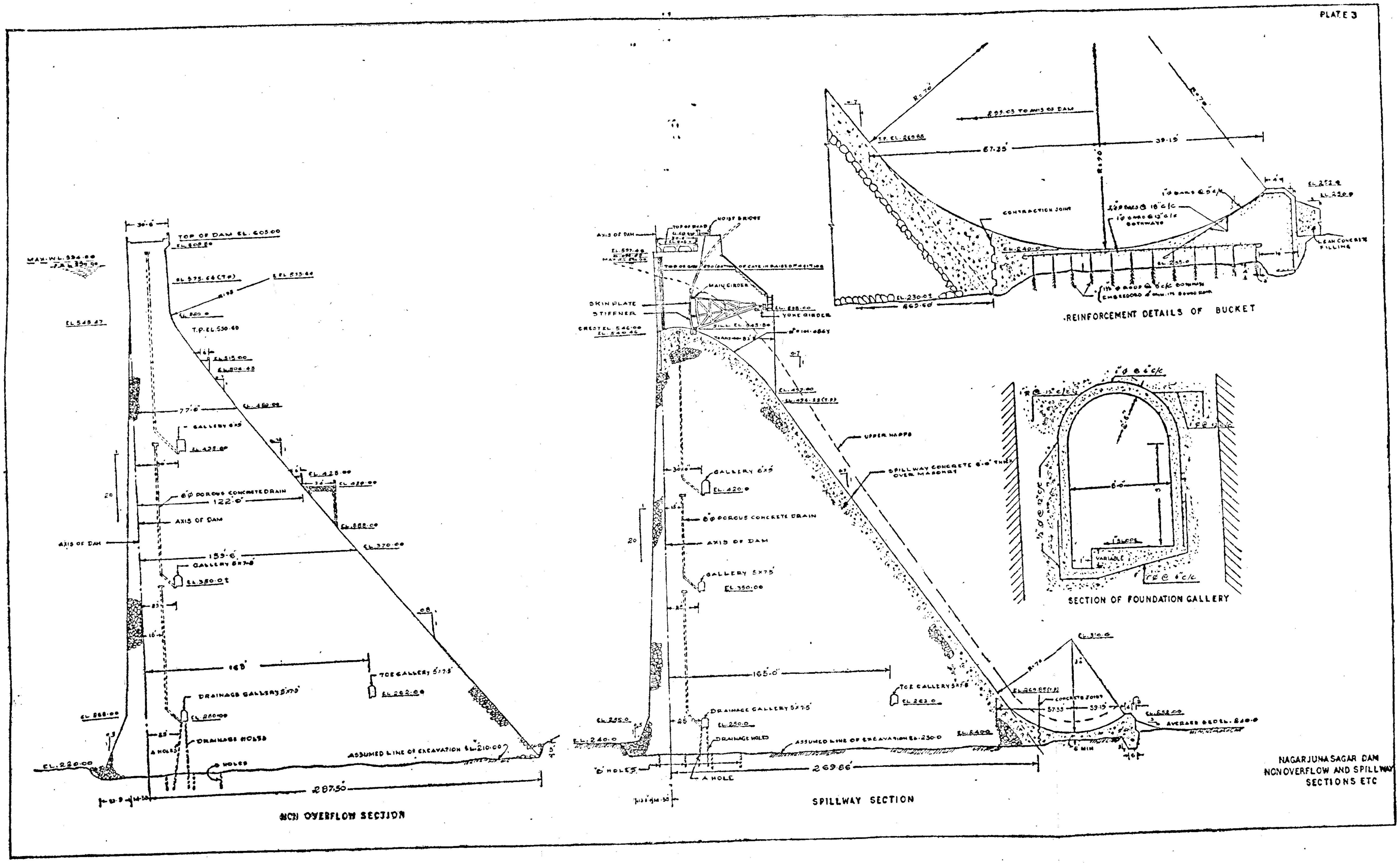
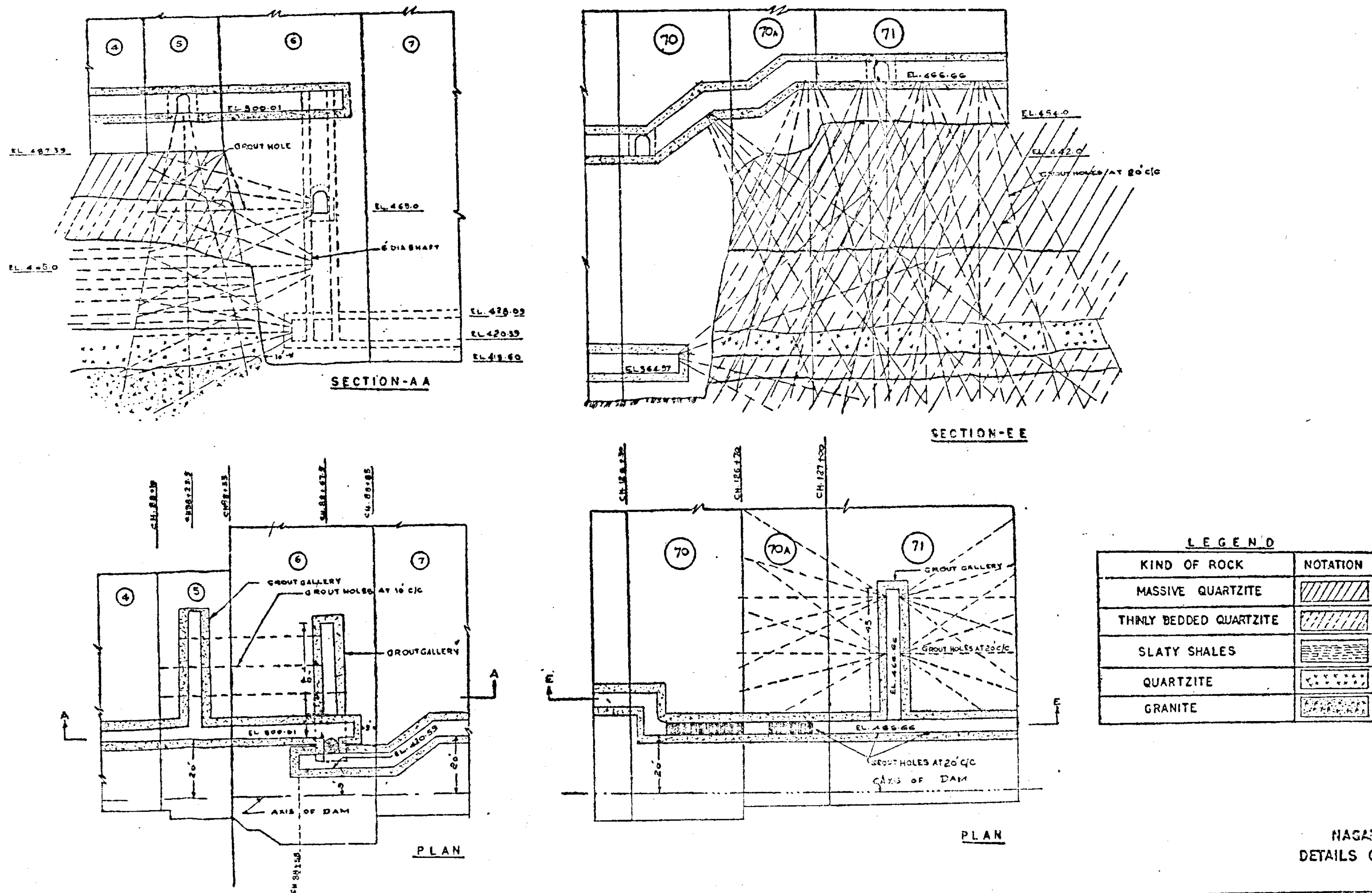


PLATE 3
TOP OF DAM EL. 605.00
AXIS OF DAM
GALLERY 6'x5'
6" Ø POROUS CONCRETE DRAIN
TOE GALLERY 5'x7.5'
DRAINAGE GALLERY 5'x7.5'
DRAINAGE HOLES
ASSUMED LINE OF EXCAVATION EL. 210.00
EL. 220.00
287.50'
NON OVERFLOW SECTION
SKIN PLATE
STIFFENER
MAIN GIRDER
HOIST BRIDGE
YOKE GIRDER
UPPER NAPPE
SPILLWAY CONCRETE 6'-0" THICK OVER MASONRY
GALLERY 5'x7.5'
ASSUMED LINE OF EXCAVATION EL. 230.0
269.86'
SPILLWAY SECTION
CONTRACTION JOINT
REINFORCEMENT DETAILS OF BUCKET
SECTION OF FOUNDATION GALLERY
NAGARJUNASAGAR DAM
NON OVERFLOW AND SPILLWAY SECTIONS ETC

PLATE 4



NAGARJUNASAGAR DAM
DETAILS OF GROUT GALLERIES

seepage water from the porous concrete pipes and disposing of the same through 0.305 m (12") dia. steel pipes in blocks 25 and 51. The seepage water in the drain of the gallery is taken out through the river training walls. (2) Facilitates inspection and helps maintain the dam and (3) to record the readings of the various instruments embedded in the body of the dam near to the gallery. Gallery at El. 132.59 m (El. 435.0): This gallery of size 1.83 m x 2.74 m (6 ft. x 9 ft.) is aligned at 9.14 m (30 ft.) downstream of axis. This was meant for operation of river sluices. In addition, its various functions are collecting the seepage water from the porous concrete pipes and disposing off the same /through 0.305 m (12") dia. steel pipes in block 25 and 51. These are taken out through the river training walls] and facilitating inspection and maintenance of the dam and recording the observations of instruments embedded in the dam.

Hoist gallery at El. 181.05 *m* (*El.* 594.0) :—This chiefly forms a connecting passage between all the hoist chambers of penstock gates in blocks 16 to 23 of non-overflow section of the dam. 1.52 m x 2.29 m (5 ft. x 7'6") in section this gallery is located at 4.11 m (13' 6") downstream of the axis.

Grout galleries on Left and Right:—On either flank the foundation grade changes abruptly from about El. 144.78 m (El. 475.0) to El. 125.58 m (El. 412.0) on left side and from El. 135.03 m (El. 443.0) to El. 109.73 m (El. 360.0) on the right side. The abutting rocks which consist of quartzites and shales are given special treatment by drilling and grouting from the foundation gallery before the dam masonry is built. In addition, grout galleries are provided at El. 141.73 m (El. 465.0) and El. 152.4 m (El. 500.0) on the left side and El. 142.24 m (El. 466.66) on the right side in blocks 5, 6 and 71 respectively. From the grout galleries radial grouting is done after the dam masonry is built in order to provide a good bond between the sloping rock surface and the block masonry by its side and also to consolidate the foundation. Please see plate No. 4. Thus the gallery system is very important and necessary to be provided in the body of any high dam irrespective of the fact whether it is of concrete or rubble concrete or rubble masonry. These openings in the body of the dam effect the stability and strength of the structure. Therefore these are to be carefully designed and adequate provisions are to be made. To meet with this situation, the gallery system is of reinforced cement concrete. Typical section of a gallery provided is given in plate No. 3. Details of reinforcement and the mix of concrete, strength, etc., are also given therein.

4.2. The other important openings in the body of the dam are that of river sluices (chute sluices), canal sluices, power sluices, penstock openings, airvents, gate operating shafts, etc. As the very name indicates the river sluices (chute sluices 2 nos. in block 25 and 51, one each of size 3.05 m x 7.62 m (10 ft. x 25 ft) with sill at El. 137.16 m (El. 450.0) are provided for letting out water down the dam when it is to be let down for Krishna Delta when the water level is less than El. 166.42 m (El. 546.0). Canal sluices are for taking out water for irrigation needs. A battery of 9 sluices of size 3.05 m x 4.57 m (10 ft. x 15 ft.) each are provided with sill at El. 149.05 m (El. 489.0) to draw of 594.65 cum/s (21,000 c/s) to serve 8.12 lakh hectares (20.06 lakh acres) under right main canal. The design of these sluices or for that matter the design of the entire block had been a complicated one and called for great care as the stresses that will come into play are high and to some extent indeterminate. Therefore all these sluices are biult in heavy R.C.C. Heavy reinforcement has been used for pier of right cannal sluice. The concrete used is 281.2 Kgs|sq.cm (4000 p.s.i.) strength since it has to stand high velocities, cavitation, abrasion and attrition under various conditions of operation. Similarly the gate shaft, airvent, are all very important and are to be reckoned with accordingly. The embedment of penstock pipes in the masonry done has called for heavy R.C.C. cover. Plate No. 5 gives the section of the penstocks.

5.0. Trash rack structure is one which prevents logs, debris and other floating matter entering the penstock openings and turbines. As could be seen from the figure 4 and plate No. 6 it is a slender structure of columns and beams and has got to be of R.C.C. with advantage. 8 such structures of 46.41 m (152.25 ft.) height are provided in the left power dam while one combined trash rack of size was built for all the three power sluices of size 4.57 m x 11.58 m (15 ft. x 38 ft.) each was built on the right side in blocks 71 and 72.

6.0. In any storage dam, flood surplussing arrangement namely spillway is an important component of the dam project. Cost of the scheme therefore depends in a large measure in the length of the spillway provided and its cost. Therefore ogee shaped spillway which gives increased co-efficient of discharge is adopted in modern engineering projects. A cross section of the spillway is given in plate No. 3. The spillway crest and the rear face are subjected to high velocity flow, cavitation, rolling and floating matter. No risk could be taken regarding the construction of this. Therefore reinforced cement concrete has been

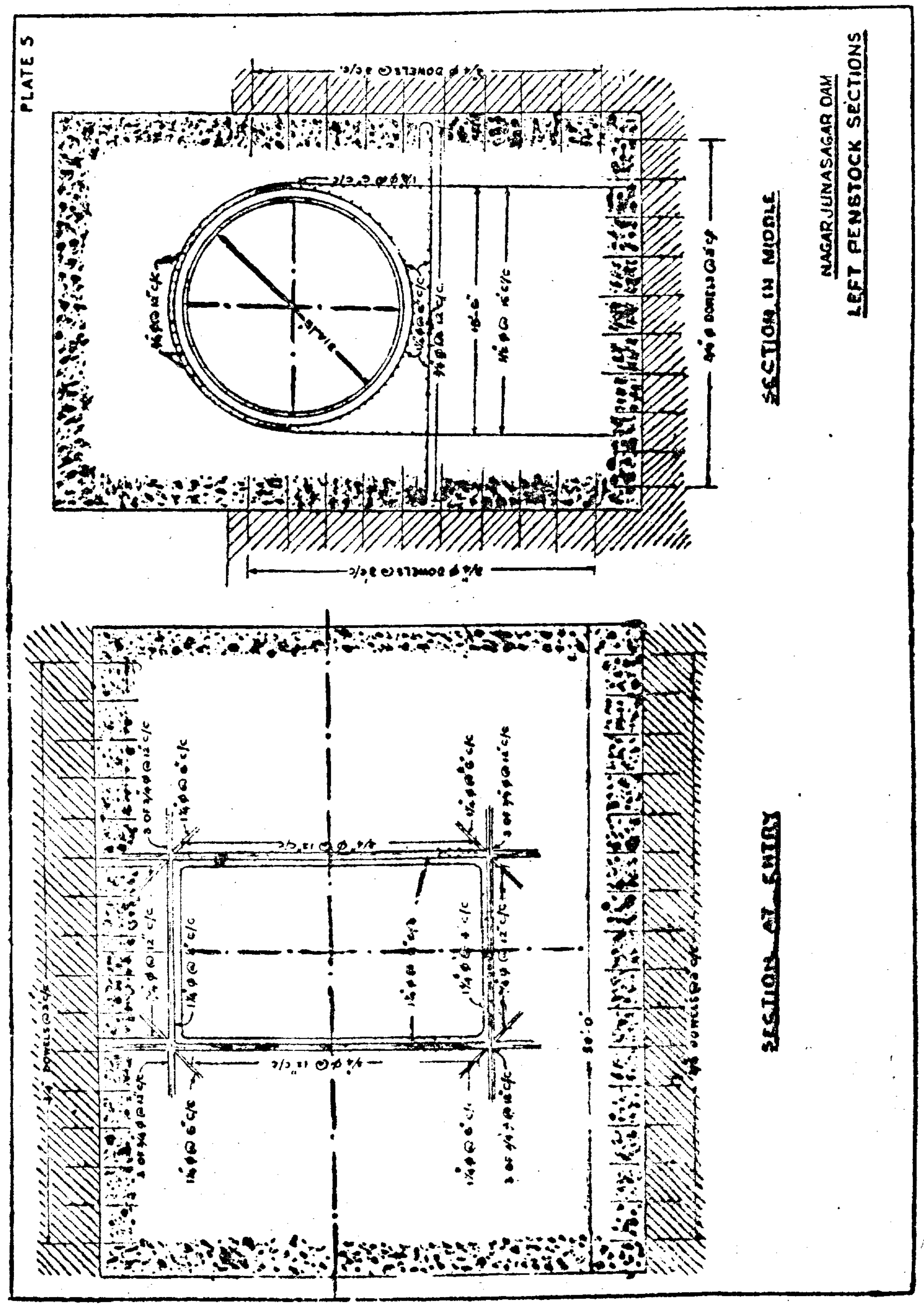
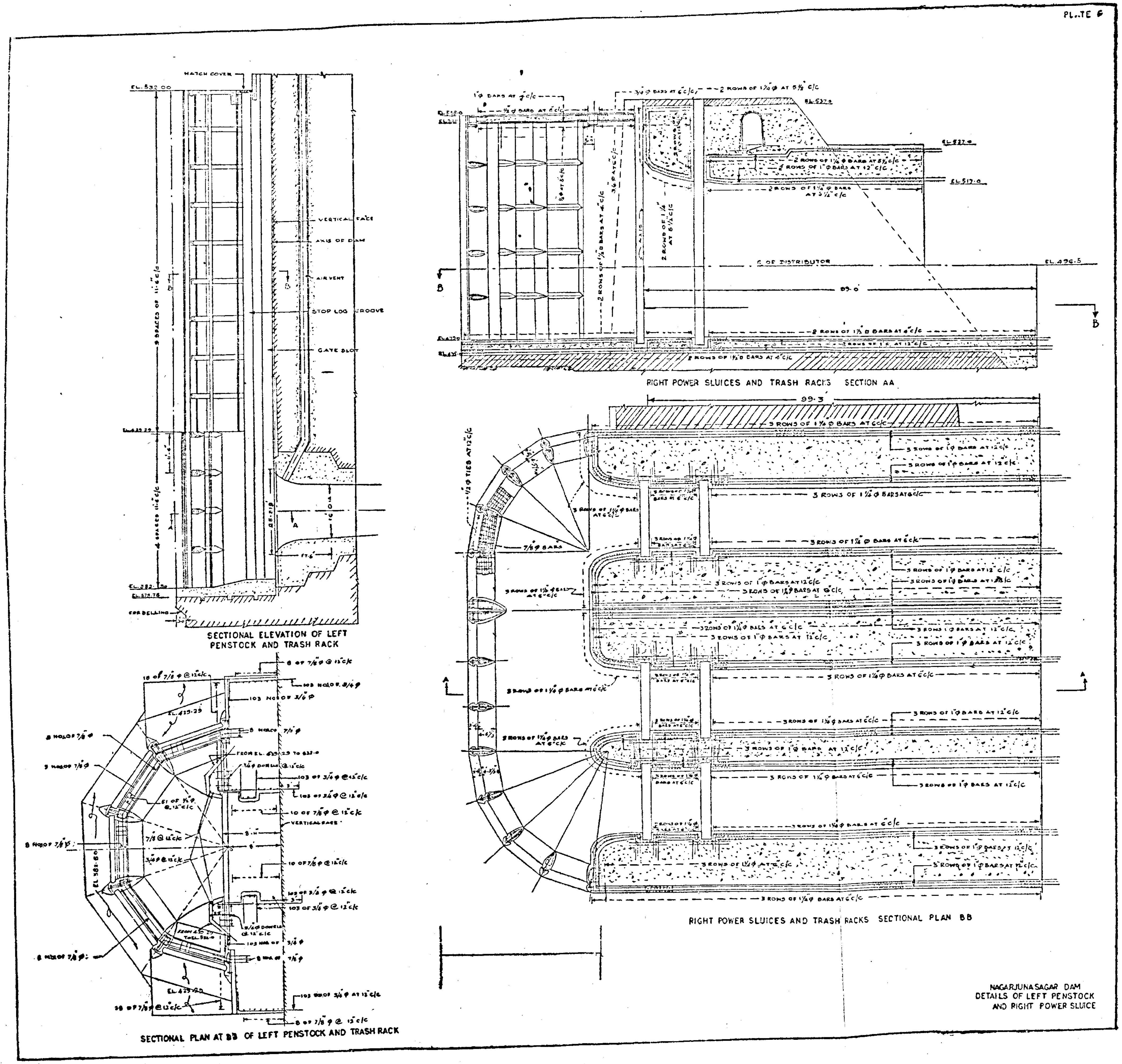


PLATE 5
SECTION IN MIDDLE
SECTION AT ENTRY
NAGARJUNASAGAR DAM
LEFT PENSTOCK SECTIONS



SECTIONAL ELEVATION OF LEFT PENSTOCK AND TRASH RACK

SECTIONAL PLAN AT BB OF LEFT PENSTOCK AND TRASH RACK

RIGHT POWER SLUICES AND TRASH RACKS SECTION AA

RIGHT POWER SLUICES AND TRASH RACKS SECTIONAL PLAN BB

NAGARJUNASAGAR DAM
DETAILS OF LEFT PENSTOCK
AND RIGHT POWER SLUICE

adopted. Ease and flexibility of concreate construction have contributed in no small measure for attaining the profile specified exactly.

6.1. Bucket provided for the spillway is essentially an energy dissipating arrangement. Its functional efficiency and cost contribute in a great way to the over-all safety and economy.

Spillway bucket:—Nagarjunasagar dam which is of straight gravity type rises about 106.68 m (350 ft.) above river bed level. The spillway is designed to discharge about 0.4355 lakh cu. m/s. (15.38 lakh c/s) which works out to 37.26 cu. m/s (1315 c/s) per running foot of spillway. The river bed is composed of sound granite rock. Advantage is taken of this hard rock and a flip bucket is provided at the toe of the dam for dissipating the enormous energy created by the drop of water from El. 181.05 m (El. 594.0) (M.W.L.) to El. 73.15 m (El. 240.0) bucket level.

High pressure of the order of 32,908 kgs/sq. metre (6.740 lbs/sft.) is developed at the bucket and it has to withstand great abrasion and attrition developed. In addition there is possibility of negative pressures developing on the glacis and bucket if the workmanship is not good and perfect. Therefore it is found to be absolutely essential to use R.C.C. A minimum thickness of 1.52 m (5 ft.) R.C.C. is provided.

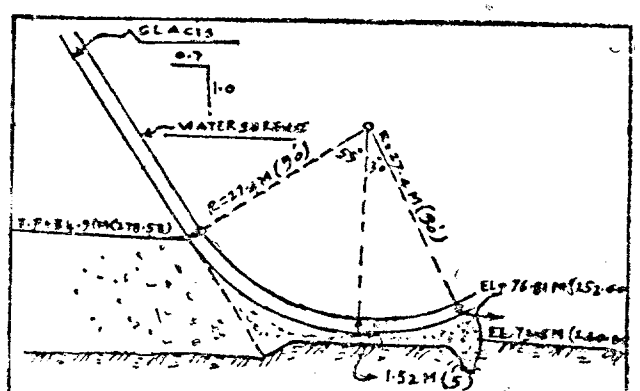
Originally it was proposed to provide a bucket with a radius of 27.43 m (90 ft.) Please see sketch 1. Later on due to certain changes made in the alignment of the training walls it was found feasible to reduce the radius of the bucket in order to economise the cost of construction. Hydraulic model experiments were conducted with the revised radius of 21.34 m (70 ft.).

Analytical studies were also made by potential method, change of momentum method and centrifugal method. The maximum pressure on bucket from these studies was 20,536 kgs/sq. metre (4206 lbs/sft.). Nature of flow for the bucket with 21.34 m (70 ft.) radius was found to be steady and free from negative pressures. Further, cost of construction of bucket with 21.34 m (70 ft.) radius is less than with 27.43 m (90 ft.) radius. The saving in quantity of concrete was about 3553 units and worth at least Rs. 11 lakhs. Therefore a bucket with 21.34 m (70 ft.) of radius (as per sketch 2) was finally adopted. Plate No. 3 gives the reinforcement details of the bucket provided for. The bucket functioned satisfactorily during the flood season of 1968. The bucket design adopted provided a stable and efficient functioning. The R.C.C. bucket and glacis is found to function satisfactorily with good maintenance and repairs.

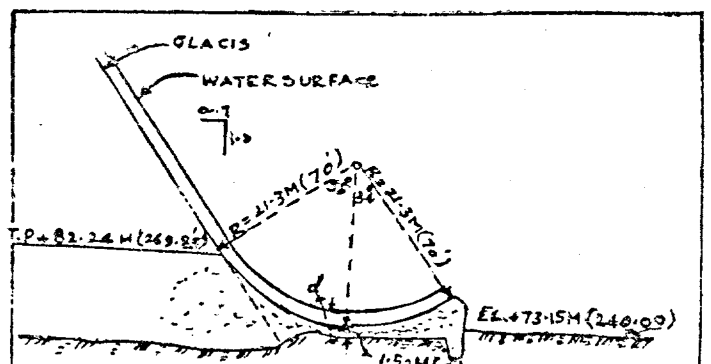
7.0. Spillway of Nagarjunasagar Dam is a gated structure and 26 nos. of radial crest gates of 13.72 m width x 13.41 m height (45 ft., 44 ft.) are provided between piers. The reaction on the crest gates, i.e., the thrust due to about 13.41 m (44 ft.) of height of water standing against the gate will be transferred on to the piers. As such the piers had to be of heavy R.C.C. Place 7 gives the reinforcement details of spillway crest and pier. These are 4.57 m (15 ft.) wide with semi-circular cut water on the upstream side. The height of the pier is about 15.24 m (50 ft.) (form El. 166.42 m) (El. 546.0) to bottom of spillway bridge). Spillway bridge on the top, connects the right and left non-overflow sections of the dam for movement of personnel machines and cranes for operation and maintenance of dam. 125 tonne gantry crane moves on this bridge. Thus the bridge is subjected to heavy loading. This bridge is inevitably a R.C.C. bridge.

8.0. Architectural features are as important as main structure in a dam like this because of the tourist traffic. Nagarjunasagar Dam especially is visited by thousands of tourists every week including quite a few foreigners. Parapets, lamp posts, etc. of required elegance cannot be constructed with any other material with economy except in R.C.C. Plate No. 8 gives details of the parapets, lamp posts and entrances to galleries.

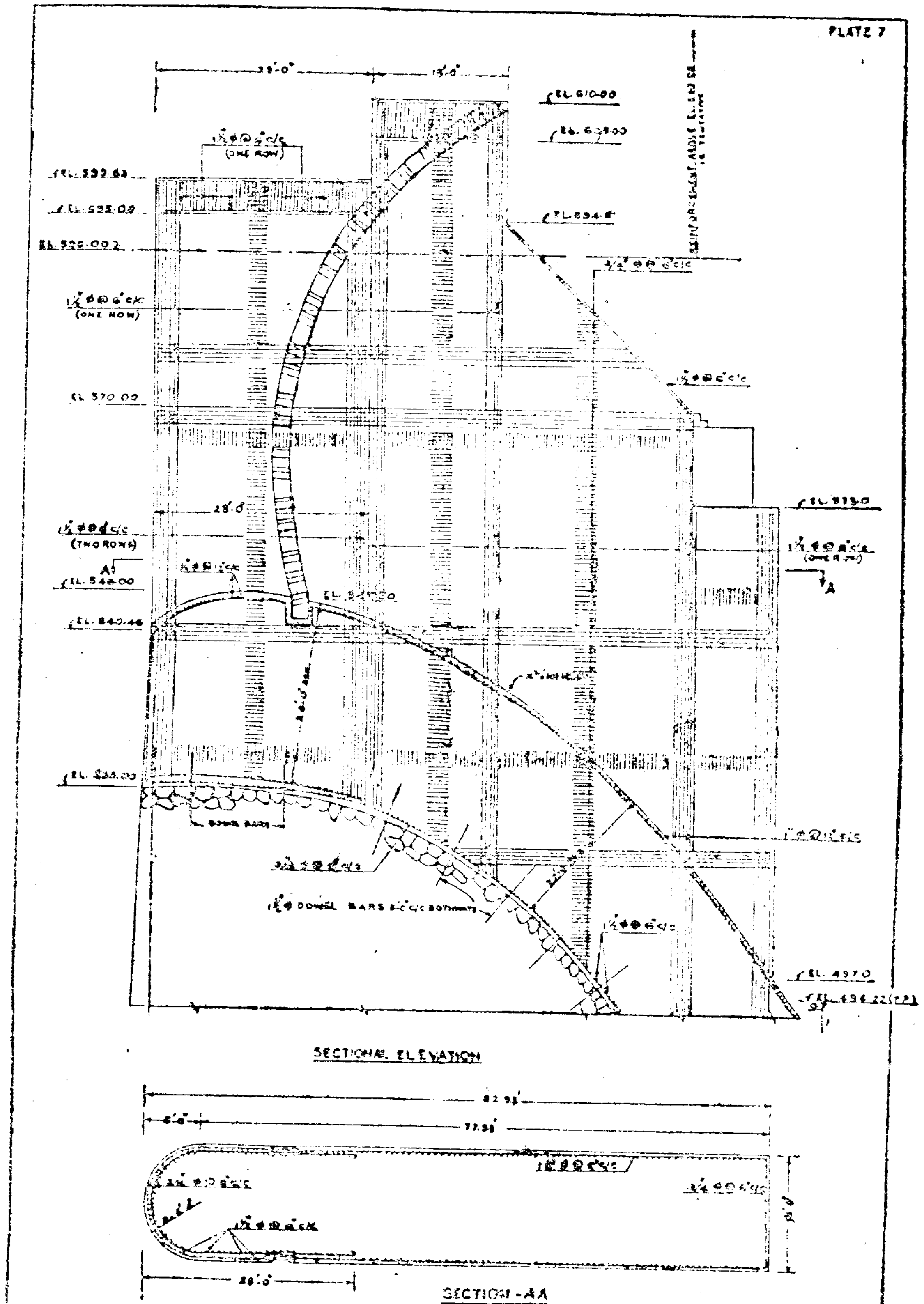
9.0. Perhaps it is feasible to replace concrete with ashlar or finely chisel dressed stone work in locations like sills of sluices, spillway rear face, parapets, lamp posts, entrances to gallery, etc. But the main criteria is one of economy, consistent with functional efficiency and that way concrete cannot be replaced. Cost analysis of various mixes of concrete given in appendix. I proves beyond doubt that finally dressed stone work in replacement of the concrete used would have costed many times more.



SKETCH-1



SKETCH-2



NAGARJUNASAGAR DAM
REINFORCEMENT DETAILS
OF
SPILLWAY CREST AND PIER

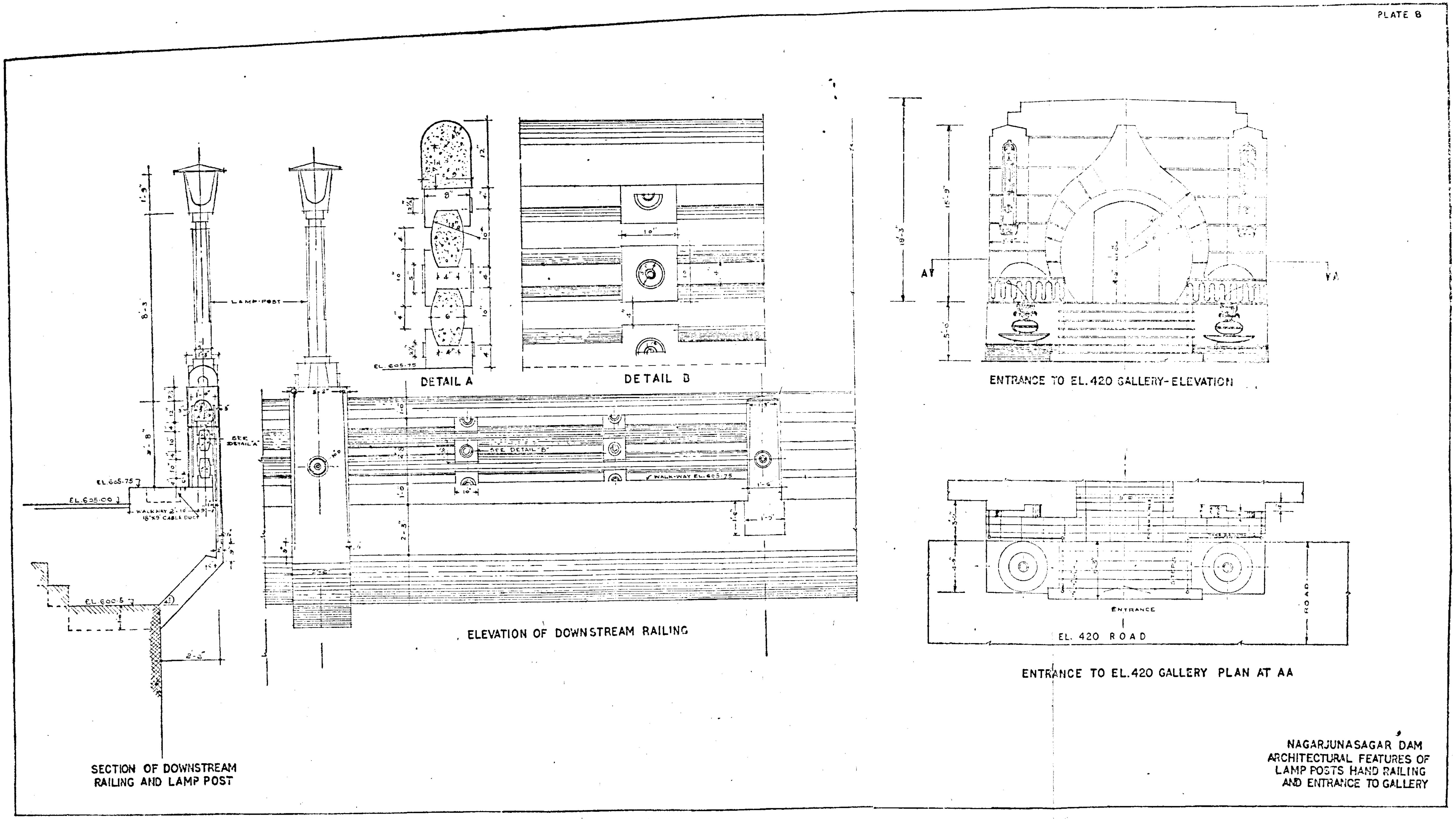


PLATE 8
LAMP-POST
SEE DETAIL "A"
EL. 605·75
EL. 605·00
WALKWAY
EL. 600·5
DETAIL A
DETAIL B
SEE DETAIL "B"
WALK-WAY EL. 605·75
ELEVATION OF DOWNSTREAM RAILING
SECTION OF DOWNSTREAM
RAILING AND LAMP POST
ENTRANCE TO EL. 420 GALLERY-ELEVATION
ENTRANCE
EL. 420 ROAD
ROAD
ENTRANCE TO EL. 420 GALLERY PLAN AT AA
NAGARJUNASAGAR DAM
ARCHITECTURAL FEATURES OF
LAMP POSTS HAND RAILING
AND ENTRANCE TO GALLERY

APPENDIX I.

Data For B.I. Type Concrete (1 : 6.87) Mix.

Serial number. (1)	*Item.* (2)	*Quantity.* (3)	*Rate.* (4) Rs.	*Amount.* (5) Rs.
1·0	Aggregate.			
1·1	3″ .... 1½″	37·625 cft.	23·00/100 cft.	8·65
1·2	1½″ .... 3/4″	38·88 ,,	33·00/100 ,,	12·83
1·3	3/4″ 3/16	27·908 ,,	53·90/100 ,,	15·04
1·4	Crushing and processing and conveyance to stock piles	104·413 ,,		
1·5	Transport from stock piles to batching plant	104·413 ,,	2·50/100 cft.	2·61
				39·13
2·00	*Sand :*			
2·1	Quarrying washing and screening	40 cft.	20·40 ,,	8·16
2·2	Transport from stock piles to batching plant	40 ,,	2·50 ,,	1·00
				9·16
3·0	*Cement:*			
3·1	Cost of cement, Road Transport and handling to site of work, storage and handling upto batching plant, etc.	12 Cwt.	6·50/Cwt.	78·00
4·0	ADMIXTURE.			
	Surki	2·86 cwt.	1·75/Cwt.	5·01
	Aerosine	0·50 lbs.	0·23/lb.	0·12
5·0	Batching and mixing	100 cft.	7·20/100 cft.	7·20
6·0	Placing including transport from batching plant and vibrating.	100 ,, 100 ,,	17·75/100 ,, 8·00/100 ,,	17·75 +8·00
7.0	Cleaning, slurry and curing	100 ,,	2·00/100 ,,	2·00
8·0	Other items.	..	..	..
9·0	Shuttering	100 cft.	23·00/100 cft.	23·00
10·0	Ancillaries	..	..	..
				Rs. 189·37/100 cft

Data for B 2 Type concrete (1 : 5·62) Mix.

1·0	*Aggregate.*			
1·1	3″ .... 1½″			
1·2	1½″ .... 3/4″	47·817 cft.	33·00/100 cft.	15·78
1·3	3/4″ .... 3/16″	41·35 ,,	52·90 ,,	22·29
				38·07
1.4	Crushing and processing and conveyance to stock piles.	89·167 cft.	2·50 ,,	2·23
1·5	Transport from stock piles to batching plant			
	Sand :			
2·1	Quarrying washing and screening	50·633 ,,	20·40 ,,	10·33
2·2	Transport from stock piles to batching plant	50·633 ,,	2·50 ,,	1·27
	Cement :			
3·1	Cost of cement Road Transport and handling to site of work storage and handling upto batching plant, etc.	17·5 cwt.	6·50/cwt.	113·75
	Admixture :			
4·0	aerosine	0·50 lb.	0·23/lb.	0·12
5.0	Batching and mixing	100 cft.	7·20/100 cft.	7·20
6·0	Placing including transport from batching plant and vibrating.	100 cft.	17·75 ,, +8·00/	17·75 +8·00
7·0	Cleaning, slurry and curing	100 cft.	3·00/100 cft	3·00
8·0	Other items	—	—	—
9.0	Shuttering	100 cft.	30·00/100 cft.	30·00
10·0	Ancillaries	—	—	—
				Rs. 231·72/100 cft.

APPENDIX I—(contd).

Data For A. I. Type Concrete (1 : 10·06) Mix.

Serial number. (1)	Item. (2)	Quantity. (3) Rs.	Rate. (4) Rs.	Amount. (5) Rs.
1·0	*Aggregate.*			
1·1	6" to 3"	30 cft.	18·00/100 cft.	5·40
1·2	3" .... 1½"	30 "	23·00 "	6·90
1·3	1½" .... 3/4"	21 "	33·00 "	6·93
1·4	3/4" .... 3/16"	27 "	53·90 "	14·55
				33·78
1·5	Crushing and processing and conveyance to stock piles.			
1·6	Transport from stock piles to batching plant	108 cft.	2·50 "	2·70
				36·48
2·0	*Sand:*			
2·1	Quarrying washing and screening	45 "	20·40 "	9·18
2·2	Transport from stock piles to batching plant	45 "	2·50 "	1·13
3·0	*Cement.*			
3·1	Cost of cement, Road Transport and handling to site of work storage and handling upto batching plant, etc.	9·6 cwt.	6·50/cwt.	62·40
4·0	*Admixture.*			
	Surki	2·375 cwt.	1·75 cwt.	4·16
	Aerosine	0·20 lb.	0·23/lb.	0·05
5·0	Batching and mixing	100 cft.	7·20	7·20
6·0	Placing including transport from batching plant and vibrating.	100 cft. +100 cft.	17·75 + 8·00	17·75 + 8·00
7·0	Cleaning slurry and curing	100 cft.	2·00	2·00
8·0	Other items	—	—	—
9·0	Shuttering	100 cft.	6·00	6·00
10·0	Ancillaries	—	—	—
				Rs. 154·35/100

Water Requirements of the Major Crops Grown in The Lower Bhavani Ayacut.

BY

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AND

A. MOHAMED ALI B.SC., (AG.),††

INTRODUCTION.

Among the basic inputs for higher crop yields adequate water supply occupies the most important place. In a tropical country such as India with erratic, inadequate and ill-distributed rainfall, assured irrigation is the only way for sound, permanent and profitable farming. Irrigation, of late, has become a costly commodity whether it is made available through construction of dams and reservoirs or through digging of wells, etc. Economic and efficient utilization of water, therefore, becomes a must, in water use programmes for which precise knowledge of water requirements of crops is imperative. In Madras State, the Lower Bhavani Project commanding 2,07,000 acres in Gobi, Erode, Bhavani and Dharapuram *taluks* of Coimbatore District and Karur *taluk* in Tiruchirappalli district, is one of the important river valley projects to be completed in the First Five-Year Plan period. This project costed the Government 10.5 crores of rupees and it is of paramount importance that irrigation water, thus, made available at tremendous expense should be utilized economically and for obtaining maximum yield of crops.

MATERIALS AND METHODS.

At the Agricultural Research Station, Bhavanisagar bulk crops of rice, Jowar, Bajra, Cotton, Groundnut, Tobacco, Redgram and Horsegram were grown for determination of irrigation delta, total water requirement and duty of water. The irrigations were scheduled for the individual crops at the optimum soil moisture regimes already determined in Madras State or elsewhere in India. The optimum soil moisture regimes adopted for the crops are given in Table I.

TABLE I

Optimum soil moisture regimes adopted for the crops.

Crop. (1)	*Optimum water regime.* (2)	*Place and author.* (3)
Rice (ADT. 27, TKM. 6)	Submergence up to 5 cm depth of water.	Madras State Chandra Mohan (1961)
Cotton. (MCU. 1)	Field capacity to 20 per cent moisture availability or 6·2 atmospheres tension measured at 30 cm depth.	Bhavanisagar. Chandra Mohan *et al* (1967)
Tobacco. (Vazhaikappal)	Field capacity to 80 per cent moisture availability or 0·5 atmoshpheres tension measured at 30 cm depth.	New Delhi. Dastane *et al* (1966)
Groundnut. (TMV. 2)	Field capacity to 60 per cent moisture availability or 1·05 atmospheres tension measured at 30 cm depth.	Bhavanisagar. Chandra Mohan and Sundaram (1968)
Ragi (Co. 7)	Field capacity to 80 per cent moisture availability or 0·5 atmospheres tension measured at 30 cm depth.	In the absence of valid data the optimum moisture regime was arbitrarily fixed based on the nature of the crop.
Jowar (Co. 18)	Field capacity to 20 per cent moisture availability or 6·2 atmospheres tension measured at 30 cm depth.	In the absence of valid data the optimum moisture regime was arbitrarily fixed based on the nature of the crop.
Bajra (Co. 3)	Field capacity to 20 per cent moisture availability or 6·2 atmospheres tension measured at 30 cm depth.	In the absence of valid data the optimum moisture regime was arbitrarily fixed based on the nature of the crop.
Redgram** (SA. 1)	Field capacity to O per cent moisture availability or 15 atmospheres tension measured at 10 cm depth.	In the absence of valid data the optimum moisture regime was arbitrarily fixed based on the nature of the crop.
Horsegram** (local variety)	Field capacity to O per cent moisture availability or 15 atmospheres tension measured at 10 cm depth.	In the absence of valid data the optimum moisture regime was arbitrarily fixed based on the nature of the crop.

NB** Redgram and horsegram are usually raised under un-irrigated conditions only. However, by giving one or two "protective" irrigations when the soil moisture touches the lowest limit of availability, i.e., O per cent moisture availability, high yields were recorded. Hence, they are also included in the list.

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The crops were grown during the main crop season of 1967-68 under normal conditions adopting the usual manurial and agronomic practices. Groundnut crop was raised during the second crop season also. The scheduling of irrigations was done at the optimum moisture regimes indicated in Table I. The moisture regimes were fixed after determining permanent wilting point in the laboratory by the sunflower plant technique originally described by Briggs and Shantz (1912) and field capacity under field conditions by the method adopted by Veihmeyer and Hendrickson (1950). The value of permanent wilting point was 8.5 percent and field capacity 20 percent and the optimum regimes were fixed within this range. The estimation of soil moisture percentage was done in the laboratory by the gravimetric method with soil samples taken up to a depth of 30 cm. The irrigation water was measured accurately by means of 90 degree triangular weirs.

RESULTS AND DISCUSSION.

The data on the Irrigation delta, water requirement, duty of water of the crops, the effective rainfall during the period of crop growth, etc., are presented in table II.

TABLE II.

Irrigation Delta, Duty of Water and water Requirement of the crops of the Lower Bhavani Project Ayacut.

Crop.	*Irrigation Delta. (mm)*	*Number of irrigations.*	*Duration of crop (days)*	*Duty. (acres per cusec)*	*Effective rainfall. (mm)*	*Water requirement. (mm)*	*Yield. (kg. perha)*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Rice—							
ADT. 27	885	25	105	74	157·5	1012·5	4700
TKM. 6	720	23	120	100	215·0	935	5039
Tobacco. (Vazhaikappal). ..	465	13	165	213	217·5	682·5	910
Ragi—							
Co. 7	460	10	97	127	187·5	647·5	2939
Groundnut—							
TMV. 2 (Ist crop season)	162·5	6	105	288	412·5	575	1685
(IInd crop season). ..	472·5	13	105	133	37·5	510	3221
Cumbu—							
X3.	215	7	90	251	35·0	250	1768
Co. 3	180	6	85	283	35·0	215	1231
Cholam—							
Co. 18	165	6	90	327	155	320	3806
Cotton—							
MCU. 1	215	6	195	544	507·5	722·5	1823
Redgram—							
SA. 1	165	4	190	690	217·5	382·5	1760
Horsegram—							
Co. 1	75	2	112	896	202·5	277·5	1151

It is seen that there is remarkable variation between the different crops in respect of irrigation deltas, duty of water and water requirements. This variation is due to the nature of the crop species, its duration, season of cropping and the effective rainfall received during the period of crop growth. The soil at Bhavanisagar is red gravelly loam admixed with Kankar nodules and fragments of quartz. It is open in texture with about 70 per cent coarse fractions and an aggregate of 30 per cent fine fractions. The clay content in the finer fraction is only 50 per cent. The moisture holding capacity is around 26 per cent under laboratory conditions. The comparatively high water requirement and low duty of water for these crops are due to the light and pervious nature of the soil. These values for the different crops can be generally applied to the Lower Bhavani Ayacut where the soil and climatic features are essentially the same as at Bhavanisagar.

SUMMARY.

The irrigation delta, duty of water and water requirement of the major crops grown in the Lower Bhavani Ayacut, which were determined at the Agricultural Research Station, Bhavanisagar during 1967--68 adopting the modern technique of soil moisture regime concept, have been reported in this paper. The variation in the values is due to the difference in the nature of crops, their duration, season of cropping and the effective rainfall received during the period. These values are applicable to the Lower Bhavani Project Ayacut where the agro-climatic features are essentially similar to that of Bhavanisagar.

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Ground Water Investigations in Tamil Nadu.

BY

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INTRODUCTION.

0.1. Ground waters from one phase in what is known as the 'Hydrological Cycle'. In the hydrological cycle, the saline ocean water is evaporated and precipitated on land in the form of rain water, snow or ice. Some of this flows back to the sea in streams and rivers; part of it is evaporated or transpired by plants; while the reminder infiltrates the land and percolates down to augment the ground waters. The ground water thus stored up in the sub-surface aquifers becomes available for extraction.

0.2. In the civilised countries the consumption of fresh water for agricultural, domestic and industrial purposes is steadily increasing and assured supply compels more and more recourse to exploitation of the underground water resources. Large scale development of Ground Water resources has assumed growing importance in the economic and social development of many countries owing to advances in technology making possible such a development as well as the increasing demand for ground water in all parts of the world. Madras State has already utilised about 94 per cent of the surface runoff and is on the threshold of such a stage of Ground Water Development.

1. *Madras State and its Irrigation Development.*—The total area of Madras State according to Census of India in 1961 is 1,30,357 Sq. Km. Out of this, the total area irrigated is 24,244.77 Sq. Km. (2,424477 hectares) as detailed below:—

Irrigated by	*Area irrigated in hectares.*
Government Canals	896,769
Private Canals	1,395
Tanks	886,221
Tube Wells	4,316
Wells, Sole irrigation	594,472
Other sources, i.e., springs, channels, etc.	41,304
Total area irrigated ..	2,424,477

Madras State has a normal rainfall of 946.8 m.m.

2. *Water Balance.*—With particular reference to soil moisture deficit :—

2.1. *Water Balance.*—Water balance is the concept which relates to the water requirements of vegetation to the available water-supply. The main source of water-supply is the precipitation, i.e. rainfall. The plant water requirement necessary for plant transpiration is supplied by rainfall. Some of the rainfall water is lost by evaporation. Usually, both evaporation and transpiration are combined and called evapo-transpiration. If evapo-transpiration and deep percolation is exceeded by precipitation, runoff results.

2.2. *Soil moisture deficiency* :—

2.2.1. In a case where precipitation is exceeded by evapo-transpiration and deep percolation the plants must draw their unsatisfied water requirements from the moisture present in the soil pores. This deficiency, which represents the difference between evapo-transpiration and rainfall, assuming negligible deep percolation, is called the 'Soil moisture deficit'.

i.e. $D = E - P$.

where D is the soil moisture deficit.

E is potential evapo-transpiration.

P is precipitation.

2.2.2. There will be soil moisture deficiency only if the equation is positive. Potential evapo-transpiration is the amount of water which could be returned to the atmosphere in the form of water vapour through the processes of transpiration and evaporation. Many research workers have developed empirical formulae for the determination of potential evapo-transpiration based on some climatological considerations. The most practical formula to use in this study considering the available data is Thornethwaite's formula which is valid for the tropics.

$$e = 1{\cdot}6\left(\frac{10t}{I}\right)^a$$

Where e = monthly potential evapo-transpiration in cm. for a standardised month of 360 hours of sunshine.

t = Mean monthly air temp.

I = an annual heat index which is the summation of the monthly indices '$I = \sum_{\text{Jan.}}^{\text{Dec.}} i$.

$$i = \left(\frac{t}{5}\right)^{1{\cdot}514}$$

$$a = 675\ I^3/10^9 - 771\ I^2/10^7 + \frac{1792\ I}{10^5} + 0.49239$$

2.3. *Water balance* : *Calculation*:—

2.3.1. Using the above formula the water balance for the Madras State can be worked out. To illustrate the principle, the water balance for Cauvery basin has

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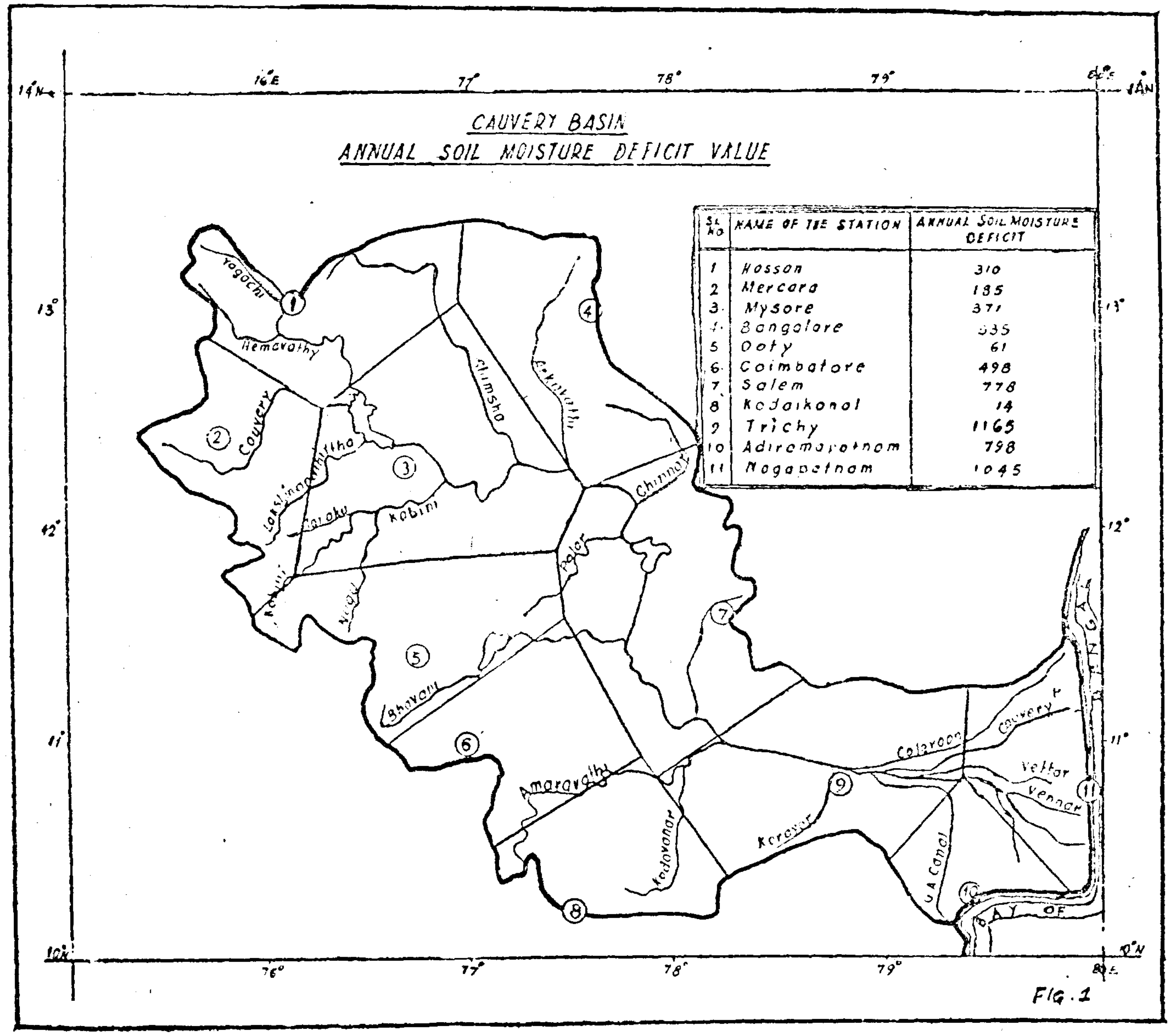


FIG. 1

been worked out. About 11 rainfall stations were taken in the basin (vide Fig. 1). The mean monthly rainfall 'P' and mean monthly temperature (t° c) for the year 1961 were collected for these 11 stations and tabulated in tables 1 and 2 respectively. The rainfall is shown in Fig. 2 also. The values of $(I=\Sigma_{Jan.}^{Dec.}\ i.)$ and 'a' were calculated for each station using the above formulae. Then the value of e, the monthly potential evapo-transpiration for a standardised month of 360 hours of sunshine, were calculated for every month. The monthly potential evapo-transpiration for each station is to be assessed by increasing or decreasing the standardised monthly evapo-transpiration in accordance with the number of possible sunshine hours in the month concerned. The following assumption was made regarding reduction of evapo-transpiration due to cloudiness of the sky.

N.E. monsoon period i.e. October to Jan.=50 o/o of standardised evapo-transpiration

Summer i.e. February to May = 90 o/o do.

S W. monsoon period i.e June to September=75 o/o do.

2.3.2. Based on the above, the monthly potential evapo-tranpsiration 'E' was calculated and shown in Table 3. The soil moisture deficit D was calculated using the formula

$$D = E - P$$

and the values were tabulated in Table 4. The *annual* potential evapo-transpiration and the annual soil moisture deficit were obtained by adding respectively the monthly evapo-transpiration and the monthly soil moisture deficit. Annual soil moisture deficit for various stations in Cauvery basin is shown in Fig. 1. The total area of the basin is worked out to be about 84,635 Km^2. From the annual soil moisture deficit values, the net amount of water requirement for the area was calculated to be 44,112.5 x 10 cubic metres by Thiessen polygonal method (vide Fig. 1). Similarly by collecting the necessary data on mean monthly rainfall, mean monthly temperature, solar radiation and latitude, detailed assessment of water requirement for Madras State may be calculated on the above lines.

3. Geology of Madras State.

3.1. In the study of the ground waters, a knowledge of the geology of an area is of fundamental importance because the occurrence, distribution, movement and quality of the waters are dependent on geological factors particularly permeability, fissures, and area of outcrop. From the investigations made, in the order of importance the water bearing formations of Madras State may be devided broadly into (1) Alluvial deposits, (2) sedimentary deposits and (3) crystalline rocks of Archean age forming the main mass of Madras State. The sedimentary deposits can be further divided according to their age as (i) Upper Gondwana formations of Jurassic age (180 to 135 million years ago) consisting chiefly of clays and shales, (ii) cretaceous formations (135 to 70 million years ago) consisting of marine clays, lime-stones and calcarerous sand stones, (iii) Tertiary formations (70 to 10 million years ago) consisting of sand stones (Cuddalore sand stones) clays and lignite. From the point of view of ground water potential the most important zones are the sand stone zone and alluvium zone.

3.2. *Crystalline rocks.*—The crystalline rocks are of Archean age and traverse the major part of Madras State. These are poor water bearers. However appreciable quantities of water could be expected wherever the rocks are weathered or traversed by fissures, joints, etc. Deep tube wells are not suited to this type of formation. Large diameter dug wells have greater chances of encountering the fissured zones and are hence favoured.

3.3. *Gondwana formation* :—These formations are found to crop out at the junction of the crystalline sedimentary formations in Ramanathapuram, Tiruchi and Chingleput districts. These are known to be very poor water bearers due to their low permeability and only small quantities of water can be extracted from dug wells.

3.4. *Cretaceous formations* :—These deposits occur in outcrops separated by the Alluvium of the Pennar and Vellar rivers. The largest outcrop is in the north-eastern parts of the Trichy district and covers about 124 x 10 square metres (200 sq. miles). The second outcrop occurs near Virdhachalam between the rivers Manimuktar and Gadilam; the third outcrop is in the Valudavur-Pondicherry areas. There the total thickness of the strata has been established to be about 275 metres.

3.5. *Tertiary formations* :—This formation occurs intermittantly from near Rameswaram through Pudukottai, Thanjavur, Cuddalore, Pondicherry to Madras and later north into Andhra Pradesh. Artesian aquifers occur within this formation near Karaikudi, Neyveli, Cuddalore and Pondicherry. These are by far the best known of all water bearing formations of the state and their potentialities appear to be unlimited.

TABLE 1.

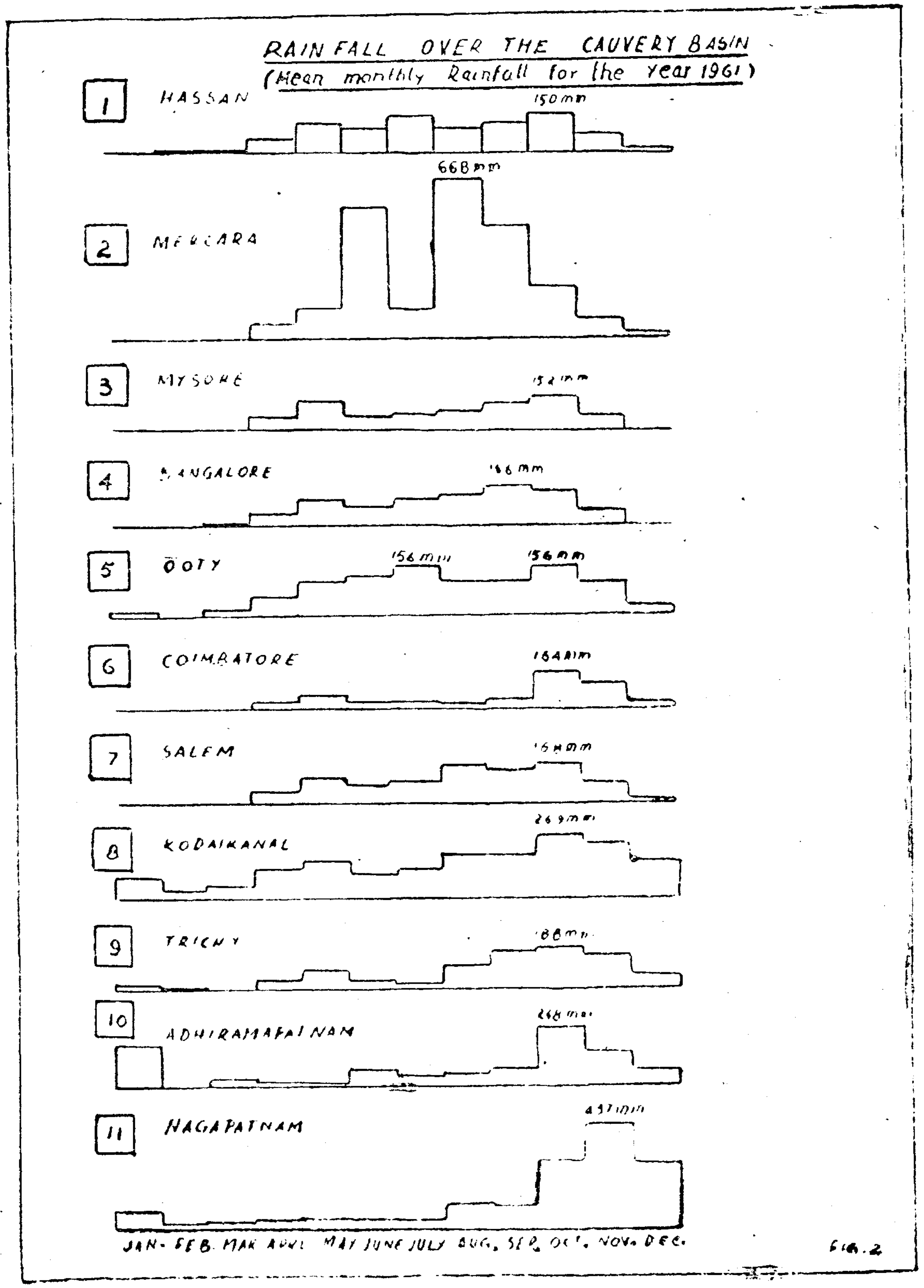
Mean monthly and mean annual rainfall for the year 1961 (in millimetre).

Serial number.	Station.	Latitude Langitude.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
1	Hassan	13° 00′—76° 09′	4	6	10	58	114	94	150	97	167	158	74	16	888
2	Mercara	12° 25′—75° 44′	4	6	20	67	129	579	119	668	467	215	72	19	2365
3	Mysore	12° 18′—76° 42′	4	5	13	63	137	63	70	85	122	152	68	10	792
4	Bangalore	12° 58′—77° 35′	6	6	11	43	103	76	100	127	166	153	65	10	866
5	Ooty	11° 24′—76° 44′	33	12	34	80	156	171	213	144	144	208	156	43	1394
6	Coimbatore	11° 00′—76° 58′	16	9	13	42	60	40	42	31	39	164	101	33	590
7	Salem	11° 39′—78° 10′	8	8	13	51	114	82	93	167	150	168	94	25	978
8	Kodaikanal	10° 14′—77° 28′	82	38	49	125	156	109	120	181	179	269	227	154	1689
9	Trichy	10° 46′—78° 43′	25	12	9	49	81	43	34	100	175	188	146	68	930
10	Adiramapatnam ..	10° 20′—79° 23′	173	2	26	18	19	07	45	50	88	248	142	62	940
11	Nagapatnam	10° 46′—79° 51′	70	20	20	29	39	33	33	89	81	289	437	266	1406

TABLE 2.

Mean monthly temperature in centigrade for the year 1901.

Serial number.	Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1	Hassan	21·0	24·5	26·5	26·0	24·5	22·5	21·5	22·5	23·0	22·0	20·5	20·0
2	Mercara	20·0	22·0	23·5	23·0	22·0	19·0	18·5	19·5	19·5	22·5	19·5	19·0
3	Mysore	23·0	26·0	27·5	27·5	26·5	23·5	23·5	24·0	24·0	23·5	21·5	22·0
4	Bangalore	21·5	25·5	26·0	27·5	25·5	23·5	23·0	23·0	23·0	22·5	20·5	19·5
5	Ooty	12·5	13·5	16·0	16·5	15·5	14·0	14·0	14·0	14·5	14·0	13·0	12·0
6	Coimbatore	24·5	27·5	29·0	29·5	28·5	26·5	26·5	26·5	28·0	25·5	24·5	23·5
7	Salem	25·5	28·0	30·5	31·5	30·5	29·0	28·5	28·0	27·5	26.0	25·0	21·0
8	Kodaikanal	13·0	13·0	14·5	16·0	16·5	14·0	14·0	14·0	14·0	13·0	12·5	12·5
9	Trichy	26·0	28.0	30·5	32·0	32·0	31·5	31·5	30·0	29·0	27·0	26·5	24·5
10	Adiramapatnam ..	26·5	25·5	28·5	28·0	30·0	29·0	29·0	27·5	28·0	27·5	24·0	25·0
11	Nagapatnam ..	25·0	27·0	29·0	31·0	32·0	31·0	30·5	29·5	27·5	27·0	25·5	25·6



3.6. *Alluvial deposits.*—Almost all the important rivers and streams in the state have deposited thick alluvium especially in deltaic regions. Large quantities of water can be tapped from the sand zones by means of shallow tube wells and dug wells.

4. *Ground Water investigations and reports*—

4.1. After recognising the essential role to be played by the ground water in agricultural, industrial and community development, investigations of ground water systems are directed towards a full understanding of the natural resource through observation, collection of data, analysis and interpretation. Deep drilling has been done by several organisations in various parts of the state for various purposes.

4.2. *Geological Survey of India—Exploratory Tube Well Organisations*—

4.2.1. Geological Survey of India had undertaken exploratory drilling in various parts of the state. They had also conducted Aquifer Performance tests by heavy pumping in Deep Tube Wells and have published data based on the well known Transient State Sub-soil flow formulae.

4.2.2. Geological Survey of India have also investigated the hydrologic properties of the aquifer in the areas around Ammapet and Anaikkaranchatram in Tanjore district, Madras State, to investigate the possibilities of constructing tube wells in the above area. During the period of investigation several tube wells were constructed, examined and necessary data relating to their depth diameter, yield, etc., were collected. It has been concluded in their report that "In view of the shallow depth of the occurrence of the concurrence of the confined aquifers and their high permeability, potentialities for further development of ground water by tube wells are bright".

4.2.3. Similar investigations have been made in the areas between Aranthangi and Kattumavadi in Thanjavur district and the hydraulic tests conducted in the tube wells indicated that the granular zones penetrated by the tube wells are highly permeable.

4.3. *Agricultural department.*—A large number of deep wells and shallow wells were drilled in Chithambaram area by Agricultural Department. About 140 deep wells of dia 15.24 cm (6") ranging from 140 metres to 300 metres depth were driven and the bore logs were prepared. About 675 shallow wells of depth ranging from 15 metres to 140 metres were driven.

4.4. *Neyveli Data.*—The Neyveli area, where lignite, reserves have been estimated to be about 3000 million tons, posed a problem in respect of its mining by open cast method because of the presence of two aquifers (first one from 9 to 12 metres and the second from 20 to 30 metres below ground level) below the lignite seam having a piezometric head of about 30 metres above the top of lignite bed in the mining area. With the aid of about 40 deep well pumps and a number of observation wells, intensive large scale hydraulic tests were conducted. It revealed that lowering of the piezo-metric surface to a satisfactory low level below the mining surface would require a constant and sustained pumpage of about 40,000 gallons per min (about 260,000 m3/day) during the life time of the mine.

4.5. *Oil and Natural Gas Commission of the Government of India (O.N.G.C.).*—Even though the Oil and Natural Gas Commission is investigating by deep drilling the possibility of obtaining oil from the Under Ground, the particulars collected by the Commission will be of very much useful for ground water investigations.

5.0. *Activity by U.N. Organisations*—

5.1. In planning large scale ground water resources, particularly where water supply may be limited an essential preliminary is to make an assessment of the water resources it is hoped to develop, its movement, storage, recharge, discharge, quality and its quantity. While such an assessment itself usually involves a detailed and prolonged, hydrogeological investigations in countries where but little scientific information is available, it must usually be proceeded by investigations into local climatology, hydrology, geology and hydrogeology so that the ground water resources can be determined. All these studies require not only highly trained and experienced scientific and technical staff but also adequate time to make necessary surveys.

5.2. In order to investigate the water problems of the Madras State a five member team of United Nations including 3 Headquarters' experts was sent to India at the end of October 1964 on a three week mission. They recommended crash programme comprising ground water exploration and development and surface water utilisation through long distance water conveyance. As an outcome of the investigation in June 1965 the special fund approved a three year project—Ground Water Investigations in Madras State—at a cost of $ 1,688,000 (Rs. 1,26,50,000) with a contribution by the special fund of $ 1,098,000. Thus Ground Water Investigations Project Organisation has been set up from 17th March 1966 with assistance

TABLE 3.

Potential evapo-transpiration (In millimetres) (Corrected for cloudiness).

Serial number. (1)	Station. (2)	January. (3)	February. (4)	March. (5)	April. (6)	May. (7)	June. (8)	July. (9)	August. (10)	September. (11)	October. (12)	November. (13)	December. (14)	Annual. (15)
1	Hassan ..	36	98	122	116	98	66	58	66	71	42	34	32	839
2	Mercara ..	36	75	80	78	74	48	45	50	50	43	33	32	644
3	Mysore ..	43	116	130	130	124	71	72	75	75	47	36	38	956
4	Bangalore ..	37	107	109	125	107	72	67	67	67	43	31	29	861
5	Ooty	23	47	60	62	57	41	41	41	43	28	25	22	490
6	Coimbatore ..	38	105	102	127	114	71	71	71	90	44	38	34	905
7	Salem	55	147	209	239	209	142	131	122	113	59	50	45	1521
8	Kodaikanal ..	26	46	55	61	64	43	43	43	43	26	24	24	498
9	Trichy ..	56	143	202	268	268	208	208	165	140	67	62	42	1829
10	Adirampatnam	65	101	158	147	194	139	139	113	122	75	44	52	1349
11	Nagapattinam ..	48	121	166	223	258	186	176	150	109	67	52	48	1604

TABLE 4.

Soil Moisture Deficit (in Millimetres).

Serial number. (1)	Station. (2)	January. (3)	February. (4)	March. (5)	April. (6)	May. (7)	June. (8)	July. (9)	August. (10)	September. (11)	October. (12)	November. (12)	December. (14)	Annual. (15)
1	Hassan ..	32	92	112	58	..	..	..	..	..	..	..	16	310
2	Mercara ..	32	60	60	11	..	..	..	..	..	..	..	13	185
3	Mysore	29	111	117	67	..	8	1	..	..	..	..	28	371
4	Bangalore ..	31	101	98	82	4	..	..	..	..	..	..	19	335
5	Ooty	..	35	26	..	..	..	..	..	..	..	..	6	61
6	Coimbatore ..	22	96	89	85	54	31	29	40	51	..	..	1	498
7	Salem	47	139	196	188	95	60	33	..	..	..	..	20	778
8	Kodaikanal	..	8	6	..	..	..	..	..	..	..	..	..	14
9	Trichy	31	131	193	219	187	165	174	65	..	..	..	..	1,165
10	Adirampatnam	..	99	132	129	176	72	94	63	34	..	..	..	708
11	Nagapattinam	..	101	146	194	219	153	143	61	28	..	..	..	1,045

from the United Nations Development Programme. This project envisages investigation and evolution of ground water resources and appraisal of the technical and economical feasibilities of ground water development in four aquifers in Madras State, viz.

1. Kudathalayaru Aquifer
2. Palar aquifer
3. Neyveli aquifer

and 4. Coleroon aquifer

5.3. This project has started investigation and is collecting hydrogeological data and is expected to make a few years for successful completion of the investigation phase. Meanwhile it has been considered expedient to plan development schemes for the Coleroon aquifer being the most promising of all the above four aquifers and also since it forms part of an ancient irrigated agricultural tract with fully established water and land management practices and hence expected to yield quick results. Hence a Ground Water Circle under the guidance of a Superintending Engineer has been formed in the Public Works Department, Madras for conducting field pumping tests in Coleroon aquifer area. A number of deep wells were constructed in the area by this Ground Water Circle and observations are being taken. A preliminary hydraulic survey was made on the Ground Water Potential of the Coleroon Aquifer, at Irrigation Research Station, Poondi and the water budget for the aquifer has been worked out based on the data available.

6. *Research activities.*—

6.1. It is noteworthy to mention here, that the research studies being done at Irrigation Research Division, Poondi on Ground Water. Studies are being done under the scheme of Research on Minor Irrigation and Water Use, sponsored by the Ministry of Food and Agriculture, Government of India. The studies, being done may be divided into three as below:

6.2. *Mathematical approach* :—

6.2.1. In the calculation of discharge drawn by a circular well situated within a circular feed contour, formulae are available. These formulae give erratic results, in case of an eccentric well system where the radius of well is appreciable comparing to the radius of circular boundary. This difficulty has been overcome by a suitable mathematical technique. Model studies are being done to confirm the theoretical results. The above studies will be useful in cases where the intake wells are located in close proximity of feed contours—for example wells situated near an irrigation canal.

6.2.2. Using the above theory a successful technique has also been developed for calculating the drawances of individual well in a *n-tiple* well system by employing the principle of Maxwell's Coefficients. Model experiments are being carried out to verify the theoretical results.

6.3. *Fundamental studies* :—

Interference among wells : In fixing up the location of wells, the spacing of wells is an important consideration. When a number of wells are introduced within a feed contour, the output increases but the production capacity of individual wells decreases. Under such conditions, it will be necessary to decide on economical point of view the spacing of wells so that, the efficiency of each well is not considerably reduced. Hence studies have been taken up using electrical analogy technique to arrive at solutions for optimum spacing for maximum efficiency.

6.4. *Applied studies* :

Design of a continuous electrical analogue computer for Coleroon River basin—Ground Water Studies :

Conducting field pumping tests, to ascertain the discharge characteristics of wells in a particular basin, will involve more time and huge expense. Electrical network theory for stimulating Ground Water basin is the readily available tool for solving such problems. Here the electrical analogue should be modified in its values of resistors and conductors such that all observed drawdown histories in the wells in the aquifer for relevant causative pumpages are correctly simulated by the electrical transients at the corresponding nodes. This will be the most difficult part of the work. Resort to discrete resistors will require plenty of time for a trial and error solution. Therefore a new method has been developed using a continuous resistance medium of suitable liquid or powder to represent the hydraulic resistance of the acquifer. The great advantage with such a resisting medium is that its continuity ensures better simulation; variation of local transmittances can be readily simulated by introducing pockets of other media of varying depths. The three dimensional effect of partially penetrating wells can also be reproduced in the Continuous Resistance Analogue. The technique of measurement is under perfection. Model for Coleroon River basin is under construction.

7. *Conclusion* :

Ground Water development will have its own merits: First of all, food production will be increased. Waste lands may be brought under cultivation. Single crop area may be changed to double crop area and even double crop area will become triple crop area. By pumping out water from available locations, water can be brought to cities where availability of water is very much limited for industrial and domestic purposes. At certain location like Cauvery delta the problem of water logging may be minimised. In the year 1970-71 the Ground Water Investigation Organisation will complete its investigations. Sufficient field data also will be available. Research studies also will get a complete shape. Hence in the year 1970-71 Ground Water investigation will reach an advanced stage, to prepare for the formulation of concrete proposals for extracting large amounts of under ground water in a planned and economical manner, conducive to utilisation for industrial, agricultural and community purposes.

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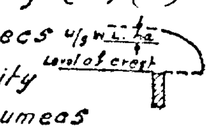
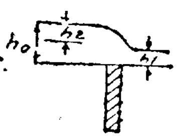
FORMULAE USED IN IRRIGATION ENGINEERING AND HYDRAULICS

III INSTALMENT

Sl. No. and description 1	Formulae in F.P.S. Units 2	Formulae in metric Units [Exact Equivalent] 3	Remarks 4
81. Aprons. Downstream apron width	Width $W = L + 1/2\, d$ or bed width of canal downstream of drop whichever greater. W, L and d = in feet	Width $W = L + 1/2\, d$ W, L and d, in metres.	
82. Length	$L = 2de = 2\sqrt{dch}$ or $4 + 2\sqrt{dch}$ Whichever is greater de: depth over sill of notch in feet L: Length area in feet h: difference between upstream and downstream water levels in ft.	$L = 2\,de + 2\sqrt{dch}$ or $1{\cdot}22 + 2\sqrt{dch}$ Whichever is greater de: depth over sill of notch in metres L: Length of area in m. h: difference between upstream and downstream water levels in metres.	
83. Thickness	Minimum $t = \sqrt{dc + h}$ t, dc and h are in ft.	Minimum $t\ \sqrt{\frac{dc+h}{1.811}}$ t, dc and h are in metres.	
84. Bed pitching upstream side and downstream side	Bed pitching $l_1 = 1\frac{1}{2} d$ - do - $l_2 = 2d$ Revetment $l_3 = 3d$ or 10' Whichever is greater	$l_1 = 1\frac{1}{2} d$, $l_2 = 2d$, $l_3 = 3d$ or 3·13 m. Whichever is greater	

1	2	3	4
85. Down stream side	$L_4 = 4(d+h)$ or 20' Whichever is greater d: depth of water over sill of notch in feet h: difference between u/s and d/s water-Level in feet	$l_4 = 4(d+h)$ or 6·1m. Whichever is greater d: depth of water over sill of notch in metres h: difference between u/s and d/s water Levels in metres.	
86. Depth of water cushion	$(dw+d_1) = \frac{1}{2}\, dc\sqrt{h}$ dw = depth of water cushion in feet d_1 = depth of water on down-stream apron in feet dc = depth of water over sill of notch in feet h : diffrence between u/s and D/s Levels of water in feet	$(dw+d_1) = 0{\cdot}905\, dc\sqrt{h}$ dw = depth of water cushion in metres d_1 = depth of down-stream apron in m. dc : depth of water over sill of notch in m. h : difference between u/s and d/s Levels of water in metres	
87. Cross drainage works thickness of arch at springing	Width of springing $W = 2 + \frac{2R}{10} + \frac{r}{10}$ R = Radius of arch in ft r = rise of arch in ft.	$W = 0{\cdot}61 + \frac{2R}{10} + \frac{r}{10}$ R = Radius of arch in m r = rise of arch in m.	
88. Batter of abutment	$n = \frac{1}{25}\,\frac{(\text{Span of arch})}{(\text{rise of arch})}$ Span, rise: in feet	$n = \frac{1}{25}\left(\frac{\text{Span of arch}}{\text{rise of arch}}\right)$	
89. Thickness of arch at crown.	$t = n\sqrt{S}$ t = in feet; S = span in ft. $n = 0{\cdot}4$ to $0{\cdot}5$	$t = \frac{\sqrt{R+\frac{S}{2}}}{7{\cdot}24} + 0{\cdot}061$ t = in m. S span in m. R = Radius of arch in m.	

1	2	3	4
90. Thickness of piers	—	$t = 0{\cdot}552\sqrt{S}$ t: thickness of piers in m S : span of arch in m. This may vary from 1/5 to 1/3 spans in exceptional cases it may be 0·4S	
91 Tank surplus weirs - discharge over the weir (clear over fall)	$Q = \frac{2}{3}\, cbh^{3/2}\sqrt{2g}$ Q = discharge in cusecs b = breadth of weir at crest Level in ft h: head of water in ft g: acceleration due to gravity in ft/sec^2 c: Coefficient of discharge (assumed as 0·62)	$Q\ \frac{2}{3}\, cbh^{3/2}\sqrt{2g}$ Q : discharge in cumecs b = breadth of weir at crest Level in m. h : head of water in m g : acceleration due to gravity in m/sec.^{2} c : Coefficient of discharge (assumed as 0·62)	
92. Clear Over fall taking upto account the Velocity of approach	$Q = \frac{2}{3}\, cb\sqrt{2g}\,\left((h+ha)^{3/2} - (ha^{3/2})\right)$ Q = discharge in cusecs ha : head due to Velocity of approach in feet	$Q = \frac{2}{3}\, cb\sqrt{2g}\,\left((h+ha)^{3/2} - (ha)\text{-}(ha)^{3/2}\right)$ Q : discharge in cumecs ha : head due to Velocity of approach in cumecs  	
93. Drowned overfall	$Q = \frac{2}{3}\, cb\sqrt{2g}\, h_2^{3/2} + cb\, h_1\sqrt{2g h_2}$ L_1, h_1 and h_2 are in feet Q = discharge in cusecs $h_2 = ho - h_1$ difference between u/s and d/s.	$Q = \frac{2}{3}\, cb\sqrt{2g}\, h_2^{3/2} + cb\, h_1\sqrt{2g}\, h_2$ L_1, h_1, h_2 are in metres Q = discharge in cumecs. $h_2 = h_0 - h_1$ (difference between u/s and d/s)  	

1	2	3	4
94 Hazen-William's formula for pipe flow	$V = 1.318C_1 \times R^{0.63} \times S^{0.54}$ R: Hydraulic mean depth in feet S: Slope of pipes	$V = 1.318C_1 \times R^{0.63} \times S^{0.54}$ R: Hydraulic mean depth in metres S: Slope in pipes	For Values of C_1 see appendix A-II
95 (i) Velocity head	$h = \frac{V^2}{2g}$ h: head in feet V: Velocity in ft/sec g: acceleration due to gravity in ft/sec^2	$h = \frac{V^2}{2g}$ h: head in m V: Velocity in m/sec. g: acceleration due to gravity in m/sec^2	
(ii) Loss of head due to bends	$h_1 = K_1 \times \frac{V^2}{2g}$ h_1: loss of head in feet K_1 = a constant depending upon the bed	$h_1 = K_1 \times$ h_1 = loss of head in metres K_1 = a constant depending upon the bed	For Values of K_1 see appendix 'A' V_1
(iii) Loss of head due to valves and fittings	$h_2 = K_2 \times \frac{V^2}{2g}$ h_2 = loss of head in ft. K_2 = a constant depending upon the fittings and valves	$h_2 = K_2 \times \frac{V^2}{2g}$ h_2 = Loss of head in m K_2 = a constant depending upon the fittings and valves	For Values of K_2 see appendix 'A' VII.
(iv) Loss of head due to sudden enlargement	$h = \frac{(V1 - V2)^2}{2g}$ h: loss of head in ft. V: Velocity in ft/sec g: acceleration due to gravity in ft/sec^2	$h = \frac{(V1 - V2)^2}{2g}$ h: loss of head in metres V: Velocity in m/sec. g: acceleration due to gravity in m/sec^2	
(v) Loss of head due to concentration	$h = 0.5\frac{V^2}{2g}$ h: Loss of head in ft. V: Velocity in ft/sec. g: acceleration due to gravity in ft/sec^2	$h = 0.5\frac{V^2}{2g}$ h: Loss of head in m. V: Velocity in m/sec g: acceleration due to gravity in m/sec^2	

95 (Contd) (vi) Loss of head at entrance to pipe	$h = 0.5\frac{V^2}{2g}$ V: Velocity in ft/sec. h: Loss of head in feet g: acceleration due to gravity ft./sec.^{2}	$h = 0.5\frac{V^2}{2g}$ V = Velocity in m/sec h: Loss of head in m. g: acceleration due to gravity in m/sec.^{2}	
(vii) Loss of head due to obstruction	$h = \left\{\frac{A}{0.66(A-a)} - 1\right\}^2 \left(\frac{V^2}{2g}\right)$ h: loss of head in feet. A: area of pipe in inch^2 a: area of obstruction in in.^{2}	$h = \left\{\frac{A}{0.66(A-a)} - 1\right\}^2 \left(\frac{V^2}{2g}\right)$ h: Loss of head in m. A: area of pipe in cm^2 a: area of obstruction in cm^2	
(viii) Darcey's formula for frictional loss in pipes	$hf = \frac{4flV^2}{2gd}$ or $\frac{flq}{10d^5}$ Where hf = head lost in friction in feet l: Length of pipe in ft. V: Velocity of flow in ft/sec. g: acceleration due to gravity in ft./sec.^{2} d: dia. of pipe in ft. Q: discharge in cusecs. f = friction co-efft.	$hf = \frac{4flV^2}{2gd}$ or $\frac{flq^2}{10d^5}$ Where hf = head lost in friction in feet l: Length of pipe in m. V: Velocity of flow in m/sec. g: acceleration due to gravity in m/sec.^{2} d = dia. of pipe in m. Q = discharge in cumecs f = friction co-efft.	For new pipes: $f = 0.005\left(1 + \frac{1}{40d}\right)$ For old pipes $f = 0.01\left(1 + \frac{1}{40d}\right)$ d: is the dia. of the pipe.
96. Forchheimer formula for loss of head in penstocks.	—	$h = 11.33\, n^2 \frac{Q^2 l}{D^{5.4}}$ h: loss of head in m. n: roughness co-efft. l: Length of penstock Q: discharge in cumecs D: dia. of the pipe in m.	
97. The Velocity 'a' with which the pressure wave traverse the pipe is given by	$a = \frac{32.470}{\sqrt{48.3 + \frac{KD}{e}}}$ V: Velocity in ft. D, e are the dia. and the thickness respectively of pipe in feet.	$a = \frac{9900}{\sqrt{483 + \frac{KD}{e}}}$ V: Velocity in m. D, e are the dia. and the thickness respectively of pipe in m.	

1	2	3	4
98. For woodenpipe the stage thickness 't'	$t = 0.52\, a \sqrt{\frac{H}{f_W}}$ (in inches) H = Max. pr. of water in ft. f_W = Working Unit stress in lbs/in². a: distance between iron (circular) bands in ft.	$t = 0.25\, a \frac{\sqrt{H}}{f_W}$ (in cms.) a: distance between iron (circular) bands in m. H = Max. pr. of water in m. f_W = Working unit stress in kg/cm²	

APPENDIX 'A'

Mannings Formula pipe	Manning's n.
I. a) Brass and glass pipe	0.009 to 0.013
b) Asbestos Cement	0.010 to 0.012
c) Wrought iron, Welded steel and wooden stave	0.010 to 0.014
d) Concrete pipe very smooth	0.011 to 0.012
e) Concrete pipe with rough joints	0.016 to 0.017
f) Vitrified sewer pipe	0.013 to 0.015
g) Corrugated iron steel pipe	0.02 to 0.022
h) Rivetted steel pipe	0.013 to 0.017

II Hazon William's formula pipe	Value of C_1
Asbestos cement Pipe	140
Extremely smooth and straight	140
Cast iron new	130
5 years old	120
10 years old	107 – 113
20 years old	90 – 100
30 years old	75 – 90
Cement Lined or Concrete	120 – 140
Welded steel	120
Rivetted steel	110
Wood Stave	120

III Basins formula-(description of channel)	Basins coefficient
a) smooth cement, planed wood	0.109
b) Planks, bricks, cutstone	0.290
c) Rubble masonry	0.833
d) Earth channel very regular or stone retment	1.540
e) Earth channels ordinary condition	2.350
f) Earth channels very rough or weed grown	3.170

IV Kutters formula:-

Description of channel or pipe.	Value of 'n'
1) Smooth cement, planed Timber	0.010
2) Iron or steel plate	0.011
3) Rough Timber, smooth concrete	0.012
4) Earthern canals in best condition	0.020
5) Earthern canals in good condition	0.0225
6) Earthern and gravel canals in fair condition and rivers in good condition	0.025
7) Canals with rough stony beds, weeds on banks and rivers in fair condition	0.030
8) Canals in bad condition and winding rivers	0.035
9) Rivers of irregular cross-section	0.040 to 0.100
10) Sewers 600mm or less in diameters	0.015
11) Sewers over 600mm. in diameter of best work	0.012
12) Sewers over 600mm in diameter under good ordinary conditions of work	0.013
13) Brick sewers lined with verified or reasonably smooth hand-burned brick and laid with great care and with close joints	0.014
14) brick work under ordinary condition	
15) Brick sewers, rough work	

V Unwin's Formula:-	a	b in feet	in metres
1) Smooth iron pipe	0.00497	0.034	0.0256
2) Encrusted iron pipe	0.00996	0.084	0.0255
3) Smooth cement plaster and planed wood	0.00316	0.100	0.0305
4) Ashlar of brick	0.00401	0.230	0.0701
5) Rubble masonry or stone pitching	0.00507	0.830	0.250

VI Values of K_1 for bends:-

$\left(\frac{\text{Dia. of Pipe}}{\text{Radius of pipe}}\right)$	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
K_1	0.13	0.14	0.16	0.21	0.29	0.44	0.66	0.98	1.4	1.98

VII Values of K_2 for fittings:-

Pipe fittings.	K_2
Globe valve, completely open	10.00
Angle Valve	2.00
Close return bend	2.20
Strainer	2.00
Standard Tee	1.80
Foot Valve	1.50
Short radius elbow	0.90
Medium sweep elbow	0.75
45° elbow	0.42
Gate Valve, Completely Open	0.19
Submerged discharge	1.00
Long radius elbow	0.60

NEWS FROM ABROAD.

U.S.S.R. STUDIES $ 100-BILLION WATER DIVERSION SCHEME

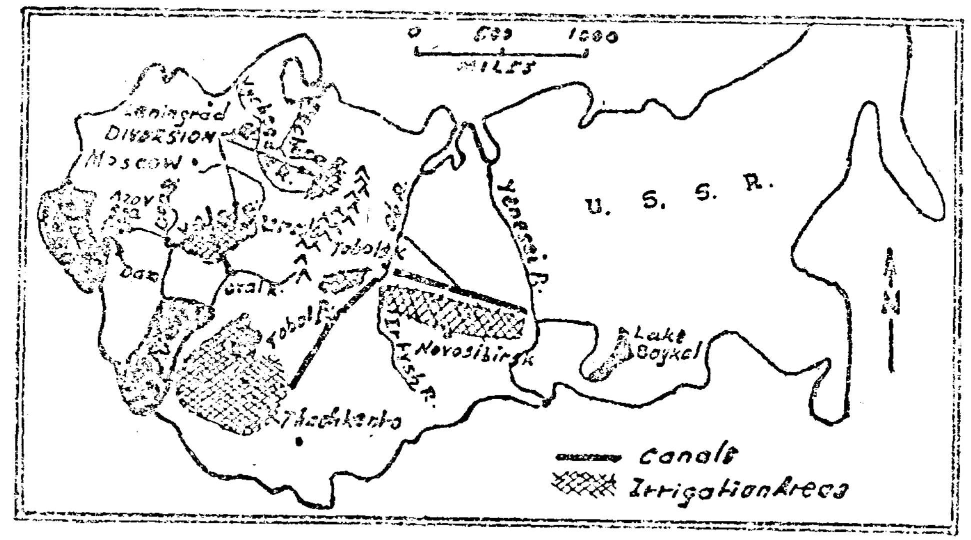
- The Soviet Union, which has an over-abundance of water where it does not need it and an undersupply where it does, is planning the world's largest diversion system to correct the imbalance.

In the works is a proposal to transfer water from northward flowing rivers to Water-scarce areas in both European Russia and Central Asia. The scheme would irrigate a minimum of 100 million acres, require atleast 6,500 miles of canals and, with associated dams and other structures, cost well over $ 100 billion.

Engineering has been carried out, economic analysis completed and, in some cases, schedules and estimates prepared for the principal segments of the scheme. While the firm decision to go ahead awaits the announcement of Russia's five-year plan this summer, all signs point to approval. To expand agriculture, as it needs to do, the Soviet Union must irrigate dry but fertile areas that would be served by the diversion scheme. The development of Central Asia, to which the Government is committed, is contingent upon new supplies of water. At stake, too, is the survival of the Capsian and Aral seas and the Sea of Azov as viable bodies of water.

The diversion scheme, in general, is in two major parts. One involves the area west of the Urals to relieve European Russia's shortages. The other will divert Siberian rivers to irrigate Central Asia.

European Russia diversion.—The project west of the Urals will tap the northward flowing Vychegda River, which comes into the White Sea at Archangel, and the Pechora River, which flows into the Barents Sea. Fifty million acre ft. a year will be diverted into the over exploited Volga, which flows southward to the Caspian Sea.



The Volga, in turn, will be tapped by two diversion canals. One will put water on a new area of farm acreage at the foot of the Urals, with return flows making their way into the Caspian Sea. The other will take water westward to the Don River, which flows into the sea of Azov.

Teamed up with the diversion into the Don River will be a dam across Kerch Strait, which separates the Black Sea and the Sea of Azov. The dam will halt the Black Sea's saltwater intrusion and the additional fresh water will replenish the Sea of Azov.

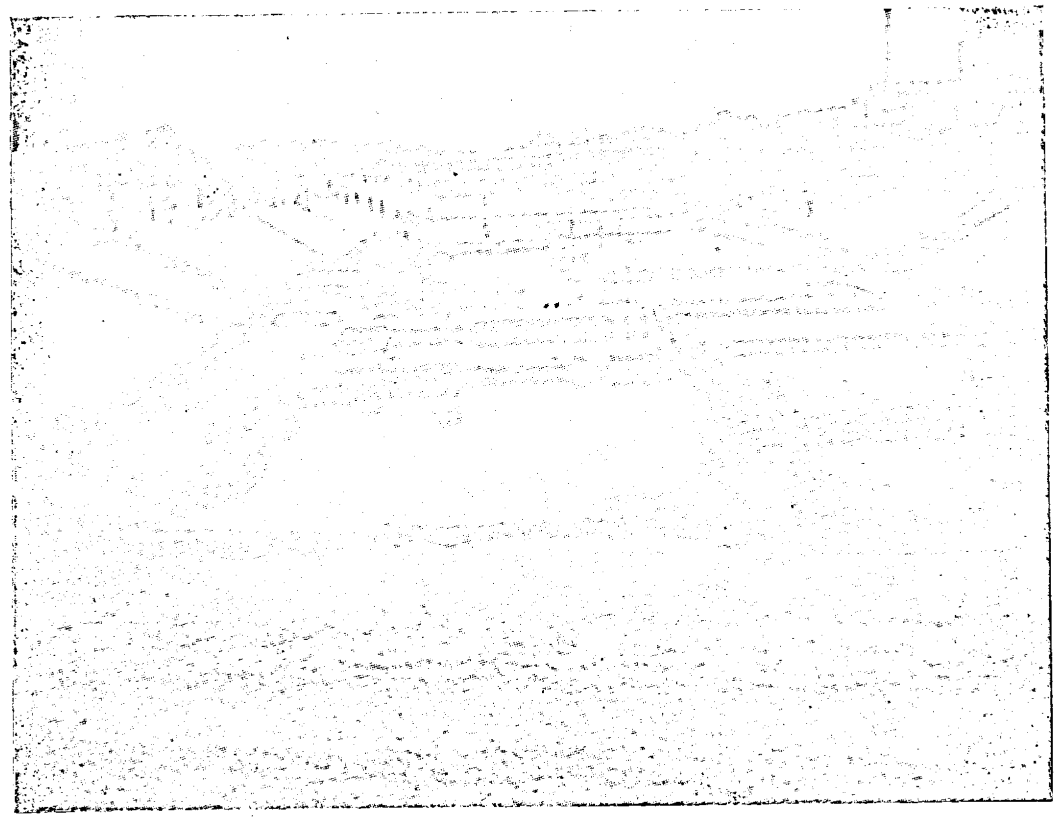
Siberia to Central Asia.—Even more wide-scaled is the Siberia-Central Asia scheme. It calls for diverting the water of the Irtyush and Tobol rivers, both tributaries of the Ob and the Yenesei. This would be carried out by a major dam at Tobolsky, blocking the north-ward flow of the Irtyush and Tobol rivers, and a cross-country canal to bring in the water of the Yenesei. In all, the scheme calls for a 2,300-mile system of canals and a network of reservoirs.

There are various estimates of how much water can be safely diverted from the Ob and Yenesei systems' total runoff of 767 million acre-ft. annually without damaging the extensive Siberian river transport network and the chain of 15 hydro plants now under development on the Yenesei. The conservative estimate is 122 million acre-ft or 16 percent. The most optimistic is 255 million-acre ft. or 35 percent.

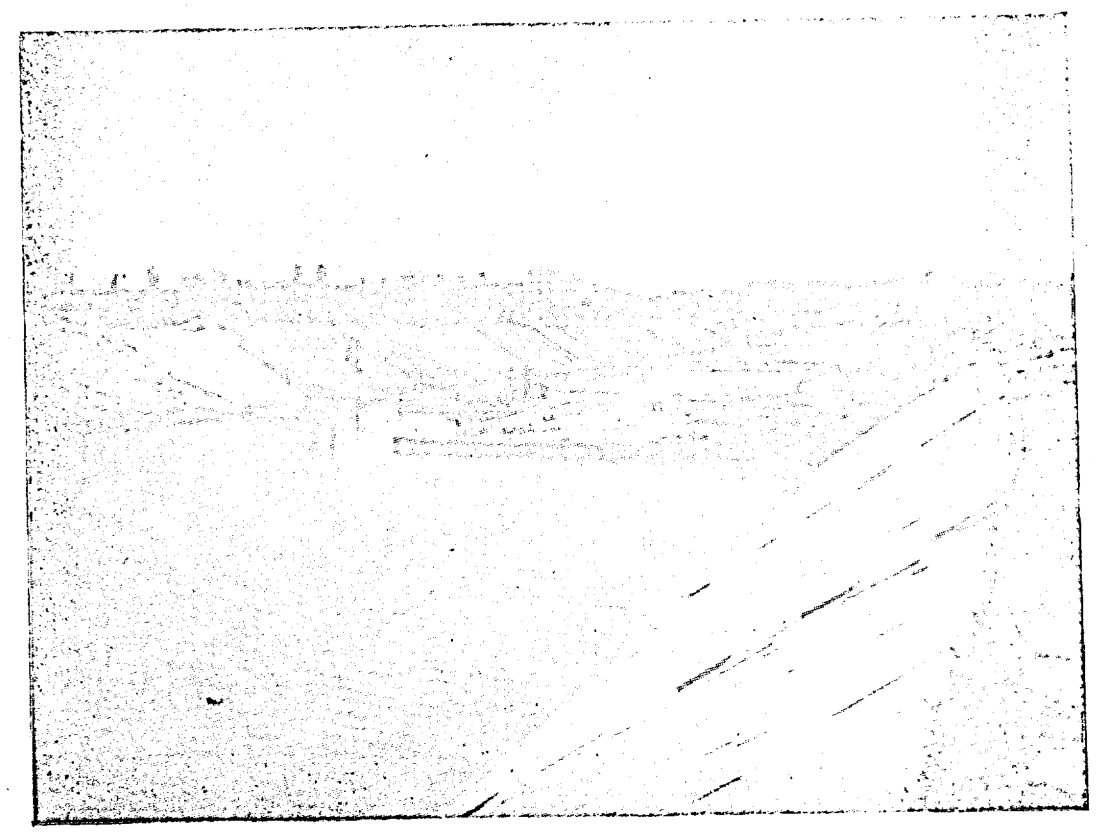
In addition to providing irrigation water for the south, the project will drain the vast marshes of Siberia that are waterlogged more than 30 ft. deep, thereby making usable between 100 million and 150 million acres.

The favoured scheme will require lifting the Siberian water a distance of 2,500 ft. over the Turgai Tableland. Contemplated are 12 pumping stations with 70,000-cft. pumps along the Tobol River to lift the water in 200 ft. jumps to make the river flow backwards.

News—Record, June 1970.



Cooum Improvements Scheme Channelisation of North Arm-View Showing Lining Work in Progress along the Right Bank below Stanley Viaduct.



Cooum Improvements Scheme Channelisation of North Arm-View Showing Lining work in progress along the Left Bank below Wallajah Bridge.

INVITATION TO READERS

Kind attention of the Engineers of the Madras Public Works Department and readers of the journal elsewhere is drawn to the meagre response to repeated requests for contribution of articles to the journal.

May we once again emphasise the two-fold objective of the journal, viz., to promote the interest of engineers and aiding their specialised work by placing before them the many problems of technical importance and ways and means of solving them, and secondly, opportunities being scarce for engineers to express their own experience in solving practical problems of design and execution, we wish to add that this journal has been the only medium of expression for those in the field. It is earnestly desired that the Engineering fraternity will come forward in large numbers to utilise this medium to its best advantage by offering their valuable contribution.

The scope of the articles to the journal need not be rigorously confined to the subjects on irrigation alone. Articles which have a direct bearing on subjects given below are also welcome :—

(1) Technical aspects of foundation soils and foundation Engineering.

(2) Auxiliary works in the field of irrigation and other water-retaining structures and works.

(3) Practical solution to hydraulic problems in canals and distribution systems with reference to their maintenance.

(4) Problems of soil erosion and conservation and reclamation of land.

(5) Practical silt problems in rivers and reservoirs.

(6) Problems of sanitation and public health and possibilities of utilisation of sewage.

(7) Inland waterways and navigation, fishing schemes and protection of land against sea erosion, etc.

(8) Problems of drainage in deltaic tracts and entrance of rivers into the sea.

(9) Run-off studies in catchments and evaporation studies in reservoirs.

(10) All allied subjects.

The Executive Engineers of the Madras Public Works Department are specially requested to encourage their Subordinate Officers to come forward with articles and enable the journal to flourish and serve the common cause of the Engineers of the State.

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PRINTED BY THE DIRECTOR OF STATIONERY AND PRINTING, MADRAS,
ON BEHALF OF THE GOVERNMENT OF TAMIL NADU—1971