The New Irrigation Era

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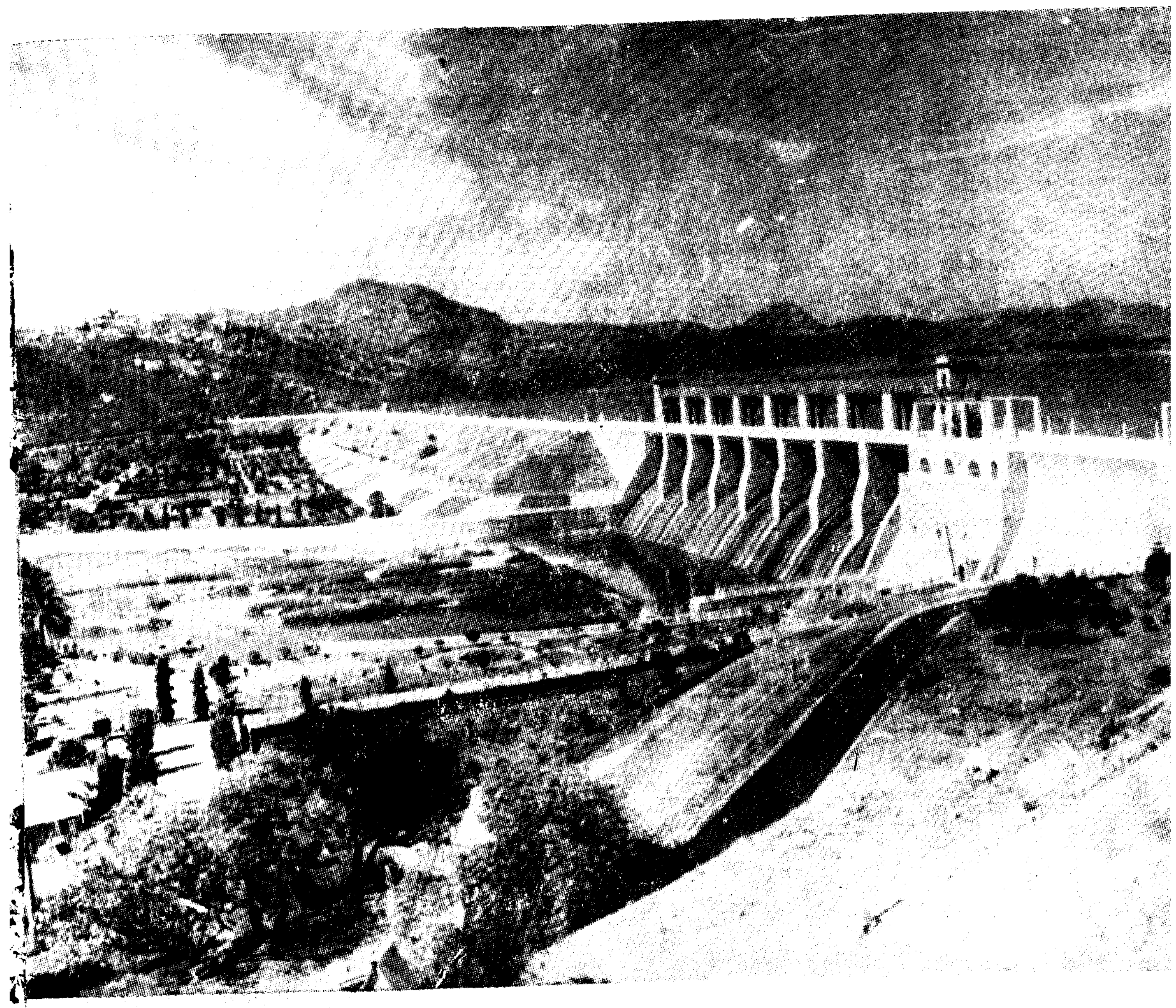
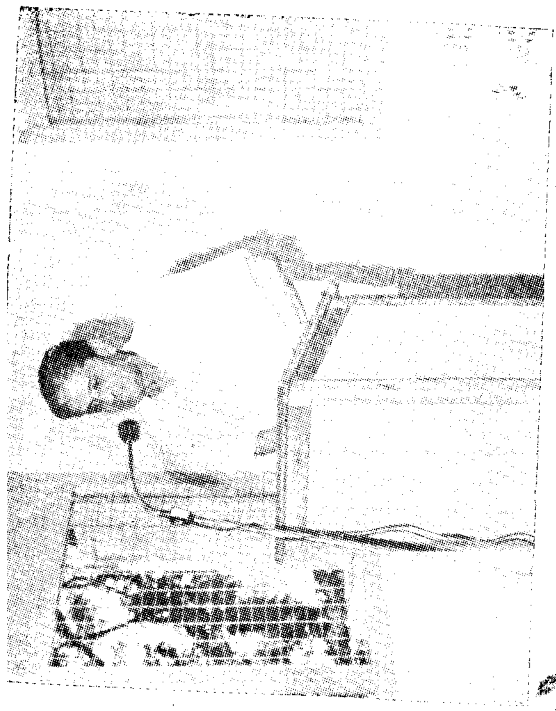
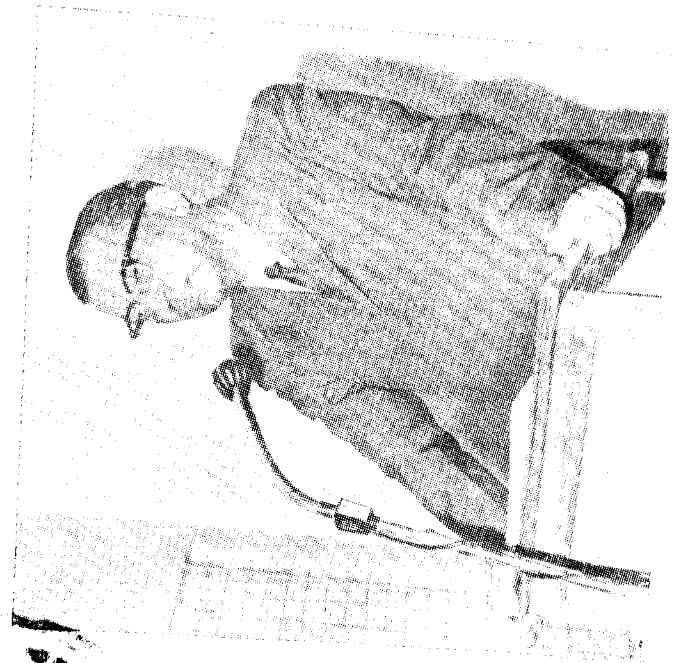
THE NEW IRRIGATION ERA



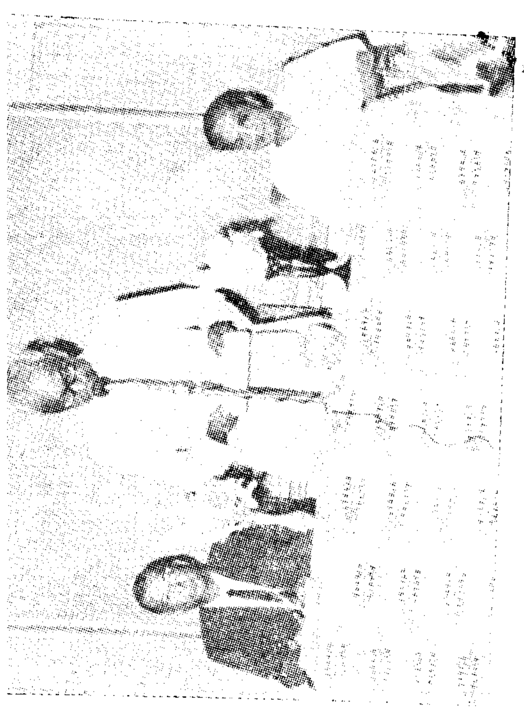
Panoramic view of Krishnagiri Dam and Reservoir.



Chief Engineer (Irrigation & General) introduced the Lecturer to the audience.



Er. D. Doddiah delivered his lecture.



Chief Engineer (Buildings) presided over the fun[illegible]

Group Discussion.

THE NEW IRRIGATION ERA

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EDITORIAL

Lining of Canals as a measure to increase the Hydraulic efficiency of the Irrigation Canal and to reduce the transmission losses is attracting the attention of the Irrigation Engineers during the recent years and most of the new medium projects sanctioned in the State have this feature included in the Project proposals. But, lining the Canals of existing projects where the Canals have attained a regime poses a problem which requires cautious handling. Such lining cannot be done straight away without reducing the cross section of the Canal and altering the position of the offtake arrangements of the existing branch channels etc. The analysis on economies may show that there would be saving in the quantities of water but this saving could be only at a very high cost. In old channels where the crosssection is to be reduced large quantities of earth have to be conveyed for filling up. To this, high cost of cement concrete has to be added. All these may make lining the old Canal a very costly project. An important aspect to be looked into in some of the systems is that the Canal itself acts as recharge area for the ground water. The lining will block the recharge to some extent and this will present a difficult situation when the surface flows diminish. In certain areas unlined channels are the main source of recharge of ground water storage to be effectively utilised at a later stage. Under these circumstances we have to cautiously approach the proposals for lining old Canals and we cannot assume blindfolded that lining would yield large benefits. In case of old Canal systems, the first thing to be done is remodelling with efficient control structures and regulators to give better command. The cost involved in this may not be very heavy compared to that required for lining but benefits can definitely expected to be more.

PILAVUKKAL PROJECT.

By

THIRU S. RAJAGOPALAN*

Name of the Project :

In the hills from where the main rivers involved in the Project take their origin, especially in the vicinity of the site where reservoirs have to be built is located prominently a standing rock split in two and the project derives its name from this rock. Pilavukkal (பிளவுக்கல்) in Tamil means a " Split rock ".

Rivers involved in the Project :

Arjuna Nadhi in Srivilliputtur Taluk a tributory of Vaippar is fed mainly by the three hill streams, Kovilar, Periyar and Chittar in its higher reaches. All these three hill streams emerge out of the eastern slopes of Western Ghats. Kovilar takes its origin from the Panchanthangimalai at an altitude of about 1,165 metres (3,821 feet, and runs from North to South and at0.8 K.M. (about half a mile) above Thungankadavukoil, it takes a turn, towards east. Periyar takes its origin in the hills at an altitude of about 1,644 metres (5,388 feet) runs from South to North up to Thavalaiperumalparai, then takes a turn towards east and joins the Kovilar river just (half a mile) 0.8 K.M. below Thungankadavukoil. The combined course called Periyar traverses for a distance of 3.2 K.Ms. (2 miles) where it is met with by the Chittar river taking its origin in an adjacent valley. Then the combined course finally enters into Viragasamudram and Watrap Periyakulam after supplying a few tanks enroute. The surplus course of Watrap Periyakulam is the origin of Arjuna Nadhi which in-turn feeds a number of tanks with the aid of a good number of anicuts across the river and finally joins Vaippar near Nemmeni Village of Sattur Taluk below the Nemmeni Anicut.

Existing Irrigation in these Rivers and Present Proposals :

The catchment of these rivers is subjected to heavy rainfall during North East Monsoon and fairly satisfactory rainfall during the South West Monsoon period also. Consequently, a considerable part of the area is irrigated with two crops one a long term crop called Pishanam (October to February) and the other a short term crop either Kar or irrigated dry crop ' ually Cholam or Ragi. All the irrigation exists below the confluence of Periyar and Kovilar and is carried out through channels and tanks fed by them taking off at the anicuts built across the river.

The system as a whole consists of 14 anicuts (including open off-take) each feeding a old number of tanks spread all over, through the various channels taking off on its left and right. The existing irrigation details under this system upto Arjuna Nadhi anicut near Nathampatti are furnished below :—

STATEMENT OF AYACUT UNDER THE VARIOUS TANKS FED BY KOVILAR, PERIYAR AND CHITTAR EXCEPTING THE TANKS EXCLUSIVELY FED BY CHITTAR UP TO ARJUNANADHI ANICUT.

Name of System.	Registered Ayacut Hectares / Acres.	Single Crop Hectares / Acres.	Double Crop Hectares / Acres.	Average Cultivation. Single. Hectare / Acres.	Average Cultivation. Double. Hectares / Acres.	G.A.P. Single. Hectares / Acres.	G.A.P. Double. Hectares / Acres.	Number of tanks fed.	Remarks.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1. Periyar and Kovilar ..	2,227·00	2,227·00	164·72	2,210·92	164·72	15·11	..	23	..
	5,501·18	5,501·18	407·04	5,463·82	407·04	37·36	..	..	..
2. Arjuna Nadhi Anicut ..	617·51	617·51	57·46	556·90	57·46	60·64	..	14	..
	1,525·91	1,525·91	142·00	1,376·05	142·00	149·86	..		..
Total .. Hectares ..	2,838·51	2,838·51	222·18	2,767·82	222·18	75·75	..	..	..
Total .. Acres ..	7,027·09	7,029·09	549·04	6,839·87	549·04	187·22	..	..	

Present Area Irrigated : 2,767·82 + 222·18 = 2,990 Hectares.

6,839·87 + 549·04 = 7,388·91 acres say 7,389 acres.

Total Area Irrigated including Tanks fed by Chittar and Other Hill streams up to Arjuna Nathi Anicut = 3,330 Hectares (8,228 acres).

*** Executive Engineer, P.W.D., Pilavukkal Project Division, Srivilliputtur.**

The maximum flood occurs in the months of October, November and December. After these monsoon months only scattered rains occur causing uncertain and irregular flows in the channels fed by this river. Large extent of wet lands in the regions under the various tanks fed by the streams do not get water up to maturity of the crop (i.e.) during the fag end of the irrigation season. When heavy rains occur the streams are in spate and the tanks fed by them get easily filled up at once. The surplus flows down the river to join the main river Vaippar, wherefrom they go to sea without much being utilised. The necessity to store a portion of the flood flows by constructing two small reservoirs in each of these hill streams Kovilar and Periyar at suitable sites with a view to release them during the period of maturity for giving one or two wettings at the end of crop season is apparent and the present scheme fulfils the above necessity.

Hydrology and storage capacity of proposed Reservoirs in Kovilar and Periyar :

The main object of the proposed reservoirs is to stabilise the existing irrigation in Kovilar and Periyar after their confluence up to and including the Ayacut under theArjuna Nadhi Anicut near Thulukkanpatti. Bringing the existing gap in present Irrigation and bringing new area into cultivation is also envisaged as there is enough yield available as surplus at Arjuna Nadhi Anicut site. This is discussed below :—

The combined catchment area of the various hill streams joining at Arjuna Nadhi Anicut site is287·2 Sq.Kms.(108·60 sq. miles) and is made up of hills and plains. An yield of 0·164MM³/KM² (15 M.Cft./Sq. mile) for the plain catchment based on the Rainfall Station at Watrap, and double the yield of 0·328 MM³/KM² (32 M.Cft./Sq. mile) for the hilly areas of altitude ranging from 1,068M. (3,500 ft.) to 1,763 M. (5,800 ft.) has been adopted and the total yield at the Anicut site is computed as 68·29 MM³ (2,412 M.Cft.).

The irrigation requirements for the existing Ayacut of 3,330 hectares (8,228 acres) up to the Arjuna Nadhi Anicut including that of tanks fed directly by Chittar and jungle streams works out to 3330/87·5 = 38·0 MM³ 8228/6=1,372 M.Cft.). Therefore the surplus available atthe Anicut site is 30·29 MM³ (1,040 M Cft.) and only about 65 per cent of the above surplus namely 18·40 MM³ (650 M.Cft.) is proposed to be stored in these reservoirs by filling them twice during the monsoonic months. The above storage helps to stabilise the existing ayacut of 2,990·21 hectares (7,389 acres on the Kovilar and Periyar and that under the Arjuna Nadhi Anicut near Thulakkapatti and to bridge an extent of 72·84 hectares (180 acres) gap existing under these systems. Besides, there is enough water to convert 532·15 hectares (1,315 acres) of dry land into wet cultivation as also for raising a second crop over an area of 463·75 hectares (1,146 acres).

Location of Dams :

(i) Kovilar Reservoir :

The proposed Kovilar Dam is located in north altitude of 9°41′ and east longtitude of 77°33′. It is situated just about 4·8 K.Ms. (3 miles) north of Thungankadavukovil across Kovilar river and 17 K.M. (10·56 miles) from Watrap Village. The dam is actually proposed to be located in forest area. The Catchment area at the proposed site is 24·77 KM² (9·57 Sq. miles).

There are two hillocks on either side of the river and they will be connected by a straight earthern dam 630 metres (2,067 feet) long. The spillway of the reservoir is proposed in the left flank end for discharging the maximum flood discharge.

(ii) Periyar Reservoir :

The dam is proposed to be located in north altitude of 9°38′ and east longitude of 77°32′. It is situated just about 3 K.Ms. (1·86 miles) south of Thungankadavukovil across Periyar river and 16 K.Ms. (9·94 miles) from Watrap Village. The catchment area at the Dam site is 45·30 KM² (13·90 Sq. miles).

The dam starts from the foot of the hill ranges at its left, runs towards east crossing the Periyar river before embracing the Thavalaperumal Karadu, which is a small hillock. Then it runs southwards joining the foot of the hillock on the right bank. The present alignment of the dam therefore will be in the form of 'L' in plan with Thavalaperumal Karadu at the kind and its total length is 872 metres (2,858 feet).

The spillway of the reservoir will be located at the right flank end for disposing the maximum flood discharge.

SALIENT FEATURES OF PROPOSED KOVILAR AND PERIYAR RESERVOIRS.

	Kovilar.	*Periyar.*
1 Catchment area	24·77 KM² (9·57 Sq. miles.)	45·30 KM² (17·50 Sq. miles).
2 Water-spread area at FRL	73·67 hectares (182·00 acres)	76·10 hectares (188·00 acres).
3 Capacity at FRL	3·766 MM³ (133 M.Cft.)	5·437 MM³ (192 M.Cft.).
3a. Number of fillings	2	2
4 Maximum flood discharge	215 Cumecs (7970 C/S.)	286 Cumecs (10120 C/S.).
5 Full reservoir level	212·00 M. (695·54′)	204·50 M. (671 feet).
6 Crest level of spillway	208·94 M. (685 feet)	199·93 M. (656 feet).

SALIENT FEATURES OF PROPOSED KOVILAR AND PERIYAR RESERVOIRS—*cont.*

	Kovilar.	*Periyar.*
7 Top of Dam	214·00 M, (702·10′)	206·50 M. (677·50′)
8 Total length of Dam	660.00 M. (2165′)	884·00 M. (2900′)
9 Length of Spillway	20·73 M. (6800′)	24·40 M. (80.00′).
10 Number and size of Spillway Vents	2×9·14×3·05 M. (2×30×10′0″)	2×9·14×4·57 M. (2×30′×15′0)
11 Height of Dam above bed level of river	18·02 M. (59·14′)	18·91 M. (6202′).
12 River bed level	195·98 M. (643 feet)	187·59 M. (615 feet).
13 Sill level of river sluices	199·00 M. (652·89′)	190·00 M. (623·36′).
14 Number and size of River Sluice Vent	1×1·52M.×1·80 M. (1×5′0″ 6′0″).	1×1·52 M.×1·80 M. (1×5′0″× 6′0″).
15 Discharge through River Sluice	5 Cumecs (172 C/S.)	5 Cumecs (172C/S.).
16 Length of Earth Dam	640·00 M. (2100′)	864·00 M. (2835′).
17 Maximum height of Earth Dam	18·02 M. (59′14′)	18·91 M. (62·02′).
18 Top width of Earth dam	365 M. (12′0″)	3·65 M. (12′0″).
19 Sill level of Irrigation Sluice	206·00 M. (675·85 feet)	194·00 M. (636·47 feet).
20 Number and Size of Canal Sluice	1×1·22 M.×1·83 M. (1×4′0″× 6′0″).	1×0·9M. × 1·22 M. (1×3′0″ × 4′0″).
21 Discharge through Canal Sluice	0·251 Cumecs (887 C/S.)	0·68 Cumecs (24 C/S.).
22 Length of Main Canal	3600 M.	(4200 + 3800 M.) = 8000 M (26247 feet).
23 Number of Irrigation Sluices	10 Nos.	22 Nos.
24 Number of tanks benefitted by the Scheme	37 Nos.	
25 New Ayacut	143·65 hectares (355 acres)	388·5 hectares (960 acres).
26 Existing ayacut to be stabilised	2990 hectares (7389 acres).	
27 Gap in existing ayacut	424 75·66 hectares (187 acres).	
28 Stabilisation of Water-rate lands	202·70 hectares (501 acres).	
29 Proposed second term crop in existing ayacut	463·75 hectares (1146 acres).	

DESIGN FEATURES :

Earth Dam : The Earth Dam will have a slope of 2:1 to a depth of 5 metres (16·40 feet) from T·B·L· and 2½:1 and 3:1 at lower levels· The rear slope will be 2:1 with berm of 3 metres (9·84 ft) in width at suitable intervals. The dam will have rolled impervious hearting section in the middle and semi-pervious casing section on both sides. Cut-off trenches will be provided and they will have to be taken to a depth equal to 1/2 of the depth of water retained or to impervious stratum whichever is higher. In places, where the depth of pervious strata is large, a clay blanket on the upstream side of the cut-off trench will be provided. Key trenches will also be provided for proper binding in the upstream side of cut-off trenches. The front face of the dam will be protected with revetment of 0·60 m. (1·96 feet) thick using jeddy stones over a course of gravel backing 0·3 m. (one feet) thick. The rear face of the dam will be turfed. Necessary chutes at frequent intervals will be provided in the rear face of dam. Horizontal zoned filters with rock toe and longitudinal toe drains are also proposed for the drainage of the rear portion of the dam. The above specifications for earth Dam eare common for both the Reservoirs.

Surplus Arrangements.—The catchment area of the Kovilar river at the proposed dam site is 24·77 km^2. (9·57 sq. miles). Adopting a value of 1750 for C in Ryve's formula the maximum flood discharged works out to 220·8 m^3. (7,886 Cusecs).

The catchment area of the Periyar river at the proposed dam site is 45·30 Km^2. (13·90 sq. miles). Adopting the same value of 'C' the maximum flood discharge works out to 283·3 m^3. /Sec. (10,120 cusecs).

The Spillways for Kovilar and Periyar Dams are located in left flank end and right flank end of Dams as no hard rock is met with at reasonable depths. Two vents of 9·14 m.×3·05 m. (30′×10′) and two vents of 9·14 m.× 4·57 m. (30′×15′) fitted with radial shutters are proposed to pass the designed maximum flood discharge of 220·80 m^3. /Section (7,886 C/S.) and 283·3 m^3. /Section (10·120 C/S.) respectively. The surplus water will be let into the river through leading channels.

River Sluices.—The river sluices are proposed to be located at L.S. 80 m. (262·46 feet) in Kovilar Dam and at L.S. 480 m. (1,575 feet) in Periyar Dam. One Vent of size 1·52 m. × 1·80 m. (5′0″×6′0″) with its sill at 199·00m. (652·89′) in the case of Kovilar and one vent of size 1·52 m.×1·80 m. (5′0″×6′0″) with its sill at 190·00 m. (623·36′) in the case of Periyar are proposed for letting down the supplies in times of needs for the existing ayacut. The ventway provided for the sluice is quite sufficient to let down the normal flows in the river without impounding, in confirmity with scope of scheme.

Irrigation Sluices.—The Irrigation Sluices are proposed to be located at L.S. 510 m. (1,673 feet) in Kovilar Dam and in the central pier of Spillway in Periyar Dam to cater to the needs of new ayacut in both reservoirs. One vent of size 1·22 m.×1·83 m. (4′0″×6′0″) with its sill at 206·00 m. (676 feet) in the case of Kovilar Reservoir and one vent of size 1·22 m.×1·83 m. (4′0″×6′0″) with its sill at 194·00 m. (636·47 feet) in case of Periyar are proposed.

Water spread and land acquisition.—The area submerged by the water spread of Kovilar Reservoir is worked out as 73·67 hectares (182 acres) and the entire water spread lies within the limits of Reserved forests. No village or house sites will be submerged by the Reservoir.

The water spread of Periyar will submerge an extent of 76·10 hectares (188 acres). Out of this area, an extent of 48·98 hectares (121·00 acres) are patta lands and remaining are Poramboke and Reserved forest lands.

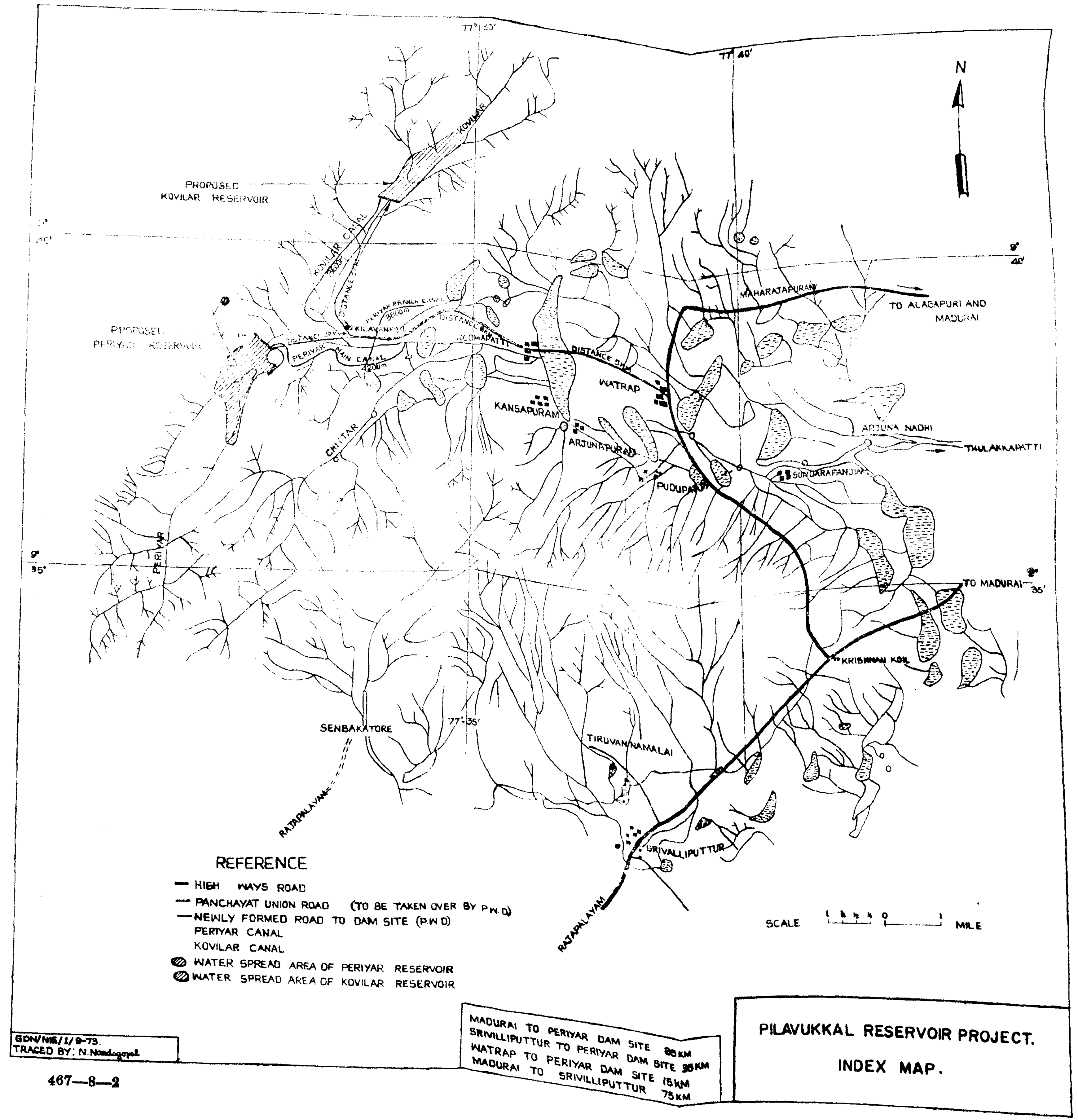
Canal System.—The new ayacut of 143·65 hectares (355 acres) and 388·50 hectares (960 acres) will be served by two supply channels taking off from Kovilar at L.S. 510 m. (1,673 feet) and from Periyar spillway-*cum*-Canal Sluice respectively. The total length of Kovilar Main Canal which takes off from Kovilar Dam will be 3,600 m. (11,811 feet). To feed the new ayacut of 143·65 hectares (355 acres) under this Canal, there will be 10 Irrigation Sluices. Necessary cross masonry works are proposed for all the drains flowing across this Canal. The total length of Periyar Main Canal which takes off from Periyar Dam will be 4,200 m. (13,779 feet). To feed the new ayacut under the Canal, there will be 13 Irrigation Sluices with one head regulator at L.S. 2,700 m. (8,858 feet) of main canal to feed water to Periyar Branch Channel which is proposed to irrigate an ayacut of 138·40 hectares (342 acres) out of 388·50 hectares (960 acres) under the Periyar Main Canal. There will be nine Irrigation sluice in this branch channel.

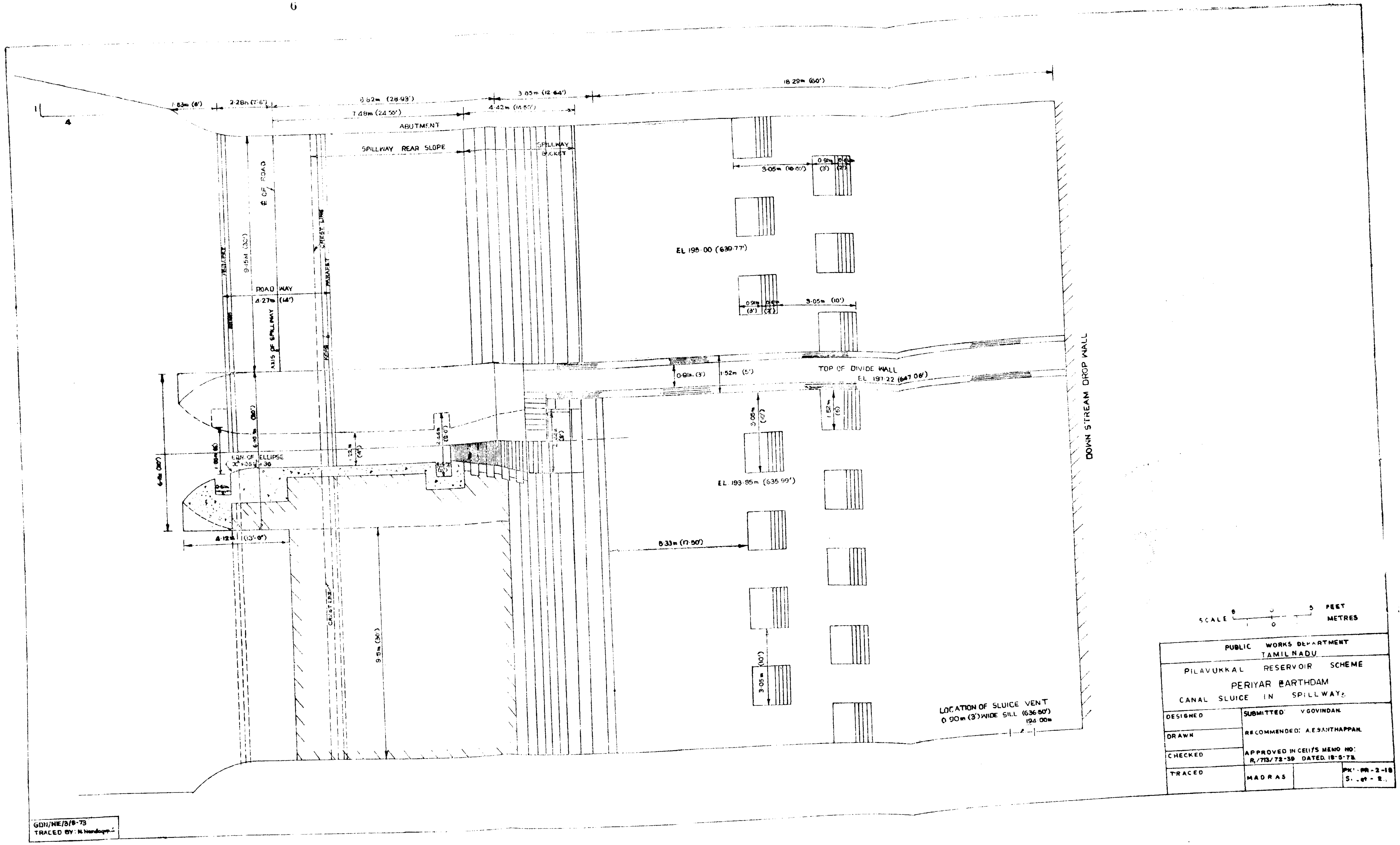
Provisions are also made to improve the existing 37 tanks and repair the 12 anicuts benefitted by this Project,

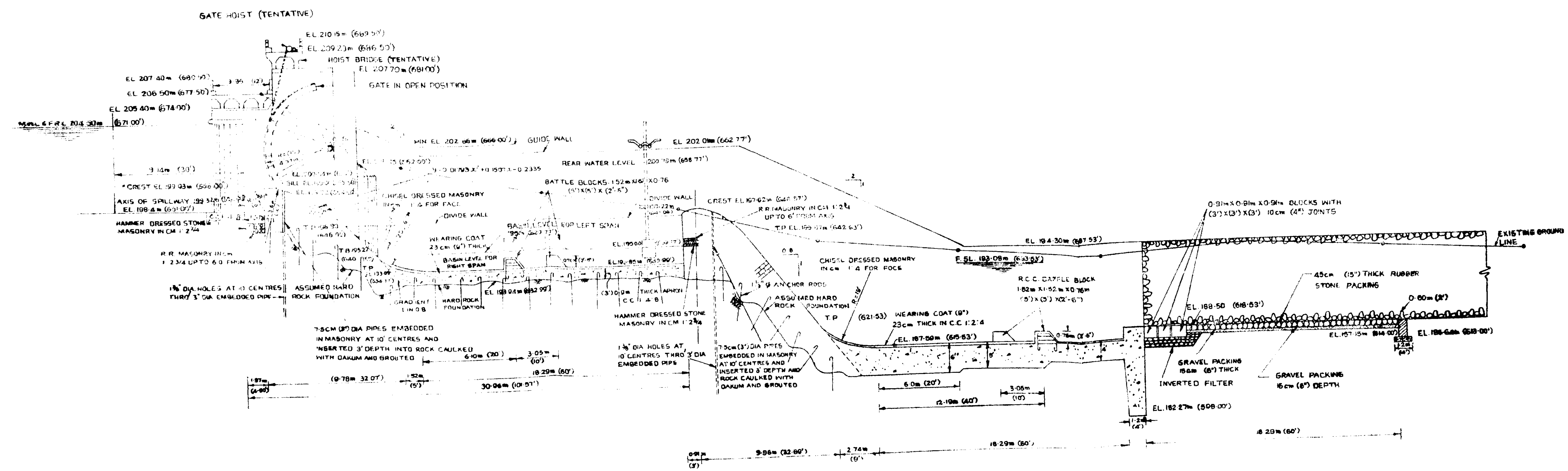
Financial and Food Production Aspects.—The Pilavukkal Scheme envisages giving assured supply to the existing ayacut of 2,990 hectares (7,389 acres) under the system, bridging up an extent of 75·66 hectares (187 acres) of the existing gap in cultivation under the system, bringing a new ayacut of 532·15 hectares (1,315 acres) of dry lands into wet cultivation and raising a second crop over an area of 463·75 hectares (1,146 acres). The benefit cost ratio for the scheme works out to 5·162 and 2.87 at 5 per cent and 10 per cent interest respectively. The Scheme is expected to yield about 6,106 m. tonne (6,022 Ton) of food grains per year. The rate per ton is Rs. 1,255.

By implementation of this scheme the economic condition of the people in this area will be improved considerably besides the entire management being put to better management than what is now being obtained.

The Project works are in full swing. It is programmed to complete the Project in all respects during 1974–75 and impound water in both the reservoirs during the irrigation season.




ABUTMENT
SPILLWAY REAR SLOPE
SPILLWAY BUCKET
ROAD WAY
4·27m (14')
℄ OF ROAD
AXIS OF SPILLWAY
CREST LINE
PARAPET
EL 195·00 (639·77')
TOP OF DIVIDE WALL
EL 197·22 (647·06')
EL 193·85m (635·99')
8·33m (17·50')
LOCATION OF SLUICE VENT
0·90m (3') WIDE SILL (636·60')
194·00m
DOWN STREAM DROP WALL
18·29m (60')
3·85m (12·64')
4·42m (14·50')
7·48m (24·50')
2·28m (7·5')
1·83m (6')
9·15M (30')
9·15m (30')
4·12m (13'-0")
3·05m (10')
0·91m (3')
1·52m (5')
SCALE
FEET
METRES
PUBLIC WORKS DEPARTMENT
TAMILNADU
PILAVUKKAL RESERVOIR SCHEME
PERIYAR EARTHDAM
CANAL SLUICE IN SPILLWAY
DESIGNED
DRAWN
CHECKED
TRACED
SUBMITTED: V.GOVINDAN.
RECOMMENDED: A.E.SANTHAPPAN.
APPROVED IN CE(I)/S MEMO NO:
R1/713/72-39 DATED 18-5-73
MADRAS
GDN/NIE/3/8-73
TRACED BY:



SCALE 0 5 10 20' FEET
0 1 2 4 METRES

HYDRAULIC PARTICULARS

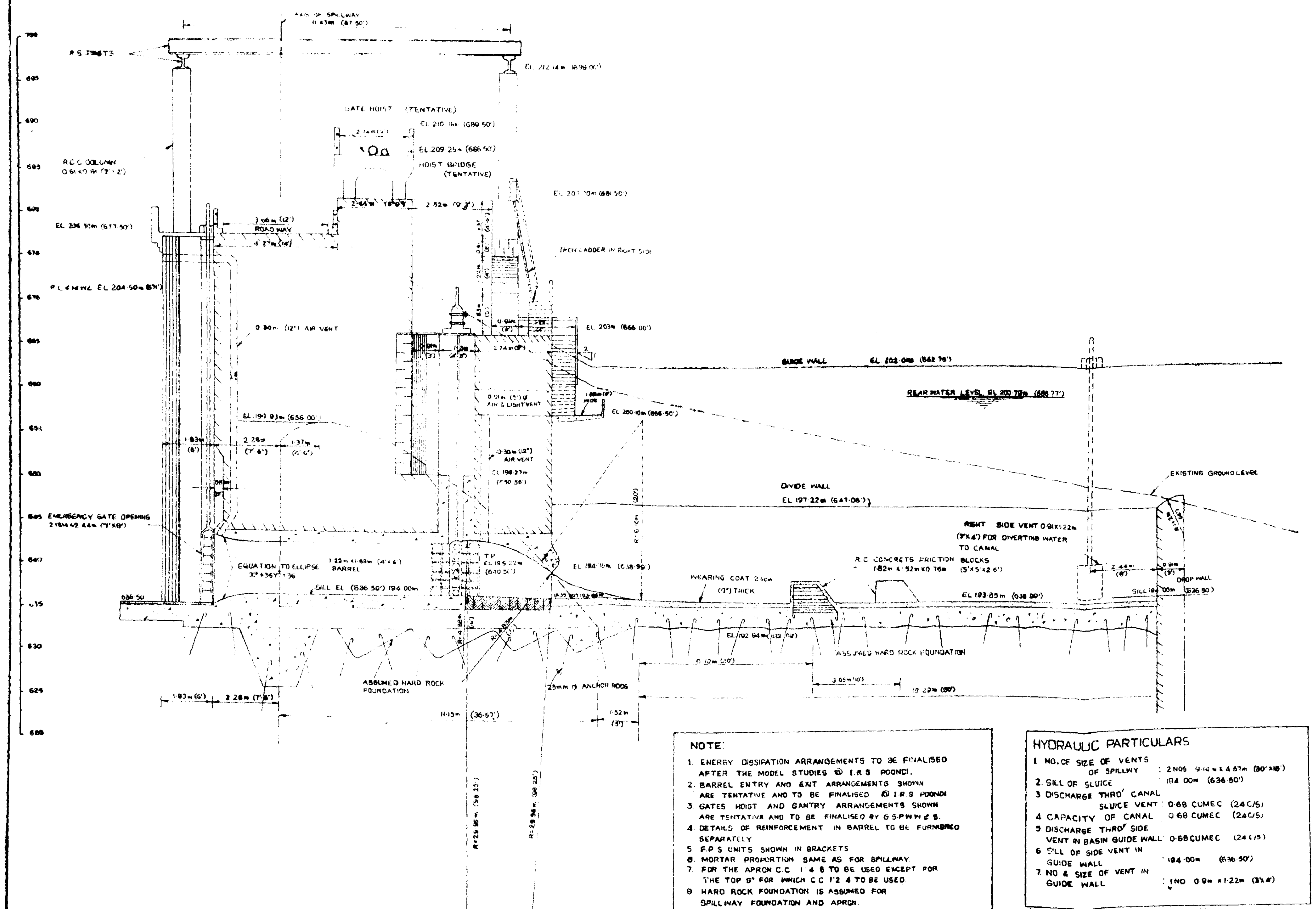
1.	MAX FLOOD DISCHARGE	286 CUMECS (10120 CU SECS)
2.	SIZE OF VENT 2 NOS	9.14 m X 4.57 m (30' X 15')
3.	DISCHARGING CAPACITY	358 CUMECS (12650 CUSECS)
4	CREST OF SPILLWAY	199.93 m (656.00')
5.	M.W.L & F.R.L	204.50 m (671.00')
6.	STILLING BASIN LEVEL	193.85 m (635.99') FOR RIGHT VENT AND SLUICE BLOCK 195.00 (639.77') FOR LEFT VENT

NOTE:

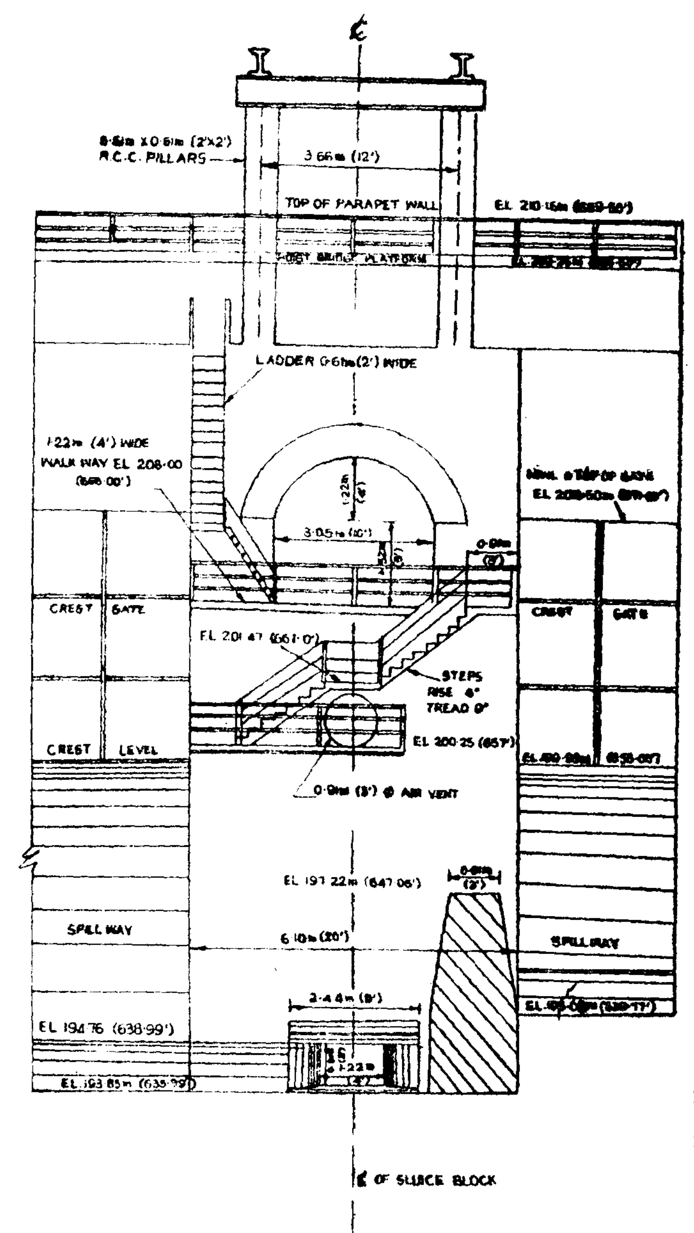
1. ENERGY DISSIPATION ARRANGEMENTS TO BE FINALISED AFTER THE MODEL STUDIES AT I R S POONDI
2. THE HOIST BRIDGE AND THE LIFTING ARRANGEMENTS - TENTATIVE AND TO BE FINALISED BY G.S. P.W.W & S.
3. PROVISION OF SPILLWAY BRIDGE TENTATIVE.
4. F.P.S. EQUALENTS SHOWN WITHIN BRACKETS
5. GROUTING IF NECESSARY TO BE DONE AFTER COMPLETION OF WORK. FROM TOP OF MASONRY OF SPILLWAY THRO' 3" DIA PIPES EMBEDED, IN MASONRY AT 10' CENTRES DURING CONSTRUCTION.
6. HARD ROCK FOUNDATION ASSUMED FOR SPILLWAY FOUNDATION APRON AND DROP BODY WALL

PUBLIC WORKS DEPARTMENT TAMIL NADU (5)			
PILAVUKKAL RESERVOIR SCHEME PERIYAR DAM SPILLWAY SECTION			
DESIGNED	SUBMITTED: V. GOVINDAN.		
DRAWN	RECOMMENDED: A.E.SANTHAPPAN.		
CHECKED	APPROVED: IN CE(I)'S MEMO NO. R/713/72-30 DATED 10-8-73		
TRACED	MADRAS		PKL-PR-2-15

GDN/ME/6/9-73
TRACED BY: N. Nandagopal



RIVER SLUICE SECTION



REAR ELEVATION

NOTE:

1. ENERGY DISSIPATION ARRANGEMENTS TO BE FINALISED AFTER THE MODEL STUDIES @ I.R.S POONDI.
2. BARREL ENTRY AND EXIT ARRANGEMENTS SHOWN ARE TENTATIVE AND TO BE FINALISED @ I.R.S POONDI
3. GATES HOIST AND GANTRY ARRANGEMENTS SHOWN ARE TENTATIVE AND TO BE FINALISED BY G.S.P.W.W & B.
4. DETAILS OF REINFORCEMENT IN BARREL TO BE FURNISHED SEPARATELY
5. F.P.S UNITS SHOWN IN BRACKETS
6. MORTAR PROPORTION SAME AS FOR SPILLWAY.
7. FOR THE APRON C.C 1:4:8 TO BE USED EXCEPT FOR THE TOP 6" FOR WHICH C.C 1:2:4 TO BE USED.
8. HARD ROCK FOUNDATION IS ASSUMED FOR SPILLWAY FOUNDATION AND APRON.
9. HOISTING ARRANGEMENTS NOT SHOWN IN PLAN

HYDRAULIC PARTICULARS

1 NO. OF SIZE OF VENTS OF SPILLWY	: 2 NOS 9.14m x 4.57m (30'x15')
2. SILL OF SLUICE	194.00m (636.50')
3 DISCHARGE THRO' CANAL SLUICE VENT	: 0.68 CUMEC (24 C/S)
4 CAPACITY OF CANAL	0.68 CUMEC (24 C/S)
5 DISCHARGE THRO' SIDE VENT IN BASIN GUIDE WALL	0.68 CUMEC (24 C/S)
6 SILL OF SIDE VENT IN GUIDE WALL	194.00m (636.50')
7 NO & SIZE OF VENT IN GUIDE WALL	: 1 NO 0.9m x 1.22m (3'x4')

SCALE 5 0 5 FEET
1 0 1 METRES

PUBLIC WORKS DEPARTMENT
TAMILNADU

PILAVUKKAL RESERVOIR SCHEME
PERIYAR EARTHDAM
CANAL SLUICE IN SPILL WAY

DESIGNED	SUBMITTED
DRAWN	RECOMMENDED
CHECKED	APPROVED IN C.E.(I)'S MEMO NO.
TRACED	MADRAS

TRACED BY

A SHORT NOTE ON THE RAMANATHI RESERVOIR PROJECT.*

General.—Ramanathiriver has its origin on the eastern slopes of western ghates near Melakadayam village in Tirunelveli District. After running for 6·43 K.M. (4 miles) through thickly wooded forests it emerges into plains. At the foot of the hills, it branches off into two arms and there are numerous anicuts across them before they unite and join Jambunathi Lower down. After the confluence the river is known as Veeranathi. Jambunathi joins Ramanathi which in turn joins Gatana River. This Gatana River empties into Thamaraparani River. The total length of the river up to its confluence with Jambunathi is 11·48 K. M. (9 miles).

Benefits of the Scheme.—Ramanathi Reservoir Schemes contemplated on the formation of a Reservoir of 4·25 mm³ (152 M. Cft.) capacity on Ramanathi and excavation of a channel to feed new ayacut of about 202·34 Hectares (500 acres). The Scheme mainly aims at giving assured water supply to about 30 per cent of the existing ayacut of 1691 Hectares (4179 acres) served by the river and which suffers for want of one or two wettings at crucial period to reap a good harvest. In addition to stabilishing the existing ayacut, a new area of 202·34 Hectares (500 acres) in Ambasamudram Taluk will be brought under irrigation. The existing ayacut will be allowed to raise double crop. Supply to the new ayacut of 202·34 Hectares (500 acres) will be allowed from the proposed reservoir for raising only one crop during October to February.

Design Aspects.—The catchment of the river is influenced by both the monsoons and there are a number of anicuts across both the branches of Ramanathi for irrigating the existing ayacut. Ramanathi Dam is proposed at about 1·60 K. M. (1 mile) lower down the first anicut known as Thalaianai, where the two hillocks on either side of the river are proposed to be connected by a straight earth dam. On the left flank a masonry dam with a spillway is proposed for disposing off flood waters.

The spillway has 2 vents of 9·14 M. (30 feet) span each and 4·57 M. (15 feet) high radial gates fixed over them. The discharging capacity of the spillway at F.R.L. condition is 311·49 Cumecs (11,800 C/S.)

The earth dam is 734·56 M. (2410 feet) long and two sluices are constructed in it for irrigating the existing ayacut and the new ayacut. The water drawn from the sluices will be let down into the existing channels taking off at the existing anicuts. The Earth Dam has rolled impervious hearting section in the middle and a semi-pervious casing section on both sides of hearting section. Cut off trench has been provided and this has been taken to a depth equal to half the depth of water retained or to impervious stratum whichever is higher. Horizontal zoned filters with rock toe and longitudinal toe drain are provided for the drainage of the rear portion of the dam.

Salient features of Dam and Reservoir :

Reservoir ..	F.R.L	.. ..	+ 193·2 M. (634'00")
	M.W.L	..	+ 193·2 M. (634' 00").
	Water spread area		0.39 K.M² (0·15 sq. mile).
	Capacity of Reservoir at F.R.L.		4·25 MM³ (152 M.Cft.)
Masonry Dam	Top level of dam		195·4 M. (641'00").
	Top width	..	6·1 M. (20').
	Maximum Height		28·04 M. (92')
Spillway ..	Number of Vents		2 vents of 9·14 M. × 4·57M. (30' × 15').
	Maximum Flood Discharges		10,310 C/s.
Earth Dam	Top level of Dam		195·4 M. (641 '.)
	Length of Dam		788 M. (2,585').
	Top width of Dam		6·1 M. (20').
Height of dam above bed level of river at crossing of		..	
	Vadakal		31. M. (102').
Do.	Kallakal	..	28·95 M. (95').
Do.	Thenkal	..	17·98 M. (59').

River Sluice—For Vadakal and Kallakal

1 Vent of 1·52 M × 1·82 M. (5' × 6').
Sill 167·64 M. (550').

For Thenkal—1 Vent of 1·52 M × 1·82 M. (5' × 6').
Sill 178·30 M. (585').

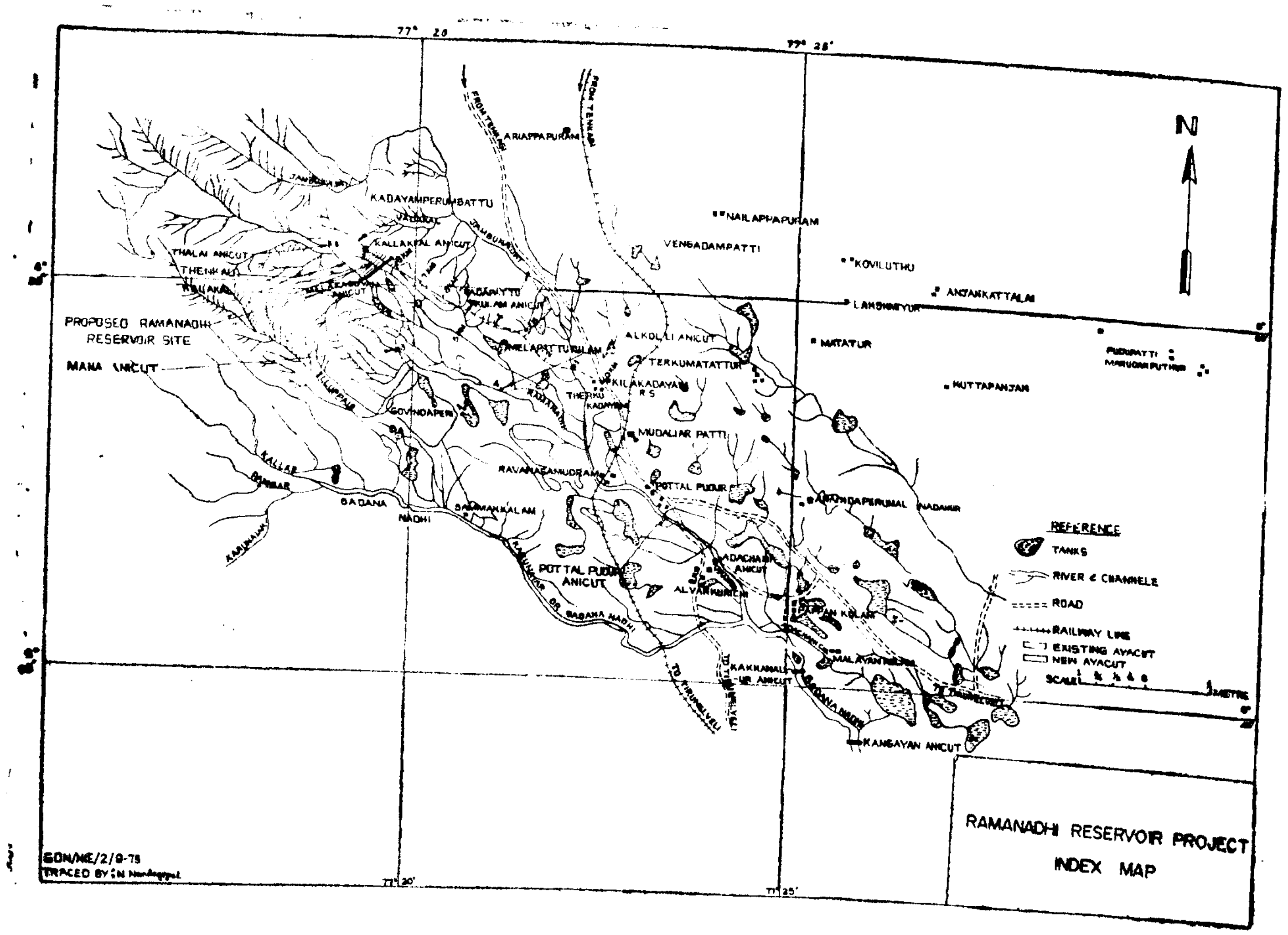
Financial Aspects of the Scheme :

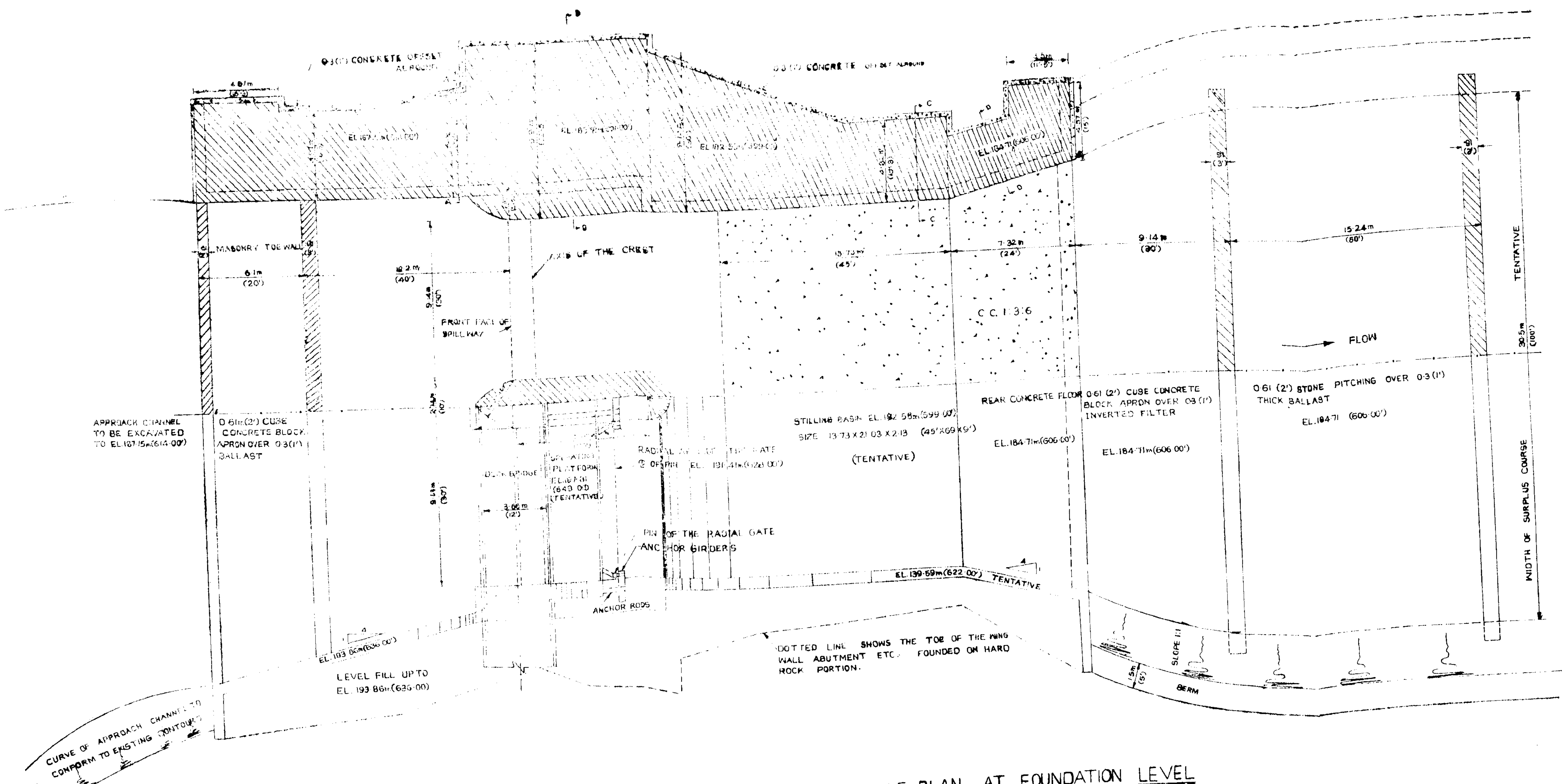
Ramanathi Reservoir Project was administratively approved by the Government for Rs. 87·00 lakhs in G. O. Ms. No. 2703, P. W. D. , dated 15th November 1966 and technically sanctioned by the Chief Engineer (Irrigation) for Rs. 95·70 lakhs in Chief Engineer (Irrigation)'s (PRN No. 1/1966-67. The additional food production anticipated after the completion of this scheme is 1776.M. tonne per annum.

Stage of Construction :

The Projects is in advanced stage of construction. During the last monsoon season (October—December 1972) water was impounded for the first time in the reservoir up to the crest level of spillway and was let down through the two irrigation sluices during January, February 1973 for giving one or two wettings at the fag end of the crop season for the standing paddy, crop which would have otherwise withered away for want of water. In this way the reservoir was very useful in reaping a good harvest in the very first year of its impounding thus fulfilling the dreams of the local agriculturists. There is no doubt that such small schemes (for which there is plenty of scope in Tirunelveli District) which are intended to stabilish the existing ayacut will go a long way in increasing the food Production in the State.

* Condensed from the "Report on the Ramanadhi Project" received from Thiru K. Doraiswamy, B.A., B.E., Superintending Engineer, P. W.D. Project circle, Tirunelveli-2.


77° 20'
77° 25'
N
ARIAPPAPURAM
KADAYAMPERUMBATTU
KALLAKKAL ANICUT
THALAI ANICUT
NAILAPPAPURAM
VENGADAMPATTI
KOVILUTHU
ANJANKATTALAI
LAKSHMIYUR
PROPOSED RAMANADHI RESERVOIR SITE
MANA ANICUT
ALKOLLI ANICUT
MATATUR
TERKUMATATTUR
KILAKADAYAM
R S
MUTTAPANJAN
GOVINDAPERI
MUDALIAR PATTI
RAVANASAMUDRAM
POTTAL PUDUR
KALLAR
GADANA
NADHI
POTTAL PUDUR ANICUT
ADACHANI ANICUT
ALVARKURICHI
GADANA NADHI
KAKKANALLUR ANICUT
KANGAYAN ANICUT
REFERENCE
TANKS
RIVER & CHANNELS
ROAD
RAILWAY LINE
EXISTING AYACUT
NEW AYACUT
SCALE
RAMANADHI RESERVOIR PROJECT
INDEX MAP
GON/ME/2/9-75
77° 20'
77° 25'



HALF PLAN AT TOP AND HALF PLAN AT FOUNDATION LEVEL

NOTE:

1. ENERGY DISSIPATION ARRANGEMENTS TO BE FINALISED AFTER THE MODEL STUDIES @ I.R.S POONDI
2. THE HOIST BRIDGE AND THE LIFTING ARRANGEMENTS ARE TENTATIVE AND TO BE FINALISED BY S.S.P.W.H.&S
3. APPROACH CHANNEL BED LEVEL HAS BEEN KEPT @ EL. 187.15 (614.00')
4. PROVISION OF SPILLWAY BRIDGE IS TENTATIVE.
5. F.P.S EQUIVALENTS ARE GIVEN WITHIN BRACKETS
6. THE D/S FLOOR IS TO BE LAID FOR FULL DEPTH AS ONE LAYER OR THE VARIOUS LAYERS TIED TO EACH OTHER BY STEEL REINFORCEMENT SO THAT THEY ARE INSEPARABLE
7. THE U/S FLOOR IS TO BE LAID WITH SUFFICIENT OVERLAPING OVER VERTICAL CONSTRUCTION JOINTS

HYDRAULIC PARTICULARS

		METRIC F.P.S
1	MAX FLOOD DISCHARGE (FOR C=3000)	296 Cumecs 10450 C/s
2	LENGTH BETWEEN ABUTMENTS	21.03m (69')
3	NO OF SPANS AND SIZE	2 Nos. 9.14 X 4.37m (30' X 15')
4	CREST OF SPILLWAY	EL. 188.67m (619.00')
5	M.W.L AND F.R.L.	EL. 193.24m (634.00')
6	THICKNESS OF PIER	2.74m (9')
7	U/S FLOOR LEVEL	EL. 187.15m (614.00')
8	STILLING BASIN LEVEL	EL. 183.18m (601.00')
9	REAR APRON LEVEL	EL. 184.71m (606.00')
10	DISCHARGING CAPACITY	334 Cumecs (1180 C/s)

SCALE 3 0 3 METRES

PUBLIC WORKS DEPARTMENT
TAMIL NADU

RAMANADHI - GADANA PROJECT

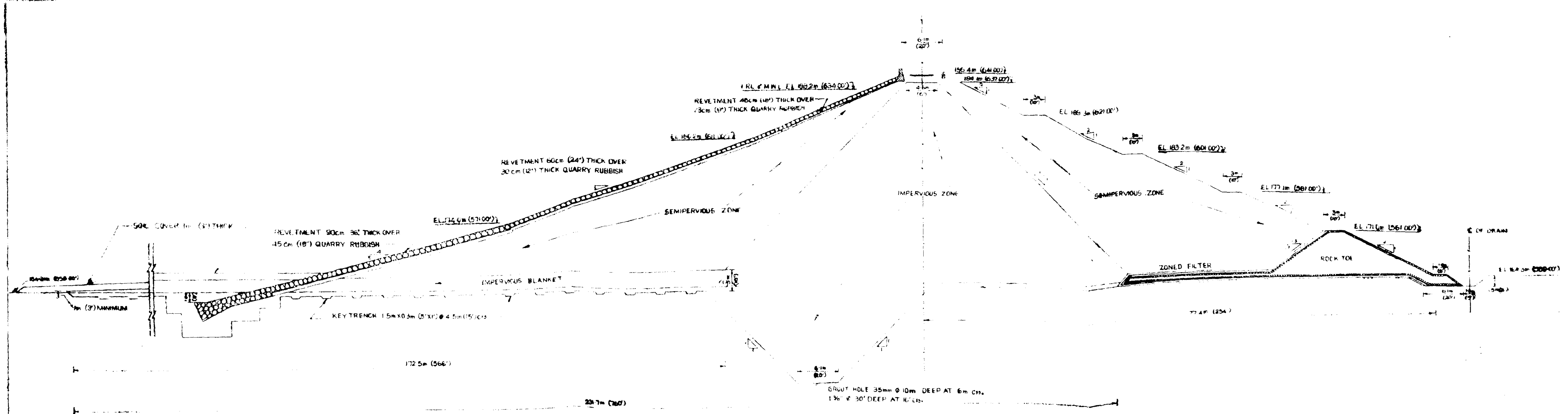
RAMANADHI DAM

SURPLUS SPILLWAY PLAN

DESIGNED	SUBMITTED: M.N. RAMANUJAN.
CHECKED	RECOMMENDED: S. RAMACHANDRAN.
DRAWN	APPROVED IN CE(I)'S MEMO NO. P1/42762/67-7. DATED. 3-7-69.
TRACED	MADRAS

GDN/NIC/11/8/74
TRACED BY H. Nandagopal

1



TYPE-4

HEIGHT 2

DEPTH OF WATER 19-28m (63'-95')

NOTE:1.

1. REVETMENT TO BE TAKEN TO A DEPTH OF ATLEAST 1.5m (5') (1m (3') FOR TYPE 1) BELOW GROUND LEVEL
2. DEPTH AND SPACING OF GROUT HOLES MAY BE ALTERED TO SUIT THE ACTUAL FOUNDATION CONDITION
3. DEPTH OF CUT OFF TRENCH TAKEN UPTO D/2 WHERE D IS THE DEPTH OF WATER (PREFERABLE TO TAKE THE CUT OFF TO ROCK LEVEL).
4. IMPERVIOUS BLANKET TO BE PROVIDED FROM THE U/S SIDE OF IMPERVIOUS ZONE. LENGTH OF BLANKET IS L=8XH WHERE H IS THE HEIGHT OF WATER THICKNESS OF BLANKET t=2+0.02L. WHERE L IS THE LENGTH OF APRON. THE MAXIMUM DEPTH RESTRICTED TO 3m (10') AND MINIMUM TO 1m (3')
5. F.P.S EQUIVALENTS GIVEN IN BRACKETS
6. THIS DRAWING IS TO BE READ WITH EARTH DAM - TYPICAL SECTIONS - SHEET 1.

NOTE 2.

1. FOR SECTIONS OF EARTH DAM 15m (50') HEIGHT THE BOTTOM WIDTH OF CUT OFF TO BE 3m (10').
2. ABOVE THE HEIGHT OF 15m (50') THE BOTTOM WIDTH OF CUT OFF TO BE 6.1m (20').
3. TRANSITION OF BOTTOM WIDTH TO BE GIVEN BETWEEN THE ABOVE TWO SECTIONS BE IN A LENGTH OF 30m (100'). KEEPING THE U/S FACE IN LINE.
4. THE TRANSITION TO BE IN A STRAIGHT LINE.

ZONED FILTER

THE MATERIAL FOR THE FILTERS MAY BE SCREENED SAND AND GRAVEL OF SUITABLE SIZES SATISFYING THE FOLLOWING.

1. $\frac{\text{D15 OF THE FILTER MATERIAL}}{\text{D15 OF BASE MATERIAL TO BE DRAINED}}$ SHALL BE GREATER THAN 4.
2. $\frac{\text{D15 OF THE FILTER MATERIAL}}{\text{D85 OF THE BASE MATERIAL TO BE DRAINED}}$ SHALL BE LESS THAN 4

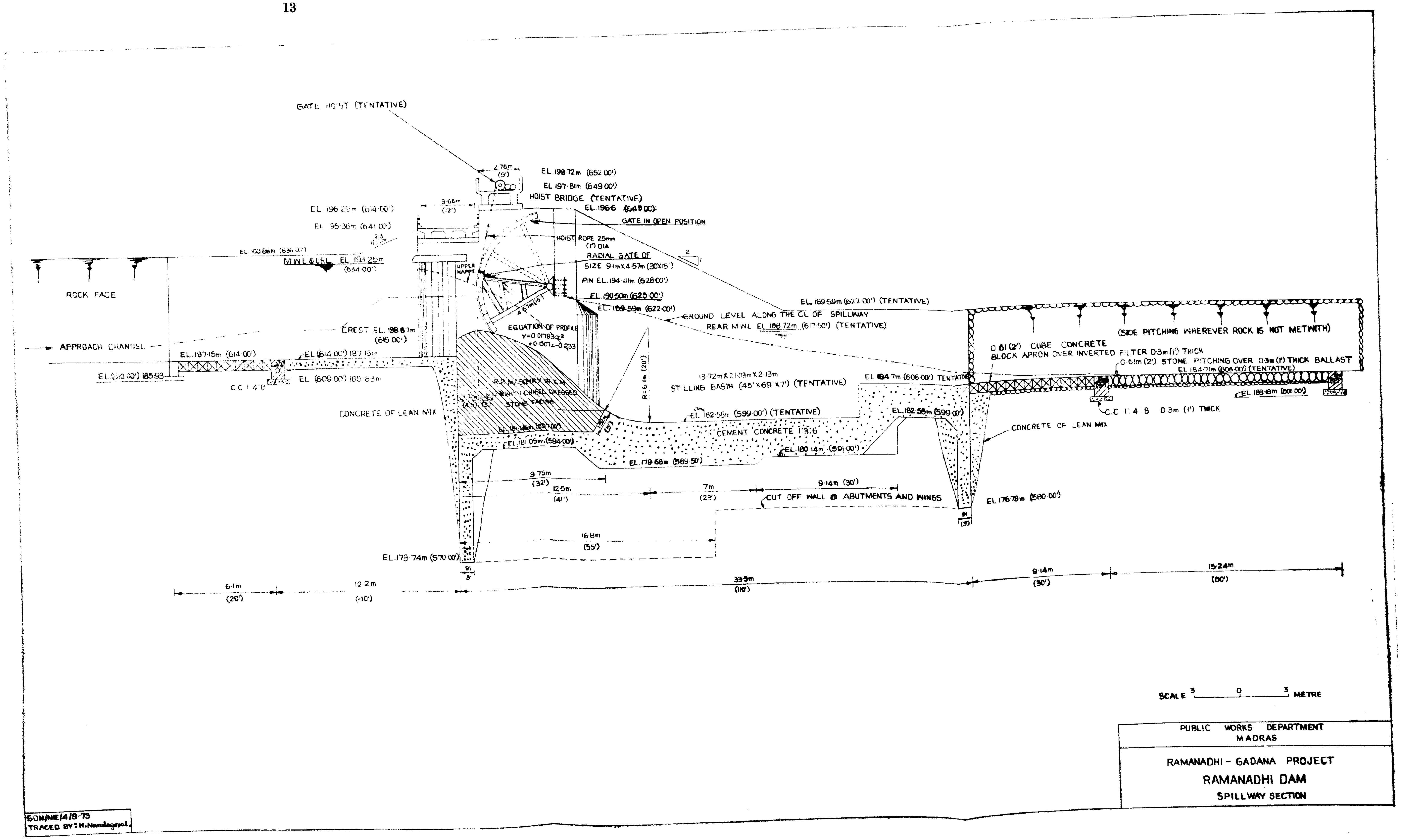
SCALE METRE

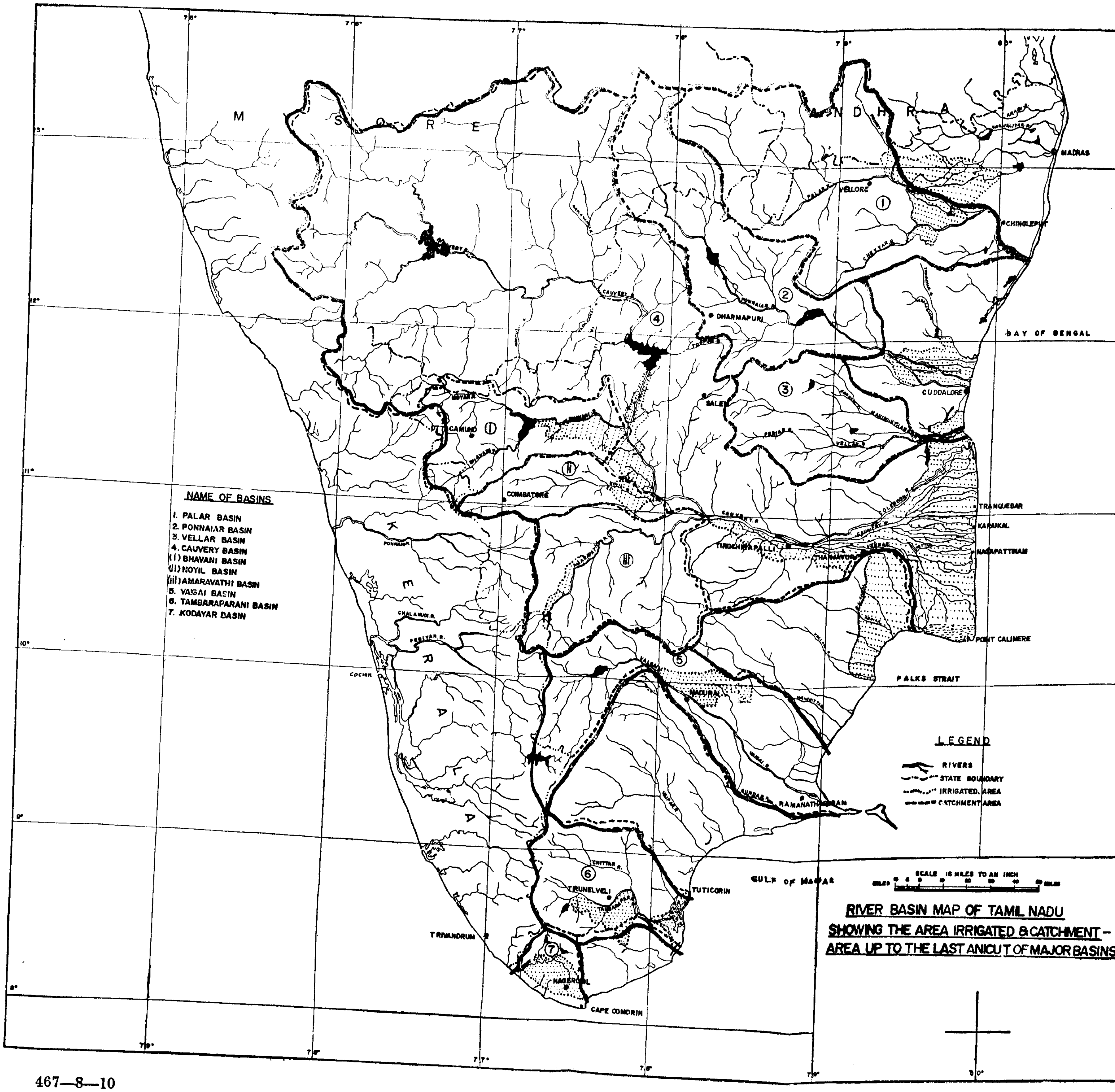
PUBLIC WORKS DEPARTMENT
MADRAS

RAMANADHI RESERVOIR PROJECT

EARTH DAM - TYPICAL - SECTIONS

TRACED BY:


GATE HOIST (TENTATIVE)
HOIST BRIDGE (TENTATIVE)
GATE IN OPEN POSITION
RADIAL GATE OF SIZE 9.1m x 4.57m (30'x15')
ROCK FACE
APPROACH CHANNEL
CREST EL.188.87m (615.00')
GROUND LEVEL ALONG THE CL OF SPILLWAY
STILLING BASIN (45'X69'X7') (TENTATIVE)
CEMENT CONCRETE 1:3:6
CONCRETE OF LEAN MIX
CUT OFF WALL @ ABUTMENTS AND WINGS
(SIDE PITCHING WHEREVER ROCK IS NOT MET WITH)
0.61 (2') CUBE CONCRETE BLOCK APRON OVER INVERTED FILTER 0.3m (1') THICK
0.61m (2') STONE PITCHING OVER 0.3m (1') THICK BALLAST
SCALE 3 0 3 METRE
PUBLIC WORKS DEPARTMENT
MADRAS
RAMANADHI - GADANA PROJECT
RAMANADHI DAM
SPILLWAY SECTION
TRACED BY


NAME OF BASINS
1. PALAR BASIN
2. PONNAIAR BASIN
3. VELLAR BASIN
4. CAUVERY BASIN
(i) BHAVANI BASIN
(ii) NOYIL BASIN
(iii) AMARAVATHI BASIN
5. VAIGAI BASIN
6. TAMBARAPARANI BASIN
7. KODAYAR BASIN
LEGEND
RIVERS
STATE BOUNDARY
IRRIGATED AREA
CATCHMENT AREA
MYSORE
ANDHRA
KERALA
MADRAS
CHINGLEPUT
VELLORE
DHARMAPURI
SALEM
CUDDALORE
OOTACAMUND
COIMBATORE
TIRUCHIRAPALLI
THANJAVUR
TRANQUEBAR
KARAIKAL
NAGAPATTINAM
POINT CALIMERE
PALKS STRAIT
BAY OF BENGAL
MADURAI
RAMANATHAPURAM
GULF OF MANNAR
TUTICORIN
TIRUNELVELI
TRIVANDRUM
NAGERCOIL
CAPE COMORIN
COCHIN
RIVER BASIN MAP OF TAMIL NADU
SHOWING THE AREA IRRIGATED & CATCHMENT-
AREA UP TO THE LAST ANICUT OF MAJOR BASINS

IRRIGATION SCHEMES IN PONNIAR BASIN FALLING WITHIN DHARMAPURI DISTRICT.

The river Ponniar originates in the southern slopes of Nandi Hills in Mysore State, flows towards south collecting monsoonic rains from the hilly Catchment lying within the Mysore State and emerges into Tamil Nadu in Hosur Taluk. The river passes through Dharmapuri, North Arcot and South Arcot Districts and finally empties into the Bay of Bengal near Cuddalore. The main tributaries joining the river within Dharmapuri District limits on its right are the Kambainallur river and Vaniar, while the minor tributary on this side is Kottampatti Kallar. Out of the tributaries Chinnar, Markandanadi and Pambar joining on its left Pambar has good irrigation potential while Chinnar (Shoolagiri Chinnar) has not so much to its credit.

A flow diagrams of Ponniar from the point it enters Dharmapuri District up to its exit into NorthArcot District is appended to this report. The location of each irrigation work, existing and proposed, across the river Ponniar and its tributaries and the points where its tributaries join the main river are shown in the flow Diagram.

The catchment area of the main river and its tributaries at each of these salient points, the yield from such catchment and the area irrigated at this point, in the case of Irrigation Works (Anicuts and Reservoirs, etc.) are also indicated.

The existing Irrigation works and future proposals across the main river and its tributaries are briefly described below river by river :—

PONNIAR RIVER.

The only reservoir across Ponniar within the Dharmapuri District limits is the Krishnagiri Reservoir at Muthur Village with a capacity of 68·24 MM³ (2,410 M.Cft.) irrigating an extent of 3,647·02 hectares (9,012 acres) besides meeting the needs of Barur Tank through Nedungal anicut. The ayacut benefited under the Barur tank is 1,618·74 hectares (4,000 acres) approximately. The catchment area at the reservoir site is 5305·04 sq. K.M. (2,048·28 sq. miles) and the available yield is worked out as 133·85 MM³ (4726·48 M.Cft.). The estimated cost of the above scheme is about Rs. 185 lakhs.

A number of old anicuts across Ponniar exist above and below the Krishnagiri Reservoir in Dharmapuri District. The catchment area of the river at each Anicut site, yield from the catchment and the area irrigated are listed out below :—

Name of the Anicut.	*Catchment area in Sq. K.M.* / *Sq. miles.*	*Yield in MM³* / *M. Cft.*	*Ayacut in Hectares.* / *Acres.*
Above Krishnagiri Reservoir.			
1 Thorapalli Anicut ..	3,326·77	71·97	13·12
	1,284·47	2,541·43	32·42
2 Aliyalam Anicut ..	3,338·60	67·26	101·69
	1,289·04	2,375·32	251·28
3 Subbagiri Anicut ..	3,353·55	66·63	6·90
	1,294·81	2,352·84	17·06
4 Bothanatham Anicut.	3,434·98	73·79	42·88
	1,326·10	2,605·82	105·97
5 Ayarnapalli Anicut.	3,438·59	70·41	26·08
	1,327·65	2,486·38	64·44
6 Mahabalrao Anicut..	3,445·59	70·75	5·38
	1,330·35	2,498·48	13·29
7 Ulagam Nallah Anicut.	3,492·05	74·16	38·25
	1,348·29	2,618·78	94·51
8 Kadavaranahalli Anicut.	3,502·59	72·75	33·22
	1,352·36	2,569·22	82·08
9 Puligundunalla Anicut.	3,567·87	77·13	5·73
	1,377·56	2,723·71	14·15
10 Guliyam Anicut ..	3,931·16	100·24	51·22
	1,517·79	3,539·87	126·56
11 Gangaleri Anicut ..	5,089·92	118·72	89·53
	1,965·23	4,192·52	221·23
Below Krishnagiri Reservoir.			
12 Nedungal Anicut ..	5,599·58	101·44	1,754·45
	2,162·00	3,583·21	4,335·34
13 Kumarampatti Anicut.	7,058·09	79·05	54·54
	2,725·13	2,791·70	134·76
14 Tambal Anicut ..	9,885·77	169·31	46·70
	3,816·90	5,979·24	115·81

* Abstracted from the Article "RIVER PONNIAR" written by Thiru P. R. Rajagopalan, B.E., Superintending Engineer, Salem-Dharmapuri Circle.

KAMBAINALLUR RIVER.

This river originates near Palacode in Dharmapuri District and runs towards east after collecting the Catchment Water of Semmandakuppam river and Solakkuttai stream and joins Ponniar near Kambainallur. The total catchment area of this river is 6,700·58 sq. km. (2587·10 sq. miles) and the net yield is worked out as 55·24 MM^3 (1958·48 M.Cft.). Almost on the ridge of hill range separating the Ponniar basin from that of the Cauvery where the Karambainallur river takes its origin is situated the famous Jarthalav Tank. There is a proposal to form a Reservoir across this river near Thumbalahalli in Palacode Taluk of Dharmapuri District to benefit lands in Thumbalahalli and surrounding villages.

THE VANIAR.

The Vaniar originates on the southern slopes of Sheveroys hills at an altitude of 1619·71 M. (5314 feet) above M.S.L. The river after a run of 24·14 kms. (15 miles) enters the plains near Pappireddipatti and flows towards east touching Harur and joins Ponniar near Theerthamalai. The Munar, Peeniar, Kallar and Varattar are the tributaries contributing major shares for Vaniar. The total catchment area of Vaniar is 956·58 sq. K.M. (369·34 sq. miles). The surplus available at the confluence of point with Ponniar is 40·97 MM^3 (1447·99 M.Cft.). The river Vaniar crosses the Salem-Harur road at 51·50 K.M. (32 miles). The river after its run of about 12 KMs. (7·45 miles) falls into Ponniar in Poonagarapatti reserve forest area.

There are three anicuts lying across Vaniar namely :

1. Venkatasamudiram Anicut.
2. Alapuram Anicut.
3. Elumichaperumalkoil Anicut

All the three anicuts are feeding three major tanks in Harur taluk of Dharmapuri, Viz.,

1. Venkatasamudiram Tank.
2. Alapurm Tank.
3. Paraiyapatti Tank.

There is a proposal for forming a reservoir across Vaniar at an estimated cost of Rs. 200 lakhs for giving irrigation facilities to Pappireddipatti and surrounding Villages in Harur Taluk.

This scheme contemplates on the construction of a storage Reservoir of capacity 9·17 MM^3 (324 M.Cft.) across the Vaniar near the hamlet of Mullikadu about 3·22 KMs. (2 miles) from Pappireddipatti Village and to irrigate 1214·06 hectares (3,000 acres) in the same village and other adjoining villages. It is understood that this proposal was thought of even prior to 1877 by Mr. Lefarne I.C.S., who was for many years employed as Collector in Salem District and the original investigation of the Project was made by Captain Jackson, Executive Engineer on famine duty in Salem District at that time.

THE CHINNAR (SHOOLAGIRI CHINNAR)

This is a tributary of Ponniar which has no existing irrigation interests. Proposed irrigation schemes across this river are mentioned elsewhere in this article.

THE MARKANADANADHI.

The river originates near Tamil Nadu State boundary after collecting the drainages of Nachikuppa river and Veppanapalli river. An anicut to feed Badathalav tank in Krishnagiri was constructed in 1947. Apart from this anicut there are two more anicuts namely, Beemandapalli anicut serving an ayacut of 60·48 hectares (149·46 acres) and Kallapalli anicut serving an ayacut of 41·13 hectares (101·64 acres). The river Markandanadhi joins Ponniar 67·5 K.M. (41·94 miles) down stream of Tamil Nadu border.

THE PAMBAR.

The river Pambar originates on the southern slopes of Ellagiri group of hills in North Arcot District. The major tributaries are the Right arm of Pambar which is also called Pambar, Mathur River and Bargur River. The river after a run of about 60 KMs. (37·28 miles) enters Dharmapuri District and empties into Ponniar at a distance of 72 K.M. (44·74 miles) down stream of Tamil Nadu border. The river has a catchment of 1791·23 sq. K.M. (691·60 sq. miles) with a surplus of 55·53 MM^3 (1968·28 M.Cft.). There is a proposal for forming a reservoir across this river, near Marampatty village at a cost of 91 lakhs and the ayacut benefited under this proposal will be 809·37 hectares (2,000 acres).

NEW PROPOSALS UNDER PONNIAR BASIN IN DHARMAPURI DISTRICT.

A net quantity of 127·43 MM^3 (4,500 M.Cft.) has been worked out as surplus available at Tirukoilur Anicut on Ponniar lower down and using this surplus six new Major and medium schemes are investigated in Ponniar basin :

1. *Forming a Reservoir across Ponniar.*

The reservoir is proposed across Ponniar itself near Keivaranpalli in Hosur Taluk at an estimated cost of Rs. 1,68,00,000. The free combined and equivalent catchment area at the proposed site are 27·71 sq. K.M. (10·7 sq. miles), 2442·36 sq. K.M. (943·00 sq. miles) and 510·64 sq. K.M. (197·16 sq. miles) respectively. The yield available from the catchment is 45·56 MM^3 (1608·82 M.Cft.) and the annual storage of this reservoir will be 21·86 MM^3 (772·88 M.Cft.).

The ayacut benefitted under this scheme will be 1449·47 hectares (3581·71 acres) and stabilisation of ayacut will be for 438·42 hectares (1083·35 acres).

2. *Forming a Reservoir across Pambar.*

The reservoir is proposed across Pambar near Marampatty in Uthankarai Taluk of Dharmapuri District estimated to cost Rs. 91·00 lakhs. The free combined and equivalent catchment area at the proposed site are 625·20 sq. K.M. (241·385 sq. miles), 1735·88 sq. k.m. (670·23 sq. miles) and 847·32 sq. k.m. (327·15 sq. miles) respectively. The yield available from the catchment is 51·79 MM^3 (1826·35 M.Cft.) and the annual storage of the reservoir will be 11·83 MM^3 (417·90 M.Cft.). The ayacut benefitted under this scheme will be 809·37 hectares (2000 acres).

3. *Forming a Reservoir across Kallar near Kottapatti.*

The reservoir is proposed across Kallar near Kottapatty in Harur Taluk to a cost of Rs. 86 lakhs. The free catchment at the proposed site works out to 146·02 sq. K.M. (56·38 sq. miles). The yield available from the catchment is 9·65 MM^3 (340·53 M.Cft.) and the annual storage of the scheme will be 8·66 MM^3 (305·82 M.Cft.). The ayacut benefited under this scheme will be 60[illegible] hectares (1,500 acres).

4. *Forming a Reservoir across Pulapatty River near in Thumbalahalli Village.*

The reservoir is proposed across Pulapatty river in Dharmapuri District to a cost of Rs. 66·50 lakhs. The free, combined and quivalent catchment at the proposed site are 78·97 sq. K.M. (30·49 sq. miles), 232·50 sq. KM. (89·77 sq. miles) and 109·66 sq. K.M. (42·34 sq. miles) respectively. The yield from the catchmet will be 11·26 MM^3 (397·78 M.Cft.) and the annual storage of the reservoir will be 6·92 MM^3 (244·45 M.Cft.). The ayacut benefited under this scheme will be 431·65 hectares (1,066·63 acres and proposed stabilisation ayacut is 175·454 hectares (433·77 acres).

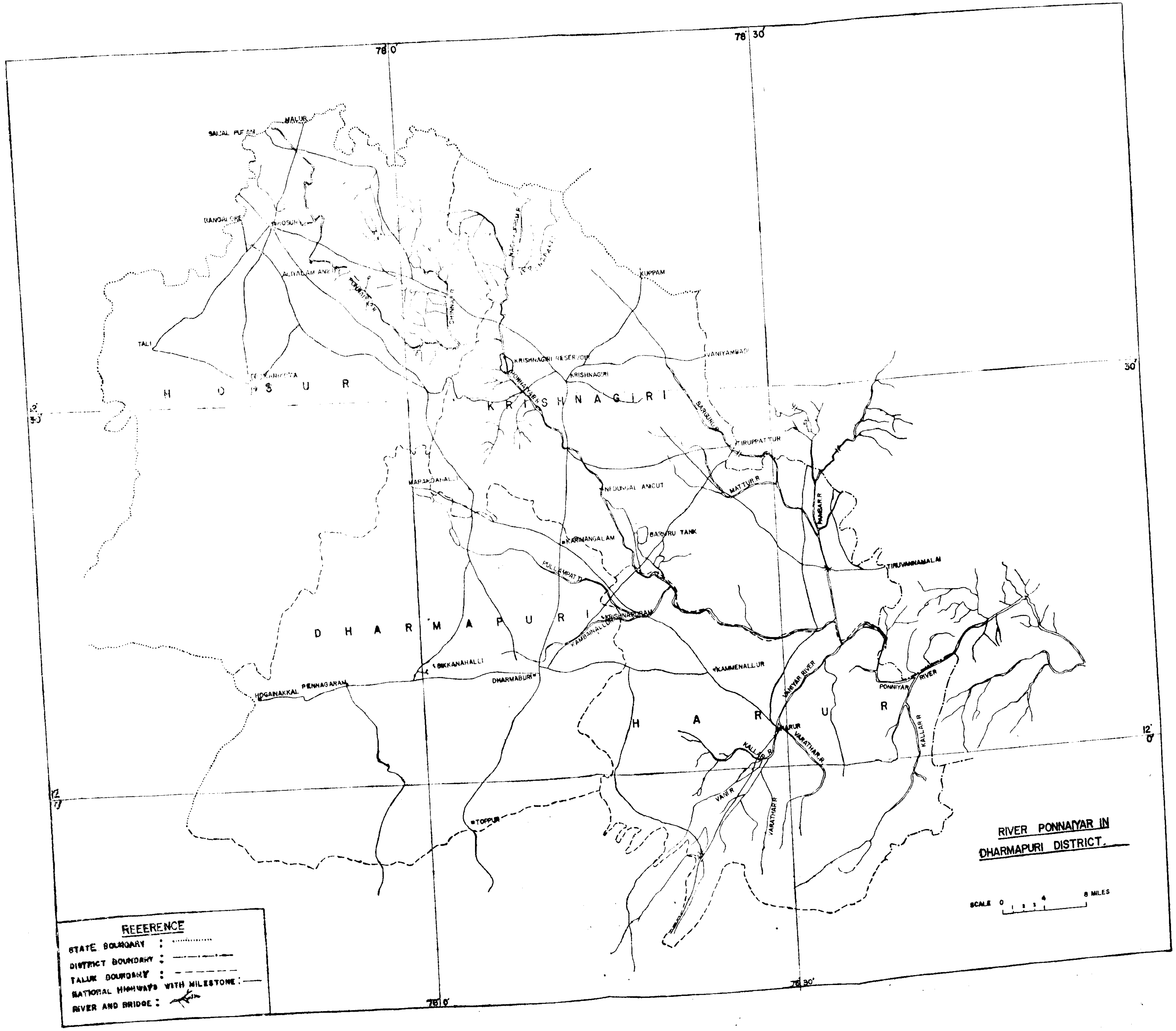
5. *Forming a Reservoir across Varattar near Vallimathrai.*

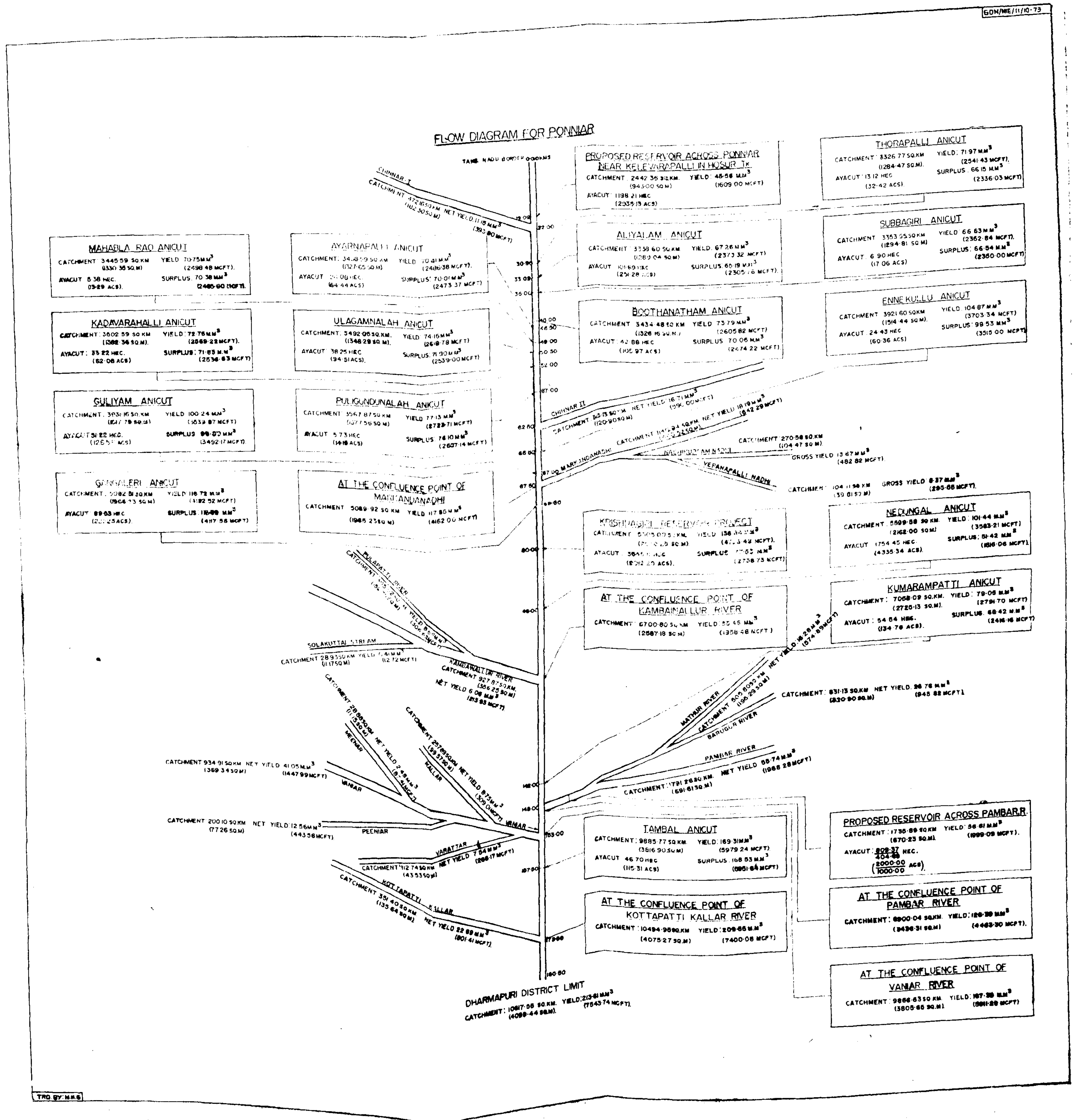
The reservoir is proposed across Varattar near Vallimathrai in Harur Taluk to a cost of Rs. 65·30 lakhs. The free catchment of the reservoir at the proposed site will be 61·49 sq. K.M. (23·74 sq. miles). The yield from the Catchment works out to 5·08 MM^3 (179·24 M.Cft.) and the storage capacity will be 2·86 MM^3 (100·727 M.Cft.). The ayacut benefitted under this scheme will be 364·22 hectares (900 acres) in Harur taluk.

6. *Reservoir Across Chinnar River near Shoolagiri.*

The reservoir is proposed across Chinnar River in Hosur Taluk to a cost of Rs. 45·90 lakhs. The free, combined and equivalent catchment at the proposed site are 76·53 sq. K.M. (29·55 sq. miles) 145·30 Sq. K.M. (56·10 Sq. miles) and 90.29 Sq. K.M. (34·86 Sq. miles) respectively. The yield from the catchment works out to 8·05 MM^3 (284·46 M.Cft.) and the annual storage will be 5·06 MM^3 (178·69 M.Cft.). The ayacut benefitted under this scheme will be 356·12 hectares (880 acres) in Hosur Taluk.

The Gross requirement of reservoirs proposed across Ponniar and its tributaries works out to 82·77 MM^3 (2923 M.Cft.) whereas the observed surplus is 127·43 MM^3 (4,500 M.Cft.) leaving a balance of 44·66 MM^3 (1577 M.Cft) that can be utilised for future extension under Ponniar River.


RIVER PONNAIYAR IN
DHARMAPURI DISTRICT.
H O S U R
K R I S H N A G I R I
D H A R M A P U R I
H A R U R
KUPPAM
VANIYAMBADI
TIRUPPATTUR
TALI
KRISHNAGIRI
TIRUVANNAMALAI
PONNIYAR RIVER
VANIYAR RIVER
HARUR
TOPPUR
DHARMAPURI
PENNAGARAM
HOGAINAKKAL
SCALE 0 8 MILES
REEERENCE
STATE BOUNDARY :
DISTRICT BOUNDARY :
TALUK BOUNDARY :
NATIONAL HIGHWAYS WITH MILESTONE :
RIVER AND BRIDGE :



FLOW DIAGRAM FOR PONNIAR
TAMIL NADU BORDER 0.00 KMS
CHINNAR I
MAHABLA RAO ANICUT
CATCHMENT 3445.59 SQ.KM YIELD 70.75 M.M³
AYARNAPALLI ANICUT
KADAVARAHALLI ANICUT
CATCHMENT: 3602.59 SQ.KM YIELD: 72.76 M.M³ (2569.22 MCFT)
AYACUT: 35.22 HEC. (62.08 ACS) SURPLUS: 71.63 M.M³
ULAGAMNALAH ANICUT
CATCHMENT: 3492.06 SQ.KM. (1348.29 SQ.M). YIELD 74.16 MM³ (2618.78 MCFT)
AYACUT 38.25 HEC (94.51 ACS). SURPLUS: 71.90 MM³ (2539.00 MCFT)
GULIYAM ANICUT
CATCHMENT 3930.16 SQ.KM YIELD 100.24 MM³ (3539.87 MCFT)
PULIGUNDUNALAH ANICUT
GANGALERI ANICUT
AT THE CONFLUENCE POINT OF MARKANDANADHI
CATCHMENT 5089.92 SQ KM YIELD 117.80 MM³ (4162.00 MCFT)
PROPOSED RESERVOIR ACROSS PONNIAR NEAR KELEVARAPALLI IN HOSUR Tk.
CATCHMENT 2442.36 SQ.KM. (943.00 SQ.M) YIELD: 45.56 M.M³ (1609.00 MCFT)
AYACUT 1198.21 HEC (2935.13 ACS)
THORAPALLI ANICUT
CATCHMENT 3326.77 SQ.KM (1284.47 SQ.M). YIELD: 71.97 M.M³ (2541.43 MCFT).
AYACUT 13.12 HEC (32.42 ACS). SURPLUS 66.15 M.M³ (2336.03 MCFT)
ALIYALAM ANICUT
SUBBAGIRI ANICUT
CATCHMENT 3353.55 SQ.KM (1294.81 SQ.M) YIELD 66.63 M.M³ (2362.84 MCFT).
AYACUT 6.90 HEC (17.06 ACS) SURPLUS: 66.54 M.M³ (2350.00 MCFT)
BOOTHANATHAM ANICUT
CATCHMENT 3434.48 SQ KM YIELD 73.79 MM³ (2605.82 MCFT)
AYACUT 42.88 HEC SURPLUS 70.06 MM³ (2474.22 MCFT)
ENNEKULLU ANICUT
CATCHMENT 3921.60 SQKM (1514.44 SQ M). YIELD 104.87 M.M³ (3703.34 MCFT)
AYACUT 24.43 HEC (60.36 ACS) SURPLUS 99.53 M.M³ (3515.00 MCFT)
CHINNAR II
MARKANDANADHI
VEPANAPALLI NADHI
CATCHMENT 270.58 SQ.KM (104.47 SQ M). GROSS YIELD 13.67 M.M³ (482.82 MCFT).
KRISHNAGIRI RESERVOIR PROJECT
NEDUNGAL ANICUT
CATCHMENT 5599.88 SQ KM. (2162.00 SQ.M) YIELD: 101.44 M.M³ (3583.21 MCFT)
AYACUT 1754.45 HEC. (4335.34 ACS). SURPLUS: 51.42 M.M³ (1816.06 MCFT)
AT THE CONFLUENCE POINT OF KAMBAINALLUR RIVER
KUMARAMPATTI ANICUT
CATCHMENT: 7058.09 SQ.KM. (2725.13 SQ.M). YIELD: 79.06 M.M³ (2791.70 MCFT)
AYACUT: 54.54 HEC. (134.78 ACS). SURPLUS 68.42 M.M³ (2416.16 MCFT)
PULAPATTI RIVER
SOLAKUTTAI STREAM
KAMBAINALLUR RIVER
MATHUR RIVER
BARUGUR RIVER
CATCHMENT: 831.13 SQ.KM NET YIELD 26.76 M.M³ (320.90 SQ.M) (945.82 MCFT)
PAMBAR RIVER
CATCHMENT: 1791.26 SQ.KM. (691.61 SQ.M) NET YIELD 55.74 M.M³ (1968.28 MCFT)
NEENAR
KALLAR
VANIAR
PEENIAR
VARATTAR
KOTTAPATTI KALLAR
TAMBAL ANICUT
CATCHMENT: 9885.77 SQ.KM. (3816.90 SQ.M) YIELD: 169.31 M.M³ (5979.24 MCFT)
AYACUT 46.70 HEC (115.31 ACS) SURPLUS 168.53 M.M³
AT THE CONFLUENCE POINT OF KOTTAPATTI KALLAR RIVER
CATCHMENT: 10494.95 SQ.KM (4075.27 SQ.M) YIELD: 209.66 M.M³ (7400.08 MCFT)
PROPOSED RESERVOIR ACROSS PAMBAR.R.
CATCHMENT: 1736.89 SQ.KM (670.23 SQ.M). YIELD: 56.61 M.M³ (1999.09 MCFT).
AT THE CONFLUENCE POINT OF PAMBAR RIVER
AT THE CONFLUENCE POINT OF VANIAR RIVER
DHARMAPURI DISTRICT LIMIT
YIELD: 213.61 M.M³ (7543.74 MCFT).
TRD BY: N.N.S

DYNAMICS OF SEDIMENTATION

BY

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1. *Synopsis.*—The object of this paper is to summarize the principal features of sediments, emphasizing the processes that lead to their formation or that cause them to change once they have been formed. As sediments are largely a product of the environment in which they are formed, attention is also given to environments of deposition.

2. *Introduction.*—Sediments are aggregates of particles that come to rest in some place after having been transported laterally or vertically for some distance. After the first deposition, cementing material is deposited in the pore spaces, new minerals form or old minerals grow, thus binding particles to one another, and pressure of overburden compresses the sediment, causing the constituent particles to interlock with one another. Soils, being weathered rocks have many of the properties of recent sediments.

3. Sedimentation consists of five fundamental processes: (*a*) Weathering, (*b*) erosion, (*c*) transportation, (*d*) deposition and (*e*) diagenesis.

3·1. *Weathering.*—Weathering and concomitant solution are the dominant processes by which rock or soil constituents are transformed into a state whereby they can be eroded and transported to some other place of deposition. Five fundamental factors influencing weathering are (i) parent rock material, (ii) climate, particularly the temperature and rainfall, (iii) physical environment on which the weathering takes place, especially, topography or shape of the land surface, (iv) length of time the processes operate, (v) action of organisms.

3·1·1. Mechanical disintegration, dependent on the thermal expansion and strength of the mineral constituents dominant in dry and cold regions and chemical weathering dependent on the exchange and movement of ions are the two processes of weathering. The longer the weathering takes place, the fuller will be the maturity of the soil formed.

3·2. *Erosion.*—Erosion, transportation and deposition are closely related and are caused by both mechanical and chemical processes.

3·2·1. Mechanical erosion consists of two processes, namely (1) plucking due to the factors, the size of the particle, the velocity of the transporting agent, and the cohesiveness of the rock or soil, and (2) abrasion of rocks by impact of moving particles depending on the size, quantity, hardness and velocity of moving particles and on the object that is struck. Temperature variations and the growth of plants in cracks are agents in the forcing apart of rocks.

3·2·2. The chief mechanical agents of erosion are water, wind, ice, gravity, volcanic explosions, plants and animals.

3·2·2·1. *Water.*—The erosive power of water depends upon the energy relationship of the moving water, particularly the turbulence. Water moving over relatively steep surfaces of land before it reaches streams acts in some ways as a thin flat sheet. If the obstacles to downward flow of the water are numerous, relatively little material is eroded, as for example, in humid, regions where plants are plentiful or in areas of highly pervious soil which absorbs the water readily. Sheet erosion results in a topography that comprises relatively steep slopes above and more gentle slopes below, where the water spreads out over a fan shaped area before collecting in a stream or some body of standing water. The steep slopes above seem to be related to the rate of weathering of the rocks and the permeability of the soil. The flatter slopes below represent an equilibrium profile determined by the average load of sediment that the water is carrying. If the water is underloaded it will cut, if overloaded it will deposit.

3·2·2·2. Erosion in the sea and in lakes is due principally to waves and currents, and to a minor extent to chemical solution. The abrasion of rocks along the shore or on the bottom in shallow water is caused chiefly by the impact of sand and rock particles carried by moving water. Loose sediment may be scoured by wave action or by ocean currents.

3·2·2·3. *Wind.*—All kinds of earth materials are worn away by impact of particles blown against them by the wind.

3·2·2·4. *Ice.*—Ice flowing like tar plucks rock fragments as it passes over them. It also pushes masses of rock and earth ahead of it as it moves. Rock fragments frozen in the ice abrade the rock or soil over which the ice flows. The hardness of ice seems to increase with decrease in temperature and therefore ice alone without aid of rock fragments, can scour soft sediments and rocks.

3·2·2·5. *Gravity.*—If the stability of the rock fragments is first upset by some agency other than gravity, fragments can become unbalanced and then slide or roll down the smooth or steep slopes due to gravity.

3·2·2·6. *Plants and Animals.*—Living material influences the erosive action of some other agent. Roots, however, are direct agents of erosion when they grow in cracks and force a part of the rocks to fall away. Man, because of his various uses of land and the resulting increase in soil erosion, is also an indirect agent.

3·3. *Transportation.*—The same six agents of erosion, namely water, wind, ice, volcanic explosions, gravity and biologic activity, also control transportation.

3·3·1. With water, the principal factors that affect transport are: turbulence, currents, shape, size, density and quantity of particles, and movement along the bottom

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by saltation (jumping), rolling or undermining. The gradient of stream bed, volume of water and presence of objects that impede flow are major factors for transport by turbulence. Turbulence may lift particles for a short distance above the bottom but it may not be strong enough to maintain them in suspension. Consequently they fall to the bottom, only to be lifted again at a later time when turbulence once more reaches a sufficient magnitude. These particles jump or roll along the bed in pulses. This process is called saltation.

3·3·2. Particles of sediments are blown through the air or moved along the ground by the same principle of saltation that applies to water. Ice transports material either within or top of the ice or by shoving masses of, earth and rock ahead of it as it moves. Transportation by volcanism is a question of the force of the explosion and the direction and strength of the prevailing wind. Transportation due to gravity is governed by the angle and smoothness of the slope along which the material moves, the co-efficient of friction, and the amount of material that moves.

3·4. *Deposition.*—The same six agents that affect erosion and transportation likewise control deposition.

3·4·1. *Water.*—Deposition in water is essentially a question of energy, place and time. If the energy available to move constituents that are in the act of being transported decreases, some of the particles can no longer be transported and they come to rest. The environment in which the particles are being transported profoundly affects the types of sediment that are deposited. Deposition is strongly influenced by turbulence when the interval of time is short, and by changes in average velocity when the time is not short. Slowly moving water, seemingly leads to poorer sorting of sediments than fast moving water. Silts are rarely as well sorted as sands. If the locus of deposition receives debris from two or more sources the materials deposited will have one or more size distributions deposited upon another. Likewise, if an area is subject to variations in average velocity, a similar result could arise. The development of layers is one of the principal characteristics of sediments.

3·4·1·1. Variations in velocity of water ordinarily are greater in shallow water than in deep water, consequently cross bedding is more likely to be indicative of a shallow water origin of sediments than of a deep water origin. Cross bedding however, can form in water of any depth so long as variable currents exist at or near the bottom.

3·4·2. *Wind.*—In arid regions the soil is poorly protected by vegetation and can be blown about by the wind. In present arid areas most wind deposits consist of sand. However, during the ice age, great masses of rock flour composed of fine particles of silt size, formed by the grinding action of the glaciers, were washed out by streams flowing from the ice and were deposited in great outwash plains. In the absence of the vegetation these silt particles could be blown away by the wind. The extensive deposits of loess, found around the southern border of the glaciated area, in part are believed to have formed from such wind-blown silt.

3·4·3. *Ice.*—Extensive deposits of glacial sediments are found in northern latitudes, in both North America, and Europe. These deposits consist of three principal types: (1) groundtill, (2) morainal material, and (3) outwash.

3·4·3·1. As the glacier moves along, it plucks up rock fragments and boulders of all sizes. In addition it scours the rocks over which it passes and these fragments embeded in the ice, settles on the surfaces of the land, forming deposits called groundtill, when the ice melts.

3·4·3·2. A similar type of deposit called morainal material is laid down at the sides or in front of glaciers.

3·4·3·3. The ice melts during summer and the melted water finds its way along the surface of the ice, in places dropping down cracks to the interior or bottom. Eventually this water emerges from the side or front of the glacier and deposits its load in broad plains. As the water flows across these plains rapidly, the deposits are well sorted, and many of the particles of gravel size are well rounded.

3·4·4. *Gravity.*—In cold climate or in arid regions where differences in temperature between night and day may be extreme, fragments of rock are dislodged owing to differential thermal expansion and contraction of the rock constituents and of the water in cracks and pore spaces. If slopes are sufficiently steep or smooth, dislodged fragments roll down and come to rest at some lower altitude.

3·4·4·1. Landslides are a manifestation of the effect of gravity. Soil and rock resting upon a slope start to slide when the weight of the overburden becomes greater than the strength or cohesion of the earth materials. Landslides commonly leave characteristic scars upon the hills, showing the places from which they slide, and the surface of the landslide deposits is hummocky.

3·4·5. *Volcanisms.*—Volcanic sediments consists mainly of layers of wind blown ash. Ash deposits commonly are interspersed with lava flows. Volcanic ash commonly gives rise to montmorillonite clay.

3·4·6. *Organisms.*—Sediments of biologic origin are essentially a product of environment. Deposits of organic origin, such as coal, diatomite, oil shale, bog iron, ore or algal limestone, require special conditions of formation. Deposits rich in organic matter commonly are relatively rich in radioactive material.

4. *Chemical action.*—

4·1. Chemical action is essentially a question of degree of saturation. If water is undersaturated it can dissolve material, if it is oversaturated it can precipitate material. The principal factors are ionic concentration, temperature, oxidation-reduction potential, amount of water microbial action, types of earth materials in contact with the water, and rate at which conditions change.

4·2. The concentration of the different ions, particularly the hydrogenion concentration, is an important factor. The presence of even a small amount of some minor element may significantly affect the solubility relations of other substances. Boron, for example, materially affects solubility of calcium carbonate in sea water.

4·3. Evaporation changes the concentration of dissolved salts and thus changes equlibrim relationships.

4·4. Earth materials lying above the water table tend to be more oxidized than corresponding materials lying below the water table.

4·5. Slow movement of water through pore spaces favours the development of a relatively high degree of saturation of dissolved substances, but if the rate is so slow that the water becomes saturated, no further material can be dissolved.

4·6. The solution of many substances is aided by the activity of microorganisms or soil forming processes. Microbial action is favoured by warm and humid climate.

4·7. Parent earth materials vary greatly in their susceptibility to solution. Limestone is readily dissolved by acid solutions and volcanic ash by basic or alkaline solutions. Salt, gypsum, nitrate and other products of chemical evaporation are dissolved by moving water of almost any character.

4·8. Chemical deposition is essentially a question of environment. The temperature, pressure, or concentration of dissolved substances must change before material can be precipitated.

5· *Environment*—

5·1. *Environment.*—An environment of deposition may be considered an area in which the combined effect of the fundamental factors of topography, temperature, water, organisms, and rates of change of conditions are similar. The fundamental factors are interrelated. Changes in environment conditions in turn influence the environmental factors themselves. Diastrophism, or deformation of the earth, exerts a dominant influence upon environment, either directly by altering the shape of the land and the distibution of water or indirectly by modifying the climate and thus in turn the rate of erosion, transportation, and deposition. The movement of water, particularly currents in the sea is greatly influenced by diastrophism.

5·2. *Oceanic Processes*—

5.2.1. *Oceanic Processes.*—The Chief locus of deposition of sediments is the ocean. The surface temperature of the ocean is high near the tropics and low near the poles. The temperature of the water decreases with depth in all latitudes, but below a depth of 1524 m (5000 feet) it is remarkably constant with respect to latitude, being everywhere less than 4.44°C (40° F) at that depth. Water in the ocean is esssentially stratified with respect to density. Water within individual layers is free to move

5·2·2. Evaporation of ocean water increases the density. Water tends to flow from the more dense area to the less dense area. This process of adjustment of mass together with the wind causes the great ocean currents, such as the Gulf stream and the Japanese current. Owing to the rotation of the earth, currents are deflected to the right in the northern hemisphere and to the left in the southern hemisphere.

5·2·3. The ocean, like a dog chasing its tail, is constantly trying to attain a condition of equilibrium but never does. However, in many parts of the ocean the rates of change on the average are fairly constant. so a condition of dynamic, in contrast with static, equilibrium is obtained. This general circulation of the water has profound effects upon climate, the growth of organisms, the concentration of dissolved substances in the sea, and thus in turn upon the deposition of sediments.

5·2·4. Tides produce currents in shallow water. In water less than 182·88m (600 feet) deep waves can stir up the bottom and winnow the sediments. Internal waves, developed in layers of denser water beneath the surface, conceivably could generate currents. Coarse sediments in deep water in some areas may have resulted from such currents.

5·3. *Bays.*—In areas where sea level is rising or has risen recently the mouths of streams become drowned and form bays. Silt and clay are deposited in quiet water, and sand or coarse silt is laid down in or near the channels. The sediments are poorly sorted and vary greatly in texture from place to place.

5·4. *Areas of calcium carbonate deposition.*—Limestone is formed in several types of environments. The most favourable environment of deposition of calcium carbonate is a shallow flat-bottomed sea adjacent to a low lying coast in a tropical or semi tropical climate. The activity of organisms is a potent influence in the deposition of calcium carbonate in lakes.

5·5. *Rivers.*—Many different types of environments of deposition are found on land. The deposits on land are mainly the result of stream action. The essential requirement is the formation of a place of deposition, particularly a flat surface upon which the rivers can deposit their load at times when they got out of their channels.

5.5.1 River deposits are characterised by cut and fill action during flood. When the discharge is great and velocity of the water is high, the bed of the stream is scoured to a greater depth than during normal periods of flow. As the flood abates and the stream returns to normal levels, the depth of scour diminishes and the bed fills up to its customary position. Large streams may be scoured more than 15·24m (50 feet), as is indicated by the undermining of deep piers during floods.

5,6 *Lakes.*—Lake sediments are influenced materially by the nature of the water in the lake. Critical factors are average temperature of water, extremes of temperature, quantity of rainfall seasonal and cyclic distribution of rainfall, activity of micro organisms, concentration of dissolved materials, size and shape of lake, depth of water, and supply of detritus.

5.6.1. When the deep water does not rise to the surface, a permanent state of stagnation may be produced in the deep water, in which hydrozen sulphide can be continually present and only a few types of organisms, particularly certain anaerobic bacteria can live. A heavy storm or a rare cold spell may cause some of the deep water to rise to the surface, killing off much of the life. Lakes that are periodically ventilated by overturning of the water are in a relatively high state of oxidation compared with those in which the water does not turnover. The depth of water, however, is a factor, because, the shallower the lake, the more likely the bottom water is to be stirred up during a storm.

5.6.2 The larger lakes have bars, spits and beaches, which have essentially the same characteristics as corresponding features in the ocean. The sediments laid down in the central parts of the large lakes, like sediments in the open sea, are relatively fine in texture, and are comparatively well stratified.

6. *Diagenesis*

6.1 Sediments change after they have been deposited. The water is squeezed out of pore spaces owing to the effect of superimposed loads, thus causing a reduction in thickness. This compaction of the deposits presses the constituents more firmly together and gives the sediments greater strength. Materials are deposited in the pore spaces and cement the particles together. New minerals form and old minerals grow by the addition of new material. Ultimately the sediment is consolidated into rock. The total of these processes is called diagenesis.

6.2 For sediments to compact, the water must be squeezed from the deposits. The permeability, therefore, is a big factor in the rate of consolidation. During consolidation of the sediment into rock, that is, while water is being squeezed out, the strength or ability of the sediment to support a load is affected to a considerable extent by deformation of mineral constituents, which cause the individual constituents to be more firmly locked together. A great variety of minerals are known to be generated in sediments.

7. *Classification*

7.1 Three main groups of sediments are generally recognised: (1) clastic deposits, composed principally of particles that have been transported mechanically and then deposited: (2) chemical deposits, composed mainly of materials precipitated from solution and (3) organic deposits resulting from the activity of organisms.

7.2 The elastic deposits are classified mainly upon the grain size of the major constituents. The names gravel, sand, silt, clay and colloid are universally adopted for classifying individual constituents by size.

7.3 Sediments are composed of particles of many different sizes. Geologists are accustomed to classify the deposit upon the basis of the diameter of the average (median) particle, the D-50 of the engineer. A consolidated sand is almost invariably called a sandstone, but a silt is classed as a siltstone or shale, depending on the degree of lamination of the rock. If massive, the rock is called a siltstone, if laminated it is called a shale.

8. *Practical applications*

8.1 The practical application of sediments depend on the properties of the sediments and the processes that affect them. The strength of sediments and the changes in strength under added or reduced stress, are of fundamental importance to the construction engineer, whether he be interested in bearing strength of foundations, stability of slopes, or the construction of tunnels.

8.2 The permeability and porosity of sediments are of great practical importance to petroleum and mining geologists, to ground water hydrologists, and also to construction engineers, because the movement of oil and water through ground depends so much upon the permeability. Both the physical and chemical properties of the constituent minerals concern mining geologists in search of ore minerals. The mass properties of sediments, such as density, resistivity, radio-activity, or compressibility, concern the geophysicist and geologists in prospecting for oil.

8.3 The processes that affect sediments concern all people who use sediments. The character of sediments and their response to stress depend on the processes that lead to the formation of the sediments. In addition, the processes themselves, have certain very special applications such as soil erosion, gullying of arable lands, degradation and aggradation of stream valleys below dams, silting in reservoirs, beach erosion, development of harbours and breakwaters stream channel control, and silting in irrigation canals.

8.4 Lastly, sediments are of great use to the geologist interested in determining the mode of origin of sediments, or the environmental conditions under which they were deposited.

Reference—

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RURAL ENGINEERING SURVEYS

by

THIRU R. L. RAJU, B.E. (Hons.), C.E. (Hons.), A.M.I.E.*

1·1. India is a country of villages with nearly 80 per cent of the total population of 518 millions, confined to the rural areas. There are as many as 5,60,000 villages spread over the length and breadth of the country and of these, nearly 27,000 villages as compared to 224 towns lie in the 21 districts of the State of Andhra Pradesh. The main stay of the rural population is agriculture which contributes nearly 50 per cent of the State income. Most of the industrial development is confined to the urban area. The per capita income of the rural population is naturally far less than that of the urban population. If this country is to be developed, the rural areas are therefore to be tackled on a massive scale.

1·2. It has been the aim and ambition of all the planners to improve these villages and make them self-sufficient as far as practicable. An ideal village should have good houses for its population, sanitary environment and essential amenities like schools, markets, roads, electricity and adequate employment potentials to keep all the people of the village engaged. The full development of these several villages is an enormous venture and it cannot be achieved in a span of few years mainly for want of resources. For the planned development of the villages in a phased manner to suit the available resources, the collection of socio-economic, agronomical and engineering data of the villages as existing, is very essential. As it is, the more vociferous and well-to-do sections of the villages are enjoying the fruits of the development better than others and the backward areas are left in the background. If the full data is collected, priorities can be fixed on the basis of need.

1·3. From the close of Third Five-year Plan, the employment potential has steeply fallen and along with others, the engineering and agricultural graduates are remaining unemployed. Government of India have evolved a scheme for the rural engineering surveys to compile the essential data for the villages mentioned above as well as to provide the much needed employment potential to the unemployed engineering and agricultural graduates. Under this scheme, a survey partly consists of two engineering graduates and one agricultural graduate assisted by one technical assistant and five unskilled labourers and 25 such survey parties are proposed for a district under the control of an Executive Engineer. The Executive Engineer is provided with the required office staff and supervising staff both on the engineering and agricultural fields. On an average, a district may have about 1,100 villages and at the rate of one village per party per month, it takes 2 years and 6 months to cover the district fully. To start with, the scheme sponsored by the Central Government is introduced in the backward districts of Mahabubnagar and Kurnool in Andhra Pradesh.

1·4. Appreciating the value and the need for this survey for the rural areas, the Government of Andhra Pradesh has further undertaken to survey the villages in the remaining 19 districts of the State under a slightly different name of Rural Engineering and Planning Surveys. But the staffing pattern is much on a smaller scale with only five survey parties for each district as against 25 survey parties under the Rural Engineering Survey Scheme. These 5 survey parties in each district are supervised by an Assistant Engineer and 4 to 5 districts are in turn attached to one Executive Engineer. With this smaller set up in each district, it would take longer time to cover the district. To expedite the surveys, it is necessary to increase the number of parties or concentrate the available parties in a few selected districts. This will be decided as the scheme gains momentum.

1·5. Both these schemes put together have created sizeable employment potentials relieving the distress in unemployment to some extent. Merely 500 technical persons and another 1,500 non-technical persons could be usefully absorbed in this venture. The schemes are supervised by the Chief Engineer, Minor Irrigation of the Public Works Department under the overall control of the Secretary, Planning and Co-operation Department of the State Government.

2·1. The survey of villages consists of 4 parts—(1) Socio-economic surveys in the shape of data collection,(2) Preparation of an engineering plan of the village to a scale equivalent to 8″ to a mile with contours super-imposed at ½ or 1 metre intervals, (3) Preparation of an agricultural plan to the same scale with suitable classifications for the soils and their land capability gradation, and (4) A report explaining the special features of the village, essential needs of the village and approximate estimates for providing the essential amenities. The entire information is presented in the form of a booklet.

2·2. The data collection is standardised into a standard form and it is mainly sub-divided into (*a*) Occupations, (*b*) Household census on land holdings, (*c*) Agricultural practices, (*d*) living accommodation, (*e*) Sanitary arrangements, (*f*) Employment details, (*g*) Land utilisation and soil characteristics, (*h*) Cropping patterns, (*i*) Irrigation facilities,(*j*) Communications,(*k*) Electric supply,(*l*) Education facilities,(*m*) Market facilities,(*n*) Industries,(*o*) Water supply for drinking and also irrigation, (*p*) Incidence of adverse seasons and (*q*) Developmental activities in the village. This information is collected from the village records and by household survey. Field to field inspections are also necessary.

2·3. The engineering plan is traced from the village revenue plan and all the up to-date physical features are marked therein. The entire village is then block-levelled with reference to the nearest G.T.S. Bench mark, adopting a 100 metre grid for the spot levels. After plotting these levels on the village plan, contours are drawn at ½ or 1 metre intervals depending on the slope of the terrain. This village plan is again traced omitting the levels and carrying over only contours. At places, where levels could not be touched for some difficulty or other, the contours are shown in dotted lines by interpolation to maintain their continuity.

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For accuracy, in levels, adequate care in check levelling as well as in reduction of levels is indispensable. The same village plan tracing with all survey numbers is again used for drawing the soils map. All the fields are inspected by the soil surveyor and then surveyed with the aid of profile pits and soil-testing. Based on the data so collected, the soil classifications and land capability gradation were marked on the plan in different colours following the standard notations. Special features like alkaline and saline patches, soil conservation measures are also indicated. In short, the plan provides all the soil characteristics required for agronomy.

2.5 The report drafted after collecting the above details is the summary of all the special features of the village, the felt-needs of the village and proposals for development taking into account the facilities and potentialities locally available. The nearest source of electric supply for electrification, the important roads to be made all-weather the essential school facilities, drinking water requirements, the markets required, the possibility of providing irrigation facilities, the employment potential that can be created in the village or nearby and the housing schemes for the economically weaker section who could not afford houses of their own, are fully discussed and the costs indicated. In making a proper assessment of the needs and costs, certain standard norms are adopted. Detailed estimates are considered necessary only if there is a prospect of immediate execution of the work.

3.0 While the socio-economic survey gives certain information as on the date of survey for immediate planning, the engineering and soil plans are the permanent assets of the scheme. They will be useful for all the time to come as detailed topographical sheets and scheme for engineering works or agronomical developments can be drafted with ease and speed. The investigation of schemes for future development will get very much simplified. The report will give an idea of the developmental work involved and will help in fixing priorities to suit the available resources. To say it briefly, the survey report on the village will be a veritable hand books for all referencing in the development of the village. If the village plans are reduced to a smaller size and combined, index map with contours at two metre intervals can be prepared for each taluk for planning schemes connected with a group of villages.

4.0 The village survey reports so prepared are reviewed by a district level committee consisting of important district officials and presided over by the District Collector to make them as complete as possible. After their finalisation, the reports are safely kept as important in the records district offices for all future referencing in planning and developmental works.

DESIGN TABLES FOR POTENTIALS UNDER WEIRS ON FINITE DEPTH OF PERVIOUS FOUNDATIONS

By

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1. *Introduction.*

Potential i.e., the uplift pressure expressed as fractions of head of water under weirs on pervious foundations are usually obtained by the procedure given by Khosla et al (1).** They have provided suitable charts based on their theoretical derivations for the cases of weirs on infinite depth of pervious foundations. It is generally recognised that when the depth of previous foundation is finite, and is comparable to the dimension of the weir profile, the results obtained from a soluation based on infinite prevoius foundation are not satisfactory (2, 3). Under these conditions, solutions must be obtained taking into consideration, the relevant depth of pervious foundations.

Solution have been obtained for finite depth cases by Pavlovsky (2) and others as listed in reference 4. A general solution has been provided by Muthukumaran (5, 6) for the case of weirs on infinite pervious foundations. A design chart has been provided by Kulandaiswamy and Muthukumaran (4) for the case of a floor with a sheet pile on finite depth of pervious foundations. It has been shown that for estimating the potentials under weirs on pervious foundations, the solution for this simple case and a mutual interference formula are sufficient (4, 5, 6). Therefore, one might conclude that the problem of finding the potentials under weirs on pervious foundations is once and for all solved. However, in order to use the chart provided in the references 4, 5 and 6 certain computations have to be made. Some designers may feel that it might be more convenient, if computations are avoided to the extent possible and tables are provided to directly read the potentials at salient points. In this paper such tables are provided.

2. *Tables for Potentials—*

The theoretical solution for potentials for the case of a weir, consisting of a floor and a sheet pile, resting on finite depth of pervious foundations is given by (4,5,6): (vide Figure 1).

$$\bar{\phi} = \frac{1}{K} \, sn^{-1} \, (P, m) \tag{1}$$

$$\text{or } \bar{\phi} = \frac{1}{K} \, dnt^{-}(\sqrt{1 - mP^2}, m) \tag{2}$$

where $\bar{\phi}$ = Potential expressed as a fraction of the head causing seepage,

K = complete elliptic integral of the first kind with modulus, m,

$$m = \frac{2(\beta_1 + \beta_2)}{(1+\beta_1)(1+\beta_2)} \tag{3}$$

$$P = \sqrt{\frac{(1+\beta_1)(\beta_2 - p)}{(\beta_1+\beta_2)(1-p)}} \tag{4}$$

$$1 - mP^2 = \frac{1-\beta_2}{1+\beta_2} \cdot \frac{1+p}{1-p} \tag{5}$$

$m^1 = 1 - m$, the complementary modulus

$$= \frac{1-\beta_1}{1+\beta_1} \cdot \frac{1-\beta_2}{1+\beta_2} \tag{6}$$

$$\sqrt{\frac{1-\beta_i}{1+\beta_i}} = \frac{\cos D \, \text{Sech} \, B_i}{1 + \sqrt{1 - \cos^2 D \, \text{Sech}^2 \, B_i}} \quad \text{for } i = 1, 2 \tag{7}$$

$$\sqrt{\frac{1-p}{1+p}} = \frac{\cos D \, \text{Sech} \, z}{1 + \sqrt{1 - \cos^2 D \, \text{Sech}^2 \, z}} \tag{8}$$

$$p = \text{Cos} \, D \sqrt{\tanh^2 + \tan^2 D} \tag{9}$$

$$\beta_i = \text{Cos} \, D \sqrt{\tanh^2 B_i + \tan^2 D} \quad \text{for } i = 1, 2 \tag{10}$$

$sn^{-1}(P, m)$ = elliptic integral of the first kind with argument, P, and modulus, m,

$dn^{-1} \sqrt{1 - mP^2}, m$ = Jacobian inverse elliptic function and is equivalent in numerical value to $sn^{-1}(P, m)$,

z = x + iy, a complex variable representing the plane of the weir.,

p = s + it, an intermediate complex variable,

B = width of the floor of the weir.

B_1 = width of the floor of the weir, on the upstream of sheet pile.

B_2 = width of the floor of weir on the downstream side of sheet pile.

D = Depth of sheet pile.

T = Depth of pervious foundation. All dimensions in the plane of the weir are expressed in the scale.

T = $\pi/2$.

The complete elliptic integral, K. and the inverse elliptic function, dn^{-1}, can be expressed and computed in terms of m_1. It was suggested in reference 4, that $\bar{\phi}$ can be obtained from Eq. 2. For this purpose, the designer is expected to compute $\sqrt{1 - mP^2}$ and m_1 from Eqs. 5 and 6. Then, using a chart provided, the potential $\bar{\phi}$ can be read for the computed values of m_1 and $\sqrt{1 - mP^2}$.

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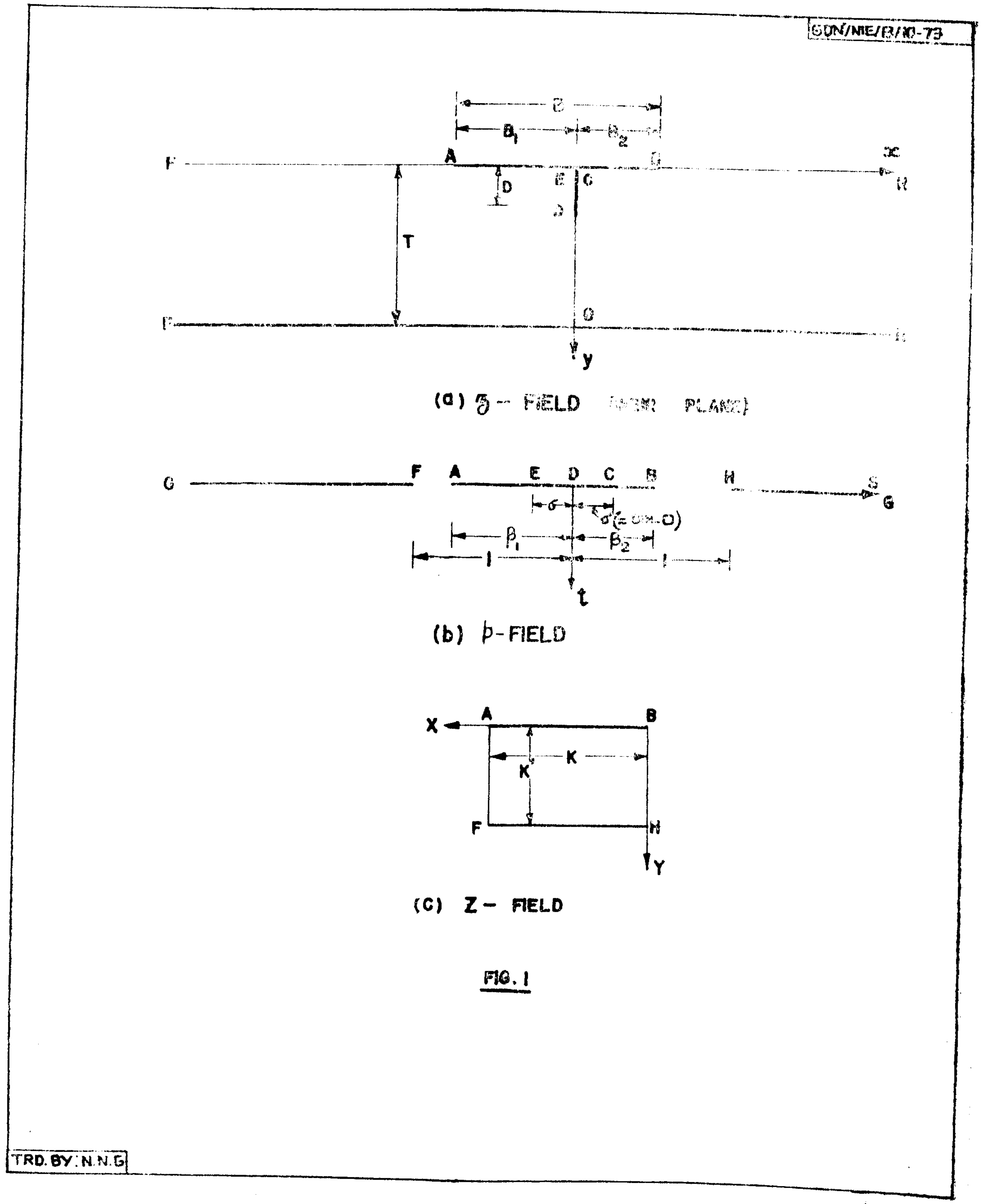
** Number in the parenthesis indicate serial number in the list of references.



(a) ζ – FIELD

(b) p-FIELD

(c) Z – FIELD

FIG. 1

Now, it is proposed to spare the designer, the trouble of computing m^1 and $\sqrt{1\text{-}mP^2}$. Suitable tables are provided from which the potential can be read directly, given the details of the weir profile, namely B_1, B_2, D and T. For this purpose, it was proposed to use Eq. 1 for computing ϕ. The elliptic integrals K and sn^{-1} vary rapidly when their modulus is close to unity. If the argument P is also close to unity, then the second integral varies more rapidly. Therefore, it is necessary to compute m and P to many significant figures, in order to compute ϕ. It is possible to express and compute the integral, K, in terms of m^1 and the integral, sn^{-1}, in terms of P, $\sqrt{1\text{-}P^2}$, and m^1, or P, $\sqrt{1\text{-}P^2}$ and m^1. $\sqrt{1\text{-}P^2}$ can be computed without computing P, by the following equations:

$$1 - P^2 = \frac{(\beta_1 + p)\ (1 - \beta_2)}{(\beta_1 + \beta_2)\ (1 - p)} \qquad (12)$$

$$1 - P = \frac{\cos^2 D\ \mathrm{Sech}^2\ z}{1 + \cos D\ \sqrt{\tanh^2 z + \tan^2 D}} \qquad (13)$$

$$1 - \beta_2 = \frac{\cos^2 D\ \mathrm{Sech}^2\ \beta_2}{1 + \cos D\ \sqrt{\tanh^2 B_2 + \tan^2 D}} \qquad (14)$$

If p, β_2 and P are close to unity, $1 - p$, $1\text{-}\beta_2$ and $1 - P^2$ may be computed using the above equations, thereby avoiding the necessity to compute the former quantities to many significant figures. In this procedure for computation of ϕ, the quantities m,m^1, P and $\sqrt{1\text{-}P^2}$ need be computed only to six significant figures in order to obtain ϕ correct to four significant figures. A computer programme was developed, potentials at salient points were computed for possible range of values of B, D, T and B_1 and presented in Tables 1—1 to 1—22 and 2—1 to 2—22.

Tables 1-1 to 1-22 give the potentials at the salient point C,corner where sheet pile and downstrem floor meet. Tables 2-1 to 2-22 give the potentials at the salient point D, the tip of sheet pile. Each table is for a fixed depth of pervious foundation. In the tables for D/T less than 0.2, the potentials for small values of B/D are omitted as in these cases, the potentials do not differ appreciably from those for infinite depth of pervious foundations. In othter words, these cases are equivalent to infinite depth cases, as regards the potentials at salient points. In such cases, the potentials for a given B/D value, can be read from that table corresponding to the smallest D/T value, in which potentials are provided. For example, if B/D = 1.0 and if D/T is less than 0.2, the potentials given in the table for D/T = 0.2 are valid.

3. *Use of Tables.*

The potentials at the salient point, C, can be read directly from the Tables 1-1 to 1-22. Where, the Tables do not provide the values directly, linear interplation is valid.

The potential at the salient point, D, can be read from the Tables 2-1 to 2-22, if B_1/B is greater than or equal to 0.5. Where B_1/B is less than 0.5, the potential can be obtained by the use of the following relationship:

Potential at D for B_1/B = 1. — Potential, at D for (1.—B_1/B). (15)

The potential at the salient point, E, corner where the sheet pile and upstream floor meet, can be obtained from the Tables for potentials at C using the following relationship:

Potentials at E for B_1/B = 1. — Potential at C for (1.—B_1/B) (16)

4. *Worked out Examples.*

Example 1: Find the potentials at C, D and E, given the following:—

B/D = 30; B_1/B = 0.3; D/T = 0·75.

From Table 1-9, Potential at C is read as 0·6411.

From Table 2-9, Potential at D for B_1/B = 0·7 is read as 0·3171. Using Eq. 15, Potential at D is computed as 1.—0·3171 = 0·6829.

From Table 1—9, Potential at C for B_1/B = 0·7 is read as 0·2753. Using Eq. 16 Potential at E is computed as 1.—0·2753 = 0·7247.

Example 2: Find the potential at C, given B/D = 15; B_1/B = 0·25; D/T = 0·65.

The following is an extract from Tables 1 - 10 and 1 - 11.

Potential at C.

B/D.	D/T.	B_1/B. 0·2	B_1/B. 0·3
16	0·7	·6873	·6017
14	0·7	·6738	·5900
16	0·6	·6939	·6079
14	0·6	·6810	·5968

Interpolating first in the direction of B_1/B, then in the direction of D/T, the following are obtained:—

B/D	D/T	B_1/B 0·2	B_1/B 0·3	B_1/B 0·25
16	0·7	·6873	·6017	·6445
14	0·7	·6738	·5900	·6319
16	0·6	·6939	·6079	·6509
14	0·6	·6810	·5968	·6389
16	0·65	..	..	·6477
14	0·65	..	..	·6354

Finally interpolating in the direction of B/D, it is seen that the potential at C is 0·6416 or 0·642. It can be checked that changing the direction of interpolation does not appreciably alter the final result.

5. Comparison with Experimental Results.

During the course of several years, work has been done at the Concrete and Soil Research Laboratory Chepauk, on this topic and their electrical analogy experimental results are presented in a report (7). A few values read from the charts provided in reference 7, are compared—with those obtained from the tables provided, in Table 3.

The differences between the experimental and theoretical results in Table 3 may be considered as permissible in a problem of this type.

6. Acknowledgment.

The numerical values for the preparation of the table were obtained using the IBM 1620 computer available at the Computer Center, College of Engineering, Guindy Madras and the help rendered by the staff of the Computer Center is gratefully acknowledged.

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TABLE 3.

COMPARISON OF EXPERIMENTAL AND THEORETICAL RESUTS.

Serial number. (1)	D/B (2)	T/B (3)	B_1/B (4)	D/T (5)	B/D (6)	Potential at E. Expt. (7)	Theo. (8)
1	0·15	0·05	0·6	0·75	6·67	57·5	57·5
2	0·20	0·05	1·0	0·80	5·00	43·5	41·0
3	0·30	0·05	0·8	0·86	3·33	59·0	60·5
4	0·40	0·05	0·6	0·89	2·50	76·5	75·2
5	0·10	0·10	0·8	0·50	10·00	37·0	35·3
6	0·15	0·10	0·6	0·60	6·67	56·2	55·8
7	0·20	0·10	0·4	0·67	5·00	73·6	73·1
8	0·30	0·10	0·2	0·75	3·33	88·0	89·1
9	0·40	0·10	1·0	0·80	2·50	57·2	58·0
10	0·60	0·10	0·6	0·86	1·67	82·0	80·8
11	0·05	0·20	0·5	0·20	20·00	56·0	54·1
12	0·10	0·20	0·9	0·33	10·00	31·0	28·6
13	0·20	0·20	0·4	0·50	5·00	72·0	71·5
14	0·30	0·20	0·6	0·60	3·33	66·5	65·2
15	0·40	0·20	0·8	0·67	2·50	62·5	61·8
16	0·60	0·20	1·0	0·75	1·67	68·0	66·5
17	0·10	0·50	0·9	0·17	10·00	30·5	30·2
18	0·15	0·50	1·0	0·23	6·67	32·5	32·5
19	0·20	0·50	0·8	0·29	5·00	47·0	45·6
20	0·30	0·50	0·6	0·38	3·33	62·0	63·3
21	0·40	0·50	0·4	0·44	2·5	78·5	78·2
22	0·60	0·50	0·8	0·55	1·67	71·0	69·2

TABLE 1—1.

POTENTIALS AT C FOR D/T = 0·99.

B/D (1)	$B1/B$: ·0 (2)	0·1 (3)	0·2 (4)	0·3 (5)	0·4 (6)	0·5 (7)	0·6 (8)	0·7 (9)	0·8 (10)	0·9 (11)	1·0 (12)
30·0	·8179	·7451	·6623	·5795	·4967	·4139	·3311	·2483	·1655	0·827	·0000
25·0	·7892	·7204	·6403	·5603	·4803	·4002	·3202	·2401	·1601	·0800	·0000
20·0	·7497	·6861	·6099	·5337	·4574	·3812	·3050	·2287	·1525	·0762	·0000
18·0	·7294	·6684	·5942	·5199	·4457	·3714	·2971	·2228	·1486	·0743	·0000
16·0	·7055	·6475	·5757	·5037	·4318	·3598	·2879	·2159	·1439	·0720	·0000
14·0	·6770	·6225	·5535	·4843	·4152	·3460	·2768	·2076	·1384	·0692	·0000
12·0	·6424	·5918	·5265	·4607	·3949	·3291	·2633	·1974	·1316	·0658	·0000
10·0	·5996	·5535	·4928	·4312	·3696	·3080	·2464	·1848	·1232	·0615	·0000
9·0	·5740	·5304	·4726	·4136	·3545	·2954	·2363	·1772	·1181	·0589	·0000
8·0	·5450	·5040	·4495	·3934	·3372	·2810	·2248	·1686	·1124	·0560	·0000
7·0	·5117	·4736	·4229	·3703	·3174	·2645	·2116	·1587	·1057	·0526	·0000
6·0	·4732	·4381	·3919	·3433	·2943	·2452	·1962	·1471	·0980	·0487	·0000
5·0	·4281	·3962	·3552	·3114	·2670	·2225	·1780	·1335	·0888	·0440	·0000
4·0	·3746	·3463	·3111	·2732	·2344	·1954	·1563	·1171	·0778	·0385	·0000
3·0	·3099	·2858	·2573	·2265	·1946	·1622	·1297	·0971	·0643	·0318	·0000
2·5	·2724	·2506	·2258	·1990	·1711	·1427	·1141	·0853	·0564	·0279	·0000
2·0	·2304	·2115	·1905	·1680	·1446	·1206	·0964	·0720	·0476	·0235	·0000
1·5	·1833	·1676	·1507	·1329	·1145	·0955	·0763	·0570	·0377	·0186	·0000
1·0	·1298	·1180	·1058	·0931	·0801	·0669	·0534	·0399	·0265	·0131	·0000
·7	·1002	·0908	·0812	·0714	·0613	·0511	·0409	·0306	·0203	·0101	·0000
·5	·0685	·0619	·0552	·0484	·0415	·0346	·0277	·0207	·0138	·0069	·0000
·3	·0417	·0376	·0335	·0293	·0251	0·210	·0168	·0126	·0084	·0042	·0000
·1	·0140	·0126	·0112	·0098	·0084	·0070	·0056	·0042	·0028	·0014	·0000

TABLE 1—2.

Potentials at C for D/T=0·98.

B/D		·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
		B1/B.										
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
30·0	.. ..	·8369	·7628	·6780	·5933	·5085	·4238	·3390	·2543	·1695	·0848	·0000
25·0	.. ..	·8105	·7402	·6580	·5757	·4935	·4112	·3290	·2467	·1645	·0823	·0000
20·0	.. ..	·7738	·7087	·6300	·5513	·4725	·3938	·3150	·2363	·1575	·0788	·0000
18·0	.. ..	·7548	·6923	·6155	·5385	·4616	·3847	·3077	·2308	·1539	·9769	·0000
16·0	.. ..	·7324	·6729	5982	·5235	·4487	·3739	·2991	·2243	·1496	·0748	·0000
14·0	.. ..	·7054	·6493	·5774	·5053	·4331	·3609	·2887	·2165	·1444	·0722	·0000
12·0	.. ..	·6724	·6203	·5518	·4829	·4139	·3449	·2759	·2069	·1380	·0689	·0000
10·0	.. ..	·6311	·5834	·5196	·4547	·3897	·3248	·2598	·1949	·1299	·0648	·0000
9·0	.. ..	·6062	·5611	·5000	·4376	·3751	·3126	·2501	·1876	·1250	·0624	·0000
8·0	.. ..	·5778	·5353	·4776	·4180	·3583	·2986	·2389	·1792	·1194	·0595	·0000
7·0	.. ..	·5449	·5053	·4514	·3952	·3388	·2823	·2259	·1694	·1129	·0562	·0000
6·0	.. ..	·5065	·4699	·4206	·3685	·3159	·2632	·2106	·1579	·1052	·0522	·0000
5·0	.. ..	·4610	·4277	·3837	·3365	·2885	·2405	·1924	·1442	·0959	·0475	·0000
4·0	.. ..	·4062	·3765	·3387	·2975	·2553	·2128	·1702	·1275	·0847	·0418	·0000
3·0	.. ..	·3391	·3135	·2826	·2489	·2139	·1784	·1426	·1067	·0707	·0348	·0000
2·5	.. ..	·2995	·2763	·2493	·2198	·1891	·1578	·1261	·0942	·0623	·0307	·0000
2·0	.. ..	·2549	·2344	·2114	·1867	·1608	·1342	·1072	·0800	·0529	·0260	·0000
1·5	.. ..	·2040	·1869	·1683	·1486	·1280	·1069	·0854	·0637	·0421	·0208	·0000
1·0	.. ..	·1455	·1325	·1189	·1047	·0901	·0752	·0601	·0449	·0297	·0147	·0000
·7	.. ..	·1127	·1023	·0915	·0804	·0692	·0577	·0461	·0345	·0229	·0114	·0000
·5	.. ..	·0773	·0699	·0623	·0547	·0469	·0391	·0313	·0234	·0156	·0078	·0000
·3	.. ..	·0472	·0425	·0378	·0331	·0284	·0237	·0190	·0142	·0095	·0047	·0000
·1	.. ..	·0159	·0143	·0127	·0111	·0095	·0079	·0063	·0048	·0032	·0016	·0000

TABLE 1—3.

Potentials at C for D/T=0·97.

B/D		·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
		B1/B.										
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
30·0	.. ..	·8480	·7731	·6872	·6013	·5154	·4295	·3436	·2577	·1718	·0859	·0000
25·0	.. ..	·8231	·7520	·6685	·5849	·5013	·4178	·3342	·2507	·1671	·0836	·0000
20·0	.. ..	·7882	·7223	·6421	·5618	·4815	·4013	·3210	·2408	·1605	·0803	·0000
18·0	.. ..	·7701	·7067	·6283	·5497	·4712	·3927	·3141	·2356	·1571	·0785	·0000
16·0	.. ..	·7486	·6882	·6119	·5354	·4589	·3824	·3059	·2295	·1530	·0765	·0000
14·0	.. ..	·7226	·6656	·5920	·5180	·4440	·3700	·2960	·2220	·1480	·0740	·0000
12·0	.. ..	·6907	·6377	·5674	·4965	·4255	·3546	·2837	·2128	·1419	·0709	·0000
10·0	.. ..	·6504	·6020	·5362	·4692	·4022	·3351	·2681	·2011	·1341	·0669	·0000
9·0	.. ..	·6261	·5802	·5172	·4526	·3879	·3233	·2586	·1940	·1293	·0645	·0000
8·0	.. ..	·5982	·5549	·4952	·4334	·3715	·3096	·2477	·1858	·1238	·0617	·0000
7·0	.. ..	·5657	·5253	·4695	·4111	·3524	·2936	·2349	·1762	·1174	·0584	·0000
6·0	.. ..	·5275	·4901	·4389	·3845	·3297	·2747	·2198	·1648	·1098	·0545	·0000
5·0	.. ..	·4820	·4478	·4020	·3526	·3024	·2520	·2016	·1511	·1005	·0498	·0000
4·0	.. ..	·4267	·3961	·3566	·3133	·2689	·2242	·1793	·1343	·0892	·0440	·0000
3·0	.. ..	·3583	·3371	·2994	·2638	·2268	·1891	·1512	·1131	·0749	·0369	·0000
2·5	.. ..	·3175	·2933	·2649	·2338	·2012	·1679	·1341	·1002	·0662	·0326	·0000
2·0	.. ..	·2712	·2498	·2256	·1993	·1717	·1433	·1145	·0854	·0564	·0278	·0000
1·5	.. ..	·2180	·2000	·1803	·1593	·1373	·1146	·0915	·0683	·0451	·0222	·0000
1·0	.. ..	·1562	·1424	·1278	·1127	·0970	·0810	·0647	·0483	·0320	·0158	·0000
·7	.. ..	·1212	·1101	·0986	·0867	·0745	·0622	·0497	·0372	·0246	·0122	·0000
·5	.. ..	·0833	·0754	·0672	·0590	·0507	·0422	·0338	·0253	·0168	·0084	0000
·3	.. ..	·0509	·0459	·0409	·0358	·0307	·0256	·0205	·0153	·0102	·0051	·0000
·1	.. ..	·0171	·0154	·0137	·0120	·0103	·0086	·0069	·0051	·0034	·0017	·0000

TABLE 1—4.

POTENTIALS AT C FOR D/T=0·96

B/D	·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
	B1/B.										
30·0	·8560	·7806	·6939	·6071	·5204	·4337	·3469	·2602	·1735	·0867	·0000
25·0	·8320	·7604	·6759	·5914	·5069	·4225	·3380	·2535	·1690	·0845	·0000
20·0	·7984	·7320	·6507	·5694	·4880	·4067	·3254	·2440	·1627	·0814	·0000
18·0	·7810	·7171	·6375	·5578	·4781	·3984	·3187	·2391	·1594	·0797	·0000
16·0	·7601	·6992	·6217	·5440	·4663	·3886	·3109	·2331	·1554	·0777	·0000
14·0	·7350	·6775	·6025	·5272	·4519	·3766	·3013	·2260	·1506	·0753	·0000
12·0	·7039	·6503	·5787	·5064	·4340	·3617	·2894	·2170	·1447	·0723	·0000
10·0	·6645	·6156	·5483	·4798	·4113	·3427	·2742	·2057	·1371	·0684	·0000
9·0	·6406	·5942	·5297	·4636	·3974	·3312	·2649	·1987	·1325	·0661	·0000
8·0	·6131	·5694	·5082	·4448	·3813	·3178	·2542	·1907	·1271	·0633	·0000
7·0	·5810	·5401	·4828	·4228	·3624	·3020	·2416	·1812	·1207	·0600	·0000
6·0	·5431	·5052	·4526	·3965	·3400	·2833	·2267	·1700	·1132	·0562	·0000
5·0	·4976	·4629	·4158	·3647	·3128	·2607	·2086	·1564	·1040	·0515	·0000
4·0	·4421	·4109	·3701	·3254	·2793	·2328	·1862	·1395	·0926	·0457	·0000
3·0	·3728	·3456	·3121	·2752	·2366	·1973	·1578	·1180	·0781	·0384	·0000
2·5	·3312	·3064	·2769	·2445	·2105	·1756	·1404	·1048	·0693	·0341	·0000
2·0	·2837	·2616	·2365	·2090	·1801	·1504	·1201	·0896	·0591	·0291	·0000
1·5	·2289	·2101	·1896	·1676	·1445	·1206	·0963	·0718	·0474	·0234	·0000
1·0	·1645	·1501	·1349	·1189	·1024	·0855	·0683	·0510	·0337	·0167	·0000
·7	·1280	·1163	·1041	·0916	·0788	·0657	·0525	·0393	·0260	·0129	·0000
·5	·0881	·0797	·0711	·0624	·0536	·0447	·0357	·0267	·0178	·0089	·0000
·3	·0539	·0486	·0433	·0379	·0325	·0271	·0217	·0162	·0108	·0054	·0000
·1	·0181	·0163	·0145	·0127	·0109	·0091	·0073	·0054	·0036	·0018	·0000

TABLE 1—5.

POTENTIALS AT C FOR D/T=0·95.

B/D	·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
	B1/B.										
30·0	·8620	·7862	·6989	·6115	·5241	·4368	·3494	·2621	·1747	·0873	·0000
25·0	·8389	·7669	·6817	·5965	·5113	·4261	·3409	·2557	·1705	·0852	·0000
20·0	·8064	·7395	·6574	·5752	·4931	·4109	·3287	·2465	·1644	·0822	·0000
18·0	·7894	·7251	·6446	·5641	·4835	·4029	·3223	·2418	·1612	·0806	·0000
16·0	·7691	·7078	·6293	·5507	·4720	·3934	·3147	·2360	·1574	·0787	·0000
14·0	·7446	·6867	·6107	·5344	·4581	·3817	·3054	·2291	·1527	·0763	·0000
12·0	·7142	·6603	·5876	·5141	·4407	·3673	·2938	·2204	·1469	·0734	·0000
10·0	·6756	·6262	·5579	·4882	·4185	·3487	·2790	·2093	·1395	·0696	·0000
9·0	·6521	·6053	·5397	·4723	·4049	·3374	·2699	·2025	·1350	·0673	·0000
8·0	·6249	·5808	·5185	·4539	·3891	·3242	·2594	·1946	·1297	·0646	·0000
7·0	·5931	·5519	·4935	·4321	·3705	·3087	·2470	·1853	·1234	·0614	·0000
6·0	·5555	·5172	·4635	·4062	·3482	·2902	·2322	·1741	·1159	·0575	·0000
5·0	·5101	·4750	·4269	·3745	·3212	·2677	·2142	·1606	·1068	·0528	·0000
4·0	·4545	·4228	·3811	·3351	·2877	·2398	·1918	·1437	·0954	·0470	·0000
3·0	·3846	·3569	·3226	·2845	·2447	·2041	·1631	·1220	·0807	·0397	·0000
2·5	·3424	·3170	·2868	·2534	·2182	·1820	·1455	·1086	·0718	·0353	·0000
2·0	·2940	·2714	·2455	·2171	·1872	·1563	·1248	·0931	·0614	·0302	·0000
1·5	·2378	·2185	·1973	·1745	·1505	·1257	·1003	·0748	·0494	·0243	·0000
1·0	·1715	·1565	·1407	·1241	·1069	·0892	·0713	·0532	·0352	·0174	·0000
·7	·1336	·1214	·1088	·0957	·0823	·0687	·0549	·0410	·0272	·0135	·0000
·5	·0921	·0833	·0743	·0653	·0560	·0467	·0374	·0280	·0186	·0093	·0000
·3	·0563	·0508	·0452	·0396	·0340	·0283	·0227	·0170	·0113	·0056	·0000
·1	·0190	·0171	·0152	·0133	·0114	·0095	·0076	·0057	·0038	·0019	·0000

TABLE 1-6

POTENTIALS AT C FOR D/T=0·90.

B/D	B1/B ·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
30·0	·8801	·8035	·7143	·6250	·5357	·4464	·3572	·2679	·1786	·0894	·0000
25·0	·8595	·7867	·6993	·6119	·5245	·4371	·3497	·2623	·1749	·0875	·0000
20·0	·8304	·7627	·6780	·5933	·5086	·4238	·3391	·2544	·1696	·0849	·0000
18·0	·8150	·7499	·6667	·5834	·5001	·4168	·3335	·2501	·1668	·0835	·0000
16·0	·7966	·7344	·6531	·5715	·4899	·4083	·3267	·2451	·1634	·0818	·0000
14·0	7741	·7154	6364	·5569	·4774	·3979	·3183	·2388	·1593	·0797	·0000
12·0	·7460	·6914	6154	·5386	·4617	·3848	·3079	·2310	·1541	·0770	·0000
10·0	·7100	·6599	·5882	·5148	·4413	·3678	·2943	·2208	·1473	·0736	·0000
9·0	·6878	·6403	·5714	·5001	·4287	·3573	·2859	·2145	·1431	·0714	·0000
8·0	·6620	·6171	·5515	·4829	·4140	·3451	·2761	·2072	·1382	·0688	·0000
7·0	·6315	·5895	·5278	·4624	·3964	·3304	·2644	·1984	·1322	·0658	·0000
6·0	·5950	·5559	·4990	·4375	·3752	·3128	·2503	·1878	·1251	·0620	·0000
5·0	·5505	·5144	·4632	·4068	·3490	·2910	·2329	·1746	·1161	·0574	·0000
4·0	·4949	·4621	·4176	·3676	·3158	·2634	·2107	·1578	·1047	·0516	·0000
3·0	·4237	·3946	·3577	·3160	·2721	·2271	·1816	·1357	·0897	·0440	·0000
2·5	3799	·3530	·3202	·2835	·2444	·2041	·1631	·1218	·0803	·0394	·0000
2·0	·3289	·3046	·2763	·2449	·2114	·1766	·1411	·1051	·0693	·0340	·0000
1·5	·2686	·2475	·2240	·1984	·1714	·1432	·1143	·0852	·0561	·0276	·0000
1·[illegible]	·1957	·1789	·1611	·1423	·1227	·1024	·0818	·0610	·0403	·0199	·0000
[illegible]	·1532	·1394	·1250	·1101	·0948	·0791	·0632	·0472	·0313	·0155	·0000
·5	·1060	·0960	·0857	·0753	·0646	·0539	·0431	·0323	·0214	·0107	·0000
·3	·0650	·0587	·0523	·0458	·0393	·0327	·0262	·0196	·0131	·0065	·0000
·1	·0219	·0198	·0176	·0154	·0132	·0110	·0088	·0066	·0044	·0022	·0000

TABLE 1—7.

POTENTIALS AT C FOR D/T=0·85.

B/D.	B1/B. ·0	0·1	0·2	0·3	0·4	0·5	·06	0·7	0·8	0·9	1·0
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
30·0	·8898	·8131	·7228	·6325	·5421	·4518	·3615	·2712	·1809	·0906	·0000
25·0	·8706	·7977	·7091	·6206	·5320	·4434	·3548	·2662	·1776	·0890	·0000
20·0	·8434	·7756	·6896	·6034	·5173	·4312	·3450	·2589	·1727	·0866	·0000
18·0	·8290	·7638	·6792	·5943	·5095	·4247	·3398	·2550	·1702	·0853	·0000
16·0	·8116	·7495	·6666	·5833	·5001	·4168	·3336	·2503	·1671	·0837	·0000
14·0	·7904	·7317	·6511	·5698	·4885	·4072	·3259	·2445	·1632	·0818	·0000
12·0	·7637	·7091	·6315	·5527	·4738	·3950	·3161	·2373	·1584	·0793	·0000
10·0	·7293	·6793	·6059	·5304	·4547	·3791	·3034	·2278	·1521	·0761	·0000
9·0	·7080	·6605	·5899	·5165	·4428	·3692	·2955	·2218	·1481	·0740	·0000
8·0	·6831	·6382	·5710	·5001	·4288	·3575	·2862	·2149	·1434	·0715	·0000
7·0	·6536	·6115	·5482	·4805	·4121	·3436	·2750	·2065	·1378	·0686	·0000
6·0	·6180	·5787	·5203	·4565	·3916	·3266	·2615	·1963	·1308	·0649	·0000
5·0	·5742	·5379	·4852	·4265	·3662	·3054	·2445	·1835	·1221	·0604	·0000
4·0	·5191	·4859	·4399	·3878	·3335	·2783	·2227	·1669	·1108	·0545	·0000
3·0	·4476	·4178	·3796	·3359	·2896	·2419	·1935	·1447	·0956	·0469	·0000
2·5	·4031	·3755	·3414	·3027	·2614	·2184	·1746	·1304	·0859	·0421	·0000
2·0	·3509	·3256	·2960	·2628	·2271	·1899	·1518	·1131	·0745	·0365	·0000
1·5	·2882	·2661	·2412	·2140	·1850	·1547	·1236	·0921	·0606	·0298	·0000
1·0	·2114	·1936	·1745	·1542	·1330	·1112	·0888	·0663	·0438	·0216	·0000
·7	·1660	·1512	·1357	·1196	·1030	·0860	·0687	·0513	·0340	·0168	·0000
·5	·1162	·1043	·0932	·0819	·0703	·0587	·0469	·0351	·0233	·0116	·0000
·3	·0708	·0639	·0569	·0499	·0428	·0357	·0285	·0214	·0142	·0071	·0000
·1	·0239	·0215	·0191	·0167	·0144	·0120	·0096	·0072	·0048	·0024	·0000

TABLE 1—8.

POTENTIALS AT C FOR D/T=0·80.

B/D.	B1/B. ·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·0	1·0
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
30·0	·8960	·8194	·7284	·6374	·5465	·4555	·3645	·2735	·1825	·0915	·0000
25·0	·8778	·8050	·7157	·6263	·5370	·4476	·3582	·2688	·1795	·0901	·0000
20·0	·8518	·7843	·6974	·6103	·5232	·4362	·3491	·2620	·1750	·0879	·0000
18·0	·8380	·7731	·6876	·6017	·5159	·4301	·3443	·2584	·1726	·0867	·0000
16·0	·8214	·7595	·6757	·5914	·5070	·4227	·3384	·2540	·1697	·0853	·0000
14·0	·8009	·7426	·6610	·5786	·4961	·4136	·3311	·2486	·1661	·0835	·0000
12·0	·7753	·7210	·6424	·5624	·4822	·4021	·3219	·2418	·1616	·0812	·0000
10·0	·7420	·6923	·6180	·5411	·4640	·3870	·3099	·2328	·1556	·0780	·0000
9·0	·7214	·6741	·6026	·5278	·4527	·3775	·3023	·2271	·1519	·0761	·0000
8·0	·6971	·6525	·5844	·5121	·4393	·3664	·2934	·2205	·1474	·0737	·0000
7·0	·6683	·6264	·5623	·4932	·4231	·3529	·2827	·2125	·1420	·0708	·0000
6·0	·6334	·5943	·5351	·4699	·4034	·3365	·2696	·2026	·1352	·0672	·0000
5·0	·5903	·5540	·5007	·4406	·3785	·3159	·2532	·1901	·1267	·0627	·0000
4·0	·5357	·5024	·4558	·4024	·3463	·2893	·2317	·1738	·1154	·0568	·0000
3·0	·4643	·4343	·3953	·3504	·3025	·2529	·2025	·1515	·1001	·0491	·0000
2·5	·4196	·3915	·3566	·3168	·2739	·2292	·1834	·1369	·0903	·0442	·0000
2·0	·3666	·3408	·3103	·2760	·2389	·2000	·1599	·1192	·0784	·0384	·0000
1·5	·3026	·2797	·2539	·2256	·1953	·1634	·1306	·0973	·0641	·0314	·0000
1·0	·2230	·2044	·1844	·1631	·1408	·1177	·0941	·0702	·0464	·0229	·0000
·7	·1755	·1600	·1436	·1266	·1091	·0911	·0728	·0544	·0360	·0179	·0000
·5	·1220	·1106	·0988	·0868	·0746	·0622	·0498	·0372	·0247	·0123	·0000
·3	·0751	·0677	·0603	·0529	·0454	·0378	·0303	·0227	·0151	·0075	·0000
·1	·0254	·0228	·0203	·0178	·0152	·0127	·0102	·0076	·0051	·0025	·0000

POTENTIALS AT C FOR D/T=0·75.

B/D.	B1/B. ·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
30·0	·9002	·8239	·7325	·6411	·5496	·4582	·3667	·2753	·1838	·0924	·0000
25·0	·8826	·8103	·7204	·6305	·5406	·4507	·3608	·2709	·1810	·0911	·0000
20·0	·8575	·7904	·7030	·6153	·5276	·4399	·3522	·2645	·1768	·0891	·0000
18·0	·8441	·7798	·6936	·6071	·5206	·4341	·3476	·2611	·1746	·0880	·0000
16·0	·8280	·7667	·6823	·5973	·5122	·4271	·3420	·2570	·1719	·0867	·0000
14·0	·8082	·7504	·6683	·5850	·5017	·4184	·3351	·2518	·1685	·0850	·0000
12·0	·7833	·7295	·6504	·5695	·4885	·4074	·3264	·2453	·1643	·0828	·0000
10·0	·7508	·7016	·6269	·5491	·4710	·3930	·3149	·2368	·1586	·0798	·0000
9·0	·7307	·6839	·6120	·5363	·4601	·3839	·3077	·2314	·1550	·0779	·0000
8·0	·7070	·6628	·5943	·5211	·4472	·3732	·2991	·2250	·1507	·0756	·0000
7·0	·6787	·6372	·5728	·5027	·4316	·3602	·2888	·2173	·1455	·0727	·0000
6·0	·6444	·6056	·5461	·4800	·4124	·3443	·2761	·2078	·1389	·0692	·0000
5·0	·6019	·5658	·5122	·4513	·3881	·3242	·2601	·1956	·1305	·0646	·0000
4·0	·5478	·5146	·4677	·4135	·3564	·2980	·2390	·1795	·1193	·0588	·0000
3·0	·4767	·4466	·4072	·3617	·3127	·2618	·2098	·1571	·1039	·0509	·0000
2·5	·4319	·4037	·3683	·3278	·2838	·2378	·1905	·1423	·0939	·0459	·0000
2·0	·3786	·3525	·3214	·2863	·2482	·2080	·1664	·1242	·0817	·0400	·0000
1·5	·3136	·2903	·2638	·2347	·2033	·1703	·1362	·1015	·0669	·0328	·0000
1·0	·2320	·2128	·1921	·1701	·1469	·1229	·0982	·0733	·0484	·0239	·0000
·7	·1830	·1668	·1499	·1322	·1139	·0952	·0761	·0569	·0377	·0187	·0000
·5	·1274	·1155	·1032	·0907	·0779	·0650	·0520	·0389	·0259	·0129	·0000
·3	·0784	·0708	·0631	·0553	·0474	·0395	·0316	·0237	·0158	·0079	·0000
·1	·0265	·0239	·0212	·0186	·0159	·0133	·0106	·0080	·0053	·0027	·0000

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TABLE 1—10.

POTENTIALS AT C FOR D/T=0·70.

B/D	B1/B										
	·0	·01	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
30·0	·9030	·8272	·7355	·6438	·5520	·4603	·3685	·2768	·1850	·0933	·0000
25·0	·8860	·8141	·7239	·6337	·5434	·4532	·3629	·2726	·1824	·0921	·0000
20·0	·8515	·7950	·7072	·6191	·5309	·4428	·3547	·2666	·1785	·0903	·0000
18·0	·8484	·7847	·6982	·6112	·5243	·4373	·3503	·2634	·1764	·0893	·0000
16·0	·8327	·7720	·6873	·6017	·5162	·4306	·3450	·2594	·1739	·0881	·0000
14·0	·8133	·7562	·6738	·0059	·5061	·4223	·3384	·2546	·1707	·0865	·0000
12·0	·7889	·7358	·6565	·5750	·4934	·4117	·3301	·2484	·1667	·0844	·0000
10·0	·7571	·7085	·6336	·5535	·4766	·3978	·3190	·2403	·1613	·0815	·0000
9·0	·7373	·6911	·6192	·4660	·4660	·3121	·3121	·2351	·1579	·0797	·0000
8·0	·7140	·6704	·6019	·5281	·4535	·3787	·3039	·2290	·1538	·0774	·0000
7·0	·6862	·6451	·5808	·5102	·4383	·3662	·2939	·2216	·2216	·1487	·0000
6·0	·6524	·6129	·5545	·4880	·4196	·3507	·2816	·2123	·1423	·0710	·0000
5·0	·6104	·5746	·5210	·4597	·3959	·3311	·2660	·20004	·1340	·0665	·0000
4·0	·5568	·5238	·4769	·4224	·3646	·3053	·2452	·1844	·1228	·0605	·0000
3·0	·4861	·4561	·4166	·3707	·3210	·2692	·2160	·1620	·1072	·0526	·0000
2·5	·4414	·4131	·3776	·3366	·2920	·2450	·1965	·1470	·0970	·0475	·0000
2·0	·3880	·3617	·3303	·2946	·2558	·2146	·1720	·1284	·0846	·0414	·0000
1·5	·3224	·2987	·2718	·2421	·2100	·1761	·1409	·1051	·0692	·0340	·0000
1·0	·2393	·2197	·1984	·1758	·1519	·1271	·1017	·0759	·0502	·0248	·0000
·7	·1890	·1724	·1550	·1367	·1179	·0985	·0788	·0589	·0390	·0193	·0000
·5	·1317	·1194	·1068	·0938	·0807	·0673	·0538	·0403	·0268	·1033	·0000
·3	·0812	·0733	·0653	·0572	·0491	·0409	·0327	·0245	·0163	·0082	·0000
·1	·0275	·0247	·0220	·0192	·0165	·0137	·0110	·0082	·0055	·0027	·0000

TABLE 1—11.

POTENTIALS AT C FOR D/T=0·60

B/D.	B1/B.										
	·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	0·10
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
30·0	·9061	·8314	·7394	·6474	·5554	·4634	·3713	·2793	·1873	·0952	·0000
25·0	·8895	·8189	·7285	·6379	·5474	·4568	·3663	·2756	·1850	·0944	·0000
20·0	·8558	·8007	·7127	·6242	·5357	·4472	·3587	·2702	·1817	·0930	·0000
18·0	·8531	·7908	·7042	·6169	·5295	·4421	·3547	·2673	·1799	·0922	·0000
16·0	·8378	·7786	·6936	·6079	·5219	·4359	·3498	·2638	·1777	·0911	·0000
14·0	·8190	·7633	·6810	·9968	·5125	·4281	·3438	·2594	·1750	·0898	·0000
1·0	·7952	·7435	·6646	·5827	·5005	·4183	·3361	·2539	·1715	·0879	·0000
10·0	·7643	·7169	·6426	·5640	·4847	·4053	·3259	·2465	·1667	·0852	·0000
9·0	·7450	·7000	·6287	·5522	·4747	·3971	·3195	·2418	·1635	·0834	·0000
8·0	·7223	·6797	·6120	·5380	·4629	·3874	·3119	·2361	·1597	·0811	·0000
7·0	·6951	·6551	·5915	·5209	·4485	·3756	·3026	·2292	·1549	·0783	·0000
6·0	·6621	·6245	·5660	·4995	·4306	·3610	·2910	·2204	·1487	·0747	·0000
5·0	·6210	·5860	·5332	·4721	·4078	·3423	·2760	·2090	·1404	·0700	·0000
4·0	·5685	·5361	·4898	·4355	·3773	·3171	·2558	·1932	·1291	·0039	·0000
3·0	·4990	·4693	·4301	·3842	·3340	·2811	·2265	·1703	·1131	·0556	·0000
2·5	·4548	·4267	·3912	·3499	·3046	·2565	·2064	·1548	·1024	·0502	·0000
2·0	·4015	·3752	·3435	·3073	·2676	·2252	·1809	·1354	·0893	·0438	·0000
1·5	·3354	·3113	·2838	·2333	·2202	·1850	·1484	·1108	·0731	·0359	·0000
1·0	·2503	·2300	·2080	·1844	·1596	·1337	·1070	·0800	·0529	·0261	·0000
·7	·1981	·1809	·1627	·1436	·1239	·1036	·0829	·0620	·0411	·0204	·0000
·5	·1384	·1255	·1122	·0987	·0848	·0708	·0567	·0424	·0282	·0140	·0000
·3	·0853	·0770	·0686	·0602	·0516	·0431	·0345	·0258	·0172	·0086	·0000
·1	·0289	·0260	·0231	·0202	·0173	·0145	·0116	·0087	·0058	·0029	·0000

TABLE 1—12.

POTENTIALS AT C FOR D/T = 0·50

B/D.	B1/B.										
	·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
30·0	·9064	·8330	·7412	·6494	·5575	·4656	·3737	·2818	·1899	·0979	·0000
25·0	·8299	·8208	·7807	·6403	·5498	·4594	·3690	·2786	·1881	·0975	·0000
20·0	·8664	·8028	·7153	·6271	·5388	·4504	·3621	·2738	·1855	·0995	·0000
18·0	·8538	·7930	·7071	·6200	·5328	·4456	·3585	·2713	·1840	·0969	·0000
16·0	·8387	·7809	·6971	·6114	·5256	·4398	·3540	·2682	·1823	·0951	·0000
14·0	·8201	·7658	·6846	·6008	·5167	·4326	·3485	·2644	·1809	·0989	·0000
12·0	·7966	·7462	·6685	·5872	·5053	·4234	·3414	·2594	·1770	·0922	·0000
10·0	·7661	·7200	·6471	·5692	·4903	·4112	·3321	·2528	·1727	·0895	·0000
9·0	·7471	·7034	·6335	·5578	·4808	·4036	·3262	·2486	·1698	·0877	·0000
8·0	·7248	·6834	·6172	·5442	·4695	·3945	·3192	·2434	·1662	·0854	·0000
7·0	·6982	·6592	·5971	·5276	·4558	·3834	·3105	·2369	·1616	·0285	0000
6·0	·6658	·6293	·5721	·5068	·4387	·3695	·2995	·2285	·1554	·0787	·0000
5·0	·6257	·5916	·5401	·4801	·4166	·8514	·2850	·2172	·1470	0738	·0000
4·0	·5744	·5429	·4977	·4443	·3867	·3268	·2650	·2013	·1353	·0672	·0000
3·0	·5065	·4775	·4390	·3936	·3436	·2906	·2352	·1777	·1184	·0584	·0000
2·5	·4632	·4354	·4008	·3593	·3140	·2654	·2144	·1614	·1071	·0527	·0000
2·0	·4105	·3842	·3526	·3163	·2763	·2332	·1879	·1410	·0933	·0458	0000
1·5	·3443	·3201	·2923	·2613	·2278	·1916	·1540	·1153	·0762	·0375	·0000
1·0	·2581	·2373	·2148	·1900	·1651	·1385	·1110	·0830	·0550	·0272	·0000
·7	·2046	·1869	·1682	·1486	·1282	·1073	·0859	·0643	·0427	·0212	·0000
·5	·1431	·1298	·1161	·1021	·0878	·0733	·0587	·0440	·0292	·0146	·0000
·3	·0883	·0797	·0710	·0623	·0535	·0446	·0357	·0267	·0178	·0089	·0000
·1	·0299	·0269	·0239	·0209	·0180	·0150	·0120	·0090	·0060	·0030	·0000

TABLE 1–13.

POTENTIALS AT C FOR D/T = 0·40.

B/D.	B1/B.										
	·0.	·0·1.	0·2.	0·3.	0·4.	0·5.	0·6.	0·7.	0·8.	0·9.	0·1
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
30·0	·9041	·8320	·7410	·6498	·5586	·4673	·3761	·2848	·1936	·1020	·0000
25·0	·8874	·8196	·7305	·6408	·5512	·4615	·3718	·2822	·1925	·1021	·0000
20·0	·8636	·8013	·7152	·6279	·5405	·4531	·3657	·2783	·1907	·1017	·0000
18·0	·8510	·7915	·7070	·6210	·5348	·4486	·3624	·2762	·1897	·1013	·0000
16·0	·8358	·7793	·6971	·6126	·5279	·4432	·3584	·2736	·1884	·1006	·0000
14·0	·8171	·7641	·6847	·6022	·5193	·4364	·3535	·2704	·1866	·0995	·0000
12·0	·7937	·7446	·6688	·5890	·5085	·4279	·3471	·2662	·1841	·0978	·0000
10·0	·7634	·7185	·6477	·5715	·4942	·4166	·3387	·2603	·1803	·0951	·0000
9·0	·7446	·7021	·6343	·5605	·4852	·4094	·3333	·2565	·1776	·0931	·0000
8·0	·7226	·6824	·6182	·5473	·4744	·4009	·3268	·2516	·1740	·0906	·0000
7·0	·6965	·6587	·5987	·5312	·4613	·3904	·3186	·2454	·1693	·0874	·0000
6·0	·6649	·6296	·5744	·5111	·4448	·3771	·3080	·2371	·1629	·0833	·0000
5·0	·6259	·5930	·5433	·4853	·4234	·3595	·2937	·2256	·1540	·0779	·0000
4·0	·5763	·5458	·5021	·4503	·3941	·3349	·2734	·2091	·1415	·0707	·0000
3·0	·5105	·4822	·4447	·4002	·3510	·2983	·2426	·1842	·1233	·0610	·0000
2·5	·4682	·4410	·4066	·3661	·3211	·2725	·2210	·1671	·1113	·0549	·0000
2·0	·4163	·3904	·3590	·3228	·2827	·2394	·1935	·1457	·0966	·0476	·0000
1·5	·3505	·3262	·2983	·2671	·2331	·1966	·1583	·1188	·0786	·0387	·0000
1·0	·2635	·2425	·2196	·1951	·1692	·1420	·1139	·0853	·0565	·0280	·0000
·7	·2092	·1912	·1721	·1521	·1314	·1100	·0881	·0660	·0438	·0217	·0000
·5	·1465	·1329	·1189	·1046	·0900	·0751	·0602	·0451	·0300	·0149	·0000
·3	·0905	·0817	·0728	·0638	·0548	·0457	·0366	·0274	·0183	·0091	·0000

TABLE 1–14.

POTENTIALS AT C FOR D/T=0·30.

B/D.	B1/B.										
	·0.	0·1.	0·2.	0·3.	0·4.	0·5.	0·6.	0·7.	0·8.	0·9.	1·0.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
30·0	·8986	·8274	·7381	·6483	·5586	·4689	·3791	·2894	·1996	·1086	·0000
25·0	·8813	·8144	·7272	·6393	·5514	·4634	·3755	·2876	·1994	·1092	·0000
20·0	·8568	·7955	·7116	·6263	·5410	·4556	·3703	·2848	·1988	·1093	·0000
18·0	·8439	·7854	·7032	·6195	·5355	·4515	·3675	·2833	·1983	·1091	·0000
16·0	·8284	·7730	·6931	·6111	·5288	·4465	·3641	·2814	·1975	·1085	·0000
14·0	·8096	·7577	·6807	·6009	·5207	·4403	·3598	·2789	·1962	·1073	·0000
12·0	·7861	·7381	·6649	·5879	·5103	·4325	·3543	·2754	·1941	·1054	·0000
10·0	·7561	·7124	·6441	·5710	·4967	·4220	·3467	·2701	·1903	·1023	·0000
9·0	7376	·6963	·6311	·5603	·4882	·4154	·3417	·2665	·1875	·1000	·0000
8·0	·7161	·6772	·6156	·5477	·4780	·4073	·3355	·2617	·1836	·0971	·0000
7·0	·6908	·6543	·5968	·5323	·4654	·3972	·3275	·2553	·1784	·0933	·0000
6·0	·6603	·6264	·5736	·5131	·4496	·3842	·3169	·2466	·1713	·0885	·0000
5·0	·6229	·5914	·5438	·4882	·4287	·3667	·3022	·2343	·1614	·0823	·0000
4·0	·5755	·5462	·5042	·4543	·3997	·3419	·2810	·2165	·1475	·0742	·0000
3·0	·5122	·4848	·4483	·4049	·3566	·3044	·2488	·1899	·1278	·0635	·0000
2·5	·4711	·4445	·4107	·3709	·3264	·2780	·2264	·1718	·1149	·0569	·0000
2·0	·4201	·3945	·3634	·3275	·2875	·2441	·1978	·1493	·0993	·0490	·0000
·5	·3547	·3304	·3025	·2713	·2371	·2003	·1616	·1214	·0805	·0397	·0000
1·0	·2674	·2462	·2231	·1983	·1721	·1445	·1161	·0870	·0577	·0286	·0000
·7	·2125	·1942	·1749	·1547	·1336	·1119	·0897	·0672	·0447	·0222	·0000
·5	·1489	351	·F1209	·1068	·0915	·0764	·0612	·0459	·0305	·0152	·0000
·3	·0920	·0830	·0740	·0649	·0557	·0465	·0372	·0279	·0186	·0093	·0000
·1	·0312	·0280	·0249	·0218	·0187	·0156	·0125	·0094	·0062	·0031	·0000

TABLE 1–15.

POTENTIALS AT C FOR D/T=0·25.

B/D.	B1/B.										
	·0.	0·1.	0·2.	0·3.	0·4.	0·5.	0·6.	0·7.	0·8.	0·9.	1·0.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
30·0	·8940	·8231	·7349	·6465	·5581	·4697	·3813	·2929	·2042	·1135	·0000
25·0	·8763	·8096	·7237	·6373	·5509	·4645	·3781	·2916	·2047	·1144	·0000
20·0	·8513	·7903	·7077	·6242	·5407	·4571	·3735	·2896	·2047	·1147	·0000
18·0	·8383	·7801	·6993	·6173	·5353	·4532	·3710	·2884	·2045	·1144	·0000
16·0	·8227	·7676	·6891	·6090	·5287	·4484	·3679	·2868	·2039	·1137	·0000
14·0	·8038	·7523	·6767	·5989	·5208	·4425	·3640	·2846	·2027	·1124	·0000
12·0	·7803	·7329	·6611	·5861	·5107	·4350	·3588	·2814	·2005	·1102	·0000
10·0	·7506	·7075	·6407	·5696	·4976	·4250	·3515	·2762	·1964	·1066	·0000
9·0	·7324	·6918	·6280	·5593	·4893	·4185	·3466	·2724	·1933	·1041	·0000
8·0	·7113	·6732	·6130	·5470	·4793	·4106	·3404	·2674	·1892	·1008	·0000
7·0	·6866	·6510	·5948	·5321	·4671	·4006	·3322	·2607	·1835	·0966	·0000
6·0	·6570	·6239	·5723	·5134	·4516	·3768	·3213	·2515	·1757	·0913	·0000
5·0	·6207	·5899	·5434	·4891	·4309	·3700	·3062	·2385	·1651	·0846	·0000
4·0	·5745	·5459	·5047	·4557	·4020	·3449	·2844	·2199	·1504	·0759	·0000
3·0	·5125	·4855	·4496	·4067	·3588	·3069	·2514	·1924	·1298	·0646	·0000
2·5	·4720	·4457	·4122	·3727	·3284	·2802	·2285	·1738	·1164	·0577	·0000
2·0	·4215	·3959	·3650	·3292	·2893	·2459	·1995	·1508	·1005	·0496	·0000
1·5	·3563	·3320	·3041	·2728	·2386	·2017	·1628	·1224	·0813	·0401	·0000
1·0	·2688	·2475	·2244	·1995	·1731	·1455	·1169	·0876	·0582	·0288	·0000
0·7	·2137	·1954	·1759	·1556	·1344	·1126	·0903	·0677	·0450	·0223	·0000
·5	·1498	·1359	·1216	·1070	·0921	·0769	·0616	·0462	·0307	·0153	·0000
·3	·0925	·0836	·0745	·0653	·0561	·0468	·0374	·0281	·0187	·0093	·0000
·1	·0313	·0282	·0251	·0220	·0188	·0157	·0126	·0094	·0063	·0031	·0000

TABLE 1.16.

POTENTIALS AT C FOR D/T=0·20.

B/D	B1/B ·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
30·0	·8878	·8166	·7299	·6434	·5571	·4707	·3843	·2978	·2108	·1201	·0000
25·0	·8695	·8027	·7183	·6340	·5499	·4658	·3816	·2973	·2119	·1212	·0000
20·0	·8440	·7830	·7020	·6208	·5398	·4588	·3777	·2961	·2125	·1214	·0000
18·0	·3808	·7727	·6935	·6139	·5345	·4551	·3755	·2952	·2124	·1210	·0000
16·0	·8151	·7603	·6834	·6057	·5282	·4506	·3728	·2938	·2118	·1201	·0000
14·0	·7963	·7451	·6711	·5958	·5205	·4451	·3692	·2918	·2105	·1185	·0000
12·0	·7731	·7261	·6559	·5834	·5108	·4379	·3642	·2884	·2080	·1158	·0000
10·0	·7439	·7016	·6364	·5676	·4981	·4281	·3569	·2829	·2033	·1115	·0000
9·0	·7262	·6864	·6242	·5577	·4901	·4217	·3518	·2788	·1998	·1085	·0000
8·0	·7058	·6685	·6098	·5459	·4805	·4139	·3454	·2734	·1950	·1047	·0000
7·0	·6818	·6471	·5925	·5316	·4685	·4039	·3369	·2661	·1887	·1000	·0000
6·0	·6533	·6210	·5708	·5135	·4532	·3908	·3256	·2562	·1801	·0941	·0000
5·0	·6182	·5882	·5428	·4897	·4328	·3729	·3099	·2424	·1686	·0868	·0000
4·0	·5734	·5453	·5049	·4568	·4039	·3475	·2874	·2229	·1530	·0775	·0000
3·0	·5126	·4860	·4505	·4080	3·606	·3090	·2537	·1945	·1314	·0656	·0000
2·5	·4726	·4466	·4134	·3741	·3301	·2820	·2303	·1754	·1177	·0584	·0000
2·0	·4225	·3971	·3663	·3306	·2908	·2474	·2010	·1520	·1014	·0502	·0000
1·5	·3575	·3332	·3053	·2741	·2398	·2029	·1638	·1232	·0819	·0405	·0000
1·0	·2700	·2486	·2254	·2005	·1740	·1463	·1175	·0882	·0585	·0290	·0000
·7	·2147	·1962	·1768	·1564	·1351	·1132	·0908	·0681	·0452	·0225	·0000
·5	·1505	·1366	·1222	·1075	·0925	·0773	·0619	·0464	·0309	·0154	·0000
·3	·0930	·0840	·0748	·0656	·0563	·0470	·0376	·0282	·0188	·0094	·0000
·1	·0315	·0284	·0252	·0221	·0189	·0158	·0126	·0095	·0063	·0031	·0000

TABLE 1.17

POTENTIALS AT C FOR D/T=0·15.

B/D.	B1/B. ·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
30·0	·8791	·8069	·7219	·6383	·5551	·4720	·3888	·3053	·2204	·1292	·0000
25·0	·8602	·7927	·7099	·6287	·5480	·4675	·3868	·3055	·2220	·1303	·0000
20·0	·8344	·7730	·6936	·6155	·5382	·4610	·3836	·3049	·2228	·1310	·0000
18·0	·8211	·7629	·6853	·6088	·5331	·4576	·3816	·3041	·2225	·1293	·0000
16·0	·8055	·7508	·6756	·6009	·5271	·4533	·3790	·3027	·2217	·1280	·0000
14·0	·7870	·7362	·6640	·5915	·5197	·4480	·3754	·3004	·2198	·1257	·0000
12·0	·7644	·7181	·6497	·5799	·5106	·4410	·3702	·2965	·2165	·1222	·0000
10·0	·7363	·6948	·6314	·5650	·4985	·4313	·3625	·2901	·2107	·1168	·0000
9·9	·7193	·6805	·6200	·5557	·4908	·4249	·3571	·2855	·2064	·1132	·000 0
8·0	·6998	·6635	·6065	·5446	·4814	·4170	·3503	·2794	·2009	·1088	·000 0
7·0	·6769	·6432	·5900	·5308	·4697	·4068	·3413	·2713	·1936	·1034	·0000
6·0	·6496	·6182	·5692	·5133	·4546	·3935	·3294	·2606	·1842	·0968	·0000
5·0	·6157	·5866	·5421	·4901	·4342	·3754	·3131	·2459	·1717	·0887	·0000
4·0	·5722	·5447	·5050	·4576	·4054	·3496	·2899	·2254	·1552	·0788	·0000
3·0	·5126	·4863	·4512	·4091	·3620	·3107	·2554	·1962	·1328	·0664	·00 00
2·5	·4730	·4472	·4142	·3752	·3313	·2834	·2318	·1767	·1187	·0590	·0000
2·0	·4232	·3979	·3673	·3317	·2919	·2485	·2021	·1530	·1021	·0506	·0000
1·5	·3584	·3341	·3063	·2750	·2407	·2037	·1646	·1239	·0824	·0407	·0000
1·0	·2708	·2494	·2262	·2012	·1747	·1468	·1180	·0886	·0568	·0291	·0000

TABLE 1·18.

Potentials at C for D/T=0.10

B/D.	B1/B.										
	·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11))	(12)
30·0	·8665	·7923	·7091	·6296	·5516	·4740	·3961	·3172	·2350	·1423	·0000
25·0	·8474	·7785	·6975	·6203	·5448	·4699	·3945	·3176	·2363	·1425	·0000
20·0	·8218	·7600	·6823	·6080	·5357	·4638	·3913	·3164	·2360	·1409	·0000
18·0	·8089	·7505	·6748	·6020	·5310	·4605	·3892	·3152	·2350	·1394	·0000
16·0	·7940	·7395	·6661	·5949	·5255	·4564	·3863	·3131	·2331	·1370	·0000
14·0	·7764	·7261	·6558	·5865	·5187	·4511	·3822	·3098	·2301	·1336	·0000
12·0	·7551	·7096	·6430	·5761	·5102	·4441	·3764	·3048	·2253	·1288	·0000
10·0	·7286	·6882	·6264	·5625	·4987	·4342	·3678	·2970	·2178	·1219	·0000
9·0	·7127	·6748	·6159	·5538	·4912	·4277	·3619	·2915	·2126	·1176	·0000
8·0	·6943	·6590	·6033	·5432	·4821	·4196	·3545	·2846	·2061	·1124	·0000
7·0	·6725	·6397	·5877	·5301	·4706	·4092	·3450	·2757	·1979	·1063	·0000
6·0	·6463	·6158	·5678	·5131	·4556	·3957	·3325	·2641	·1875	·0990	·0000
5·0	·6137	·5851	·5415	·4903	·4353	·3773	·3155	·2486	·1742	·0903	·0000
4·0	·5712	·5442	·5050	·4581	·4065	·3511	·2917	·2274	·1569	·0799	·0000
3·0	·5125	·4865	·4516	·4098	·3630	·3119	·2567	·1974	·1339	·0671	·0000
2·5	·4733	·4476	·4148	·3760	·3323	·2844	·2328	·1777	·1195	·0595	·0000
2·0	·4237	·3985	·3679	·3324	·2927	·2493	·2028	·1537	·1027	·0509	·0000
1·5	·3590	·3348	·3069	·2757	·2413	·2043	·1652	·1244	·0827	·0409	·0000

TABLE 1·19.

Potentials at C for D/T=0·05.

B/D	B1/B.										
	·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
30·0	·8490	·7719	·6904	·6165	·5461	·4768	·4070	·3034	·2544	·1600	·0000
25·0	·8312	·7607	·6814	·7092	·5405	·4729	·4044	·3329	·2541	·1557	·0000
20·0	·8078	·7456	·6659	·5998	·5328	·4668	·3997	·3290	·2503	·1528	·0000
18·0	·7961	·7379	·6640	·5949	·5288	·4634	·3968	·3264	·2477	·1497	·0000
16·0	·7826	·7286	·6570	·5892	·5239	·5492	·3931	·3229	·2441	·1458	·0000
14·0	·7666	·7171	·6485	·5821	·5178	·4538	·3881	·3181	·2392	.1407	·0000
12·0	·7471	·7025	·6375	·5729	·5097	·4465	·3813	·3115	·2325	·1343	·0000
10·0	·7276	·6831	·6226	·5605	·4987	·4364	·3717	·3021	·2232	·1259	·0000
9·0	·7076	·6707	·6129	·5523	·4915	·4297	·3653	·2959	·2171	·1208	·0000
8·0	·6902	·6557	·6011	·5423	·2485	·4214	·3574	·2883	·2098	·1150	·0000
7·0	·6694	·6373	·5861	·5296	·4711	·4108	·3474	·2787	·2008	·1083	·0000
6·0	·6441	·6142	·5668	·5130	·4563	·3971	·3345	·2664	·1898	·1005	·0000
5·0	·6123	·5842	·5410	·4904	·4360	·3785	·3171	·2503	·1758	·0913	·0000
4·0	·5706	·5439	·5050	·4584	·4072	·3521	·2929	·2286	·1579	·0805	·0000
3·0	·5124	·4866	·4519	·4103	·3636	·3126	·2575	·1982	·1345	·0674	·0000
2·5	·4734	·4479	·4152	·3765	·3328	·2850	·2334	·1783	·1200	·0598	·0000

TABLE 1–20.

POTENTIAL AT C FOR D/T=0·03.

B/D.	B1/B.										
	·0.	0·1.	0·2.	0·3.	0·4.	0·5.	0·6.	0·7.	0·8.	0·9.	1·0.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
30·0	·8419	·7637	·6830	·6112	·5439	·4780	·4113	·3413	·2636	·1672	·0000
25·0	·8253	·7543	·6758	·6054	·5390	·4739	·4079	·3382	·2604	·1631	·0000
20·0	·8033	·7411	·6660	·5972	·5319	·4677	·4023	·3328	·2547	·1565	·0000
18·0	·7923	·7341	·6609	·5929	·5282	·4643	·3990	·3296	·2514	·1528	·0000
16·0	·7794	·7255	·6545	·5876	·5235	·4600	·3949	·3256	·2471	·1482	·0000
14·0	·7639	·7148	·6466	·5809	·5175	·4544	·3896	·3202	·2416	·1427	·0000
12·0	·7451	·7008	·6361	·5721	·5096	·4471	·3825	·3132	·2343	·1357	·0000
10·0	·7211	·6819	·6217	·5600	·4987	·4369	·3726	·3033	·2245	·1269	·0000
9·0	·7064	·6697	·6122	·5520	·4915	·4301	·3661	·2969	·2182	·1216	·0000
8·0	·6892	·6549	·6005	·5421	·4826	·4218	·3581	·2891	·2106	·1156	·0000
7·0	·6687	·6367	·5858	·5294	·4713	·4112	·3480	·2794	·2015	·1087	·0000
6·0	·6436	·6138	·5666	·5129	·4564	·3974	·3349	·2669	·1903	·1008	·0000
5·0	·6120	·5840	·5409	·4905	·4362	·3787	·3175	·2507	·1762	·0916	·0000

POTENTIALS AT C FOR D/T=0·01.

B/D.	B1/B.										
	·0.	0·1.	0·2.	0·3.	0·4.	0·5	00·6.	0·7	0·8.	0·9	01·
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
30·0	·8372	·7585	·6782	·6079	·5425	·4787	·4140	·3456	·2688	·1718	·0000
25·0	·8217	·7505	·6725	·6031	·5381	·4745	·4099	·3414	·2642	·1664	·0000
20·0	·8007	·7386	·6639	·5958	·5315	·4682	·4037	·3350	·2572	·1586	·0000
18.0	·7901	·7320	·6591	·5981	·5278	·4647	·4002	·3314	·2534	·1545	·0000
16·0	·7776	·7239	·6532	·5868	·5232	·4604	·3959	·3270	·2488	·1496	·0000
14·0	·7625	·7135	·6455	·5803	·5174	·4548	·3904	·3214	·2429	·1437	·0000
12·0	·7440	·6998	·6354	·5717	·5096	·4474	·3831	·3140	·2353	·1365	·0000
10·0	·7203	·6812	·6212	·5598	·4987	·4371	·3731	·3040	·2251	·1274	·0000
9·0	·7058	·6692	·6119	·5518	·4916	·4304	·3665	·2975	·2187	·1220	·0000
8·0	·6887	·6545	·6003	·5419	·4827	·4220	·3585	·2895	·2111	·1159	·0000
7·0	·6683	·6365	·5856	·5294	·4713	·4114	·3483	·2797	·2019	·1090	·0000

TABLE 1–22.

POTENTIALS AT C FOR D/T=0·005.

B/D.	B1/D.										
	·0.	0·1.	0·2.	·03.	0·4.	0·5	0·6.	0·7.	0·8.	0·9.	1·0.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(01)	(11)	(12)
30·0	·8367	·7580	·6778	·6076	·5424	·4788	·4143	·3461	·2694	·1723	·0000
25·0	·8213	·7501	·6721	·6028	·5380	·4746	·4101	·3417	·2646	·1667	·0000
20·0	·8005	·7384	·6637	·5957	·5314	·4683	·4038	·3352	·2575	·1588	·0000

TABLE 2-1.

POTENTIALS AT D FOR D/T=0·99.

B/D.	B1/B. ·5.	0·6.	0·7.	0·8.	0·9 .	1·0.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
30·0	·4999	·4172	·3344	·2516	·1688	·0971
25·0	·5000	·4200	·3399	·2599	·1798	·1125
20·0	·5000	·4238	·3475	·2713	·1951	·1335
18·0	·5000	·4257	·3514	·2772	·2030	·1443
16·0	·5000	·4280	·3561	·2841	·2123	·1571
14·0	·5000	·4308	·3616	·2924	·2235	·1723
12·0	·5000	·4342	·3684	·3026	·2374	·1907
10·0	·5000	·4384	·3768	·3153	·2549	·2136
9·0	·5000	·4409	·3818	·3229	·2655	·2272
8·0	·5000	·4438	·3876	·3316	·2778	·2427
7·0	·5000	·4471	·3943	·3417	·2921	·2604
6 0	·5000	·4510	·4020	·3537	·3090	·2810
5·0	·5000	·4555	·4113	·3680	·3293	·3050
4·0	5·000	·4611	·4227	·3858	·3539	·3336
3·0	·5000	·4683	·4373	·4084	·3843	·3680
2·5	·5000	·4727	·4464	·4222	·4021	·3881
2·0	·5000	·4781	·4571	·4380	·4221	·4104
1·5	·5000	·4844	·4695	·4559	·4444	·4352
1·0	5·000	·4913	·4830	·4752	·4682	·4622
·7	·0500	·4947	·4894	·4845	·4799	·4757
·5	·5000	·4974	·4949	·4925	·4901	·4878
·3	·5000	·4990	·4981	·4971	·4962	·4953
	·5000	·4999	·4998	·4997	·4996	·4995

TABLE 2-2.

POTENTIALS AT D FOR D/T=0·98.

B/D.	B1/B. 0·5.	0·6.	0·7.	0·8.	0·9.	0·1.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
30.0	·5000	·4152	·3305	·2457	·1610	·0878
25·0	·5000	·4178	·3355	·2533	·1710	·1021
20·0	·5000	·4212	·3425	·2637	·1850	·1218
18·0	·5000	·4231	·3461	·2692	·1924	·1320
16·0	·5000	·4252	·3504	·2757	·2011	·1441
14·0	·5000	·4278	·3556	·2835	·2116	·1586
12·0	·5000	·4310	·3620	·2931	·2248	·1764
10·0	·5000	·4351	·3701	·3052	·2416	·1987
9·0	·5000	·4375	·3750	·3126	·2520	·2121
8·0	·5000	·4403	·3806	·3211	·2640	·2274
7·0	·5000	·4435	·3871	·3311	·2783	·2451
6·0	·5000	·4474	·3948	·3430	·2953	·2658
5·0	·5000	·4520	·4042	·3575	·3159	·2903
4·0	·5000	·4577	·4158	·3758	·3414	·3197
3·0	·5000	·4651	·4312	·3996	·3733	·3559
2·5	·5500	·4699	·4409	·4143	·3923	·3772
2·0	·5000	·4757	·4524	·4314	·4139	·4012
1·5	·5000	·4826	·4660	·4510	·4382	·4282
1·0	·5000	·4903	·4810	·4723	·4645	·4579
·7	·5000	·4940	·4882	·4826	·4775	·4729
·5	·5000	·4971	·4943	·4916	·4889	·4864
·3	·5000	·4989	·4979	·4968	·4958	·4947
·1	·5000	·4999	·4998	·4996	·4995	·4994

TABLE 2–3

POTENTIALS AT D FOR D/T=0·97

B/D.	B1/B ·5	0·6	0·7	0·8	0·9	1·0
20·0	·5000	·4140	·3281	·2422	·1563	·0823
25·0	·5000	·4164	·3329	·2493	·1658	·0960
20·0	·5000	·4197	·3395	·2592	·1790	·1149
18·0	·5000	·4215	·3429	·2644	·1860	·1247
16·0	·5000	·4235	·3470	·2706	·1943	·1364
14·0	·5000	·4260	·3520	·2780	·2044	·1504
12·0	·5000	·4291	·3582	·2873	·2171	·1677
10·0	·5000	·4330	·3660	·2990	·2335	·1896
9·0	·5000	·4353	·3707	·3062	·2436	·2028
8·0	·5000	·4381	·3762	·3145	·2555	·2179
7·0	·5000	·4413	·3826	·3243	·2696	·2355
6·0	·5000	·4451	·3903	·3362	·2866	·2562
5·0	·5000	·4497	·3996	·3508	·3074	·2809
4·0	·5000	·4554	·4114	·3693	·3333	·3109
3·0	·5000	·4631	·4271	·3938	·3662	·3480
2·5	·5000	·4681	·4372	·4091	·3860	·3701
2·0	·5000	·4741	·4494	·4270	·4086	·3951
1·5	·5000	·4815	·4638	·4477	·4342	·4235
1·0	·5000	·4897	·4797	·4704	·4621	·4550
·7	·5000	·4936	·4874	·4814	·4759	·4710
[illegible]	·5000	·4969	·4939	·4910	·4881	·4855
·3	·5000	·4988	·4977	·4966	·4955	·4944
·1	·5000	·4999	·4997	·4996	·4995	·4993

TABLE 2–4

POTENTIALS AT D FOR D/T=0·96

B/D	B1/B ·5	0·6	0·7	0·8	0·9	1·0
30·0	·5000	·4133	·3265	·2398	·1531	·0786
25·0	·5000	·4155	·3310	·2465	·1621	·0917
20·0	·5000	·4187	·3373	·2560	·1747	·1099
18·0	·5000	·4203	·3406	·2610	·1814	·1195
16·0	·5000	·4223	·3446	·2669	·1894	·1308
14·0	·5000	·4247	·3494	·2741	·1992	·1446
12·0	·5000	·4277	·3553	·2830	·2115	·1615
10·0	·5000	·4315	·3629	·2945	·2275	·1830
9·0	·5000	·4338	·3676	·3015	·2375	·1960
8·0	·5000	·4365	·3729	·3097	·2492	·2110
7·0	·5000	·4396	·3793	·3194	·2632	·2286
6·0	·5000	·4434	·3869	·3311	·2802	·2492
5·0	·5000	·4480	·3962	·3457	·3011	·2741
4·0	·5000	·4537	·4081	·3645	·3273	·3043
3·0	·5000	·4615	·4241	·3895	·3608	·3421
2·5	·5000	·4666	·4345	·4052	·3812	·3648
2·0	·5000	·4729	·4471	·4237	·4045	·3906
1·5	·5000	·4806	·4620	·4453	·4311	·4200
1·0	·5000	·4892	·4787	·4690	·4603	·4529
·7	·5000	·4933	·4867	·4805	·4748	·4696
·5	·5000	·4968	·4936	·4905	·4876	·4847
·3	·5000	·4988	·4976	·4964	·4952	·4941
·1	·5000	·4999	·4997	·4996	·4995	·4993

TABLE 2-5

POTENTIALS AT D FOR D/T=0·95

B/D	B1/B ·5	0·6	0·7	0·8	0·9	1·0
30·0	·4999	·4126	·3252	·2379	·1505	·0756
25·0	·5000	·4148	·3296	·2444	·1592	·0884
20·0	·5000	·4178	·3357	·2535	·1714	·1062
18·0	·5000	·4194	·3389	·2583	·1778	·1155
16·0	·5000	·4213	·3427	·2640	·1856	·1266
14·0	·5000	·4237	·3473	·2710	·1951	·1400
12·0	·5000	·4266	·3531	·2797	·2071	·1567
10·0	·5000	·4303	·3605	·2909	·2228	·1779
9·0	·5000	·4325	·3651	·2978	·2327	·1908
8·0	·5000	·4352	·3704	·3058	·2443	·2057
7·0	·5000	·4383	·3766	·3154	·2582	·2231
6·0	·5000	·4420	·3841	·3271	·2751	·2437
5·0	·5000	·4466	·3934	·3417	·2961	·2686
4·0	·5000	·4524	·4054	·3606	·3225	·2991
3·0	·5000	·4603	·4216	·3860	·3565	·3374
2·5	·5000	·4655	·4323	·4021	·3773	·3605
2·0	·5000	·4720	·4452	·4211	·4013	·3869
1·5	·5000	·4799	·4607	·4433	·4287	·4172
1·0	·5000	·4888	·4779	·4679	·4589	·4512
·7	·5000	·4930	·4863	·4798	·4739	·4685
·5	·5000	·4967	·4934	·4902	·4871	·4842
·3	·5000	·4987	·4975	·4963	·4951	·4939
·1	·5000	·4999	·4997	·4996	·4994	·4993

TABLE 2·6.

POTENTIALS AT D FOR D/T =0·90.

B/D.	B1/B. ·5	0·6	0·7	0·8	0·9	1·0
30·0	·4999	·4107	·3214	·2321	·1429	·0670
25·0	·5000	·4126	·3252	·2378	·1504	·0786
20·0	·5000	·4153	·3305	·2458	·1612	·0949
18·0	·5000	·4167	·3334	·2501	·1669	·1035
16·0	·5000	·4184	·3368	·2552	·1739	·1139
14·0	·5000	·4205	·3410	·2614	·1825	·1264
12·0	·5000	·4231	·3462	·2693	·1936	·1422
10·0	·5000	·4265	·3530	·2796	·2083	·1623
9·0	·5000	·4286	·3572	·2860	·2176	·1747
8·0	·5000	·4311	·3622	·2936	·2288	·1892
7·0	·5000	·4340	·3681	·3028	·2423	·2062
6·0	·5000	·4376	·3753	·3142	·2591	·2267
5·0	·5000	·4420	·3845	·3288	·2802	·2516
4·0	·5000	·4479	·3966	·3480	·3072	·2827
3·0	·5000	·4562	·4136	·3747	·3429	·3226
2·5	·5000	·4618	·4251	·3920	·3651	·3470
2·0	·5000	·4689	·4392	·4127	·3909	·3754
1·5 ..	·5000	·4776	·4563	·4371	·4210	·4048
1·0	·5000	·4875	·4755	·4643	·4544	·4459
·7	·5000	·4923	·4848	·4776	·4710	·4650
·5	·5000	·4963	·4927	·4891	·4857	·4825
·3	·5000	·4986	·4972	·4959	·4945	·4932
·1	·5000	·4998	·4997	·4995	·4994	·4992

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TABLE 2·7.

POTENTIALS AT D FOR D/T=0·85.

B/D	B 1/B. ·5	0·6	0·7	0·8	0·9	1·0
(1)	(2)	(3)	(4)	(5)	(6)	(7)
30·0	·5000	·4096	·3193	·2290	·1387	·0627
25·0	·5000	·4114	·3228	·2342	·1456	·0736
20·0	·5000	·4139	·3277	·2416	·1556	·0891
18·0	·5000	·4152	·3303	·2455	·1609	·0973
16·0	·5000	·4167	·3335	·2502	·1674	·1072
14·0	·5000	·4187	·3374	·2561	·1755	·1193
12·0	·5000	·4211	·3423	·2635	·1861	·1345
10·0	·5000	·4243	·3487	·2732	·2000	·1541
9·0	·5000	·4263	·3527	·2793	·2093	·1662
8·0	·5000	·4287	·3574	·2867	·2202	·1804
7·0	·5000	·4315	·3631	·2956	·2335	·1972
6·0	·5000	·4350	·3702	·3068	·2502	·2174
5·0	·5000	·4394	·3793	·3213	·2713	·2424
4·0	·5000	·4452	·3915	·3409	·2988	·2737
3·0	·5000	·4538	·4091	·3683	·3353	·3144
2·5	·5000	·4597	·4211	·3863	·3583	·3396
2·0	·5000	·4672	·4359	·4081	·3854	·3691
1·5	·5000	·4764	·4540	·4339	·4169	·4037
1·0	·5000	·4869	·4743	·4626	·4521	·4431
·7	·5000	·4919	·4840	·4765	·4696	·4633
·5	·5000	·4961	·4923	·4886	·4850	·4817
·3	·5000	·4986	·4971	·4957	·4943	·4929
·1	·5000	·4998	·4997	·4995	·4993	·4992

TABLE 2·8.

POTENTIALS AT D FOR D/T=0·80.

B/D.	B1/B. ·5	0·6	0·7	0·8	0·9	1·0
(1)	(2)	(3)	(4)	(5)	(6)	(7)
30·0	·4999	·4090	·3180	·2270	·1360	·0600
25·0	·5000	·4106	·3213	·2319	·1425	·0706
20·0	·5000	·4129	·3259	·2388	·1519	·0856
18·0	·5000	·4142	·3283	·2425	·1570	·0936
16·0	·5000	·4157	·3313	·2470	·1632	·1032
14·0	·5000	·4175	·3350	·2526	·1710	·1150
12·0	·5000	·4199	·3397	·2596	·1812	·1298
10·0	·5000	·4229	·3458	·2690	·1951	·1491
9·0	·5000	·4248	·3497	·2749	·2040	·1610
8·0	·5000	·4271	·3543	·2821	·2148	·1750
7·0	·5000	·4298	·3598	·2909	·2280	·1916
6·0	·5000	·4332	·3668	·3020	·2446	·2118
5·0	·5000	·4376	·3758	·3165	·2658	·2367
4·0	·5000	·4435	·3881	·3363	·2935	·2682
3·0	·5000	·4522	·4062	·3644	·3308	·3095
2·5	·5000	·4584	·4186	·3830	·3543	·3352
2·0	·5000	·4662	·4340	·4054	·3821	·3654
1·5	·5000	·4758	·4528	·4320	·4146	·4010
1·0	·5000	·4866	·4737	·4616	·4509	·4417
·7	·5000	·4917	·4837	·4760	·4689	·4624
·5	·5000	·4961	·4922	·4884	·4847	·4812
3·	·5000	·4985	·4971	·4956	·4942	·4928
·1	·5000	·4998	·4997	·4995	·4993	·4991

TABLE 2—9.

Potentials at D for D/T=0·75.

B/D.	B1/B					
	·5	0·6	0·7	0·8	0·9	1·0
(1)	(2)	(3)	(4)	(5)	(6)	(7)
30·0	·5000	·4085	·3171	·2256	·1342	·0584
25·0	·5000	·4101	·3202	·2303	·1404	·0688
20·0	·5000	·4123	·3246	·2369	·1495	·0835
18·0	·5000	·4135	·3270	·2405	·1544	·0913
16·0	·5000	·4149	·3299	·2448	·1604	·1007
14·0	·5000	·4167	·3334	·2502	·1681	·1123
12·0	·5000	·4190	·3379	·2570	·1781	·1270
10·0	·5000	·4219	·3439	·2661	·1917	·1460
9·0	·5000	·4238	·3476	·2719	·2005	·1578
8·0	·5000	·4260	·3521	·2790	·2113	·1717
7·0	·5000	·4287	·3576	·2877	·2245	·1882
6·0	·5000	·4320	·3644	·2988	·2411	·2083
5·0	·5000	·4364	·3735	·3134	·2624	·2332
4·0	·5000	·4423	·3860	·3335	·2903	·2649
3·0	·5000	·4513	·4045	·3621	·3280	·3065
2·5	·5000	·4576	·4172	·3810	·3520	·3326
2·0	·5000	·4656	·4330	·4039	·3803	·3633
1·5	·5000	·4754	·4521	·4311	·4134	·3996
1·0	·5000	·4864	·4733	·4612	·4503	·4409
·7	·5000	·4916	·4835	·4757	·4685	·4620
·5	·5000	·4960	·4921	·4882	·4846	·4810
·3	·5000	·4985	·4970	·4956	·4941	·4927
·1	·5000	·4998	·4997	·4995	·4993	·4992

TABLE 2—10.

Potentials at D for D/T=0·70.

B/D.	B1/B.					
	·5	0·6	0·7	0·8	0·9	1·0
(1)	(2)	(3)	(4)	(5)	(6)	(7)
30·0	·5000	·4082	·3164	·2247	·1330	·0575
25·0	·5000	·4097	·3195	·2292	·1390	·0677
20·0	·5000	·4119	·3238	·2357	·1478	·0823
18·0	·5000	·4130	·3261	·2391	·1526	·0900
16·0	·5000	·4144	·3289	·2433	·1586	·0993
14·0	·5000	·4162	·3323	·2485	·1661	·1108
12·0	·5000	·4184	·3367	·2552	·1761	·1253
10·0	·5000	·4212	·3425	·2642	·1899	·1442
9·0	·5000	·4231	·3462	·2700	·1984	·1560
8·0	·5000	·4252	·3506	·2770	·2091	·1698
7·0	·5000	·4279	·3561	·2857	·2224	·1863
6·0	·5000	·4312	·3629	·2968	·2390	·2064
5·0	·5000	·4356	·3720	·3116	·2604	·2313
4·0	·5000	·4416	·3847	·3318	·2886	·2631
3·0	·5000	·4508	·4035	·3608	·3266	·3050
2·5	·5000	·4572	·4164	·3800	·3508	·3313
2·0	·5000	·4654	·4325	·4032	·3794	·3623
1·5	·5000	·4753	·4518	·4307	·4129	·3990
1·0	·5000	·4864	·4732	·4610	·4501	·4407
·7	·5000	·4916	·4834	·4757	·4684	·4619
·5	·5000	·4960	·4921	·4882	·4845	·4810
·3	·5000	·4985	·4970	·4955	·4941	·4927
·1	·5000	·4998	·4997	·4995	·4993	·4992

TABLE 2—11.

Potentials at D for D/T=0·60.

B/D.	B1/B.					
	0·5	0·6	0·7	0·8	0·9	1·0
(1)	(2)	(3)	(4)	(5)	(6)	(7)
30·0	·5000	·4079	·3159	·2239	·1319	·0571
25·0	·5000	·4094	·3188	·2282	·1378	·0673
20·0	·5000	·4115	·3230	·2345	·1465	·0818
18·0	·5000	·4126	·3252	·2379	·1513	·0895
16·0	·5000	·4140	·3279	·2420	·1572	·0988
14·0	·5000	·4157	·3313	·2471	·1648	·1102
12·0	·5000	·4178	·3356	·2537	·1747	·1247
10·0	·5000	·4206	·3414	·2627	·1884	·1436
9·0	·5000	·4224	·3450	·2684	·1972	·1553
8·0	·5000	·4246	·3494	·2755	·2080	·1691
7·0	·5000	·4272	·3549	·2843	·2214	·1857
6·0	·5000	·4306	·3618	·2956	·2382	·2058
5·0	·5000	·4350	·3711	·3106	·2598	·2308
4·0	·5000	·4413	·3841	·3312	·2882	·2627
3·0	·5000	·4507	·4033	·3607	·3265	·3049
2·5	·5000	·4572	·4164	·3801	·3509	·3313
2·0	·5000	·4654	·4326	·4034	·3797	·3626
1·5	·5000	·4754	·4520	·4310	·4132	·3993
1·0	·5000	·4865	·4734	·4612	·4503	·4410
·7	·5000	·4917	·4836	·4758	·4686	·4621
·5	·5000	·4960	·4921	·4883	·4846	·4811
·3	·5000	·4985	·4970	·4956	·4941	·4927
·1	·5000	·4998	·4997	·4995	4993	·4992

TABLE 2·12.

Potentials at D for D/T=0.50

B/D	B1/B					
	·5	0·6	0·7	0·8	0·9	1·03
(1)	(2)	(3)	(4)	(5)	(6)	(7)
30·0	·4999	·4081	·3162	·2243	·1325	·0583
25·0	·5000	·4096	·3192	·2287	·1386	·0687
20·0	·5000	·4117	·3234	·2351	·1475	·0834
18·0	·5000	·4128	·3256	·2385	·1524	·0913
16·0	·5000	·4142	·3284	·2427	·1585	·1007
14·0	·5000	·4159	·3318	·2480	·1663	·1123
12·0	·5000	·4181	·3362	·2547	·1765	·1270
10·0	·5000	·4210	·3421	·2639	·1904	·1460
9·0	·5000	·4228	·3458	·2698	·1994	·1579
8·0	·5000	·4250	35·03	·2770	·2104	·1718
7·0	·5000	·4277	·3559	·2860	·2239	·1884
6·0	·5000	·4311	·3630	·2975	·2408	·2086
5·0	·5000	·4357	·3724	·3127	·2624	·2337
4·0	·5000	·4420	·3855	·3334	·2908	·2656
3·0	·5000	·4514	·4047	·3626	·3289	·3075
2·5	·5000	·4579	·4177	·3818	·3530	·3337
2·0	·5000	·4660	·4336	·4049	·3814	·3646
1·5	·5000	·4758	·4528	·4320	·4145	·4008
1·0	·5000	·4867	·4738	·4618	·4511	·4418
·7	·5000	·4918	·4838	·4761	·4691	·4626
·5	·5000	·4961	·4922	·4885	·4848	·4814
·3	·5000	·4985	·4971	·4956	·4942	·4928
·1	·5000	·4998	·4997	·4995	·4993	·4992

TABLE 2-13.

Potentials at D for D/T=·40.

B/D		0·5	0·6	0·7	0·8	0·9	1·0
		B1/B					
(1)		(2)	(3)	(4)	(5)	(6)	(7)
30·0	.. ..	·5000	·4087	·3175	·2262	·1352	·0613
25·0	.. ..	·5000	·4103	·3207	·2310	·1417	·0720
20·0	.. ..	·5000	·4126	·3252	·2378	·1512	·0873
18·0	.. ..	·5000	·4138	·3276	·2415	·1564	·0954
16·0	.. ..	·5000	·4153	·3305	·2459	·1628	·1051
14·0	.. ..	·5000	·4171	·3342	·2515	·1709	·1170
12·0	.. ..	·5000	·4194	·3388	·2586	·1814	·1320
10·0	.. ..	5000	·4224	·3449	·2682	·1957	·1514
9·0	.. ..	·5000	·4243	·3488	·2743	·2048	·1634
8·0	.. ..	·5000	·4266	·3535	·2816	·2159	·1774
7·0	.. ..	·5000	·4294	·3591	·2907	·2294	·1941
6·0	.. ..	·5000	·4328	·3663	·3022	·2462	·2143
5·0	.. ..	·5000	·4373	·3756	·3171	·2676	·2392
4·0	.. ..	·5000	·4435	·3884	·3374	·2955	·2707
3·0	.. ..	·5000	·4526	·4070	·3658	·3327	·3118
2·5	.. ..	·5000	·4588	·4195	·3844	·3562	·3373
2·0	.. ..	·5000	·4667	·4350	·4068	·3839	·3674
1·5	.. ..	·5000	·4762	·4536	·4333	·4161	·4027
1·0	.. ..	·5000	·4869	·4742	·4624	·4519	·4428
·7	.. ..	·5000	·4919	·4840	·4765	·4695	·4632
·5	.. ..	·5000	·4961	·4923	·4886	·4850	·4816
·3	.. ..	·5000	·4986	·4971	·4957	·4943	·4929
·1	.. ..	·5000	·4998	·4997	·4995	·4993	·4992

TABLE 2-14.

Potential s at D for D/T=0.30

B/D		0·5	0·6	0·7	0·8	0·9	1·0
		B1/B					
(1)		(2)	(3)	(4)	(5)	(6)	(7)
30·0	.. ..	·5000	·4102	·3205	·2307	·1410	·0664
25·0	.. ..	·5000	·4121	·3241	·2362	·1482	·0778
20·0	.. ..	·5000	·4146	·3293	·2439	·1586	·0939
18·0	.. ..	·5000	·4160	·3320	·2479	·1641	·1024
16·0	.. ..	·5000	·4176	·3352	·2528	·1709	·1125
14·0	.. ..	·5000	·4196	·3392	·2587	·1793	·1218
12·0	.. ..	·5000	·4221	·3442	·2662	·1901	·1402
10·0	.. ..	·5000	·4253	·3506	·2760	·2045	·1599
9·0	.. ..	·5000	·4273	·3545	·2821	·2136	·1720
8·0	.. ..	·5000	·4295	·3591	·2893	·2245	·1861
7·0	.. ..	·5000	·4322	·3646	·2981	·2378	·2027
6·0	.. ..	·5000	·4355	·3714	·3091	·2541	·2226
5·0	.. ..	·5000	·4297	·3802	·3233	·2748	·2468
4·0	.. ..	·5000	·4454	·3921	·3424	·3015	·2773
3·0	.. ..	·5000	·4539	·4095	·3694	·3372	·3168
2·5	.. ..	·5000	·4598	·4215	·3872	·3597	·3414
2·0	.. ..	·5000	·4674	·4364	·4088	·3864	·3704
1·5	.. ..	·5000	·4767	·4545	·4345	·4177	·4046
1·0	.. ..	·5000	·4871	·4746	·4630	·4526	·4437
·7	.. ..	·5000	·4920	·4842	·4768	·4700	·4638
·5	.. ..	·5000	·4962	·4924	·4888	·4852	·4819
·3	.. ..	·5000	·4986	·4972	·4958	·4944	·4930
·1	.. ..	·5000	·4998	·4997	·4995	·4994	·4992

TABLE 2-15.

Potentials at D for D/T=0·25.

B D.		·5	0·6	0·7	0·8	0·9	1·0
		B1/B.					
30·0 ..	.. ..	·5000	·4115	·3231	·2347	·1458	·0702
25·0 ..	.. ..	·5000	·4136	·3272	·2406	·1535	·0821
20·0 ..	.. ..	·5000	·4164	·3328	·2488	·1643	·0987
18·0 ..	.. ..	·5000	·4179	·3357	·2531	·1700	·1073
16·0 ..	.. ..	·5000	·4196	·3391	·2582	·1768	·1177
14·0 ..	.. ..	·5000	4217	·3433	·2643	·1853	·1302
12·0 ..	.. ..	·5000	·4243	·3483	·2718	·1961	·1458
10·0 ..	.. ..	·5000	·4275	·3546	·2814	·2104	·1655
9·0 ..	.. ..	·5000	·4294	·3584	·2873	·2193	·1776
8·0 ..	.. ..	·5000	·4315	·3628	·2943	·2300	·1915
7·0 ..	.. ..	·5000	·4341	·3681	·3027	·2428	·2079
6·0 ..	.. ..	·5000	·4371	·3744	·3131	·2587	·2274
5·0 ..	.. ..	·5000	·4410	·3826	·3266	·2787	2511
4·0	.. ..	·5000	·4464	·3939	·3450	·3046	·2807
3·0 ..	.. ..	·5000	·4545	·4107	·3711	·3393	·3192
2·5 ..	.. ..	·5000	·4603	·4224	·3885	·3613	·3433
2·0 ..	.. ..	·5000	·4677	·4370	·4097	·3875	·3718
1·5 ..	.. ..	·5000	·4768	·4548	·4350	·4184	·4054
1·0 ..	.. ..	·5000	·4871	·4748	·4632	·4530	·4441
·7 ..	.. ..	·5000	·4921	·4843	·4770	·4702	·4640
·5 ..	.. ..	·5000	·4962	·4925	·4888	·4853	·4820
·3 ..	.. ..	·5000	·4986	·4972	·4958	·4944	·4931
·1 ..	.. ..	·5000	·4998	·4997	·4995	·4994	·4992

TABLE 2-16

Potentials at D for D/T=0·20.

B D.		·5	0·6	0·7	0·8	0·9	1·0
		B1/B.					
30·0 ..	.. ..	·5000	·4136	·3271	·2405	·1525	·0753
25·0 ..	.. ..	·5000	·4159	·3317	·2470	·1607	·0877
20·0 ..	.. ..	·5000	·4190	·3378	·2558	·1718	·1048
18·0 ..	.. ..	·5000	·4206	·3409	·2602	·1776	·1137
16·0 ..	.. ..	·5000	·4224	·3445	·2654	·1845	·1242
14·0 ..	.. ..	·5000	·4246	·3486	·2714	·1929	·1369
12·0 ..	.. ..	·5000	·4271	·3535	·2787	·2034	·1525
10·0 ..	.. ..	·5000	·4301	·3595	·2878	·2172	·1721
9·0 ..	.. ..	·5000	·4318	·3630	·2933	·2257	·1839
8·0 ..	.. ..	·5000	·4337	·3670	·2998	·2359	·1976
7·0 ..	.. ..	·5000	·4360	·3717	·3075	·2482	·2135
6·0 ..	.. ..	·5000	·4388	·3775	·3172	·2634	·2324
5·0 ..	.. ..	·5000	·4423	·3850	·3299	·2825	·2554
4·0 ..	.. ..	·5000	·4473	·3957	·3474	·3075	·2841
3·0 ..	.. ..	·5000	·4551	·4118	·3726	·3412	·3215
2·5 ..	.. ..	·5000	·4607	·4232	·3896	·3628	·3450
2·0 ..	.. ..	·5000	·4679	·4375	·4105	·3885	·3729
1·5 ..	.. ..	·5000	·4770	·4551	·4355	·4189	·4062
1·0 ..	.. ..	·5000	·4872	·4749	·4635	·4532	·4445
7 ..	.. ..	·5000	·4921	·4844	·4771	·4703	·4642
·5 ..	.. ..	·5000	·4962	·4925	·4889	·4854	·4821
·3 ..	.. ..	·5000	·4986	·4972	·4958	·4944	·4931
·1 ..	.. ..	·5000	·4998	·4997	·4995	·4994	·4992

TABLE 2-17.

POTENTIALS AT D FOR D/T=0·15.

B/D.	B1/B. ·5	0·6	0·7	0·8	0·9	1·0
30·0	·4999	·4168	·3335	·2494	·1623	·0822
25·0	·5000	·4194	·3385	·2565	·1707	·0951
20·0	·5000	·4228	·3450	·2654	·1818	·1127
18·0	·5000	·4244	·3481	·2697	·1874	·1217
16·0	·5000	·4262	·3515	·2746	·1940	·1323
14·0	·5000	·4282	·3553	·2802	·2020	·1449
12·0	·5000	·4304	·3597	·2868	·2118	·1603
10·0	·5000	·4329	·3648	·2948	·2246	·1793
9·0	·5000	·4344	·3678	·2996	·2326	·1908
8·0	·5000	·4360	·3712	·3053	·2420	·2039
7·0	·5000	·4379	·3752	·3122	·2535	·2191
6·0	·5000	·4403	·3803	·3211	·2678	·2373
5·0	·5000	·4434	·3872	·3329	·2860	·2593
4·0	·5000	·4481	·3972	·3494	·3100	·2870
3·0	·5000	·4555	·4127	·3739	·3428	·3234
2·5	·5000	·4610	·4238	·3906	·3640	·3465
2·0	·5000	·4681	·4379	·4111	·3893	·3739
1·5	·5000	·4771	·4554	·4358	·4194	·4068
1·0	·5000	·4873	·4750	·4636	·4535	·4448

TABLE 2.18.

POTENTIALS AT D FOR D/T=0·10

B/D.	B1/B ·5	0·6	0·7	0·8	0·9	1·0
30·0	·5000	·4223	·3439	·2633	·1765	·0919
25·0	·5000	·4249	·3489	·2701	·1844	·1052
20·0	·5000	·4280	·3547	·2780	·1945	·1228
18·0	·5000	·4293	·3572	·2817	·1995	·1316
16·0	·5000	·4307	·3600	·2856	·2052	·1419
14·0	·5000	·4322	·3629	·2900	·2121	·1540
12·0	·5000	·4338	·3661	·2952	·2206	·1686
10·0	·5000	·4357	·3699	·3015	·2318	·1866
9·0	·5000	·4367	·3722	·3055	·2390	·1973
8·0	·5000	·4380	·3749	·3103	·2476	·2097
7·0	·5000	·4395	·3782	·3163	·2582	·2242
6·0	·5000	·4415	·3827	·3243	·2715	·2414
5·0	·5000	·4443	·3889	·3352	·2888	·2625
4·0	·5000	·4487	·3983	·3511	·3120	·2893
3·0	·5000	·4559	·4134	·3749	·3440	·3249
2·5	·5000	·4613	·4243	·3913	·3649	·3475
2·0	·5000	·4683	·4382	·4115	·3899	·3746
1·5	·5000	·4772	·4555	·4361	·4198	·4072

TABLE 2·19.

POTENTIALS AT D FOR D/T=0·05.

B/D	B1/B. 0·5	0·6	0·7	0·8	0·9	1·0
(1)	(2)	(3)	(4)	(5)	(6)	(7)
30·0	·4999	·4305	·3592	·2831	·1961	·1053
25·0	·5000	·4321	·3622	·2873	·2016	·1178
20·0	·5000	·4337	·3653	·2918	·2084	·1340
18·0	·5000	·4344	·3666	·2938	·2119	·1420
16·0	·5000	·4350	·3680	·2961	·2160	·1514
14·0	·5000	·4358	·3695	·2987	·2211	·1624
12·0	·5000	·4366	·3713	·3020	·2279	·1757
10·0	·5000	·4377	·3738	·3066	·2374	·1923
9·0	·5000	·4384	·3754	·3098	·2437	·2023
8·0	·5000	·4394	·3775	·3138	·2515	·2140
7·0	·5000	·4406	·3803	·3191	·2614	·2277
6·0	·5000	·4423	·3842	·3264	·2740	·2442
5·0	·5000	·4449	·3900	·3368	·2907	·2647
4·0	·5000	·4491	·3990	·3521	·3132	·2908
3·0	·5000	·4561	·4138	·3755	·3448	·3258
2·5	·5000	·4614	·4246	·3917	·3654	·3482

TABLE 2·20.

POTENTIALS AT D FOR D/T=0·03.

B/D	B1/B. 0·5	0·6	0·7	0·8	0·9	1·0
(1)	(2)	(3)	(4)	(5)	(6)	(7)
30·0	·4999	·4338	·3653	·2910	·2040	·1107
25·0	·5000	·4347	·3669	·2934	·2077	·1224
20·0	·5000	·4355	·3686	·2961	·2128	·1376
18·0	·5000	·4358	·3693	·2974	·2155	·1452
16·0	·5000	·4362	·3702	·2990	·2190	·1541
14·0	·5000	·4367	·3712	·3010	·2236	·1647
12·0	·5000	·4373	·3726	·3038	·2298	·1775
10·0	·5000	·4382	·3747	·3079	·2388	·1937
9·0	·5000	·4388	·3762	·3108	·2449	·2035
8·0	·5000	·4397	·3781	·3146	·2525	·2150
7·0	·5000	·4408	·3808	·3197	·2621	·2285
6·0	·5000	·4425	·3846	·3269	·2746	·2449
5·0	·5000	·4450	·3903	·3371	·2911	·2651

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TABLE 2.21.

POTENTIALS AT D FOR D/T. = 0·01.

B/D	B1/B 0·5	0·6	0·7	0·8	0·9	1·0
(1)	(2)	(3)	(4)	(5)	(6)	(7)
30·0	·4999	·4359	·3692	·2961	·2091	·1144
25·0	·5000	·4361	·3697	·2970	·2114	·1252
20·0	·5000	·4364	·3704	·2985	·2152	·1397
18·0	·5000	·4366	·3708	·2994	·2176	·1470
16·0	·5000	·4369	·3714	·3005	·2206	·1556
14·0	·5000	·4372	·3722	·3022	·2248	·1659
12·0	·5000	·4377	·3733	·3047	·2308	·1785
10·0	·5000	·4385	·3752	·3085	·2395	·1944
9·0	·5000	·4390	·3766	·3113	·2455	·2042
8·0	·5000	·4398	·3784	·3150	·2529	·2155
7·0	·5000	·4410	·3810	·3201	·2625	·2289

TABLE 2.22.

POTENTIALS AT D FOR D/T0 = ·005

B/D	B1/B 0·5	0·6	0·7	0·8	0·9	1·0
(1)	(2)	(3)	(4)	(5)	(6)	(7)
30·0	·5000	·4361	·3696	·2966	·2097	·1148
25·0	·5000	·4363	·3700	·2974	·2118	·1255
20·0	·5000	·4365	·3706	·2987	·2155	·1399

SETTLEMENT TORPEDO.*

With the big spurt in the construction of reservoirs, maintenance of dams has assumed a great importance. At present in the absence of suitable devices assessment of settlement in the earthen dams has become difficult. Research and development work were put on sound footing during the post-war era and the significant mark was r ade in the Soil Mechanics and Research Division during the recent years in the field of instrumentation.

Many earthen dams in the State of Tamil Nadu are provided with vertical settlement gauges which are on U.S.B.R. pattern consisting of series of 37 mm. and 50 mm. pipes telescoping into each other. The 37 mm. pipe is fixed to the 75 mm. channel and embedded in the earthen bund at pre-determined levels. A specially designed torpedo fixed to a 8 mm. wide steel measuring tape is lowered into the installation. The torpedo is provided with pawls which open in one direction. If the steel tape is pulled up the pawls engage the lower end of the 37 mm. pipe, and prevent the upward movement of torpedo (see fig. 1). The readings at different periods give the settlement of earthen bunds. This equipment though reliable is confronted with many difficulties, one such is pulling out this torpedo finally by means of a specially installed latching plate.

Many attempts were made to improve on this system. The Maharashtra Engineering Research Institute evolved a design which consists of steel plates 60cm. × 60cm. × 6mm. with central hole of 60 mm. dia. fixed in the bund at 3 metre intervals during the construction. A rigid PVC pipe of 40 mm. passes through holes of the plate from top to bottom. A permanent magnet surrounded by a coil of copper wire the terminals of which are brought out and connected to the sensitive spot galvanometer is sent down through the pipe. When the probe passes the vicinity of the embedded plate there is disturbance in the magnetic field and the electromotive force is induced in the coil according to the laws of electromagnetic induction which is recorded in the galvanometer. The system is not perfect because the kicks are recorded in the galvanometer both when the magnet approaches and recedes the vicinity of the plate. Also when the probe is held steady there is no deflection because of non-disturbance in the magnetic field.

Electric and electronic devices for settlement determination have been made use of in foreign countries. The Building Research Station in United Kingdom also developed a type of equipment which is claimed to be fairly accurate. The equipment developed in Soil Mechanics and Research Division, Madras is based on the system adopted by the Maharashtra Engineering Research Institute. The same steel plate and pipes are adopted here also. The probe has been improved by dispensing with the permanent magnet and replaced by two solinoid inductors mounted on the same axis with the spacing of 3·8 cm. between the coils. The direction of winding and flow of current are so regulated that the magnetic fields are opposing each other. When the number of turns in the two coils are identical and the same current passes through them the magnetic fields produced neutralise each other at the plane exactly equidistant from the two coils. Another pick-up coil is suitably fixed in the same neutral plane which will detect a conducting material in the vicinity.

In the prototype finally evolved, the main field coils consist of 1,200 turns of 36 S. W.G. super enamelled copper wire wound on a 19 mm. (¾ in.) diameter former over a length of 2·54 cm. (1 inch). The pick up coil also consists of the same wire wound on 25mm. × 6 mm. (1 in. × ¼ in.) bobbins and three such coils are fixed in the axial plane at 120° apart. The D. C. resistances of the main field coils and pick up coils were 65 ohms and 12 ohms for each coil respectively. Figure 2 shows the details of the coil assembly.

The oscillator functions at the frequency of 8,000 cycles and delivers an output voltage of 6 volts to the field coils.

Three systems of detection have been developed. In the first system the output of the search coil is amplified and then fed to a rectifier, a gain control and a micro-ammeter. Figure 3 furnishes the circuit diagram of the amplifier-*cum*-detector. Under steady conditions when the coil system is free in space the output of the pick-up coil is nil and so the meter reads zero. When the coil system is lowered into the P.V.C. pipe, as the lower coil approaches any of the embedded plates the field due to the lower coil gets disturbed, upsetting the balance condition so that there is an output from the pick-up coil which is fed to the amplifier which after amplification is rectified and is shown by a deflection of the meter. Further approach of the coil system to the burried plate increases the signal and so the deflection in the meter. Soon the deflection becomes maximum and remains in this position till the first coil clears the plate. Thereafter the deflection decreases till at the position when the burried metal plate occupies a symmetric position with respect to both the coils, i.e., when the central plane of the metal plate coincides with the mid-plane between the two coils, the meter reading becomes zero. Similarly for the second coil the deflection increases, becomes a maximum and when the probe completely passes the plate the deflection comes back to zero. Figure 4 gives a plot of deflection in the meter against position of the probe and it is quite apparent from the figure that the central line of the burried plate could be easily located correct to + or − 1mm. It is to be noted that all these readings are steady readings and could be read quite coveniently and does not require any relative movement for taking observations, etc.

The second system of measurements developed makes use of the principle of phase change detection. Figure 5 furnishes a block diagram of the arrangemet while Figure 6 gives the circuit diagram adopted. In short, the phase of the signal received from the pick-up is compared with the phase of the input signal. This enables us to judge whether the burried plate is in the vicinity of the lower coil or the upper coil. A centre zero micro-ammeter is used and the micro-ammeter deflects to one side or the other depending on whether the plate is nearer to coil one or coil two. When it is equidistant from both the coils the meter reads zero. The advantage of this arrangement is that the system is most sensitive near to the zero position so that even a very small movement of the plate away from the null point produces an immediate change in the meter reading. Changes of even 0·5 mm. from the central position produces a measurable deflection in the meter from the zero reading By suitable miniaturisation it has been possible to accommodate all the required circuits as well as a battery in the body of probe itself. Only the indicating meter is

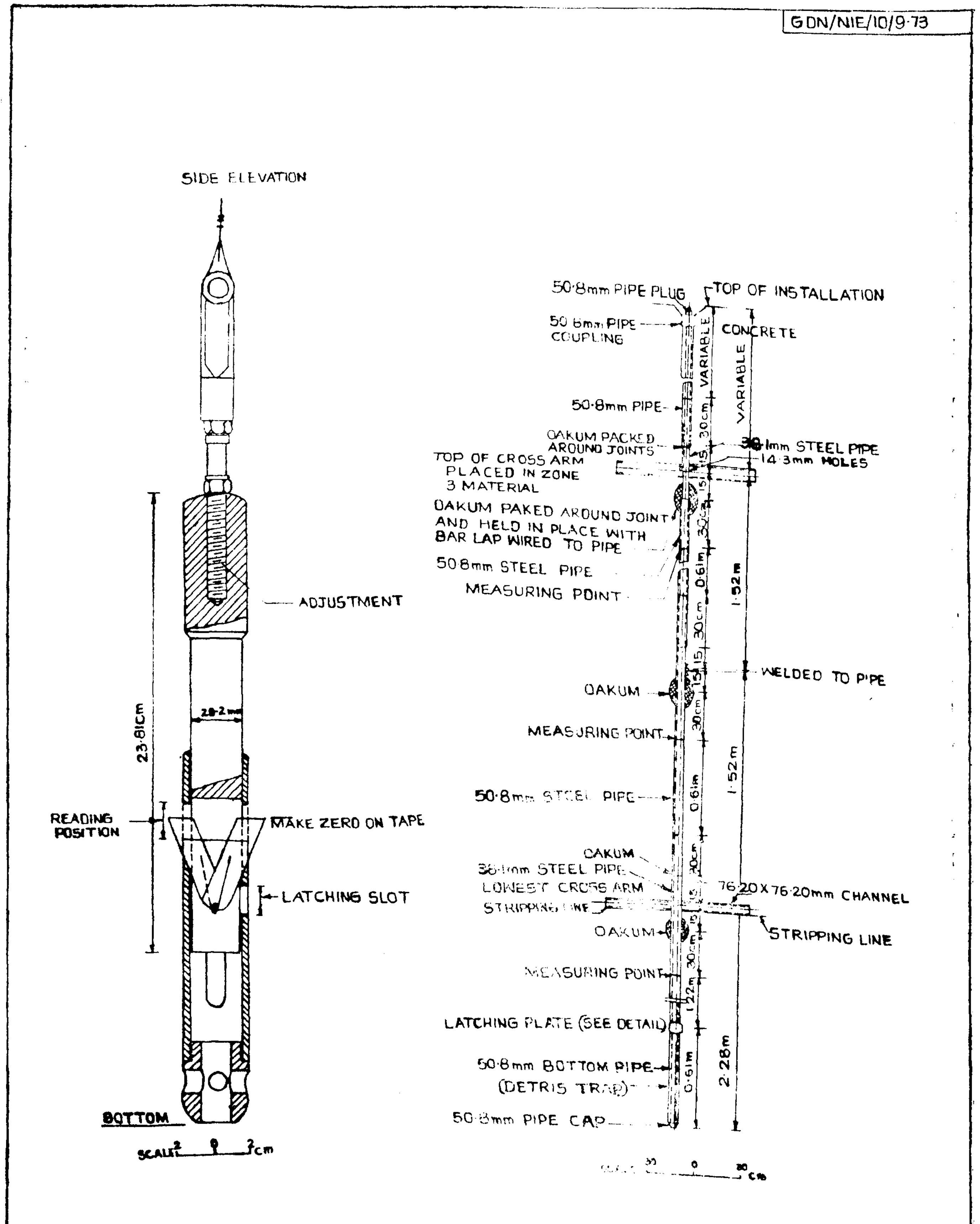


FIG. 1

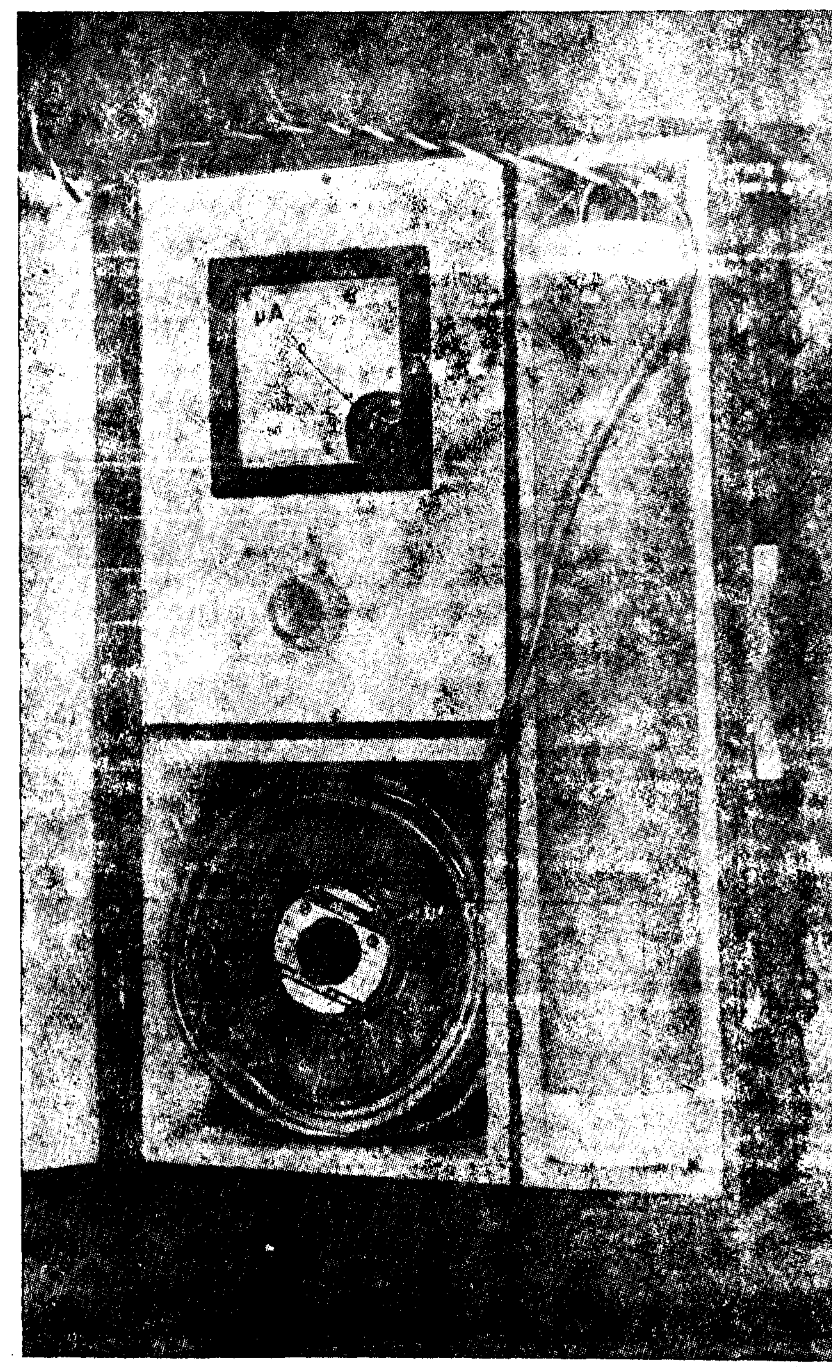
held at the ground level. A steel measuring tape is used for determining the levels with respect to the top reference point. Figure 7 gives the details of the assembly inside the probe and figure 9 shows a photograph of the complete equipment.

The above devices required two electrical leads to be taken from the probe to the ground level in addition to the steel measuring tape. In the third system developed a small radio frequency transmitter is located in the probe itself, so that the signal from the pick-up coil can be transmitted to the ground surface without the need for the connecting wires. A suitable receiver with an output meter is located at the surface to receive the signals. Figure 8 gives details of the arrangement used.

Condensed from the Paper " A TRANSISTRISED SETTLEMENT TORPEDO FOR USE WITH EARTH DAM SETTLEMENT APPARATUS". Written by Thiruvalargal L. Venkatanarasimhan, R. Rajaraman and T. K. S. Ramanujam.

Field Trials.—

A system incorporating the above arrangements has been installed in the sand embankments at Ennore. Observations will be taken at intervals of one month. In the same location a conventional device according to U.S.B.R. standards is also installed so that comparative data could be obtained. Results obtained will be reported in due course.



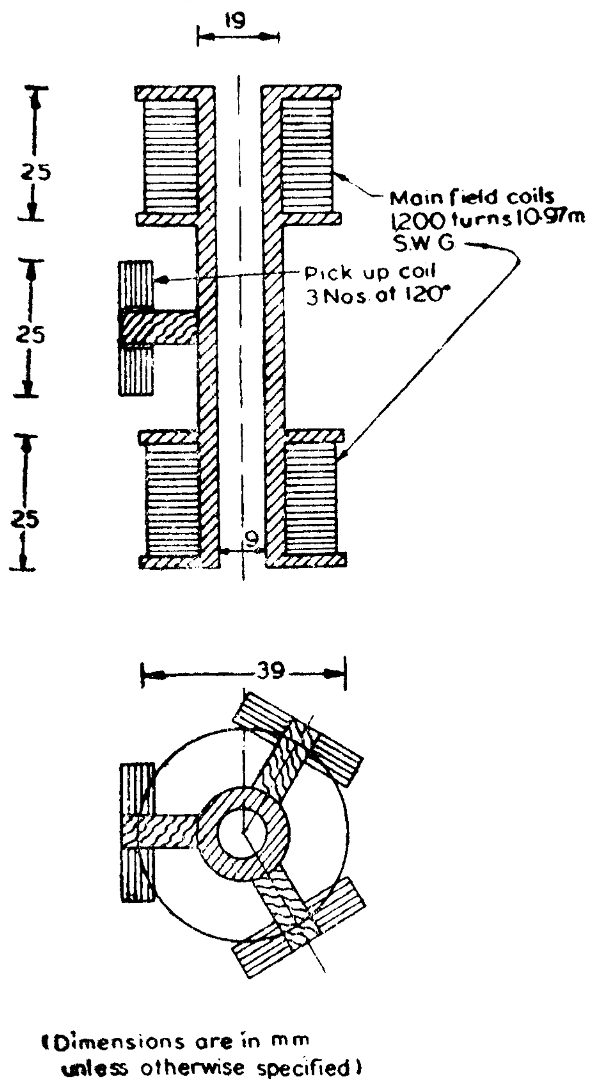


Fig. 2.

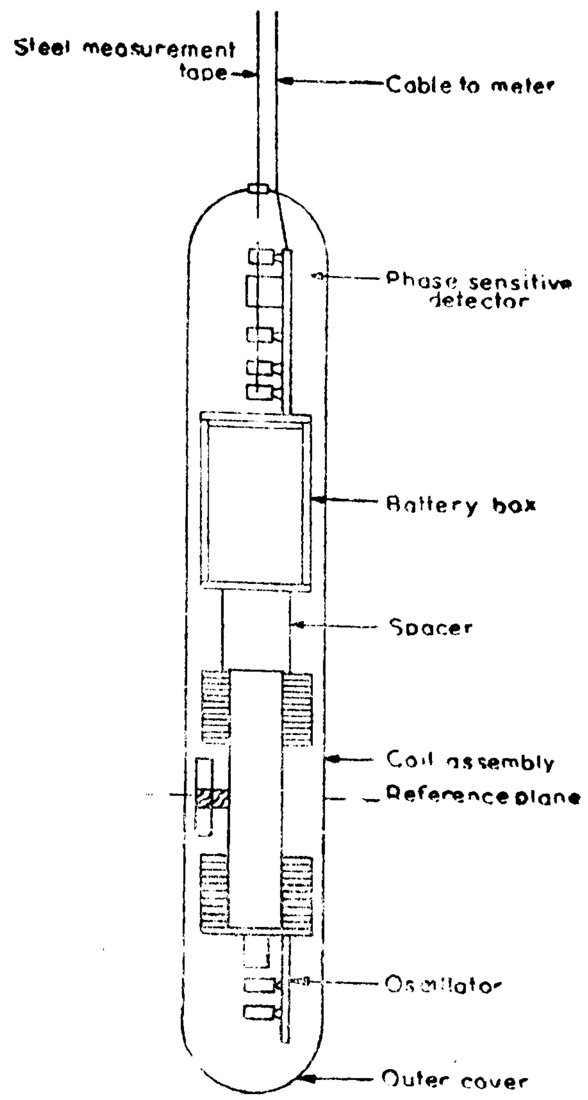


Fig. 7.

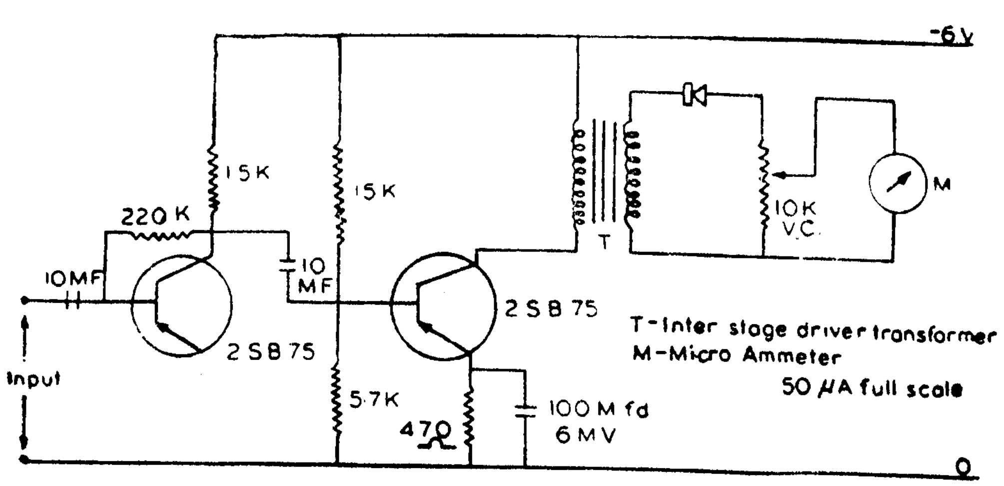


Fig. 3.

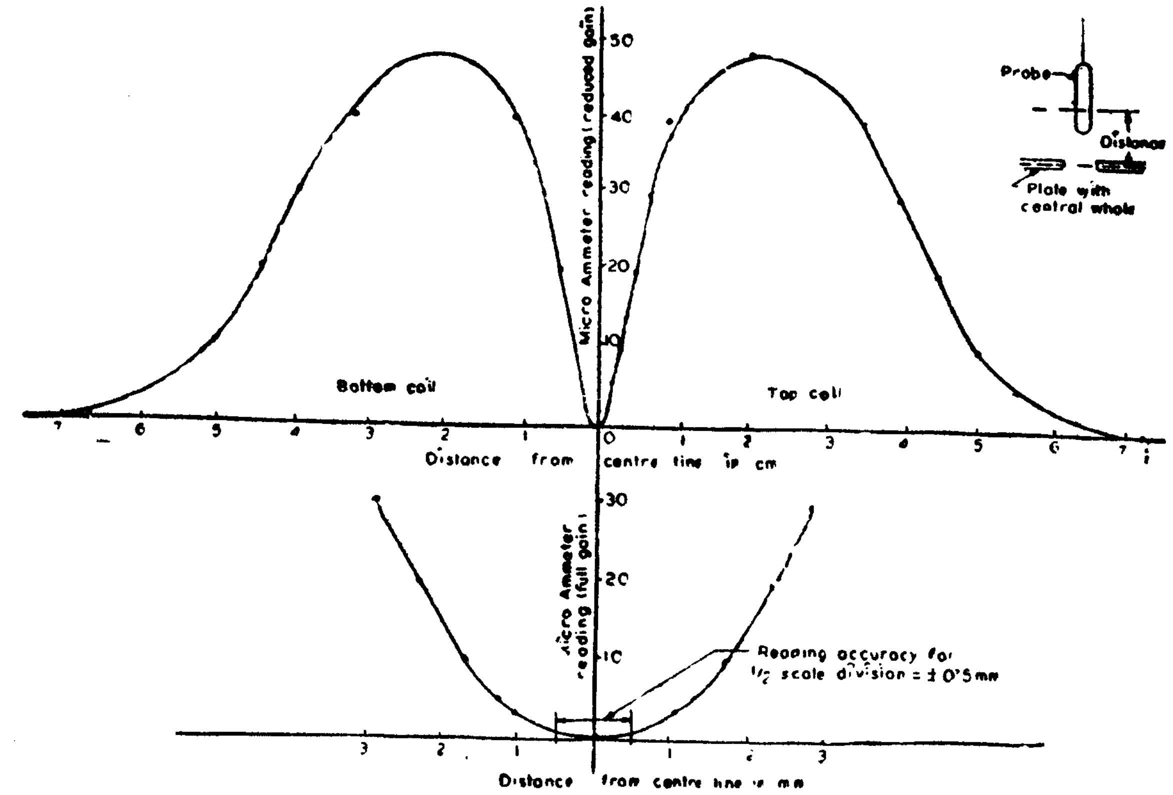


Fig. 4.

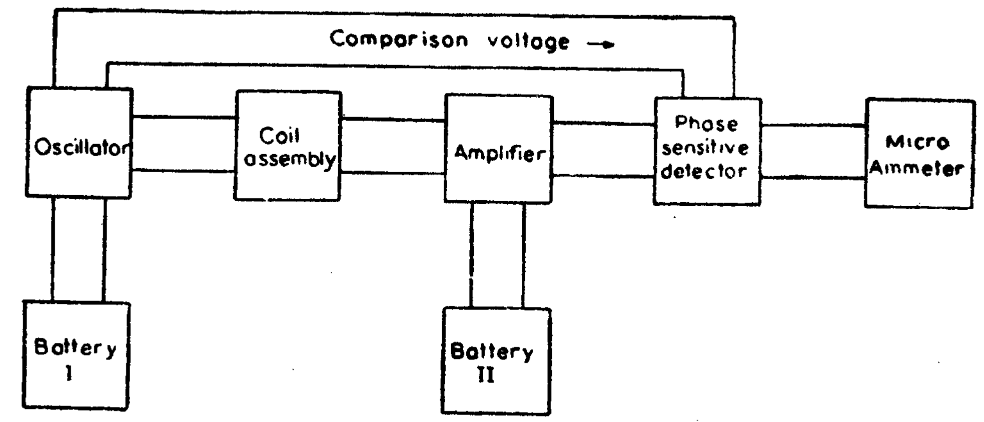


Fig. 5.

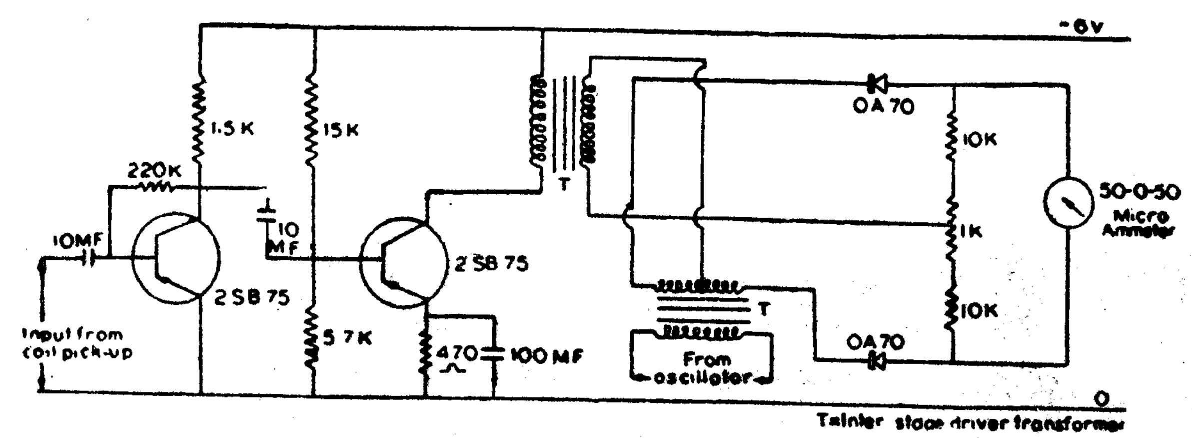


Fig. 6.

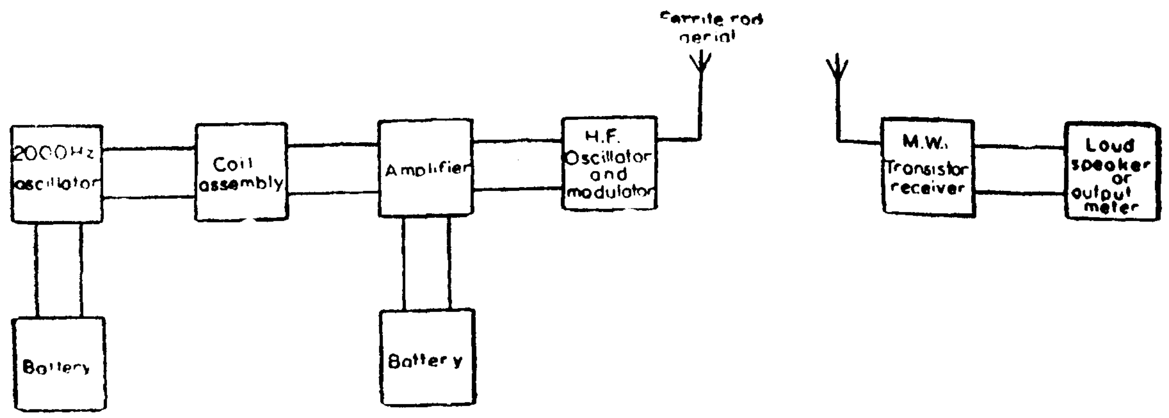


Fig. 8.

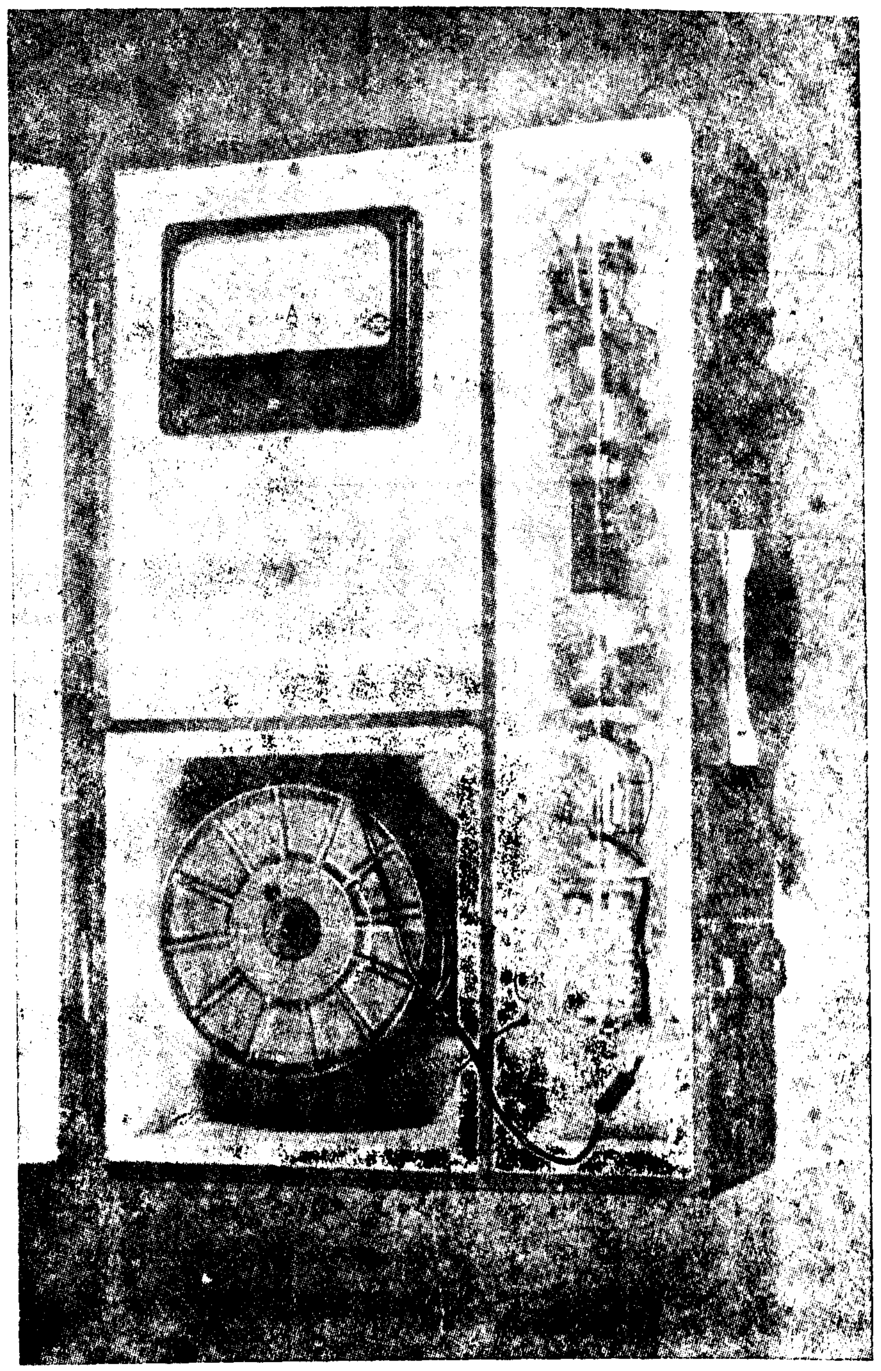


Fig. 9.

CAVITATION IN IRRIGATION STRUCTURES.

BY

G. PADMANABHAN *.

I Introduction:

The phenomenon of cavitation was first recognised by Euler in 1774 in connection with the theory of hydraulic machines. It was after the first Atlantic crossings by the British ships, the failure of propellers of ships were attributed to this phenomenon. After the World War I and II, Cavitation problems have been encountered in varied fields such as high head hydraulic structures, high head gates, spillways, high head hydraulic machines, high speed ships, submarines, high speed under water ballistics and in the development of high speed rocket engines.

In General Civil Engineers met with this Phenomenon much later than Mechanical Engineers. The study of cavitation became predominant when dam building programmes began in America and Europe. In India, serious research in the study of this phenomenon and its delitereous effects on various materials and structures was taken up after the intense damage that occurred to the world's largest siphons at Hirebha Sagar Dam in Mysore.

In an irrigation scheme or in a multipurpose project, the various components that are likely to be affected by cavitation are spillway sections, outlet works, energy dissipation structures such as baffle piers and other stilling basin appurtenances, control gates and valves.

II. Cavitation Defined:

Cavitation is defined as the formation, growth and collapse of cavities that are formed in flowing water due to the hydrodynamic reduction of pressure. If the pressure falls below the vapour pressure of the liquid cavities are formed. They grow in size and are carried by flowing water. When carried to a region of higher pressure they collapse or 'implode' causing damage to adjacent boundary in the form of pitting and erosion of solid material.

III. Delitereous Effects of Cavitation in Hydraulic Structures:

(i) *Deterioration of hydraulic performance:*

Because of pitting, the bounding surfaces of flow loose the shape of the guiding surface. This may induce formation of vortices and turbulent secondary motions. Consequently energy losses increase and the hydraulic performance deteriorates.

(ii) *Vibration:*

Some of the mechanical failures of the components of a hydraulic structure such as siphones, penstocks conduits, gates and valves are attributed to the intense vibration imparted due to violent collapse of the cavities.

(iii) *Cavitation erosion:*

Guiding surface of spillway dams, piers of spillway dams, gate slots, stilling basins and energy dissipators are often subjected to severe cavitation erosion. This leads to weakening of structures.

(iv) *Noise:*

Cavitation occurs with a characteristic crakling noise. Such noise generally increases the noise level considerably. This may also pose a serious problem in future in view of "noise pollution."

IV. Different forms of Cavitation in Hydraulic Structures:

In general, there are three main types of vacuum zones in all kinds of hydraulic structures and vacuum zones are known to be potential sources of cavitation.

(i) Vacuum zones inside flow without separation of flow from steamlined surface.

(ii) Vacuum zones inside flow with separation of flow from steamlined surface.

(iii) Vacuum zone under free falling stream.

The first type occurs in spillway dams (Figure 1). This is also met with in intake structures of conduits, siphons and shaft spillways. Sometimes this is favourable in the sense that it increases the co-efficient of discharge as in the case of a siphon. But the periodical breaking down of this vacuum is to be prevented.

The second type occurs in gate slots (Figure 2). This also occurs in sharp edged structures, closed conduits and tunnels beyond the gates, gate slots and energy dissipators. This is to be completely avoided because of increase of energy losses and intense vibrations of the structure due to the separation of flow and the presence of vortices and secondary flows. As an energy dissipating agency this is allowed to take place in energy dissipating structures, sufficient precaution being taken to prevent material erosion.

The third type occurs free falling stream (Figure 3). Very intense vibrations of the structure occur by the periodical break of the vacuum.

V. Case Studies of Cavitation Damage in Hydraulic Structures:

The typical hydraulic structures are spillway dams, siphons, tunnels, and conduits, energy dissipators, gates and gate slots. For avoiding or reducing cavitation in structures, the design should be based on calculations and especially model experiments.

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† Metric equivalents to F.P.S., Units used in this article are furnished at the end.

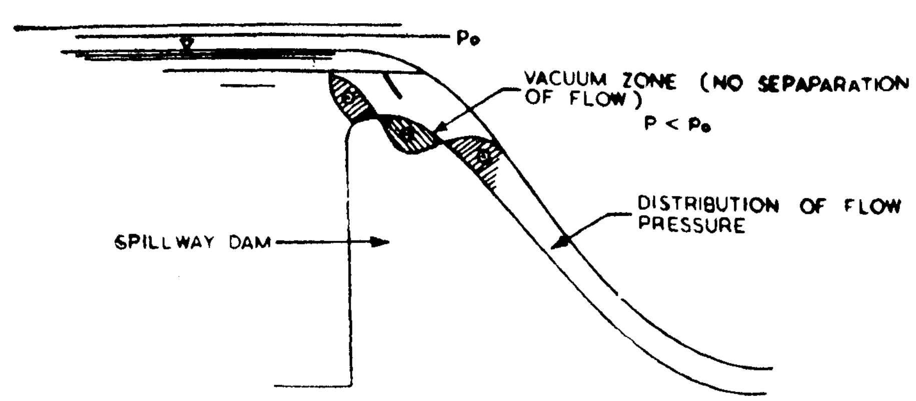

FIG. 1 SPILLWAY DAMS

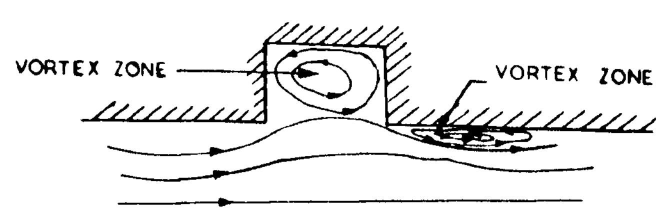

FIG 2 GATE SLOTS.

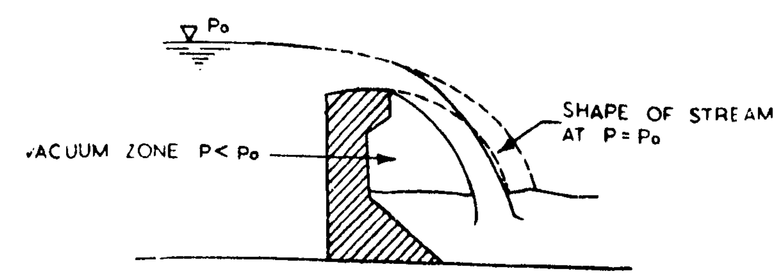

FIG. 3 FREE FALLING STREAM.

Some failures of hydraulic structures by cavitation in the past have revealed that the failure is due to any one or combinations of the following factors :—

(i) *Misalignment of conduits :*

After the completion of the Hoover arch gravity dam across the river Colarado in U.S.A. during the first fill, the reservoir surplussed and the spillways were operated. The spillway drops 500′ with a 225′ radius bend at the junction of horizontal portion and the inclined shaft. The spillway has been designed for 2,00,000 c/s, the actual discharge was only 13,500 c/s. After the floods, the tunnel was inspected and a large eroded area was discovered in the bottom of the tunnel downstream of the bend. The eroded portion was approximately 140′ long, 30′ wide and 36′ deep and extended through the concrete portion into the supporting rock below. The velocity of flow has been estimated to be 150 feet/second. After detailed studies it was established that the scour was due to cavitation and the damage was due to misalignment of the tunnel a few feet upstream of the bend. This was only a few inches in the vertical direction. The misalignment has resulted in a change in flow pattern resulting in the formation of low pressure regions and consequent formation of cavities which have collapsed downstream of the bend and caused damage. Very careful alignment of the structure, i.e., tunnel and proper curvature at the junction would have avoided cavitation in the structure.

(ii) *Surface roughness :*

The spillway surface of Grand Coulee dam with a hydraulic height of 355′ is an ogee shaped one with a discharge capacity of 1 million cfs. At the first operation severe damage occurred to the spillway surface concrete. The cause was traced to surface roughness or protrusions.

Another example is the damage caused to the 18′ siphons at Hirebasagar Jog Power Scheme, Mysore State (Sharavathi Project). The dam at Hirebasagar is a composite dam with masonry for a length of 1,120′ in the river portion and flanked by earthen bund on either side. The expected maximum flood of 2,00,000 cfs. was impossible to be disposed of through the masonry portion. Therefore it was decided to pass a portion of the flood through 10′×20′ sluices and the rest by means of siphons of 18′ outlet diameter. Volute siphons with dome located at top of a number of pillars was a new innovation. Though it was first thought to have the siphon barrel of cast iron embedded in the masonry of the dam, finally it was decided to have R.C.C. construction. When the siphons were operated for the first time due to the high velocities of more than 50′/second severe damage occurred at the tip of the funnel and the bend portion (Fig. 4). The cavitation occurring was so severe that the crackling noise due to the bursting of bubbles could be heard half a mile away and the vibrations were so severe that everyone was hesitant to go near the dam. Later, model studies revealed that areas of negative pressure were due to bad configuration of bend. Therefore the damage was attributed to the rough surface of concrete and bad alignment of conduits.

Sudden passage of flow from a smooth boundary to rough boundary gives rise to severe cavitation damage. This was observed in Pine Flat dam located on the Kings river in California. Here steel liners were provided downstream of the control gate for a distance of about 8′ in conduits as a protection measure against cavitation downstream of the gate. Steel liners joined concrete surface. Pitting was observed after the first operation. The reason is attributed to passage of flow from smooth surface to rough concrete surface.

Cavitation and damage to concrete surface is related to the relative height of particles forming the boundary roughness and the thickness of the turbulent boundary layer. At the downstream end of a gate, a turbulent boundary layer begins to form in the vicinity of the gate. Velocities are greatest next to the floor of the conduit. At distances far away from the gate the thickness of boundary layer increases. Model experiments show that cavitation could be produced by protrusions only 1/16″ high in the first 11 feet downstream from a gate whereas at distances greater than 64 feet from the gate even a 1/2″ protrusion could not cause cavitation.

(iii) *Presence of slots as in gate groves :*

This has been observed in a large number of dams such as Fort Peak dam in Montana, the Denison dam in Texas and the Norfork dam in Arkansas. The high velocity flow over the slots creates vortices in the slots. At smaller gate openings this is carried downstream. Lowest pressures occur at the core of the vortex and cavitation pocket collapses at the high pressure region at the junction of the downstream edge of the slot and the base of the conduit.

(iv) *Badly designed transitions :*

Cavitation damage is observed to be quite severe in the transitions from gated sections to circular or any other shape in a downstream direction. Reduction in length of transition often leads to a rapid change of flow pattern and consequent reduction in pressure.

At Fort Randoll dam in South Dakota, the two 11′×23′ rectangular gate passages converge in a 49′ long transition section to a 22′ diameter circular section. This reduction in area results in an increase of velocity and a corresponding reduction of pressure. The downstream end of the transition could have been made tangential to the conduit. It is reported that the conduit section and the transition sections were constructed by two separate contracts.

(v) *Simultaneous operation of spillway and sluices located in the spillway portion :*

In many high dams it is the practice to locate the sluices for regulation in tiers in the spillway portion itself. In Folson dam in California the drop is 303′ and the regulating gates 5′×9′. Curved sluices were in the spillway section. No damage occurred either when the sluice alone or the gate alone was operated; but damage was observed to the exit portals of the gate openings, when in both the spillway and sluices functioned simultaneously. The flood passed over the spillway for seven days and the depth of flow was 37′. A definite line of damage occurred on each side wall beginning at the block out section and extended to the spillway face. This has been attributed to the abrupt change in the alignment at the block out section, resulting in low pressure areas extending up to the exit portal. If the height of block out section is reduced, the areas of negative pressure could be eliminated. Damage was also observed on the spillway face immediately downstream from the sluice exit (Fig. 5). A similar damage was observed in Table Rock dam also.

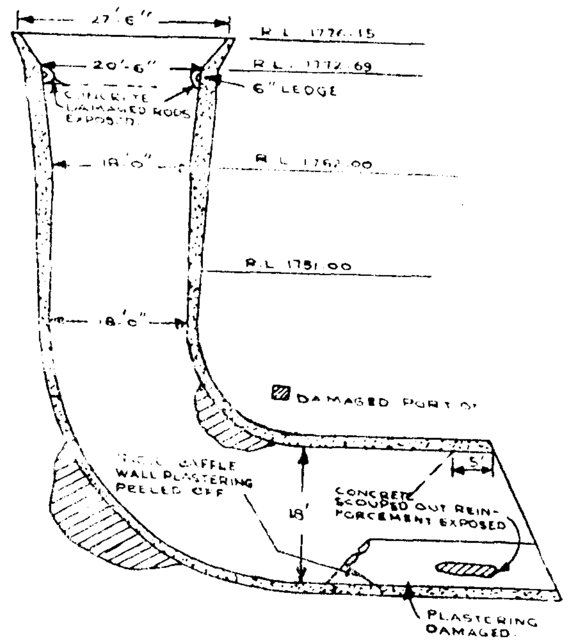

FIG. 4 SIPHON AT HIREBASAGAR.

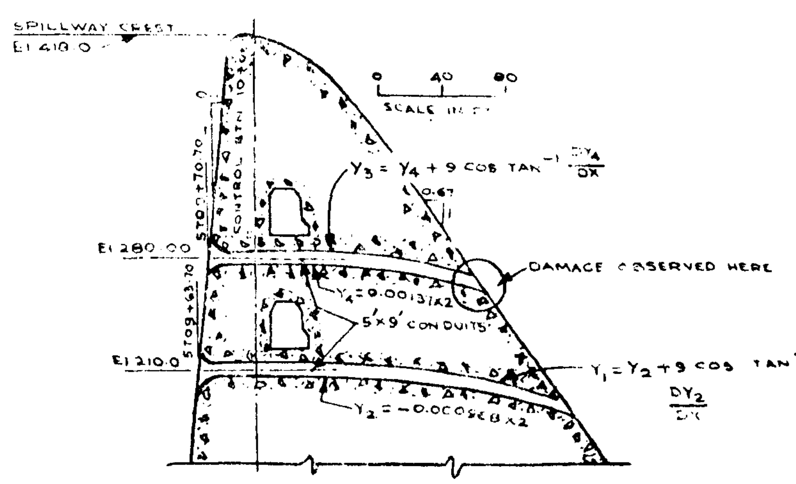

FIG. 5 DETAILS OF FOLSOM DAM CONDUIT.

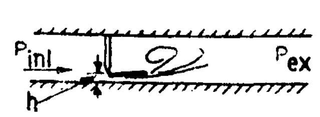

FIG. 6 GATE WITH STABILIZER

(vi) *Steps in stilling basins*:

Severe cavitation damage was observed in the stilling basin of the Bull Shoals dam when the spillway and gates were operated. The spillway is an ogee shaped one with a drop to stilling basin of about 225 feet. It was of hydraulic jump type with a 200′ long apron containing four steps with their faces ellipsoidal to avoid cavitation. A 4′ high stepped sill was also provided for the basin. Most severe damage occurred just downstream from the top of the first stilling basin step. When the steps were replaced by paved ramps and the height of the end sill was raised to 8′ from 4′ no further damage occurred.

(vii) *Impact of high velocity flow*:

Baffle piers and friction blocks are used for energy dissipation either independently or in conjunction with stilling basins. Because of the flow separation from the face of these blocks cavitation damage occurs to the edge of these blocks. Several cases of pitting due to cavitation at the baffle piers are reported such as Bonneville dam in U.S.A. Cavitation being a local phenomenon, the pressure fluctuation at a point due to turbulence may be more significant than the average pressure itself. Knowledge of the amplitude and frequency of pressure fluctuations caused by turbulence enables the determination of locations of cavitation region. The pressure fluctuations are reported to be maximum on the sides of baffle piers just downstream of the leading edge. The greater the drop of pressure below zero and the greater the percentage of time that the pressure is below zero, the more severe is the cavitation likely to be.

(viii) *Due to vibrations* :

Many hydraulic structures have failed due to severe vibration because of cavitation.

Bhakra dam tunnel outlet gate failed causing considerable damage. While trying to operate the gate of the tunnel outlet, the gate got stuck up and gate cavitation occurred. When it was forced down by external force, it could not be closed. Gates and gate structure started vibrating due to severe cavitation and resulted in blowing up of the roof of gate chamber.

In the Panchet dam above Poona City, a conduit outlet was partially opened. The high velocity flow struck the roof of the conduit and resulted in cavitation. It produced severe vibration in the embankment. The new embankment absorbed a lot of water. Saturation of the soil and the severe vibrations caused settlement of the bank and it was over toppled. If the gate had been completely closed or completely open, this would not have occurred.

In Krishnarajasagar dam also, the sill of the gate has been reported to be damaged due to vibrations when the deep level sluice gates got stuck up while lowering.

VI. PREVENTION OF CAVITATION DAMAGE.

In most of the cases either it will not be possible to design a cavitation free structure or it may not be economic to go in for a cavitation free structure. Therefore the delliterious effects of cavitation erosion are taken care of by any one of the following methods allowing cavitation to take place: —

1. By constructional changes of structures and their components.

2. By giving smooth finish to the surface. Surface irregularities form favourable locations for cavitation.

3. Protecting the surface by cavitation resistant materials.

4. Use of cavitation resistant materials.

5. Injection of air into low pressure regions.

Spillway dams may be of angular profiles with the free falling stream partially separated from the spillway, or those having rounded crests and inclined upstream sides, or spillway dams with very smooth profiles having parabolic shape and those with vacuum profile. The presence of vacuum zones in the first three types is undesirable while it can be permitted in vacuum profile after due model studies.

Siphons are spillway structures operating with very high vacuum. It is necessary to provide adequate air supply system. All the construction must be smooth and streamlined with no misalignment. It has been established from experience that surface irregularities such as voids roughness, change of alignment, protrusions and abrupt off-sets can cause cavitation damage in regions of high velocity flow. A careful control of concrete surfacing and use of high strength concrete would prove better against cavitation damage. It is preferable to use smaller aggregate particles near the surface and this would provide better wearing surface.

The mechanical properties of concrete depend on type of cement, water/cement ratio, composition, quantity and quality of aggregates and mixing of concrete. Cavitation damage is inversely proportional to its compressive strength. Reduction of water/cement ratio likewise increases the resistance to cavitation erosion.

Though steel plates have been tried as lining material, they are often torn away due to cavitation. A simple painting of concrete surface with two layers of 50 per cent epoxy varnish over a base coat of epoxy varnish increases the resistance of concrete to cavitation erosion by three to five times. However in the case of metal surfaces epoxy coatings proved less effective while rubber, nyrite and other rubber-like materials adhere fairly well to metals and are highly resistant to cavitation. But these rubber based materials have very poor adhesion to concrete and therefore can not be used with concerte. A neoperene compound applied with a brush to achieve 70-ml. thickness at the rate of two mils for each application with a waiting period of up to two hours between each is reported to have withstood cavitation in laboratory studies.

In tunnels and closed conduits, intake structures with gates, transition section, tunnel section and exit portal must all be properly aligned and extensive model experiments would only show the possible vacuum zones. In the case of energy dissipators, the baffle piers are often damaged due to cavitation. If the corners are rounded off to avoid cavitation, the piers become less effective in dissipating energy. Injecting water or air into the vacuum zones in the baffle piers is reported to be most effective in improving cavitation characteristics of baffle piers. In stilling basins with steps, the damage du to cavitation can be avoided by replacing steps by paved rampes to give a smooth flow. Also protective linings at the corners reduce the damage. The baffle piers are to be located as far downstream possible to take advantage of the cushioning effect of tail water.

Cavitation in gates refers to cavitation erosion to gate itself, to gate slots and cavitation erosion beyond the gate conduit walls and floor. The partial opening has been observed to be the major cause for cavitation damage in gate structures as is evident from the case studies. Special air chamber beyond the gate is necessary to admit air into the vacuum zones. Experiments show that the shape of the gate lip has no effect on the tendency of vortex type cavities to move down the slot. It is established that there is the dependance between the width of flow separation region behind the slots and the erosion intensity. The presence of leakage through the gap between the seal and sealing surface causes the cavitation which in turn erodes the seal and sealing surface. Improvements of dynamic characteristics of flat and radial gates, especially because of separation of vortices from gate bottom edge at partial openings can be achieved by using a stabilizer connected with bottom edge of the gate by means of a hinge. It enlarges the stream lined surface. Set in working position by flow itself, it increases the pressure in the throat (Figure 6).

Aeration of the wall boundary layer has been found to be a very effective method of protection of hydraulic structures against cavitation. The under portion of the nappe falling over a spillway surface is to be aerated sufficiently to prevent the periodic breaking vacuum to avoid severe vibrations.

VII. *Conclusion :*

The phenomenon of cavitation and its delitereous effects on hydraulic structures have been explained. The possible locations of cavitation in hydraulic structures have been in identified from the case studies discussed. Precautionary measures to be observed in the design and execution of hydraulic structures to avoid cavitation and if it is allowed to occur remedial mesures to prevent cavitation damage have been detailed at length.

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F.P.S. Unit. (1)		*Metric unit.* (2)
4 feet	..	1·22 m
8 ,,	..	2.44 ,,
11 ,,	..	3.35 ,,
18 ,,	..	5.49 ,,
22 ,,	..	6.70 ,,
23 ,,	.	7.01 ,,
30 ,,	..	9.14 ,,
36 ,,	..	10.97 ,,
37 ,,	..	11.28 ,,
49 ,,	..	14.93 ,,
64 ,,	..	19.51 ,,
146 ,,	..	42.67 ,,
150 ,,	..	45.72 ,,
200 ,,	..	60.96 ,,
225 ,,	..	68.58 ,,
303 ,,	..	92.35 ,,
355 ,,	..	108.20 ,,
500 ,,	..	154.40 ,,
1120 ,,	..	341.38 ,,

F.P.S. Unit. (3)		*Metric Unit.* (4)
5' × 9'	=	1.52 m × 2.74 m
10' × 20'	=	3.05 ,, × 6.10 ,,
200000 C/S	=	5663.4 cu.m/Sec
13500 ,,	=	382.27 cu.m/Sec
1/16"	=	1.6 mm
½"	=	1.27 cm
50'/Sec	=	15.24 m/Sec

FEW HINTS FOR EXTENDING THE SCOPE OF IRRIGATION WORKS IN PUBLIC WORKS DEPARTMENT.

By Er. K. ETHIRAJAN, B.E. *

In these advancing days of the world, it becomes very important that the water sources in our State are to be utilised in the most efficient and scientific manner, to achieve our full satisfaction of social and economic needs. Further, the quantity of water that is being obtained from all the available sources (Surface and sub-surface) is rapidly diminishing which has now lead to the scarcity of water. In some of the districts, the ground water table is receeding too deep by 10'—15' every year and even that available water is unsuited for use, as it contains much of dissolved salts and other impurities. Thus, time has come to introduce us to treat the water as "*Economic goods*".

As regards to the Irrigation, now, we are able to irrigate only 27 per cent of the available ayacut area by all the surface as well as ground water sources and the rest go as rainfed. On the other hand, the rapid advancements in the Green revolution introduce new and better specis of foodgrains with different soil and water requirement: the crop period, the behaviour of the plants of the crop in consuming water and soil nature are studied and different results arrived quite often with the aim of producing more of foodgrains with minimum land labour and capital investments in the shortest duration instead of the conventional period of 4 to 6 months. This necessitates the Irrigation Engineers to study and improve or develop the methods of irrigation, type and duration of various crops, the water requirements of various crops at their different stages of plant life, the new methods of cultivation of crops and soil water relation in an elaborate and efficient manner in respect of irrigation aspects.

Apart from the above facts, the careful distribution and utilisation of water from all its sources increase the efficiency of water use management. Further, an elaborate study on the losses of water in Irrigation, viz., evaporation, percolation, transpiration and transmission by the Water or Irrigation Engineers will help to increase the revenue to a large extent. This is an ideal fact when on one understands that out of the total water supplied to the crop fields by irrigation that required for the metabolism in the plants of the crop is to the extent of only 1 percent and the rest of the irrigation water is lost by (i) transpiration through the plants themselves to the extent of 80 per cent and (ii) by percolation and evaporation to the extent of 19 per cent. Fortunately for us, there are many Dwarf varieties of crops (from paddy to coconut) which minimise the Transpiration loss through their stem and foliage. (the stem and foliage are much less in the Dwarf varieties). Moreover, minimising the Transpiration loss goes behind the field of Agriculture which is successfully tackling this task. Now it becomes responsible on the part of irrigation Engineers to study the percolation and evaporation losses of irrigation water and to minimise the same to save the water from going waste.

In Western countries, advancements are introduce in the field of irrigation and Agriculture, to the extent that the evaporation loss is minimised or even completely arrested by covering the whole field of the crops with polythene sheets, reserving sufficient opening for the growing population of the crop. Similarly, the water use efficiency is so high to the effect that a sub-surface irrigation, i.e., tapping the water (conveyed through porus drains upto the root system of each plant of the crop) exactly at the root zone of each plant of the crop, without the loss of even a drop of water, by way of percolation and evaporation is carried out.

From all the above facts, it is well established that the responsibility of the Irrigation Engineers is more to study the main factors affecting Irrigation, viz., (1) Rain and Atmospheric changes (Temperature, relative humidity) (2) Variation in the water holding capacity of soils, (3) soil moisture regime concept and to bring the losses and wastages of irrigable water under control and putforth maximum efforts and use all known knowledge to increase the efficiency of water use management in collaboration with field of Agriculture. An intensive study and revision of the duty of water which mainly depends on soil texture, relative humidity, losses of irrigated water, rate of consumption of water by the different crops etc., for irrigation shall also keep the water use management in its highest efficiency.

The water holding capacity of the soils in the different parts of our State and the soil moisture regime concept mainly depend on the soil texture. Thus it becomes inevitable that the soils in the different parts of our State should be thoroughly studied for purposes of irrigation and water use management to decide their textures apart from their fertility. The whole state may be divided into different zones of different soil textures and the like properties and corresponding charts may be prepared for each and every zone so that the above said method of irrigation, Type and duration of crops to be adopted, Method of cultivation in the Zone, the water holding capacity and the net water requirement for the crop at its different stages at different seasons, losses of irrigated water in that Zone etc., can be readily known. This will also lay a guide path to the future generations to advance in the field of Irrigation in collaboration with the other departments like Agriculture. This work of soil study and demarcating the whole State according to the soil classification in respect of irrigation may be entrusted to special staff of the Public Works Department trained for the purpose as in the Ground Water Directorate, which is meant for investigating ground water potential.

Similarly, the intensive study on the Duty of water for irrigation for different crops in the different seasons or periods over the different zones of soil texture in our State must be done. The duty of water that is being adopted now 6 and 7½ acres/m.cft. for paddy crops uniformly seems to be much less while a higher duty of about 120 acres/cusec (highest) in clayey soil in the Cauvery river system around Nagamangalam area in Thanjvur district is arrived at by repeated research wotks by the Agriculture Department of our State. This aspect of irrigation can also be entrusted to such special staff.

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RESEARCH AND DEVELOPMENT OF WATER RESOURCES IN INDIA.

(SECOND BHARAT RATNA DR. M. VISVESAVARAYA MEMORIAL ENDOWMENT LECTURE, INSTITUTE OF HYDRAULICS AND HYDROLOGY, POONDI, DELIVERED AT MADRAS.)

BY

D. DODDIAH *

Prelude

Mr. President and brother Engineers,

I am greatly indebted to Bharat Ratna Dr. M. Visvesavaraya Memorial Endowment Committee for having invited me to deliver the second lecture. It was very kind and thoughtful of the Committee to have conferred this honour on a humble research worker. When I remember that the author of the first lecture, Shri J. I.Coilpillai was also connected with research for some years, I feel that the Committee, as is not uncommon with Tamil Nadu, appears to have struck a new line in bestowing this privilege.

This privilege is of special significance as the occasion is connected with name of a unique personality, an eminent son of India. Dr. Visvesavaraya was the embodiment of all the good qualities in man that are emulative. His industry, punctuality and discipline have become proverbial. Above all, whether in statesmenship, administration or engineering he was a great experimenter. The uniqueness of his experiments was that they combined both research and developmental activities in one step which many would hesitate to undertake. Whether in the design and construction of engineering works, expansion of education or promotion of industries, his experiments were characterised by originality, boldness and success. By way of paying my homage to this unique and bold experimenter I thought it appropriate to speak to you on " Research and Development of Water Resources for Irrigation in India ".

INTRODUCTION.

The demand for water is always on the increase. It is required in a greater measure not only for agriculture but also for power, industries, urban needs, recreation, etc. There is, therefore, a greater and more urgent need to keep under constant consideration all problems relating to water resources.

Appreciable development has already taken place during the plan periods stepping up the potential from surface water resources from 17 to 37 per cent upto end of 1968–69. Greater efforts are required to utilise the remaining quantity. There is a paramount need, however, to consider whether the potential created is being put to optimum use. Optimum utilisation involves two important aspects : one deals with the use of maximum possible quantity out of the potential created and the other refers to its use to realise the maximum benefits. So optimum utilisation connotes maximum utilisation to get maximum benefit. To achieve this, the entire gamut of water management has to be kept in view.

Water resource may be available in a form or condition that it may be readily used for irrigation or other purposes or it may require modification. The water that is so conditioned to make it usable may be considered to have augmented the available supplies in any particular locality or country. A stage has been reached in this country also when attention has to be paid to reaserch and development projects towards such increase in water-supplies.

An attempt has been made in this paper, in so far as it relates to irrigation, to deal with the quantum of water resources available, current level of development and utilisation and augmentation of fresh water-supplies.

WATER RESOURCES OF THE WORLD.

The water resources of the world can be broadly divided into three categories, those available in air, on the surface of the earth and underground. The resources are apparently in plenty as indicated in Table 1, but the small percentage of these resources that are readily available for use and its uneven geographical distribution call for all the ingenuity of man for its proper management.

It may be observed from the table that 97·13 per cent of the worlds' water-supply is in the oceans. Of the remaining 2·87 per cent, 2·24 per cent consists of polar ice caps and glaciers. Saline lakes and inland seas account for 0·008 per cent and readily available surface water constitute only 0·0091 per cent of total world supply.

While the total sub-surface waters constitute 0·61 per cent of world's supply of water, about half of this, at depths more than 0·75 kilometre may be assumed either as inaccessible or saline leaving 0·30 per cent available for use. Available or accessible surface and sub surface waters form therefore about 0·32 per cent of the world's water supply. It is interesting to note that sub-surface water accessible for use, without any treatment constitutes 33 times the surface waters.

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TABLE 1.

DISTRIBUTION OF THE WORLD'S ESTIMATED SUPPLY OF WATER.

Location.	*Surface area in 10^6 ha.*	*Volume of water in milliard cu. m.*	*Percentage of total.*
(1)	(2)	(3)	(4)
World-Total area	51,023	..	100
Oceans	36,130	..	70·8
Land	14,893	..	29·2
Atmospheric moisture	..	13	0·0001
Oceans of the world	..	13,21,256	97·13
Surface water on the continents	..	..	..
Polar ice caps and glaciers	1,787	30,463	2·24
Fresh water lakes	85	125	0·009
Saline lakes and inlald seas	70	104	0·008
Average in rivers and streams	..	1·2	0·0001
Total Surface water	1,942	30,693	2·26
Sub-surface water on the continents—			
Root-zone of the soil	12,950	25	0·0018
Ground water above depth of 0·75 kilometre.	..	4,168	0·306
Ground water between 0·75 and 4·0 kilometre.	..	4,168	0·306
Total Subsurface water	12,950	8,361	0·61
Total water on the land	..	39,054	2·87
Total world supply of water	..	13,60,323	100

INDIA'S SHARE OF WORLD'S WATER—SUPPLY.

Surface waters

India is the seventh largest country in the world with an area of 3·276 million square kilometres or 327 million hectares. The annual rainfal over the entire country repesents something more than 3,700 milliard cu·m. of water. Of this amount about 1220 milliard cu.m. are lost immediately due to evaporation. The flow in the river systems is estimated at 1,675 milliard cu.m. Utilisable flow is reckoned at 550 milliard cu.m. annually (Table 2)

Ground Waters

On the basis of the geographical area, India's share of ground water supply in the upper 0·75 km. of the earth's mantle is about 92,363 milliard cu.m. It has been estimated that out of 3,700 milliard cu.m. of rainfall 800 milliard cu.m. of water seeps down annually, about 430 milliard cu.m. gets absorbed in the top layers thereby contributing to soil moisture which is essential for the growth of vegetation. The remaining 370 milliard cu.m. constituting an average of 10 percent of precepitation percolates down into porous strata and represents the annual enrichment of ground water. The total storage underground at any time is therefore several times this amount and can be assessed correctly if a country wide investigation is undertaken.

POTENTIAL ALREADY CREATED.

Surface Waters

India has more than one fifth of the world's irrigated area and leads the rest of the world in the field of irrigation. With diverse physiographic and climatological, regions coupled with the vagaries of monsoons, agricultural production in the country can rest on a firm basis only by assured supplies of waters for irrigation. When India

TABLE 2.

INDIA'S ESTIMATED SUPPLY OF WATER AND UTILISATION.

Details.	*Surface area in 10^6 ha.*	*Volume of water in milliard Cu.m.*	*Percentage of total.*
(1)	(2)	(3)	(4)
Land area-World	14,893	..	..
Land area-India	328	..	2·2
Culturable area..	181	..	..
Area under cultivation	156·6	..	..
Area that can be irrigated	82	..	..

Details.	*Surface area in 10^6 ha.*	*Volume of water in milliard Cu.m.*	*Percentage of total.*
(1)	(2)	(3)	(4)
Area irrigated (1950–51)	22·7	..	..
Area irrigated (1968–69)	37·7	..	..
Total yearly rainfall	..	3,700	..
Yearly flow in the river systems	..	1,675	..
Yearly utilissable flow in the river systems	..	550	..
Utilisation in 1950–51	..	93	..
Utilisation in 1968–69	..	205	..
Groundwater above a depth of 0·75 Km. ..	..	92,363	..
Groundwater between 0·75 to 4·0 Km. ..	..	92,363	..
Total ground ater	..	1,84,726	..
Natural recharge assuming 10 per cent of annual rainfall.	..	370	..

Entered upon an era of planned development in 1950 it was well recognised that the foremost requirement in rebuilding agricultural economy of the country was by large scale development of irrigation and power ; irrigation therefore, occupied the pride of place in the planned development. At the beginning of the plan period, the area under irrigation from all sources in the country amounted to 22·66 million hectares, 9·71 million hectares from major and medium projects and 12·95 millions hectares from minor irrigation works. The additional irrigation potential created from major and medium sources was 2·49 million hectares in the first plan, 2·14 million hectares in the second plan, 2·23 million hectares during the third plan and 2·02 million hectares during the annual plans 1968–69 bringing the total to 8·88 million hectares up to end of 1966–69. During this period minor schemes created an additiona. potential of 6·15 million hectares.

When the planning was started in 1951, only about 93·0 million cubic metres out of the utilised qulality of 500 milliard cu.m. had been utilised to develop an irrigation potential of 22·66 million hectares. This was only 17 per cent of the estimated utilised resources. By the end of March 1969, this percentage is estimated to have reached 37 per cent with the total utilization of 205·0 milliard cu.m. Assuming that 550 milliard cu.m. is all that is capable of being utilised, there still remains quite a substantial quantity of water to be hardnessed. It will be seen that while the increase in area was 19 per cent of total potential, the utilisation of water increased from 17 to 37 per cent i.e., 20 percent increase against 19·0 per cent increase in area.

During the above decades of planning, 537 major and medium schemes were taken up for construction. Of these over 300 schemes were completed in the sense that full potential has been created already. The remaining schemes are continuing into the Fourth Plan.

The total anticipated outlay in all the major and medium irrigation projects is about Rs. 17,557 million. The increase in foodgrains was from 54·92 to 94·00 million tonnes both from irrigated and non-irrigated areas (1968–69).

Groundwater.

The actual utilisation of ground water at present is estimated at less than 25 per cent of the annual increment due to precepitation. A reference to the statistics (Table 3) collected by the Directorate of Economics and Statistics, Government of India, on the extent of ground water irrigation in different states in the country during 1968–69. indicates that the percentage area irrigated with ground water in terms of total area irrigated varies from 0·4 in Jammu and Kashmir to 59 in Maharashtra.

A reference to the data collected (Table 4) in respect of southern states of Andhra Pradesh, Kerala, Tamil Nadu, Maharashtra and Mysore which are predominantly made up of hard rocks indicates that Tamil Nadu at present utilises about 27 per cent of annual recharge while in Kerala the utilisation is almost negligible.

All these indicates the urgent need for greater utilisation of at least the annual recharge.

TABLE 3.

AREA IRRIGATED WITH GROUND WATER IN DIFFERENT STATES IN INDIA (1966–67).

States.	*Total cropped area in 1,000 ha.*	*Net irrigated area in 1,000 ha.*	*Area irrigated with ground water in 1,000 ha.*	*Area irrigated with Ground water Expressed as per cent of.*	
				Cropped area.	*Irrigated area.*
(1)	(2)	(3)	(4)	(5)	(6)
1 Andhra Pradesh	12,676	3,070	456	3·6	15·0
2 Assam	2,853	612	..	..	..
3 Bihar	9,225	1,601	387	4·2	24·0
4 Gujarat	10,188	1,041	866	8·5	82·7
5 Haryana	4,599	1,293	290	6·3	22·4
6 Jammu and Kashmir	857	288	88	0·1	0·4
7 Kerala	2,622	393	5	0·2	1·3
8 Madhya Pradesh	18,336	1,089	367	2·0	34·1
9 Maharashtra	18,973	1,230	721	3·8	59·0
10 Mysore	10,467	1,022	178	1·7	17·4
11 Nagaland	49	12	..	..	..
12 Orrissa	7,446	977	648	8·7	66·3
13 Punjab	5,171	2,276	982	19·0	43·1
14 Rajasthan	15,447	2,121	1,236	8·0	58·5
15 Tamil Nadu	7,305	2,511	643	8·0	25·5
16 Uttar Pradesh	22,082	6,225	3,268	14·8	52·4
17 West Bengal	6,653	1,478	13	0·2	1·1
18 Himachal Pradesh, Manipur, etc., and Union Territories.	1,687	245	33	1·9	13·2

TABLE 4.

UTILISATION OF GROUND WATER IN SOME SOUTHERN STATES IN INDIA.

State.	*Amount of annual re-charge in milliard cu.m.*	*Present annual draft in milliard cu.m.*	*Percentage utilisation of ground water.*
(1)	(2)	(3)	(4)
Andhra	24·67	4·40	18
Kerala	11·72	0·005	04
Tamil Nadu	15·90	4·28	27
Maharashtra	24·42	4·205	17
Mysore	18·26	1·270	7

FUTURE REQUIREMENTS.

Requirements by the end of 1971–81

To meet the needs of food and other agricultura products of the growing population, irrigation facilities have to be increased. A long-term perspective planning is necessary to enable advance action to be taken for detailed investigation and timely sanctioning of projects. Accordingly, the Ministry of Irrigation and Power has prepared a decade plan for the period 1971–81 on the basis that the population at the end of the decade will be about 650 million and the additional food requirement will be 55 million tonnes. Of this, 26 million tonnes are expected to be available from improved seeds. agricultural practices, etc. Nine million tonnes are expected from targeted expansion of irrigated areas in the period 1971–74. Of the balance of 20 million tonnes, it is assessed that 12 million tonnes will have to come out of additional irrigation facilities to be created under major and medium irrigation projects. This requires an incarease in the irrigated area of about 8million hectare For adding this area an outlay of Rs. 2,250 crores will be required.

Requirements by 2,000 A.D.

Dr. K. L. Rao, in a masterly analysis of " The Demand Patterns of India of Tomorrow " has indicated that by 2,000 A.D. 70 million hectares would have to be brought under irrigation against about 37·7 million hectares under irrigation at the end 1968–69. Of this 40 million hectares would come under major and medium and 30 million hectares under minor irrigation due to surface and sub-surface extractions. This indicates that tremendous efforts are required to achieve the target. From the figures furnished in the paper, it is seen that there would not be any increase in the sown area.

It is further indicated in the paper that with the completion of all the irrigation projects, it will be possible to produce 120 million tonnes of foodgrains but this will have to be stepped up to by 50 to 100 per cent by double cropping, improved methods of cultivation, use of fertilisers and other modern agricultural practices.

Management of Irrigation Potential Created.

Proper management of water stored, diverted or extracted from ground water calls for sustained inter-diciplinary endeavours. An irrigation system can be divided into three distinct parts—storage reservior conveyence system and the area to be irrigated. There are several factors that affect proper management of water from the system.

Losses from the system :

Water when stored in the reservoir, while conveyed by the canal system and finally spread over land to feed the crops suffers loss from evaporation and seepage. Inadequate maintenance of, and lack of proper control in the distribution of water from the conveyance system, improper preparation of land and unscientific method of application of water on to the land help to increase these losses.

Losses from the storage Reservoir :

The stored water sufferd loss on account of evaporation and seepage. Apart from numerous climatological and other factors, evaporation is affected by the extend of water-spared at different levels. Of two reservoirs, which store the same quantity of water one might suffer greater loss due to evaporation than the other because of the configuration of the water-spread.

In arid tropical regions, where water is more scarce evaporation may amount to as much as 375 cms. a year On reservoirs in South-West Africa, evaporation losses were found to range from 200 cms. to 250 cms. 250 cms being recorded at kimberley and 145 cms at Cape Town. In East Africa losses generally amount to 120 to 240cms. of water according to the locality and may be as high as 300 cms. In Australia the normal loss by evaporation is four times the consumption. In Krishnarajasagar in Mysore State, India, elaborate data collected indicate that 11 per cent of the live storage is lost by evaporation. From the extensive studies carried out in India and abroad, it is clear that evaporation losses in a year could be anywhere from 1·25 to 2·5 m. water or more from the exposed water surface.

Seepage from a reservoir cannot be estimated accurately. It may not be as important as the loss due to evaporation. Roughly minimum loss due to evaporation and seepage may be taken as 10 per cent of stored water. Losses from the existing storages may therefore be of the order of several million cubic metres.

Sedimentation in Reservoirs :

The storage suffers loss from the day a reservoir comes into operation because of the sediment that is brought in by river or rivers across which the reservoir has been formed. The factors that generate sediment in the catchment area of the reservoir, its transportation to the reservoir and its entrapment therein require serious consideration when a reservoir site is fixed up.

The Nizemsagar reservoir in the state of Andhra Pradesh which was completed in 1939 and by 1969 lost 97·11 per cent of its dead storage capacity, i.e., the capacity specially earmarked for the deposition of silt that is expected to be received in the reservoir and 44·97 per cent of its live storage capacity, i.e., capacity which is utilisable year after year for irrigation. In eight major reservoirs for which hydrographic surveys have been completed under research schemes sponsored by the Central Government through the Central Board of Irrigation and Power, the rate of sedimentation is very much more than what is generally assumed. These and other studies in this field, have given rise to intensive thinking on the need for measures to minimise siltation in the reservoirs.

An earlier conception was that if enough storage space in a specified part of the reservoir is set apart for all the sediment that is likely to be brought and deposited, the project would be able to serve its purpose or purposes for any period that one desires. This conception has now undergone a change on the basis of actual observations of the deposition of silt in the reservoir area.

One is therefore interested not only in the rate of silting of the reservoir but also in the pattern of silt deposition in the water-spread area. Further, a knowledge of these tow aspects is not the end but perhaps the beginning of several enquires to be made and the resulting questions to be solved. Such enquiries relate to the possibility of reducing the rate of silting, changing the pattern of siltation, effect of the pattern of siltation on the design criteria and the most important, possibility of foretelling from a knowledge of the conditions of the existing reservoirs, research studies, etc., the rate of silting and the pattern of siltration of the reservoirs that are proposed to be built.

The reservoir is the fountain head of the irrigation system. Non-impairment of its live storage for as long a period as possible should be of primary concern.

Losses in the Conveyance System :

The conveyance system specially in the case of major irrigation works may aggregate in length to several hundred kilometres traversing different terrain crossing tens of natural drainages and studded with masonry works of various types. Losses during transmission comprises of evaporation from water surface, secpage through bed and sides of the canals and leakage through canal structures. Weeds may be responsible for considerable loss of water. Uncontrolled distribution and lack of proper maintenance also contribute to avoidable losses. A broad-based assumption of these losses and of eventual utilisation of canal supplies in different countries of the world indicates that about one-third to half of all the water diverted for irrigation is lost in conveying it to the fields and farms. Based on extensive observations, transit losses in the alluvial planes in Utter Pradesh and Punjab in India are taken at 45 per cent . Allowing about 20 per cent of this transit loss for evaporation, the loss due to seepage alone is as much as 36 per cent of the supply entering a canal head. Thus out of 100 units of stored water only available at the head of canal, 10 having been lost in the reservoir. Of this 90 units, evaporation accounts for 8 units and seepage percolation, etc., take a total of 32 units, the total of 40 units constituting 45 per cent of 90 units.

Losses from the Irrigated Area :

As water is applied to the land there will be further unproductive losses due to seepage, evaporation and wastage as overflow from the fields. This is estimated to be about 30 per cent of the quantity that reaches the fields that is about 15 units out of 50 reaching the field.

The seepage losses from the fields depend largely on the permeability characteristics of the soil, mode of supply and irrigation practices.

Summarising, out of every 100 units of water stored for irrigation, about 18 units are lost due to evaporation, 47 by seepage and other causes and only 35 units are used for production of crops. (Table 5) Minimisation of these losses calls for great efforts.

Suppression of Evaporation

From Reservoir Water-spreads :

Investigations have been carried out for quite some time with solutions of long chain alkanols which while being insoluble in water, spread over water surface forming a mono-molecular film. These studies were carried out first in Australia, and then in U.S.A., Africa, United Kingdom and Japan. In India for the last few years, both laboratory and field stupies have been conducted.

TABLE 5.

EVAPROATION, SEEPAGE, ETC., IN AN IRRIGATION SYSTEM.

Component of the irrigation system.	*Quantity to start with in units.*	*Evaporation in units.*	*Seepage, etc., in units.*	*Bclauce.*
(1)	(2)	(3)	(4)	(5)
Reservoir	100	8	2	90
Conveyance system	90	8	32	50
Irrigated area	50	2	13	35
		18	47	

In Delhi Madras and Mysore under a scheme of basic research. Though evaporation loss can be reduced by 80 per cent under laboratory conditions, field studies, however, indicate a reduction of 15 to 20 per cent only. Disruption of the film by wind remains a serious and unsolved problem with alkanols.

Alkanol films reduce evaporation by acting as a physical barrier to vapour transfer. With the suppression of evaporation, the water temperature increases. When the film is disrupted, the rate of evaporation from the treated water surface exceeds that from an untreated surface.

Floating materials which reflect incoming radiation appear promising as a means of reducing evaporation. Reflection of radiation reduces water temperature which results in lower evaporation rates. Promising results have been obtained by the use of foamed plastic cellular material such as expanded perlite ore and hydrophobic calcium carbonate dust.[11]

From irrigated Area :

Because of the vastness of the area, it is difficult to control or restrict evaporation from the soil surface. Research studies are, however, being carried out to find out the possibilities in this direction. In some of the laboratory studies, it has been found that evaporation from soil mixed with cetyl alcohol indicated reduction. The concentration used was equivelant to about 62 kg/ha.[12]

In another study carried out with a few typical soils like the Delhi alluvium, the black cotton soils of Poona and sand, the film of cetyl alcohal was able to reduce evaporation by 27 to 82 per cent.

Laboratory studies in Japan show that the evaporation from the soil surface can also be retarded by the multi-molecular film of OED. The evaporation is reduced by 30 per cent by the emulsion in the dosage of 2 gr./m^2 by 50 per cent in 7 gr/m^2 and 70 per cent in 20 gr/m.^{2}

The water lost by growing plants during their life cycle is many times more than the amount of water lost through the soil surface. Any reduction of transpiration losses therefore helps to save the water consumed. It has been found that corn plants, jower and sunflower grown in soil enriched with cetyl alcohol showed lesser transpiration rates than those growing in untreated soil.

Studies in Japan have also indicated that OED 70, emulsion, even in very thin concentration such as 0·10 per cent easily sticks and covers the plant leaves and causes a reduction in transpiration loss. It was found that in an experiment with citrus trees, transpiration from the sprayed trees was reduced by about 20 per cent even with 0·1 per cent concentration. Duration of the effectiveness of the film was over three months, indicating that the fixed film was fairly stable.[14]

The information given in the above paragraphs indicate that there are possibilities of reducing lossess due to evaporation and even transpritaion but semi-field and field trials are necessary before adoption of the measures on a large scale.

Minimising Seepage Losses.

Of all the losses, those due to seepage are more amenable to be dealt with at the present time. The most effective method for this purpose in the conveyance system is by lining. The conservation of existing water supply alone may provide ample justification for taking steps to control seepage losses. In addition, however, there are several other well known benefits that can be considered.

Typical economic studies of lined and unlined canals of U.P. in India indicate that on the basis of construction alone, the lined canal may cost nearly 3·25 times as much as unlined canals. But taking the value of water loss due to seepage, the unlined canal costs about 1·08 times as much as the lined canal, even, when the saving in maintenance charges and prevention of water logging are not accounted for. If these and additional agricultural production are also taken into account, the lining is justifiable on many of the projects.

There is a constant search for low cost lining materials. Recently studies in U.S.A. with chemical sealants have shown great promise. There are two varieties of sealants (a) sediment sealants with clay or bentonite and (b) chemical sealants which may be water-borne sealants sprayed in places or injected surface sealants.

MENACE OF WEEDS AND PHREATOPHYTES.

Weeds and phreatophytes transpire tremendous quantities of water from canals, reservoirs and ground water table into dry air. They cause reduction in the carrying capacity of canals, sedimentation and damage to canal banks. They aggravate waterlogging of adjacent lands and alkaline conditions on farm lands.

Weeds and Their Eradication.

Aquatic weeds grow sub-mersed in, floating on or emergent from the water in irrigation and drainage canals, in reservoirs and in farm ponds or tanks. Bank weeds grow at the waterline or immediately above with their roots extending into saturated or moist soil.

The problem of weeds is like a creeping disease which, if not controlled at the right time, may assume very menacing proportions in irrigation systems. The removal of weeds by manual labour can at best be adopted on a limited scale and is a temporary remedy. Mechanical control also is not a permanent measures. The control of weeds with the application of herbicides appear to be cheaper. Bilogical methods are cheaper than others but they are still in an experimental stage. The research work in India on eradication of weeds requires to be increased severalfold specially on herbicidal and biological studies.

It is very necessary, that the possible menace of weeds is considered seriously even at the state of planning an irrigation Projects. In connection with the problem of weeds in the multipurpose water resource projects in the Lower Mekong Basin, Laos-Thailand, the U.S. Agency for international Development requested the crops of Engineers U.S.A. " to assess the anticipated problems, evaluate present methods of dealing with these problems and make design and research recommendations ". One of the recommendations[16] of this committee is that research should be carried for at least ten years with an annual expenditure of $200,000.

Phreatophytes and Their Control.

Phreatophytes are somewhat different from aquatic and bank weeds as regards both the nature of the problem and the methods of control. Phreatophytes are notoriously heavy users of water. Most of them grow best when the groundwater table or capillary frings above it is only 2 to 3 m below the surface . Some will extend the roots 5 to 6 m deep and even 30 m to reach water.

Along a 64 km. stretch of the Gila River flood plain in Arizona, the U.S.G.S. found that phreatophytes consumed 34·60 million cu.m. of water from 3,766 of land in a 12 month period, an average of about 9200 mi.cu.m. of water per hectare. In an area with dense growth of salt cedar, the loss is estimated at 15440 mi.cu.m.per hectare.

Most of the weedy phreatophytes are heavy sprouters, Root and crown sprouts which develop after mowing buldozing, disking, sawing off, grubbing or burning usually grow 2 to 2·5 m in the first year. Mechanical treatment must be repeated one to three times each year to maintain control. Some phreatophytes can be controlled effectively by 2, 4-D at rates of 1·1 to 3·4 Rg. per hectare.

USE OF CLOSED CONDUITS.

Possibility of using closed conduits for conveying water for irrigation requires to be studied. It may be remembered that almost the entire seepage and evaporation losses in the conveyances system may be saved by the adoption of closed conduits.

The conveyance of water from the government outlet to the fields is though field channels excavated in earth and very often poorly aligned. Considerable quantity of water is lost in these field channels. Besides loss of water by seepage through the field channels, the crops in the lands adjacent to them also suffer damage. When it comes to the question of rice irrigtion, the irrigation is very often from field to field which means the fields near the outlet get over-irrigated and the fields further away suffer from nsufficient irrigation. So studies have got to be mad as to how bestthe water could be conveyed to the individual fields, the alignment to be adopted, to what limits the field channel should be taken and the type of lining that should be used so that seepage could be minimised.

ACCOUNTING OF IRRIGATION WATER.

As basic information for initiation of suitable measures to minimise losses in the conveyance system is a correct knowledge of the losses themselves, it is necessary that the whole conveyance system is provided with measuring devices to find out the whereabouts of every cubic metre of water that is let into the conveyance system. Every efforts should be made by the design and research engineers to make use of canal structures as measuring devices specially the irrigation outlets.

BETTER METHODS OF IRRIGATION.

Some countries are giving greater attention to sprinkler and trickler irrigation methods. Experimènts on these will have to conducted in our research stations their economics studied and reported upon.

WATER REQUIREMENTS OF CROPS.

It would be quite necessary to study also the water requirements of crops. New high-yielding varieties are being evolved from time to time and so the study will have to be practically continuous. The quantity of water that is needed and the critical time at which it should be applied should all be known. As our water resources are limited and as we desire to utilise the waters that are available to secure the maximum benefit, a very

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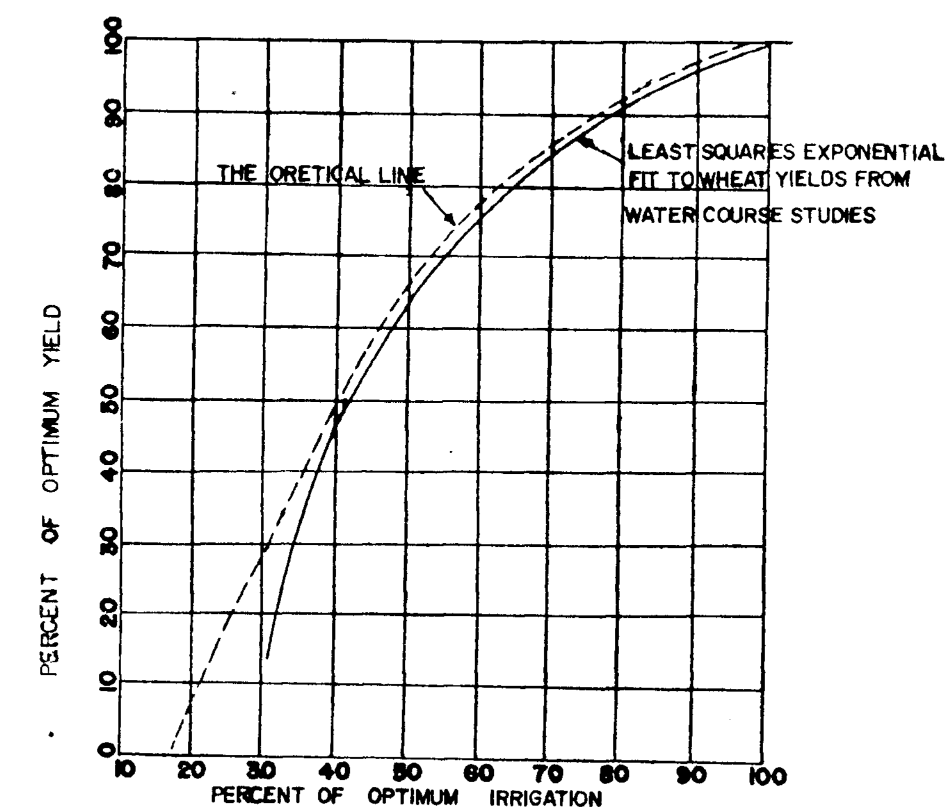

RELATIONSHIP BETWEEN YIELD & IRRIGATION

EXTRACTED FROM "WATER AND POWER RESOURCES OF WEST PAKISTAN" VOL.II BY A WORLD BANK STUDY GROUP JOHNS HOPKINS PRESS BALTIMORE

TRD. BY: N.N.G

careful study of the water requirements of different crops and the variation of yield with water supplied is needed. Information of the type given in Fig. 1 helps to maximise production with a given quantity water. From Fig. 1 and Table 6, it may be observed that with 60 per cent of optimum irrigation, intensity of irrigation increases by 66·7 per cent and yield by 27·2 per cent.

Semi-field and field studies and particularly the latter relating to the water requirements of crops and irrigation practices require to be intensified to suggest modifications in the existing practices of conservation of water. In order to solve some of the problems, however, knowledge of how and why water enters the soil and how to

TABLE 6.

RELATIONSHIP BETWEEN IRRIGATION APPLICATION AND WHEAT YIELDS.

Irrigation application.	*Yield at irrigation application.*	*Cropping intensity at respective irrigation application.*	*Production from area and yield.*
(1)	(2)	(3)	(4)
100	100·0	100·0	100·0
90	96·0	111.1	106·7
80	90·8	125·0	113·5
70	84·2	143·0	120·4
60	76·3	166·7	127·2

effect more efficient water utilisation by increasing the water holding power of the soil and increased understanding, of the permeability of the soils and similar factors in necessary.

DRAINAGE NEEDS

Studies with regard to the ideal location of the drainage channels and designs for underground drains where they are required, are needed. It is well known that if land can be kept properly drained, the agricultural production could be quite high. On the other hand, want of care can lead to waterlogging and salinity which would considerably bring down the agricultural production.

ANNUAL OPERATION PLAN FOR IRRIGATION PROJECTS.

An Irrigation system is a dynamic one. A plan per pared for its operation when it is first conceived cannot be assumed to hold good for all the years to come. It is evident that the objective of proper utilisation of water supply can be achieved only through careful budgeting of anticipated water supply against anticipated water demand. Technical end product of this budgeting is an annual operating plan. An operation plan every year has to be prepared and its working assessed at the end of the year and changes introduced, if necessary, the following year. Operating plans are prepared for reasonable maximum and reasonable minimum conditions of water supply and requirements as well as for the most probable conditions. Such a plan can be produced only by electronic data processing method utilising computers.

Optimisation of water resource development involves the problem of land, water and people and of the interaction among them. An interdisciplinary approach has become quite obligatory involving participation of the departments of civil engineering, agricultural engineering, agronomy, sociology, economics and political science. It has, indeed, become a highly complex problem virtually impossible to obtain satisfactory solution without the use of modern computing machinery. It is necessary that the computer oriented techniques are adopted in the country in a large and increasing measure to solve problems of water resources development including optimum water and land management.

AUGMENTATION OF WATER SUPPLIES

Management of Atmospheric Water.

The atmosphere contains a vast amount of water, most of which is in the form of vapour. It is reckoned that about $5{\cdot}8\times(10)^{12}$ cu.m. of water pass across the United States during an average year about one-tenth of which will fall out as precipitation.

Precipitation, in any part of the world, is not evenly distributed in either time or space. It falls in areas where it may not be used at all. It is far in excess of requirement in some areas and deficient in other parts. Confronted with this distressing situation, man has been dreaming for centuries to control precipitation. But it was not until 1940's that a scientific approach was made towards the problem. In 1946, Vincent J. Schaefer discovered a small piece of dry ice when dropped into a cold chamber filled with supercooled water droplets, caused the formation of millions of tiny ice crystals. In November 1946, Bernard Vonnequt discovered that minute crystals of silver iodide acted as ice-forming-nuclei at temperatures lower than—5°C. The first large scale trials using silver iodide took place in June 1950 in U.S.A. Extensive Studies have been carried out thereafter in U.S.A., Australia, Israel and Russia. These studies indicated that precipitation can be increased by cloud seeding to the extent of 20 per cent over the target area.

In U.S.A. " Project Skywater ", as the programme is called, envisions a stage by stage development of a precipitation modification programme. The aim is to develop the technology for a nationally operational capacity by 1985, and to increase precipitation by an average of 10 per cent.

It is stated that the programme will be capable of adding some 590 milliard cu.m. of new water annually to the nation's water-supply. Production costs of \$ 1 to \$ 4 per 1,235 cu.m. are expected, with benefits ranging from \$ 5 to \$ 50 and higher from this quantity. Some \$ 25 million are expected to be spent on there studies.

Studies in India.

India has carried out some experimental studies in rain-making between 1957 and 1966. It involved the release of common salt from ground based power sprayers. Experiment was also made by disposal of common salt from air craft during one monsoon at Delhi. The results indicated an increase in rain of about 20 per cent over the target area. The Institute of Tropical Meteorology has programmed to conduct more experiments in different parts of the country. India should strengthen its effort for management of atmosphere not only in the field of rain-making but also in hurricane control, etc.

Desalination.

The oceans, which cover 70 per cent of the earth contain 97·20 per cent of its water. Sea water is unfit to drink, unsatisfactory for industrial processes and can be used in agriculture only under very limited conditions.

Generally, water containing less than 1,000 parts of salt per million parts of water is considered fresh. Brackish water has the salt content ranging from 1,000 PPM to 35,000 PPM. Sea water ordinarily has 35,000 PPM or more.

Man's interest in desalting the sea water dates back centuries. It has been one of the great engineering dreams. In the fourth century B.C., Aristotle described a method of evaporating sea water to produce drinking water. The first known treatise on distillation was written by an Arabian chemist in the eighth century.

The processes used for desalting water may be classified into three groups : (1) Distillation involving liquid, gas and liquid phases ; (2) Freezing process with liquid, solid and liquid phases ; and (3) Other processes where separation takes place from the liquid phase—Electrodialysis, and Reverse Osmosis.

Perhaps, the most important modern advance in desalination technology was the development of the principle of multi-stage flash distillation in the early 1950. The Baldwin Lima Hamilton Corporation has built for Israel 4·54 mi. litres per day flash plant and was commissioned in 1965.

A 0·9 mlpd freezing pilot plant is in operation in North Carolina, U.S.A. from 1964. The advantages of freezing process are the possible lower cost because of low energy requirements and minimisation of maintenance problems associated with scale and corrosion, because of low temperature operation.

The plant in operation in South Dakota, U.S.A. has a capacity of 0·3 mlpd and makes use of electrodialysis process. The water costs are reported to be as low as 50/4,500 litres when operating on a feed water of 1,800 PPM. The Division of Research of U.S.B.R. at Denver, Colorado, prepared the specifications for this South Dakota plant. They have also programmed to study evaluate and develop electrodialysis equipment and membranes.

Reverse Osmosis.

The term osmosis is used to describe spontaneous flow of water into a solution, or from a dilute to a more concentrated solution when separated from each other by a semipermeable membrane. In " reverse osmosis " the process is reversed with fresh water flowing from solution. The most successful membranes are being made out of cellulose acetate. Membrane surface fouling problems are already being encountered and the membrane life will have to be answered for reverse osmosis membranes just as they have to for electrodialysies membranes.

Use of Nuclear Energy.

The most discussed proposal has been the plan of coupling a nuclear reactor with a power and water plant. The report prepared jointly by the Bechtel Corporation of San Francisco under the joint authorship of the Department of the Interior, the Atomic Energy Commission, and the Metropolitan Water District of Southern California, in 1965 indicates that fresh water can be produced from the sea at a cost of 22 to 30 cents a thousand gallon. This is based on the use of the nuclear fuel to produce 1,800 megawatts of electricity and 680 million litres of fresh water daily. Cost of such a combination plant is estimated at \$ 300 million.

Trade papers in the water-supply field have predicted that world desalting expenditure would be \$ 2·1 billion between 1967 and 1975—\$ 950 million for plant construction, \$ 500 million for associated steam and power facilities and \$ 680 million for research and development. The bulk of the research and development money will come from the U.S. Office of Saline Water and the Atomic Energy Commission, while the rest will come largely from the Governments of Israel, the United Kngdom, Japan, the U.S.S.R., and West Germany. Of the predicted 1-billion-gallon capacity expected to be in use by the late 1970's, 85 per cent was expected to be for sea-water conversion, with most of the capacity in plants producing 230 mlpd or more, or in plants producing 4·5 to 45 mlpd.

The above is a state of the art of desalination. India should also get interested in the subject. A co-operative research programme should be initiated.

Fresh Water from Icebergs.

It is proposed that icebergs be tapped as a new and much needed source of fresh water. Two researchers of the Rand Corporation have received a grant from the U.S. National Science Foundation to develop their iceberg delivery plan in detail.

Neil Ostrander and John Hult say Antarctica icebergs could be towed in bunches to California or elsewhere and moved close to shore. There, blocks of ice would be quarried from the icebergs and sent to a coastal platform The ice blocks would be melted and pumped ashore. yielding water more pure in content than that from ground water sources. The cost of moving and converting icebergs to drinking water could be substantially cheaper than present methods of transporting large amounts of water. It is stated that icebergs that break off from Antarctica in one year equal the amolnt of. rainfall in the United States during the same period.

Interbasin Diversion of Water.

It was mentioned earlier that though the river systems in the country carry annually 1,675 milliard cubic metres only 1/3 of this quantity is utilisable. It is available so plentifully in some parts that floods are a menace. On the other hand, there are large areas which are arid and semi-arid, visited by famines and droughts frequently. Inter-basin diversions by linking the rivers of the country will bring relief to these areas. The Ministry of Irrigation and Power has initiated action to collect data to work out the details of the scheme. This scheme should be viewed as part of the programme of optimum utilisation of country's water resources.

Research Development Cycle.

With research and consequential developments, one has to consider interrelation between creation or profounding of some findings or ideas, communication of these findings to the person or group for application, the resulting product with its cost and advantages, studying its behaviour with respect to time and space and lastly feed back to the research worker. This cycle should repeat itself continuously. This is very necessary in the field of technology as against the field of basic sciences. For such a cycle to work satisfactorily there should be a broad based agency with adequate powers and resources.

Water Resources Council.

There cannot be any difference of opinion on the need to use the country's water to the best maximum advantage. This objective should be achieved quickly. Achievement is not easy but it is possible with sustained Rural and Development endeavours of an inter-disciplinary character. The foregoing paragraphs have attempted to give an idea of the magnitude of the task and Research and Developmental efforts that are needed. To initiate, guide and control such activities, it is essential to create an authority, which may be designated "Water Resources Council". It should be invested with adequate powers and should be provided with enough funds. All the ministries connected with planning investigation and management of Atmosphere, surface and sub-surface waters should be represented. It should have economists, sociologis and members from all the connected disciplines. It should be the highest authority in the Central Government to identify, sponsor and finance various Rural and Development activities.

It naturally should have a number of divisions. To name a few, these may relate to water cycle, quantity, quality and location of water resources, water-supply, and augmentation, water management and control, technique of planning and evaluation, compilation and dissemination data, engineering works, etc.

At the state level there should be a similar Water Resources Council. All the grants-in-aid given by the Central body should be routed through the state councils. The states would be free to finance and sponsor studies on their own as they are doing now.

Without such an arrangement, fragmentation of efforts in the field of Research and Development is bound to occur and the achievement of the supreme objective within *minimum period* and *cost* may be extremely difficult, if not possible.

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ROUND THE RESEARCH LABS.

(i) SOIL MECHANICS & RESEARCH DIVISION.

Engineering Properties of Soils :

1. *Pressure distribution on burried structures—Prestressed concrete pipes in expansive and non-expansive clay back fills.*

The aim of the study is to instal instruments to measure the pressures, deformations and strains in the pipe line, changes in moisture conditions of the fill up to different depths, settlement in the fill, etc. The actual pressures measured will be compared with the theoretical computations so that a suitable design can be evolved in future. An attempt will also be made to pin point the difference in behaviour when the fill material is expansive and non-expansive type of cohesive soils. Few selected reaches of the pipe line laid for the city water supply under Veeranam Water Supply Scheme will be taken up under this research scheme and design evolved.

2. *Earth pressures on retaining walls with expansive clay back fills.*

The aim of the study is to evolve a standard design procedure where the wall has to retain a highly expansive clay soil subjected to repeated wetting and drying. A review on the theoretical work on the same will be prepared and the experimental semi-field study will be conducted on at least three different expansive clay soils under different conditions of moisutre, surcharges, etc. The data will be analysed and compared with theoretical predictions and will be presented in a suitable non-dimensional form.

Instrumentation :

1. *Automatic control of height of fall of the drop weight for conducting penetration tests.*

As per Indian Standards, a hammer of weight 65 kg. falling through 75 cm. shall be used for conducting standard penetration tests on soils insitu. During actual operation in the field with manually operated boring equipment., difficulty is felt to control the height of fall of 75 cms. which leads to a variation in the height of fall resulting in erroneous values. The aim of this project is to develop, a suitable economical device with an automatic drop weight which is simple, accurate and suitable for operation under Indian conditions. It is also proposed to evolve three methods, viz., mechanical, hydraulic, and electrical and the relative advantages and disadvantages studied.

2. *Development of an Autographic Recorder for Swelling Pressure/consolidation/Field Load bearing and Shear studies.*

In all swelling pressure/consolidation/shear/load tests, etc., it is necessary to measure swelling/settlement, etc., for a duration of about 24 hours, or more and at present dial gauges are utilised and assistants are deputed to observe and record the readings. It becomes very difficult and much inconvenient to observe readings round the clock. The aim of this project is to develop an automatic device which will produce a continous record of swelling/consolidation/ desplacement, etc., and will be of great help in a soil research laboratory. A sensing unit with associated electronic processing circutary will be developed which will enable the unit to be used as freely and simply as a dial indicator. This will include necessary arrangements for calibration of the sensor. Both Photographic and electronic recording are proposed to be developed to suit these sensing elements.

Structures on permeable foundations :

1. *Studies on the design of hydraulic structures on more permeable strata like bouldary strata and gravelly beds.*

The nature of pressure distribution below bouldery reaches, in the case of flashy rivers of mountainous regions, would be far different from the pressures developed in sandy strata. In such cases the design assumption will have to be changed based on the data on studies on more porous strata like gravel beds and bouldery reaches. The laws governing the non-linear flow conditions have to be studied for checking up the range and validity of Darcey's law. The studies will have practical utility in the designing of barrages and weirs on bouldery beds.

It is therefore proposed to conduct research experiments for calculating uplift pressures below structures resting on bouldery beds and to examine the laws governing non-linear flows likely in such cases. The data will be used to determine the safe allowable exit gradient in gravelly or bouldery strata for studying the mechanics of piping and scour in such reaches. Suitable analogy devices are to be assembled for conducting the required model studies and the data thus collected will be analised.

Mix Design and Properties of Pozzolana Concretes

1. *Mix design and properties of Pozzolana concretes.*

The study is made under the Research problem " Use of Surki and other pozzolanic materials in mortar and concrete ". The objective of the research project is to study the effect of a new mix design approach suggested by the Soil Mechanics and Research Laboratory for pozzolana concretes on vital properties like elastic modulus, shrinkage, bond, tensile and flexural strength and extensibility.

Till recently no special procedures were adopted for the design of concretes with pozzolanas. The result has been that pozzolana concretes gave lessor strength than plain concretes at early ages of maturity. On the basis of investigation carried out in the Soil Mechanics and Research Division, it has been shown how this deficiency could be overcome by making suitable alterations in the mix proportions. While equality of strength could be accomplished by this new approach, it should be ensured that other properties of concrete mentioned above do not suffer. With this in mind tests are being conducted on plain and pozzolana concretes for assessing the following properties of concretes :—

(a) Modulus of elasticity of concrete.
(b) Tensile strength.
(c) Shrinkage.
(d) Bond between steel and concrete.

2. *Study of the thermal fatigue of concretes and mortars by the sonic method.*

The aim of the study is to assess the deterioration in the strength of concretes and mortars fatigued by diurnal variations in the ambient temperature.

In a tropical country like ours, engineering structures are exposed to heating cycles due to daily variations in ambient temperature as well as direct exposure to solar radiation. In course of time the thermal stresses developed may lead to deterioration and cracking of the structures at least to some depth from the exposed surfaces. How far such variation in temperature are responsible for the deterioration does not appear to have been studied so far. Hence useful results can be obtained by such studies. The studies conducted will be of considerable application to practical works in deciding upon the treatment to be given to the exposed surfaces of structures.

Concrete and mortar specimens of different mix protions are cast and tested for sonic moduli of elasticity after subjecting them to heating and cooling cycles. These results will be correlated with results of destructive tests. Effects of using pozzolanic additions has also, been included in the test programme.

Principles of Mortar and Concrete Mix Design.

1. *Hot weather concrete problems : Water requirement plastic shrinkage, temperature rise and strength aspects.*

The problem with hot weather concreting is the increased rate of hardening and evaporation of mixing water. Both factors contribute to plastic shrinkage and consequent lowering of strength. The relative advantages of presocled water for mixing with ordinary water will be tondied.

2. *To study the influence of the size of coarse aggregate and the maximum size on the compressive strength of concrete.*

The strength of concrete generally depends upon the water cement ratio and the mix proportion. However it is worthwhile studying the impact of metal shape and size on the strength of concrete. This study will throw some light on the selection of aggregate for concrete in river valley projects.

Experimental Methods of Stress Analysis in Hydraulic Structres.

1. *Study of the behaviour of deep reinforced concrete beams.*

This research project contemplates on undertaking a detailed study of the stress distribution in reinforced concrete breast walls provided in regulators, head sluices, etc., under the action of self weight and water loads.

At present the breast walls in many regulators, head sluices and other control structures for regulation of flow in river and canals are designed to stand the horizontal water thrust and vertical load due to self weight assuming that the wall spans between the piers. In most cases the depth of the breast wall is appreciable as compared to the span and in certain cases the depth is even more than the span (depth/span ratio greater than 1). The present practice is to design these walls as simple beams, though it is well recognised that they correctly fall under the classification of deep beams. (Beams with a height to span ratio of one half or more are said to be deep beams.) The action of reinforced concrete deep beams are not similar to those of simple beams and they have to be separately treated. A widely accepted design procedure for design of such breast walls is not now available and it is therefore proposed to study the problem in depth, carry out experimental tests to obtain the stress distribution pattern and thereafter evolve suitable placement of reinforcements.

(ii) INSTITUTE OF HYDRAULICS AND HYDROLOGY.

Model Studies conducted on Palaru Spillway of Palaru-Porandalaru Project.

Palaru Porandalaru Project is a scheme to form a combined reservoir by constructing dams across Porandalaru and Palaru rivers flowing near Palani in Madurai District, Tamil Nadu. The Palaru spillway is designed with its crest level at El.334·140m. to pass a maximum discharge of 554·84 cum/sec at M.W.L. and F.R.L. of 339·852m. Palaru masonry dam consists of a spillway block 20·117m. long and the river sluice block 9·144m. long. The spillway consists of two vents of size 8·53m.×6·70m. fitted with vertical lift gates. The river sluice consists of two vents of size 1·52×1·83m. with its sill at El. 320·04m. The energy dissipating arrangement downstream of the spillway consists of a stilling basin of total length 42·67m. depth 2·44m. with one row of trapezoidal friction blocks of size, 1·22m. length, 1·83m. height, 2·44m. bottom width and 0·61m. top width, two numbers of Tee blocks and baffle wall of size 20·12m. length, 2·96m. bottom width 3·35 m. height situated at a distance of 15·24 m. from the toe of the spillway.

A geometrically similar two-dimensional model was constructed representing the two vents completely to a scale of 1 in 40. The spillway portion is made of masonry with smooth cement finish. Water inlet arrangements are made with shutter for regulating the flow and honey combs for smoothening the flow of water. A portion of the river course is also represented by moulding with course gravel downstream of the stilling basin for studying the scour pattern. Stilling basin floor is made of teak wood to facilitate easy alterations and also to fix baffles, friction blocks, etc. Experiments were conducted for determining the coefficient of discharge and to note the pressures recorded on the spillway for the discharges ranging from 5·41 to 596·65 cum/sec when the gates were fully opened. No sub atmospheric pressure was recorded and it was also observed that at the F.R.L., the discharge passing over spillway was found to be 596·65 cum/sec which is slightly above the design discharge of 554·99 cum/sec. This might be due to the contractions imposed on the flow due to end piers. Hence the design of the spillway profile as proposed by the project authorities was recommended for adoption.

Initially the level of the stilling basin was kept at El. 314·55m. and the energy dissipation studies were conducted. A single basin of length 12m., 15m. and 18m. with and without blocks was tried. In order to avoid the secondary jump, a secondary basin was also tried. Finally it was decided that a primary basin of length 15·24m. with trapezoidal friction blocks and Tee blocks and a secondary basin of length 27·43m. and depth 2·44m. with the floor elevation of both at El. 314·55m. was most suitable and the same was recommended to the field engineers for adoption.

(Studies on current Problems will appear in the next issue.)

NEWS ROUND UP

1. Kodaganar Reservoir Scheme

The river Kodaganar, a tributary of Amaravathi originating from the Eastern slopes of the Lower Palani Hills runs through Dindigul and Vedasandur taluks of Madurai district and traverses in Karur taluk of Tiruchirappalli district and finally joins the River Amaravathi near Karur town.

The above scheme contemplates on the formation of a reservoir across Kodaganar near Alagapuri village in Vedasandur taluk of Madurai district.

By implementing this scheme, a new area of 2,080·09 hectares (5,140 acres) will be brought under plough besides bridging a gap of 144·09 hectares (356 acres) and assuring supplies to an existing ayacut of 331·44 hectares (819 acres) under four tanks in Madurai and Tiruchirappalli districts. The net additional food production anticipated by the scheme is 4,484 tonnes and the rate per tonne of additional food production works out to Rs. 4,728. The benefit cost ratio, at 10 per cent rate of interest, works out to 1·12 : 1.

The scheme was approved in G.O. Ms. No. 1296, P.W.D., dated 23rd August 1973 for Rs. 212 lakhs and was inaugurated on 25th August 1973 by Dr. Kalaignar Karunanidhi, the Honourable Chief Minister of Tamil Nadu. The work has been taken up for execution and is expected to be put to beneficial use by the end of December 1975.

2. Second Visvesvaraya Memorial Endowment Lecture.

The Second Visvesvaraya Memorial Endowment Lecture was delivered by Er. D. Doddiah, Advisor (Retired), Central Board of Irrigation and Power on 15th September 1973 in the Library Hall of the Building Centre Division, P.W.D., Chepauk, Madras-600005. The topic chosen by Er. Doddiah was "Research and Development of Water Resources for Irrigation" which appears elsewhere in this issue.

The meeting was presided over by Er. D. Ambrose, B.E., M.I.E. (India), Chief Engineer (Buildings), P.W.D. Er. S. P. Namasivayam, B.E., F.I.E., Chief Engineer (Irrigation and General) welcomed the guests and the distinguished speaker.

In his welcome address, Er. S. P. Namasivayam, B.E., F.I.E., outlined the contributions of Er. D. Doddiah as the Advisor, Central Board of Irrigation and Power and during his long tenure as Director, Mysore Engineering Research Station.

Er. D. Ambrose, in the President's opening remarks, introduced the Chief Guest to the audience with the guest's detailed Bio-data and expressed, his happines and that of the Visvesvaraya Memorial Endowment Committee to Er. D. Doddiah for having agreed to deliver the lecture.

Er. D. Doddiah in his address on "Research And Development of Water Resources For Irrigation" discussed in detail the distribution of worlds estimated availability of water, and the potential in various forms, like surface water, sub-surface water, etc., already created in India through the Fiver-Year Plans. He also estimated our future requirements of water by the end of 1971–81 and the financial outlay required to achieve the same.

Er. Doddiah called for proper management of water stored, diverted or extracted from ground with sustained inter-disciplinary endeavours.

Regarding the Research and Development of Water Resources, the speaker hilighted the areas that required sustained research for the proper and economical utilisation of water.

3. Improvements to Buckingham Canal.

Major improvements to the reach of Buckingham Canal falling within the jurisdiction of Tamil Nadu by way of widening and deepening the same and lining of the side slopes to carry mechanised crafts have been taken up during this year. Based on the recommendations of the High Power Technical Committee appointed by the Tamil Nadu in G.O. Ms. No. 2206, P.W., dated 11th August 1958, the Canal will have the following standards within the Madras City limits :—

	North Canal.	*South Canal.*
Bed Width	10·06 M. (33′)	6·10 M. (20′)
Bed Level	+4·27 M.* (+14′)	+4·27 M. * (+14′)
Draught	1·83 M. (6′)	1·83 M. (6′)

*Assuming + 6. 10 M. (+20′) as mean sea level.

Based on the suggestions of the above committee and in consultation with the officials of Andhra Pradesh a Master Plan for Rs. 600 lakhs has been prepared and sent to Government for approval. As per this, the works in North Buckingham Canal costing Rs. 350 lakhs are programmed to be completed in six years in Fourth and Fifth Plan periods. The works in south canal costing Rs. 250 lakhs will be taken up in Fifth and Sixth Plan periods.

If this scheme is implemented it is expected that there is every possibility of generating a traffic of eight lakhs tonnes in North Canal within Tamil Nadu and three lakhs tonnes in South Canal.

வ ள ரு ம் த மி ழ க ம்

நீர்ப்பாசனம்

திரு. சே. பா. நமசிவாயம், பி. இ., எப். ஐ. இ.,*

ஆறுகளின் நீர்ச் செல்வத்தை அதிக அளவில் பயன் படுத்திய மாநிலங்களில் முன்னோடியாக உள்ள பெருமை தமிழ் நாட்டிற்கு உண்டு. இங்கு விவசாயம் தொன்று தொட்டு நடைபெற்று வருகின்றது. இதற்கு நமது புகழ் வாய்ந்த தமிழ் வேந்தர்கள் அளித்த ஊக்கமும், உதவி யும் குறிப்பிடத்தக்கது.

தமிழ் நாட்டின் பரப்பளவு 50,000 சதுர மைல்கள். இங்கு பல ஆறுகள் உள்ளன. ஆனால் மேற்குத் தொடர்ச்சி மலையில் உற்பத்தியாகி மைசூர் மாநிலத்தின் வழியாக நமது தமிழ் நாட்டில் ஓடி கடலில் சேரும் காவேரி நதி ஒன்றுதான், ஓரளவு நிலையான நீர்வளம் உள்ளது. இதன் ஆற்றுமுகப் பகுதி நமது மாநிலத்தின் நெற் பெட்டகமாகத் திகழ்கிறது. நமது நாட்டின் முன்னேற்றத் திற்காக இதுவரை நான்கு ஐந்தாண்டுத் திட்டங்களும், மூன்று ஆண்டுத் திட்டங்களும் மேற்கொள்ளப்பட்டன. நான்காவது ஐந்தாண்டுத் திட்டம் 1973–74-ல் முடிவடை கின்றது. ஐந்தாவது ஐந்தாண்டுத் திட்டத்தில் மேற் கொள்ள வேண்டிய வேலைகள் தீர்மானிக்கப்பட்டு வரு கின்றன. ஐந்தாவது ஐந்தாண்டுத்திட்ட காலத்தில், தமிழ் நாட்டில் கிடைத்துவரும் அளவான நீரை வைத்து சாகுபடி அளவை அதிகப்படுத்துவதே முக்கிய குறிக்கோளாகும்.

ஐந்தாண்டுத் திட்ட காலங்களுக்கு முன் தமிழகத்தில் 22 இலட்சம் ஏக்கர்களுக்கு, 24 பாசன அமைப்புகள் மூலம் பாசன வசதி கிடைத்துக் கொண்டிருந்தது. இதுவரை எடுத்துக் கொண்டு நிறைவேற்றிய பத்தொன்பது பெரிய, நடுத்தரத் திட்டங்கள் மூலம் சுமார் 4·5 இலட்சம் ஏக்கர் புதிய நிலங்களுக்குப் பாசன வசதியும் சுமார் 2·60 இலட்சம் ஏக்கர் நிலங்களுக்குப் பாசன உறுதியும் அளிக்கப்பட்டுள்ளன. இதைத் தவிர, தற்போது நிறைவேற்றப்படும். பரம்பிக் குளம்-ஆளியாறு திட்டத்தின் மூலம் 2·52 இலட்சம் ஏக்கர் நிலங்கள் பயன்பெறும். இதில் இதுவரை முடிவடைந் துள்ள வேலைகளின் மூலம் சுமார் 2·17 இலட்சம் ஏக்கர் நிலங்கள் பயன் பெற வசதி உண்டு. மேலும் 34 ஆயிரம் ஏக்கர் புதிய நிலங்களுக்குப் பயன் அளிக்கவும், 1·50 இலட்சம் ஏக்கர் நிலங்களுக்குப் பாசன உறுதியளிக்கவும் 12 திட்டங்களில் வேலைகள் நடைபெற்று வருகின்றன. இதில் பொன்னியாறு, பரப்பலாறு திட்டங்கள் இரண்டும் இந்த ஆண்டில் முடிவடைந்துவிடும் என எதிர்பார்க்கப்படு கிறது. மற்றவை ஐந்தாவது திட்ட காலத்தில் முடிக்கப் படும். இவற்றைத் தவிர சுமார் 94 ஆயிரம் ஏக்கர் நிலங் களுக்குப் பயனளிக்கக் கூடிய 20 நடுத்தரத் திட்டங்கள் அரசின் ஆய்வில் உள்ளன. மத்திய திட்டக் குழுவின் ஒப்புதல் பெற்ற பின் இவை செயல்படுத்த எடுத்துக்கொள் ளப்படும். நான்காவது திட்டக் காலத்தில் மேற்கொள்ளு வதற்கு கருதிய 13 திட்டங்களில் 9 திட்டங்களில் வேலைகள் நடைபெற்று வருகின்றன. மற்ற 4 திட்டங்களினால் 4·30 இலட்சம் ஏக்கர் நிலங்கள் பயன்படும். இவை மத்திய திட்டக் குழுவின் பரிசீலனையில் உள்ளன.

தமிழ் நாட்டின் மேற்பரப்பு நீர்ச் செல்வம் பெருமளவில் உபயோகப்படுத்தப்பட்டுவிட்டது. எஞ்சியுள்ள உபரி நீரை யும் நல்ல முறையில் பயன்படுத்தத் திட்டங்கள் வகுக்கும் பொருட்டு 10 ஆய்வுக் கோட்டங்கள் செயல்பட்டு வருகின்றன. சுமார் 43 திட்டங்கள் தீவிர ஆய்வில் உள்ளன. மேலும் தமிழகத்தில் உள்ள ஆறுகளில் உள்ள நீர்வளத்தைக் கணக்கிட்டு நிர்ணயிப்பதற்காகச் சுமார் 200 இலட்சம் மதிப் பீடுள்ள ஒரு திட்டம் மத்திய அரசின் நிதி உதவிக்காக ஒப்புதலுக்கு அனுப்பப்பட்டுள்ளது. இதன் மூலம் பொறி யியல் பட்டதாரிகளுக்கு வேலை வாய்ப்பும் கிட்டும்.

தமிழகத்தில் உள்ள பழமையான பாசனத் திட்டங் களின் செயல்திறனை அதிகரிப்பது மிக அவசியமான ஒன்றாகும். மத்திய அரசும் ஐந்தாவது திட்ட காலத்திற் கான குறிப்பில் இதை வலியுறுத்தியுள்ளது. பாசனக் கால் வாய்களின் செயல்திறனை அதிகரிக்க அவற்றைச் சீர்படுத்த வேண்டும். இச் சீரமைப்புத் திட்டத்தின் கீழ் கால்வாய்ப் படுகையின் அகலம் அதிகமாக உள்ள இடங்களில் தேவை யான அளவுக்குக் குறைக்கப்படும். மதகுகள் இல்லாத கால்வாய்களுக்கு மதகுகள் அமைக்கப்படும். ஆயக்கட்டுக்கு ஏற்றவாறு மதகுகளின் அளவு திருத்தி அமைக்கப்படும். இக்குறிக்கோளுடன் ரூபாய் 49 கோடி மதிப்பீடு கொண்ட பழைய காவிரி டெல்டா பாசனத்தை நவீனப்படுத்துவதற் கான திட்டம் மத்திய அரசின் பரிசீலனையில் உள்ளது. வைகைக் கால்வாய்களை நவீனப்படுத்தும் திட்டம் நிறை வேற்றப்பட்டு வருகின்றது. தாமிரபரணி-அமராவதிக் கால் வாய்களின் சீரமைக்கும் பணி எடுத்துக் கொள்ளப்பட்டு பெரும் பகுதியான வேலைகள் முடிவடைந்துள்ளன.

கால்வாய்களுக்குக் காரை பூசுவதன் மூலம் கணிசமான அளவு நீர்ச் சேதத்தைத் தவிர்க்கலாம். இவ்வாறு சேமிக் கப்பட்ட நீரைக் கொண்டு மேலும் பாசன வசதி அளிக்கலாம் அல்லது குடிநீர்த் தேவை, தொழிற்சாலைகளுக்கான தேவைகளைத் தீர்க்கலாம். அமராவதித் திட்டக் கால்வாயின் சில பகுதிகளிலும் தாமிரபரணி, மருதூர், ஸ்ரீவைகுண்டம் அணைக்கட்டுகளிலிருந்து பிரிந்து செல்லும் கால்வாய்களி லும் காரைபூசும் வேலைகள் நடைபெற்று வருகின்றன.

தமிழகத் திட்டக் குழுவின் விவசாய செயற் குழு (Task Force on Agriculture) தனது அறிக்கையில் தமிழகத்தில் உள்ள பாசனத் திட்டங்களைக் சீரமைப்பது, காரை பூசுதல் இவற்றைப் பரிந்துரைத்துள்ளது.

பெரிய நடுத்தரப் பாசனத் திட்டங்களைத் தவிர சிறிய நீர்த் தேக்கங்கள், அணைக்கட்டுகள், ஏரிகள் அமைக்கும் வேலைகள் முதலானவை சிறப்புச் சிறு பாசனத் திட்டங்களின் கீழ் நிறைவேற்றப்பட்டு வருகின்றன. தூர்ந்து போன ஏரி களைச் செம்மைப்படுத்தி முழுநீர் மட்டத்தை உயர்த்துவதற் காகத் தூர் பாரல் நிலமீட்புத் திட்டங்களும் நிறைவேற்றப் படுகின்றன. இவை குறுகிய காலத்தில் பயன் அளிக்கும் திட்டங்கள் ஆதலால் அரசு இவற்றில் தனி கவனம் செலுத் துகின்றது.

இவற்றின் கீழ் 1972–73 ஆண்டு முடிய 15,144 திட்டங் கள் சுமார் 4 இலட்சம் ஏக்கர் புதிய நிலங்களுக்குப் பாசன வசதியளிக்கவும் சுமார் 16 இலட்சம் ஏக்கர் நிலங்களுக்குப் பாசன உறுதியளிக்கவும் நிறைவேற்றப்பட்டுள்ளன.

தமிழகத்தில் சுமார் 37,000 ஏரிகள், குளங்கள் உள்ளன. சுமார் 25 இலட்சம் ஏக்கர் நிலங்கள் இவற்றி னால் பாசன வசதியடைகின்றன. இவற்றின் பாதுகாப்பு மிக அவசியமானது. இவைகளைப் பரிசீலித்து அவற்றிற் கான தரத்தை (Standards) நிர்ணயிக்க தமிழக அரசு ஏரிச் சீரமைப்புத் திட்டத்தை (Tank Restoration Scheme) சில மாவட்டங்களில் திரும்பவும் ஆரம்பித்துள்ளது. ஏரி களின் செயல் திறன் அதிகரிப்புத் திட்டத்திற்கான (Efficiency Improvement Scheme) குறிப்பும் அரசின் பரிசீலனையில் உள்ளது.

* தலைமைப் பொறியாளர் (நீர்ப்பாசனம், பொது) அவர்கள் 19–8–73-ல் வானொலியில் நிகழ்த்திய உரை.

நிலத்தின் கீழ் உள்ள நீர்ச்செல்வத்தை அளவிட்டு அதை பாசன வசதி குறைவாக உள்ள இடங்களில் உபயோகப் படுத்தவும், மேற்பரப்பு நீர்வளத்திற்குத் துணையாக உப யோகப்படுத்தவும் தமிழ்நாடு ஒரு தனி நிலத்தடி இயக்குனரகத்தை (Ground Water Directorate) ஏற்படுத்தி யுள்ளது.

உணவு உற்பத்தியைப் பெருக்க ஒருபோக நிலங்களில் இரண்டாம் போகம் சாகுபடி செய்வதற்கு உதவும் திட்டத் தையும் அரசு மேற்கொண்டுள்ளது. இதற்கான உரம், குறுகிய காலப் பயிர் விதைகள் ஆகியவை கிடைக்கவும் வசதி செய்யப்பட்டு உள்ளது.

வறட்சிப் பகுதிகளில் பற்றுக் குறையைத் தவிர்ப்பதற்கான திட்டத்தை (Drought Prone Area Programme) அமுல் படுத்த தமிழ்நாட்டில் தர்மபுரி, இராமநாதபுரம் மாவட்டங்கள் மத்திய அரசால் தேர்ந்தெடுக்கப்பட்டுள்ளன. இதன் கீழ் தர்மபுரி மாவட்டத்தில், 26 பாசனத் திட்டங்களில் வேலை நடைபெற்று வருகின்றது. இராமநாதபுரம் மாவட்டத்தில் 105 பாசனத் திட்டங்கள் வேலைக்கு எடுத்துக் கொள்ளப் பட்டன. அவற்றில் 61 திட்டங்களில் வேலைகள் முடிந்து விட்டன.

அண்டை மாநிலங்களில் உள்ள உபரி நீரைத் தமிழகத் திற்குக் கொண்டு வருவதற்கான திட்டங்களிலும் அரசு தனிக் கவனம் செலுத்தி வருகின்றது. கேரள அரசின் ஒத்துழைப்புடன் பரம்பிக்குளம்-ஆளியாறு திட்டம் மேற் கொள்ளப்பட்டது. இதே போல் மற்ற திட்டங்களையும் மேற் கொள்ள கேரள அரசுடன் நல்லதொரு முடிவுக்கு வர அரசு ஆவன செய்யும். பாசனக் குழு (Irrigation Commission) அதன் அறிக்கையில் தமிழ் நாட்டின் இந்த கோரிக்கைக்குக் கேரள அரசு சாதகமான பதில் அளிக்கும் என்ற அதன் நம்பிக்கையைக் கூறியுள்ளது.

கங்கை, காவேரி இணைப்புத் திட்டத்தின் முதல் கட்டத்தி லேயே காவேரி, கோதாவரி நதிகளின் இணைப்பை எடுத்துக் கொள்ள வேண்டும் என்று மத்திய அரசுக்குத் தமிழக அரசு கூறியுள்ளது. இது ஒப்புக்கொள்ளப்படும் என்பதற்கு வேண்டிய அறிகுறிகள் இருக்கின்றன. இது ஒப்புக் கொள்ளப்பட்டு விட்டால் இந்த இணைப்பு மற்ற இரண்டு இணைப்புகளை விட, அதாவது கங்கை—நர்மதை, நர்மதை—கோதாவரி இணைப்புகளைவிட விரைவில் முடிந்து பயனளிக்க ஆரம்பித்து விடும். இந்த கோதாவரி—காவேரி இணைப்பினால் தெலுங்கானா, ராயலசீமை, மைசூர் சேலம், வட ஆற்காடு, தென் ஆற்காடு பேட்டைப் பிரதேசங்கள் போன்ற வறட்சியான இடங்களுக்குப் பாசன வசதி விரைவில் கிடைக்க வழி உண்டாகிவிடும்.

பூண்டியில் உள்ள நீரியியல் ஆராய்ச்சி நிலையத்தை விரிவுபடுத்தி அதனை ஒரு நீரியல் ஆராய்ச்சி உயர்தர நிறுவனமாக (Institute of Hydraulics and Hydrology) மாற்ற அரசு ஒப்புதல் அளித்துள்ளது. இதனால் இவ் வாராய்ச்சி நிலையம் அதன் ஆராய்ச்சிகளை விரிவு படுத்திக் கம்ப்யூட்டர் மூலம் ஊற்று நீர் ஆராய்ச்சி, ஆற்றில் வெள்ளம் வருதலை முன்கூட்டி அறிதல் முதலிய அறிவியல் புதுமை இணைப்பு வேலைகளிலும் கவனம் செலுத்தும்.

தமிழ்நாட்டில் போதுமான அளவு நீர்ச் செல்வம் இல்லாதிருந்த போதிலும், இருப்பதை சீரிய முறையில் மக்களுக்கு வேண்டிய பயனை விஞ்ஞான அடிப்படையில் அதிகரித்துக் கொண்டே போக அரசு ஆவன செய்து வருவது இதனால் புலனாகும். இத்தகைய ஆக்கப்பணிகளால் தமிழகம் மிகுந்த வளம் பெறும் என்பதில் ஐயமில்லை.

செயற்கை மழை.

பொ. குமாரசாமி. *

1. முன்னுரை:—

இயற்கையில் அமைந்துள்ள பலவற்றிலும் மழையே மிகச் சிறந்தது. நீரெல்லாம் ஆவியாகி மேலே கிளம்பி முகில்களாய்த் திரண்டு இயங்குதலும், பருவம் வந்தவுடன் காற்றின் துணையால் மழையாய்ப் பெய்தலும், மழை நீர் மண்ணில் ஊறியும் பரந்தும் பாய்தலும், ஆறாய்ப் பெருகி இணைறு குளமெல்லாம் நிரம்பி கடலில் கலத்தலும், மீண்டும் சூரிய வெப்பத்தால் ஆவியாகி முகிலாய்த் திரளு தலும் ஆன சுழற்சிகள் திரும்பத் திரும்ப நடை பெறுதலால் தான் உலகம் அழியாமல் இருக்கிறது. மழை யின் மாட்சிமையை திருவள்ளுவர் மிக நன்றாக உணர்ந் திருந்தார். ஆகவேதான் மழையைப் பெரிதும் உயர்த் திப் பாடினார் "வான்சிறப்பு" என்ற அதிகாரத்தில்

"விண் இன்று பொய்ப்பின் விரிநீர் வியனுலகத்து
உள் நின்று உடற்றும் பசி"

என்று கூறினார்.

மாபெரும் பரப்பளவுள்ள கடலையே தன்னகத்தே கொண் டிருந்தாலும் வானம் பொய்த்து விட்டால், உலகமே பசி யினால் அழிந்துவிடும் என்பதை மிக அழகாக எடுத்துக் காட்டியுள்ளார். இன்று நாம் கண்கூடாக பார்க்கிறோம் மழை பொய்த்ததினால் மின்சாரம் பெருக்கும் திறன் குறைந்து நாடே எவ்வளவு அல்லலுக்கு உட்பட்டது என்பதை.

மழையின் இன்றியமையாமையைக் கண்டோம். ஆகை யினால் மழை பொய்ப்பிக்கும்போது, மனிதன் என்ன செய்ய வேண்டும் என்பதை அறிவியற் கண்ணுடன் ஆராய்ந்த பொழுது மழையைச் செயற்கையாகத் தருவிக்கலாமே என்ற எண்ணம் தோன்றியது. அறிவியற் காலமான இன்று உயிரையே செயற்கை முறைகள் மூலம் உண்டாக்க நாம் முயலும்பொழுது, அதே நோக்குடன் மழையையும் செயற்கையாக உண்டாக்க முடியாதா என்ற ஒரு நோக்கம் தோன்றியது. அந்த நோக்கம் அறிவியல் ஆய்வுகளின் மூலமாக செயலுருவம் பெற்று வருகிறது.

2. செயற்கை மழை வருவிக்கும் முயற்சிகளுக்கான வரலாறு:—

1938-ம் ஆண்டில் (Findeisen) என்ற ஜெர்மன் அறி வியல் நிபுணர் தனிகுளிர்ந்த (Supercooled) மேகங்களுடே பனிக்கட்டித் தூளைத் தூவினால் மழை பெய்திடும் என்பதைக் கண்டறிந்தார். ஆயினும் 1946-ம் ஆண்டில்தான் ஏராள மான அளவு பனிக் கட்டித் தூள்களைத் தூவுவதற்கான ஏற்பாடுகள் நல்லமுறையில் அமைக்கப்பட்டன. அமெரிக்கா வில் (Sehenactady) என்ற ஊரினருகே, (Langmuir, Schaefer, Vonnegut) என்ற மூன்று அறிவியல் அறிஞர்கள் செயற்கை மழை வருவிப்பதற்கான முயற்சிகளை மேற்கொண் டனர். முதல் முயற்சியிலேயே (Solid Carbon-dioxide) துகள் களைத் தனி குளிராயிருக்கும் மேகங்களினூடே தூவி சிறிது மழையை வருவித்தார்கள். இதற்குப் பின்னர் (Vonnegut) ஒரு சிறிய மாறுதலுடன் (Silver Iodide) என்ற பொருளைப் பொடியாக்கி தனிகுளிர் மேகங்களினூடே தூவினால் செயற்கை மழையை வருவிக்கலாம் என்பதை கண்டறிந்தார். மேலும் இந்த (Silver Iodide) என்ற இரசாயனப் பொருளை, தரையிலிருந்தே புகையாக்கி மேலனுப்பி இந்தப் புகை மண்டலம் மேகங்களுக்குச் சென்று ஊடுருவி செயற்கை மழையை உண்டாக்கும் என்பதை ஆராய்ச்சி மூலம் கண்டறிந்தார்.

3. செயற்கை மழைக்காக பாரதத்தின் முயற்சிகள்:—

செயற்கை மழை வருவிப்பதற்காக நம் நாட்டில் இதுவரை செய்துள்ள முயற்சிகளை சற்று விவரிக்கின்றேன். நமது நாட்டிலே செயற்கை மழையுண்டுபண்ணிட அறிவியல் முறையிலே முயற்சிகள் மேற்கொண்டதாக வரலாறு இல்லை. கல்விக்கென்றே ஒரு கடவுளச்சியையும், செல்வத்துக்கென்றே மற்றொரு கடவுளச்சியையும் வணங்கும் நம் பாரதத்தில் எப்படி அறியாமையும் வறுமையும் தாண்டவமாடுகிறதோ அப்படியே மழைக்கென்றே வணங்குதற்குரிய வருணன் இருந்தாலும் மழைவளமும் குன்றியேயுள்ளது, என்பது வியப்பதற்கில்லை. அறிவியல் முறைகளைக் கையாளாது அறியாமை நிறைந்த மூட நம்பிக்கைகளையே பல சமயங் களில் இந்திய அறிவியலாரும் சார்ந்திருப்பதுதான், செயற்கை மழை உண்டாக்கும் வரலாறு நம் நாட்டில் இல்லாததற்குக் காரணம்.

சில வருடங்களுக்கு முன்னால் தமிழ்நாடு பொதுப் பணித்துறையினர் நீலகிரி மலைத் தொடர்ச்சிப் பகுதிகளில் தரை அடுப்புகள் மூலம், (Silver Iodide) புகையை மேலனுப்பி செயற்கை மழையை வருவிக்க முயற்சித்தனர். மழை சிறிது உண்டாயினும் அது செயற்கை மழை தானா என்பதை நிச்சயமாகச் சொல்லிட முடியவில்லை. கடந்த ஜூன் திங்கள் முதல் இந்திய வானிலை ஆராய்ச்சித் துறை யினர் செயற்கை மழை வருவிப்பதற்காக திருவள்ளூருக்கு அருகே தரையடுப்புகளை நிறுவியுள்ளனர். சாதாரண உப்பைத் தூளாக்கி புகை மண்டலம் மூலம் நிலத்திலிருந்து மேகத்துக்கு அனுப்பி செயற்கை மழை உண்டாக்க முடி யுமா என்று முயன்று வருகிறார்கள். அறிவியற் கோட் பாடுகள் மூலம் செயற்கை மழையை வருவிக்கும் இந்த முயற்சிகள் நல்ல பயனை அளிக்கும் என்று நம்புவோமாக.

4. செயற்கை மழை வருவிப்பதற்கான கோட்பாடுகளும் கொள்கைகளும்:

மேகங்களிலிருந்து இயற்கை, மழையை இரண்டுவிதமாக உண்டாக்குகிறது. மேகங்களிலுள்ள சிறு நீர்த்துளிகள் ஒன்றோடொன்று மோதியும் ஒன்றோடொன்று இணைந்து கலந்தும் பெருந்துளிகளாக மாறியவுடன், ஒவ்வொரு துளி யின் எடையும் அதிகமாவதால் கீழே விழுந்து மழைத் துளியாக மாறும். இவ்வண்ணம் எல்லா வெப்ப நிலை களிலும் மழை ஏற்படலாம். இரண்டாவது விதமாக மழை உண்டாகும் முறை பின்வருமாறு. ஒரு மேக மண்டலத்தின் மேற்பகுதி அதன் கீழ்ப்பகுதியை விட மிகவும் குளிர்ந்ததாக இருக்கும். தனி குளிர்ந்த மேகத்தின் மேற்பகுதியிலே பனிக்கட்டித் தூள்கள் இயல்பாகவே தோன்றுகின்றன. இவற்றைச் சுற்றியிருக்கும் நீராவது ஆவியாக மாறும்பொழுது .அந்தப் பனிக் கட்டித் தூள்கள் கொஞ்சம் கொஞ்சமாக பெரிதாகின்றன. அவை ஓரளவு எடையை அடைந்தவுடன் தாமாகவே கீழ்விழுந்து, வெயிற் காலமாயின், பனிக்கட்டி, நீராகி, மழைத்துளியாக நிலத்தின் மேல் விழுகிறது.

ஆகவே செயற்கை முறையில் மழையை வருவிப்பதற்கு ஒரு மேகத்தினூடே பொடியொன்றைத் தூவினால், அப் பொடித் துகள்களை மையமாக வைத்து சிறு நீர்த்துளிகள் பெருந்திவலைகளாக மாறி மழையுண்டாகும் என்று தெரி கிறது. பொடியாக (Solid Carbon-dioxide) ஐயோ, (Silver Iodide) ஐயோ பயன்படுத்தலாம் என்று கண்டுபிடிக்கப் பட்டுள்ளது. (Silver Iodide) ஐத் தூவுவதற்கு விமா னங்களைக் கொண்டு மேகத்திற்கே சென்றிடலாம். அல்லது தரையிலிருந்தே புகை மண்டலம் மூலமாகப் பொடியை

* இயக்குநர், நீரியல் நீர்நிலையியல் ஆய்வுக் கழகம்.

மேலனுப்பலாம். விமானத்தின் மூலம் சென்று செயற்கை மழையை வருவித்தல் நிச்சயமான முறையென்றாலும், அதற்கான பணச் செலவு மிக அதிகம். ஆனால் தரையிலிருந்து புகை மண்டலத்தின் மூலமாக மேலனுப்புவது சிக்கனமானதொன்றாயினும் விமானத்தின் மூலம் தூவுவது போன்று அவ்வளவு திறன் பெற்றதல்ல. ஆகவே அந்தந்த இடத்திற்குத் தகுந்தவாறு ஏதாவது ஒருமுறையைக் கடைப்பிடித்து செயற்கை மழையை வருவித்தல் அறிவியல் முறையாகும். இது வரையும் செய்துள்ள ஆராய்ச்சிகளின் மூலம் கீழ்கண்ட சில உண்மைகள் கிடைத்திருக்கின்றன.

(1) ஒரு மேகத்தின் மேற்பரப்பின் சூட்டளவு 7°. சென்டிகிரேடுக்கும் தணிவாக இருந்தால், செயற்கை மழையினை 100 சதவிகிதம் நிச்சயமாக வருவிக்க இயலும்.

(2) ஒரு மேகத்தின் உச்சப் பகுதி 7° சென்டிகிரேடை விட வெப்பமாக இருந்தால் செயற்கை மழை வருவிப்பது **அவ்வளவு நிச்சயமில்லை.**

(3) செயற்கை மழை உருவாகும் கால அளவு, அந்த மேக மண்டலத்தின் தடிமத்தைப் பொறுத்திருக்கிறது. பெரும்பாலும் பத்து நிமிடங்களில், செயற்கை மழை உருவாவதற்கான அறிகுறிகள் ஏற்பட்டுவிடும். ஒவ்வொரு 800 அடி கூடுதல் தடிமத்துக்கும் ஒவ்வொரு நிமிடத்தை இத்துடன் கூட்டிக் கொள்ளவேண்டும்.

(4) மேக மண்டலத்தின் தடிமன் அதிகமாக ஆக மழையின் பெய்யளவும் கூடுகிறது. மேகமண்டலத்தின் உயரம் அதன் தடிமத்தை விடக் குறைவாக இருந்தால், உருவாகும் செயற்கை மழையின் பெரும்பகுதியும் நிலத்தில் விழும்.

இவைதாம் இதுவரை நாம் கண்டறிந்துள்ள செயற்கை மழை உண்மைகள்.

"நீரின்றி அமையாது உலகு."

செ. ச. சீனிவாசன்,* பி. இ., எம். எச்சி. (பொறியியல்).

வள்ளுவப் பெருந்தகை மக்கள் வாழ்க்கைக்கு நீர் அச்சாணி போன்றது என்ற முக்கால உண்மையை நீரின் இன்றியமையாமையை அழகாக, "நீரின்றி அமையாது உலகு" என்று தம் மணிக் குறளில் மொழிந்துள்ளார். இதை ஒட்டியே நல்லிசைப் புலமை வாய்ந்த மெல்லியல் ஔவையும் "கொன்றை வேந்தனில்",

"நீரகம் பொருந்திய ஊரகத்து இரு" என்றும் தனிப்பாடலில்,

"வரப்புயர நீருயரும்
நீருயர நெல்லுயரும்
நெல்லுயர குடியுயரும்
குடியுயர கோலுயரும்
கோல் உயர கோன் உயரும்"

என்றும் பாடியுள்ளார்.

மேற்கூறியவற்றால் "நீரின்றி அமையாது உலகு" என்ற வாக்கின் உண்மையை எவராலும் மறுக்க முடியாது. அஃது எவராலும் மறுக்க இயலாது, எளிதில் இசைவைத் தெரிவிக்க வேண்டிய தொன்றாகும். இன்னணம் இருக்க இவ்வாராய்ச்சி எற்றுக்கு ? பாமரர்களே அறிந்த பொருள் பற்றி பொறியாளர்களுக்கு அறிவிக்க எத்தனிப்பது எற்றுக்கு ? நீரில் என்ன புதிர் உள்ளது ? என அடுக்கடுக்காக வினவலாம்.

இதைப் போன்றே மூதறிஞர் பலர் "உள்ளங்கை நெல்லிக் கனி" போன்று தெரிந்த பொருள்களில் புதிர் உள்ளது, யாவரும் மேற்போக்காக அறிந்துள்ளனரே அன்றி நுண் கருத்தை முற்றிலும் அறிந்ததில்லை. "கைப்புண்ணைக் காண கண்ணாடி தேடும்", நிலையில் உள்ளனர் என்று தெள்ளத் தெளிய காட்டியுள்ளனர். இரண்டாயிரம் ஆண்டுகளுக்கு முன்னர் தயாசெனிசு (Diogenes) பட்டப்பகலில் கடை வீதியில் விளக்கு ஒன்றை ஏந்திக் கொண்டு சென்றாராம். வீதியில் உள்ளோர் திகைத்து எதைத் தேடுகின்றீர்கள் ? என வினவ, அன்னார் "நான் மனிதனைத் தேடுகின்றேன்" என்றாராம். குறிப்பாக "நீவிர் மக்கள் இனத்தை சார்ந்தவர்" எனக் கருத அருகதை அற்றவர் என சுட்டிக் காட்டியுள்ளார். அவருக்கு பின்னர் வந்த சாக்ரடீசு (Socrates), "மனிதனே ! உன்னை அறிவாயாக" (Man, know thyself) என்றார். இவ்வாறு கூறி, மனிதன் தன்னைப் பற்றியும் தன் ஆற்றலைப் பற்றியும் அறிந்திலன் என்று சுட்டிக் காட்டியுள்ளார். கலிலியோ (Galileo) "கண்ணுக்குப் புலப்படாத அண்டங்களைப் பற்றி எளிதில் அறிய இயலுகிறது, எனினும் அருகிலுள்ள நீரைப் பற்றி ஒன்றுமே அறிய இயலவில்லை" என்று ஏங்கினாராம். அண்மையில் நோபல் பரிசு பெற்ற மருத்துவர், அலெக்சு கரெல் (Alexis Carrel) என்பார் "மனிதன் ஒரு புதிர்" (Man the unknown) என்ற நூலில் மனிதன் தன்னை அறிந்திலன் என்று வியந்து அவன் அறியாமையை நீக்க மனமிரங்கி எழுதியுள்ளார். வள்ளுவப் பெருந்தகையும் உலகப் பொதுமறையாம் திருக்குறளில், "வான் சிறப்பு" என்ற அதிகாரத்தில் மழையைப் பற்றியும் மக்கள் இனத்திற்கு அதன் இன்றியமையாமையையும் அழகாக தன் மணிக்குறளில் பல சொல்லக் காமுறுது நுண்ணிய கருத்துக்களைத் திண்மையாகத் தீட்டியுள்ளார். இவரை ஒட்டியே தமிழ் மூதாட்டியாம் ஔவையாரும், "மாரியல்லது காரியமில்லை" என அறுதியிட்டுள்ளார். ஒழுக்கத்திற்கு மாரியால் உண்டாகும் நீரே அடிப்படை என்றும் சுருக்கமாக நாகரிகத்தின் அடிப்படையே நீர் என்றும், ஏனைய எல்லா நாகரிகமும் நீர் நாகரிகமே (Hydraulic Civilisation) என்றும் மொழிந்துள்ளார்.

மேற்கண் கூறியவற்றால் ஒரு பொருளைப் பற்றி யாவரும் மேலாக பொதுவுற அறிந்திருப்பதால் அதைப் பற்றிய நுண்ணறிவு பெற்றனர் எனக் கொள்ளக்கூடாது எனப் புலப்படும். மாறாக, ஒரு பொருளைப் பற்றிப் பரவலாக யாவரும் அறிந்துள்ளதே அதன் இன்றியமையாமைக்குச் சான்று. ஆம் : நீர் ஒரு அதிர்ச்சி தரவல்ல செய்தி அன்று. "நீரின்றி அமையாது உலகு" என்ற வள்ளுவ திருமகனாரின் வாக்கும் ஒரு பொதுச் செய்தி அன்று (Common Place News), புதுச் செய்தியும் அன்று. நீரைப்பற்றி நுணுகி அறிவது இன்று மிக மிகத் தேவையான ஒன்றாகும்.

நீர் ஒரு செய்தி அன்று. (Water is not news) அஃது நிலத்தை விட பரந்துள்ளது எனினும் பொன்னை விட அருகியது. மனித இனத்திற்கு அரசியலை விட தேவையானது எனினும், அது செய்தி அன்று. உணவு, உடை, இருப்பிடம் இம்மூன்றும் பெற நீரைப் பயன்படுத்துகின்றோம். நாம் மின்சார உற்பத்தி செய்கின்றோம்., நீரைப் பங்கீடு செய்கின்றோம், வீணாக்குகிறோம், மாசுபடுத்துகின்றோம். நீர், தனிப்பட்டவர்களுக்கிடையே பொது மக்களுக்குகிடையே (குழாய் சண்டைக்கும்) நாடுகளுக்கிடையே சச்சரவுகளுக்கு மூல காரணமாகின்றது. நீர், உடல் நலத்திற்கும், பொருள் ஈட்டிற்கும், வெள்ளத்தால் கொள்ளை நோய்க்கும், பொருள் அழிவிற்கும் காரணமாக அமைகிறது. இதனை தெய்வப் புலவர்,

"துப்பார்க்குத் துப்பு ஆய துப்பு ஆக்கித் துப்பார்க்கு
துப்பாய தூ ஊம் மழை"

"கெடுப்பதும் கெட்டார்க்குச் சார்வாய் மற்றாங்கே
எடுப்பது உம் எல்லாம் மழை",

என அழகாக அருளியுள்ளார்.

குரங்கிலிருந்து வால் அற்று, காட்டில் விலங்குகளுடன் வாழ்க்கை நடத்திய மனிதன் நாகரிகமாகி நாடமைப்பதற்கு வழிகாட்டியது நீரன்றி, வேறொன்றுமில்லை, ஏன் ? காட்டிலிருந்து நீரோடை காட்டும் பாதையிலேயே நடந்து சிறுக சிறுக வாழ்க்கையை வளமாக்கிக் கொண்டான். தொன்று தொட்டு திகழ்ந்த நாகரிகங்கள் யாவும் ஆற்றங் கரைகளிலும், கழிமுகங்களிலும்தான் திகழ்ந்தன. எகிப்து நாகரிகம், வளங் கொழிக்கும் நைல் நதியால் தோன்றியது. சிந்து, கங்கை, கிருட்டிணை, பொன்னி ஆற்றங்கரைகளிலே, சமவெளிகளிலே மிளிர்ந்த நாகரிகங்களைப் பற்றி கூறவும் வேண்டுமோ ? "சோழ வளநாடு சோறுடைத்து" என்று ஔவை மொழிந்தது காவிரியின் அருளால் அன்றோ ? திரை கடலோடி "திரவியம்" தேடியதும் நீர் மேல்தான். யவனர்கள் பாண்டி நன்னாட்டின் முத்தைப் பெற கடல் கடந்துதான் வந்தனர். கடாரம் கடந்தான் கங்கை கொண்ட சோழன். பண்டைய மனிதன் மழையை வருணன் என்று வருணித்தான். இடிக்கு இந்திரனை உருவகித்தான். கிரேக்கர்கள் தாம் வணங்கும் கடவுளர் குழாம் மாரியின் உறைவிடமான வானத்தை உறைவிடமாகக் கொண்டுள்ளனர் எனக் கருதினர். எனவே இயல், இசை, நாடகம், ஆடல், பாடல்

* உதவிப் பொறியாளர் (சிறப்பு). தலைமைப் பொறியாளர் (பாசனம்) அலுவலகம்.

யாவும் ஆற்றங்கரைகளிலே ஆற்றோட்டம் போல் நன்கு தடை இன்றி பொங்கிப் பெருகி நாகரிகப் பரிமாற்று, பண்ட மாற்று, இனக்கலப்பு, மொழிக்கலப்பு, அறிவியற் பரிமாற்று முதலியவை நீரின் வழியாக நிகழ்ந்தன. இங்ஙனம் பல மொழிகள் பேசும் பல நாட்டு நாகரிகங்கள் தோன்றின.

நீர் வியக்கத்தக்க விந்தையான ஒருகூட்டுப் பொருள். (Compound) இது உயிர் வளி (Oxygen), நீர் வளி (Hydrogen) முதலியவற்றின் சேர்க்கையினால் உண்டான கூட்டுப்பொருள். ஆயினும், அதன் தன்மையே தனித்தன்மை. உயிர் வளியைப் போன்றோ நீர் வளியைப் போன்றோ அமையாது தனித்தன்மை பொருந்திய தனிப் பொருளாகும். மெல்லியதாகத் தோன்றினும் கல்லையும் கரைக்க வல்லது. ஏன்? மலையைத் சிறு துகள்கள் ஆக்குவது வானின்று இழியும் மணிநீர்த்துளிகளே. மண் தோன்றுவதற்கு நீர்தான் காரணம். பரிதியின்று திக்கோளமாகப் பிரிந்து கல்லாகிக் குளிர்ந்து, மெல்லிய நீரால் கணக்கற்ற ஆண்டுகளில் தாக்கித் தகர்க்கப்பட்டு பொடிந்து மண்ணானது. புவியியல் வல்லுனர் (Geologist) இதனை வானிலைத் தாக்கம் (Weathering) என்பர். அன்னார், ஆறுகளை மனிதனாக உருவகிப்பர்! வானின்று தோன்றும்போது பச்சிளங் குழந்தையாம். மலையில் வீழ்ந்து, கல்லையும் காட்டையும் தாக்கித் தூளாக்கி, தூக்கிச்செல்லும் போது இளமை பருவமாம். மண்ணைத் தூக்கிச் செல்லும் திறமும் தூக்கிச் சென்ற மண்ணை கைவிடும் ஆற்றலும் சமமாக இருக்கும் நிலை முதிற்சியுற்ற நிலையாம். ஆறு இறுதியில் கடலில் கலக்கும் நிலை, தள்ளாடி, கோலூன்றி பார்வை இழந்த முதுமைப்பருவமாம். வெள்ளப் பெருக்கால் திண்மையான அணைகள் அழியும். காடுகளும், வீடுகளும் இம்மெல்லிய நல்லியல் நங்கை நல்லாள் திருவளர் செல்வி நீரம்மையால் கடிது அடித்துச் செல்லப்பட்டுக் கடலில் சேர்க்கப்படும் வண்டலை அடித்துச் சென்று சமவெளிகளில் பரப்பி நிலத்தை வளமாக்குவது நீர். நீர் எதையும் கரைக்க வல்லது. நீர் எங்கும் உலகெங்கும் தோன்றுவதாலும் தனிப்பட்ட பருப் பொருள் (Physical) வேதியியல், (Chemical) பண்புகளால் செருமை (Mass) அடர்த்தி விழுக்காடு, (Specific gravity) தட்பவெப்ப நிலை (Temparature), வெப்பம் (Heat), குழைமை (Visconity) போன்ற அறிவியல் கூறுகளுக்கு தரமாக (Standard) அமைகிறது.

நீர்பரப்பு நிலப்பரப்பை விட பெரிதாகும். நீர் பரப்பு பூவுலகின் ஐந்தில் மூன்று பங்கு; நிலப் பரப்போ எஞ்சியது. பூமி நீரால் சூழப்பட்டால் 800 அடி ஆழம் இருக்கும். பூமியில் மொத்த தூய நீர் 9,000 கன மைல்கள். இது ஆண்டொன்றுக்கு 34 அங்குலம் மழைப் பொழிவால் விளைவது.

நீரின் தேவை வியக்கத்தக்கது. ஆழாக்கு அரிசி விளைவிக்க 1.8 டன் நீர் தேவை. 1 பவுண்டு அரிசிக்கு 4.10 டன் நீர் தேவை. 1 பவுண்டு கோதுமைக்கு 500 பவுண்டு நீர் தேவை. 1 பவுண்டு கத்திரிக்காய்க்கு 380 பவுண்டு நீர் தேவை. 1 பவுண்டு காய்கறிக்கு 608 பவுண்டு நீர் தேவை. 1 வாழைப் பழத்திற்கு 304 பவுண்டு நீர் தேவை. 1 முட்டைக்கு 1 டன் நீர் தேவை. 1 மனிதனுக்கு தேவையான 2,500 கலோரி (Calorie) உணவு தயாரிக்க நாளொன்றுக்கு 33 டன் நீர் தேவை. இக்கணக்கின்படி ஒருவர் 70 ஆண்டுகள் வாழ்ந்தால் உணவுக்கே 7,50,000 டன் நீர் தேவை. 1 முழம் துண்டுக்கு 600 பவுண்டு நீர் தேவையாகிறது. 1 டன் எஃகு தயாரிக்க 290 டன் நீர் தேவை. 1 டன் விறகிற்கு 304 பவுண்டு நீர் தேவை. ஒரு பவுண்டு எடையுள்ள செடி, கொடியில்4/5 பவுண்டு நீர் உள்ளது. பருவக் காலங்களில் 500 பவுண்டு நீரை உட்கொள்ளும். பகலில் நீர் விடாய் கொண்ட மனிதனைப் போல் இரவில் உறிஞ்சுவதைப் போல இருபது மடங்கு உறிஞ்சுமாம். மேற்கூறிய புள்ளி விவரங்களை விட வியக்கத்தக்க அளவில் உண்ணும் பொருட்களில் ஏன்? மனிதன் மரம், செடி, கொடிகளின் எடையில் பெரும் பங்கு நீர்தான். அரிசி, கோதுமை முதலியவற்றில் 13 நூற்று விழுக்காடு நீராகும். கம்பு, உளுந்து, பயறு முதலியவற்றில் 10 நூற்றுவிழுக்காடு, கிழங்குகளில் 75 நூற்று விழுக்காடு, முள்ளங்கி, கத்திரிக்காய் முதலியவற்றில் 90 நூற்றுவிழுக்காடும், உருளைக் கிழங்கு மீன் முதலியவற்றில் 75 நூற்று விழுக்காடுக்கு மேலும் நீர் உள்ளது; பாலில் 90 நூற்றுவிழுக்காடும், முட்டையில் 75 நூற்று விழுக்காட்டுக்கு மேலும் நீர் உள்ளது. மனித உடலில் சுமார் 65 நூற்று விழுக்காடு நீராகும். தசையில் 75 நூற்று விழுக்காடும், இரத்தத்தில் 90 நூற்று விழுக்காடும் நீர் உள்ளது. நீர் உடலுக்கு ஊட்டச்சத்தையோ, ஆற்றலையோ தராவிட்டாலும் உடலுக்கு பல இன்றியமையாத பயன்களைக் கொடுக்கிறது. உணவைச் செரிக்கச் செய்து இரத்தத்துடன் கலக்கச்செய்யவும், உடலில் ஏற்படும் கழிவுப் பொருள்களை வெளியேற்றவும், குருதியை நீர்ம நிலையில் (Liquid state) வைத்திருக்கவும், நுண்ணுயிர் (cell) களை உயிருடன் இருக்கவும், செரிப்பு நீர்கள் நன்கு சுரக்கவும் நீர் அவசியமாகின்றது. உடலின் வெப்பம் சமநிலையில் இருக்கவும் நீர் பயன் படுகிறது. உணவின்றி பல வாரங்கள் வாழலாம். ஆனால் நீரின்றி சில நாட்களுக்கு மேல் உயிர் உடலில் தங்காது.

மேற்கண்ட புள்ளி விவரங்கள் நீரை எந்த அளவுக்கு இயற்கை பயன்படுத்துகிறது என்று காட்டுகிறது. உயிருக்கு உயிராக இருப்பது நீர் எனப் புலப்படும். இங்ஙனம் இருக்க மழையின் அளவும், உலகின்கண் உள்ள நீரின் அளவும் என்றுமே மாறாது இருக்கும்போது நீரின் தேவை பெருமளவில் பெருக்கிக் கொண்டே வருகிறது. இந்தியாவின் தரைக்கு மேல் ஆண்டுதோறும் ஓடும் நீரின் அளவு 1,525 மில்லியன் ஏக்கர் அடி, ஊற்று நீர் அளவு 344 மில்லியன் ஏக்கர் அடி என்று கணக்கிடப்பட்டுள்ளது. மக்கள்தொகை சென்ற நூற்றாண்டு இருந்ததைப் போல் தற்போது இருமடங்காகும். இந்த நூற்றாண்டின் முடிவில் இன்று இருப்பதை போல இருமடங்காகும். எனவே நீரின் தேவை அஞ்சத் தக்க அளவு விரியும். அமெரிக்கா மற்றும் நாகரிகம் மிக்க மேலை நாடுகளிலும் உள்ள மக்கள் நீரை மாசு படுத்துவதில் நிபுணர்கள். தானியங்கிகளின் (Automobiles) எண்ணிக்கை அளவு கடந்து பெருகுவதால் நச்சு படுத்தப்பட்டு உள்ளதாம். ஜப்பானில் தூய காற்றை விலைக்கு வாங்கும் அளவுக்கு வந்து விட்டதாம். கழிவுப் பொருள்களை ஆறுகளிலும் நீர் நிலைகளிலும் கண்மூடித் தனமாகக் கலந்து நச்சுப் படுத்தி அவதியுறுகின்றனர். மாசு படுத்துவதை கட்டுப்படுத்த சட்டங்கள் பல சடுதியில் நிறைவேற்றுகின்றனர். அமெரிக்கா, பிரான்சு, உருசியா, ஜப்பான், சீனா முதலிய நாடுகள் கதிரியக்க ஆய்வுகள் (Neuclear Tests) செய்வதால் கடலையே நச்சுப் படுத்துகின்றனர். ஜப்பான் நாட்டில் குடிநீர் பற்றுக் குறையால் ஊற்று நீரை (Ground water) அதிகமாக வெளியேற்றி பல இடங்களில் 10, 20 அடி நில மட்டம் தாழ்ந்து விட்டனவாம். பல கட்டடங்கள் பைசா கோபுரமாக சாய்ந்துள்ளனவாம்.

தேவை அளவின்றி பெருகுவது ஒரு புறமிருக்க அருகி வரும் நீரை இவ்வாறு மாசு படுத்தலாமா? பொய்யில் புலவர் இந்நெருக்கடியினின்று நீங்குவது எங்ஙனம் என்று கூறியுள்ளார்.

“ ஆகு ஆறுஅளவு இட்டிது ஆயினும் கேடில்லை
போகு ஆறு அகலாக் கடை ”.

“ வருமுன்னர் காவாதான் வாழ்க்கை எரிமுன்னர்
வைத்தூ று போலக் கெடும்”.

பொறியாளர்கள் திருவள்ளுவர் வாயுறை வாழ்த்தில் மேற்கூறிய அறவுரைகளையும் சிரமேற்கொண்டு விரைந்து செயல்பட வேண்டியது எங்ஙனம்? நீர் நெருக்கடி வரும் முன்னர் காக்க வேண்டும். மழையின் அளவை அளக்க மழை மானிகள் அதிகமாக நிறுவ வேண்டும். ஆற்றில் போகும் நீரை அளவிட வேண்டும். நீர்த்தேக்

கங்கள், ஏரிகள், குளங்கள் முதலியவை மண்ணால் தூறுவதை தடுக்க நில அரிப்பைத் தடுக்க வேண்டும். அவைகளினின்றும் கால்வாய்களிலும், நிலத்தின் அடிக்கு ஊறிச் செல்லும் நீரையும் வானத்திற்கு ஆவியாகும் நீரையும் குறைக்க வேண்டும். நீரை வீணாக்காது அளவறிந்துப் பங்கீடு செய்ய வேண்டும். விளைச்சலுக்கு குறைந்த அளவும் பெருகிய விளைச்சலும் உள்ள உணவுப் பொருள்களை விளைவிக்க ஆவன செய்தல் வேண்டும். நீரை மாசுபடுத்துவதை தவிர்க்க வேண்டும். வெள்ளச் சேதத்தை நீக்க வேண்டும். கடல் நீரை குடிநீராக மாற்ற வேண்டும். ஊற்று நீரை அளவறிந்து பயன்படுத்த வேண்டும். செயற்கை மழை பொழிவிக்க கடிதே ஆராய்ச்சி நிகழ்த்தி, “பெய்யென பெய்யும் மழை” என்ற நிலையைக்கடிதே உருவாக்க வேண்டும். ஒரு வடிநிலத்தினின்று (Basin) கடலில் வீணாக கலக்கும் நீரை, நீர் பற்றுக் குறையால் அவதியுறும் வடி நிலத்துக்கு செலுத்த வேண்டும் (Inter Basin Transfer) மேலும் அறிஞர் பலர், நீர் அருகி வருவதை அறிந்து அதைப் பற்றி ஆராய்ச்சி நடத்த, “பலநாட்டு நீர்மவியல் பத்தாண்டுகள்” (International Hydrological Decade) என 1964–74, ஆண்டுகளை முடிவு செய்துள்ளனர்.

*மால்தூஸ் (Malthus) மக்கள் தொகை பெருக்கத்தைப் பற்றி பல ஆண்டுகளுக்கு முன்னர் எச்சரித்து உள்ளார். ஆனால் அவர் கணித்தபடி மக்களினம் பூண்டற்றுப் போகவில்லை. ஆங்கிலத்தில் தேவைதான் புது கண்டுபிடிப்புகளுக்கு தாய் (Necessity is the mother of Invention) என்ற முது மொழி உண்டு. எனவே, வள்ளுவர் நெறியில் அருமை உடைத்து என அயராது முயற்சி செய்வோமானால் கடைதேறி வழியேற வழியுண்டு. நீர், அருக அருக நீரை பற்றிய அறிவு பெருகி வளமாகி வாழ வழியுண்டு.

SECOND WORLD CONGRESS ON WATER RESOURCES, NEW DELHI, INDIA.

NOVEMBER—DECEMBER 1975

Organised by

CENTRAL BOARD OF IRRIGATION AND POWER

Under the auspices of International Water Resources Association.

WATER FOR HUMAN NEEDS.

FIRST ANNOUNCEMENT AND CALL FOR PAPERS.

The Second World Congress on Water Resources will be held at New Delhi, India, in November-December 1975.

2. The Congress is being organised by the Central Board of Irrigation and Power (New Delhi) under the auspices of the International Water Resources Association which is functioning for the advancement of water resources planning, development, management, science, technology, research and education on an international level.

3. "Water for human Needs" will be the theme for the Congress.

4. The Congress will establish an international forum for planners, administrators, managers industrialists, lawyers, engineers, educators, researchers, oceanographers and others interested in water resources to discuss the various problems connected with the development and utilisation of water resources.

5. Participation in the Congress is open to members as well as non-members.

6. Papers are invited on any subject related to the theme. However, special attention will be given to those dealing with:

Water Resources : Planning
Development
Management
Technology
Ecology.
Education
Information

Additional subjects covered by the theme are :
Irrigation Practices
Meteorology including Cloud Seeding
Pumped Storage Power Plants.

7. The intending authors may send six copies of the abstracts of their papers through their respective National Committees for IWRA so as to reach the Secretary, Indian National Committee by 31st May 1974. The Secretary, Indian National Committee is also the Organising secretary of the Congress.

8. In case of authors whose countries do not have a National Committees, the abstracts of papers may be sent direct to the Secretary, Indian National Committee before the due date.

9. Abstracts are to be submitted in English and must provide the following :
(i) Title of paper, authors, affiliation and mailing address.
(ii) Abstract is not to contain more than 700 words and should be type-written in double space. One or two sketches may be enclosed, if necessary, to facilitate review of the abstract.

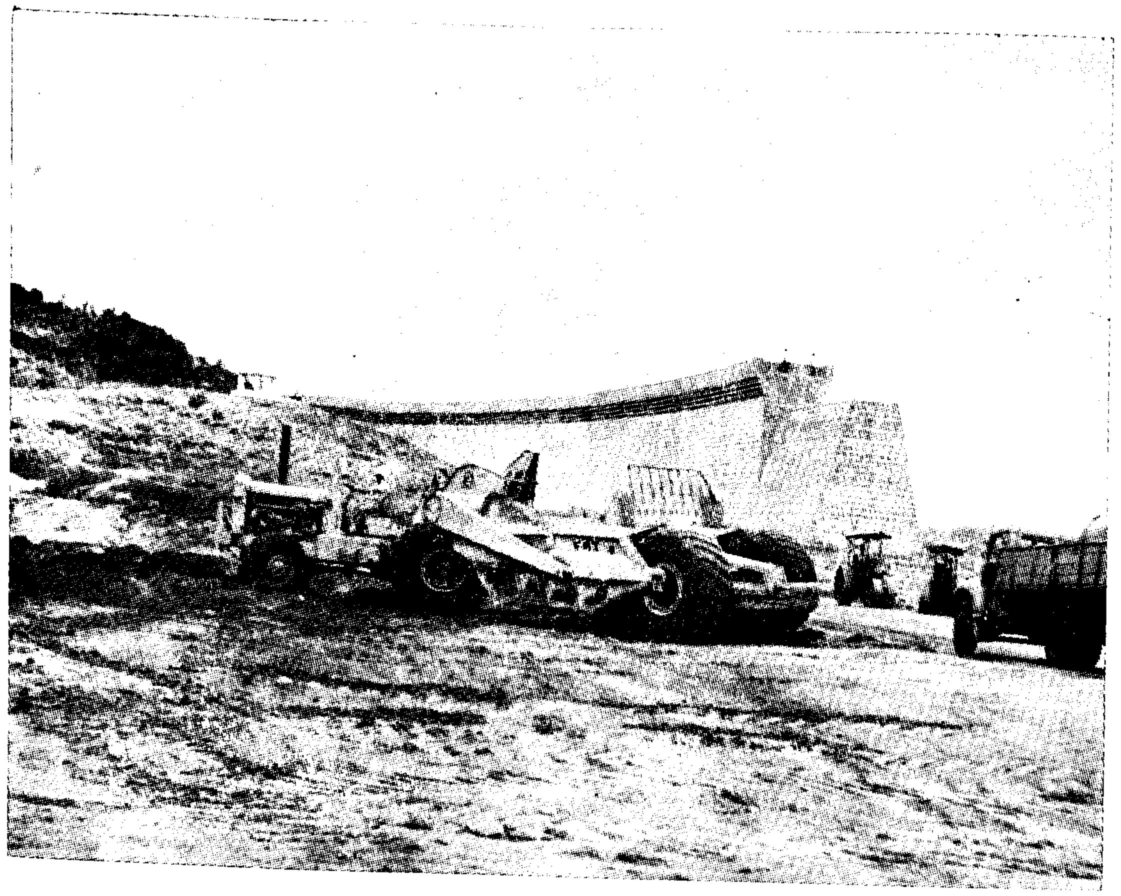
10. The abstracts will be reviewed by the Paper Committee of the Congress and the authors will be intimated about acceptance of the papers and given instructions for the preparation of the manuscripts by 31st July 1974. The authors will be required to send the full text of the papers by 31st January 1975. The final papers may be in English only. It is intended to provide preprints to the participants well in advance of the Congress.

11. Prospective authors and participants are requested to complete the attached card and return it to the Secretary, Indian National Committee.

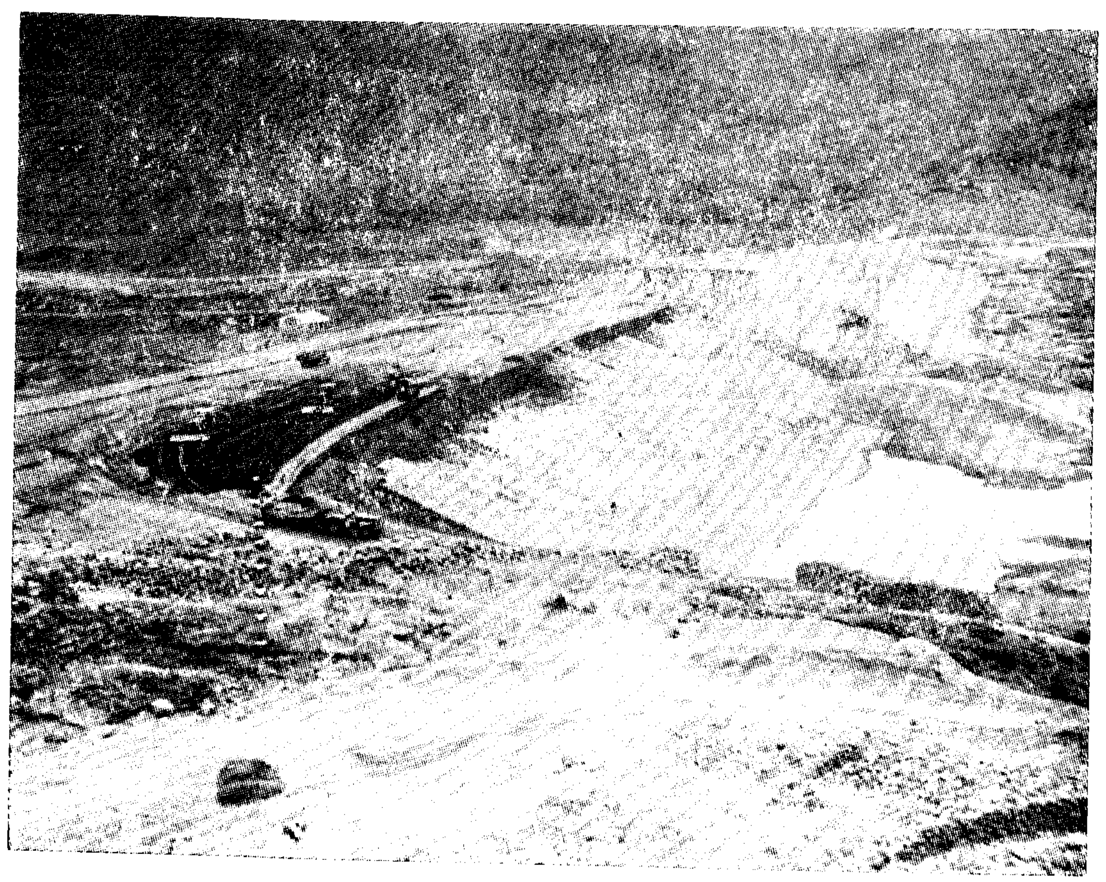
12. For further details please write to :
C.V.J. Varma
Secretary
Indian National Committee for
International Water Resources Association
Care
Central Board of Irrigation and Power.
Kasturba Gandhi Marg.
New Dlehi- 110001
India.

* * * *

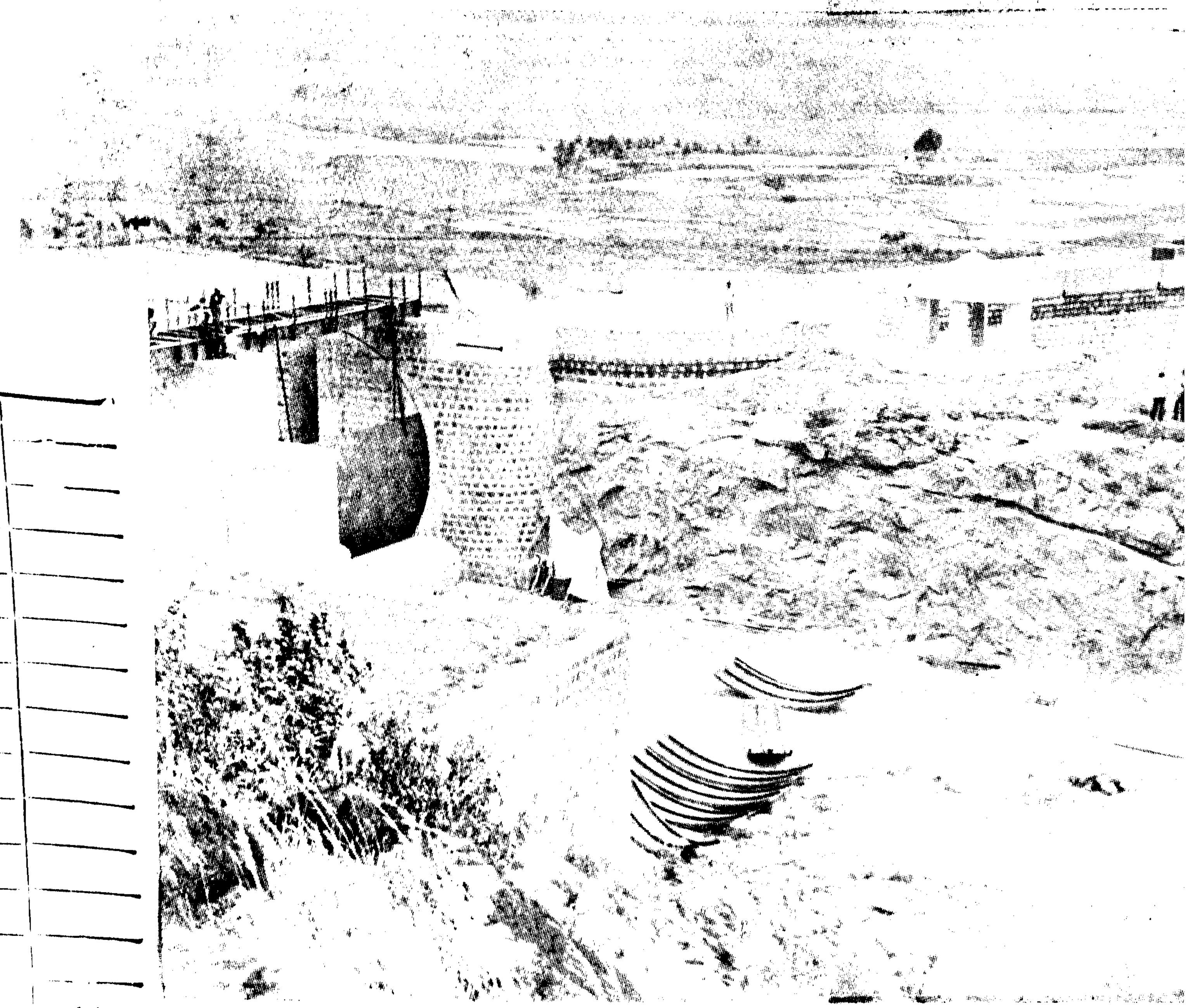
Second World Congress on Water Resources
New Delhi.



Ramanadhi Project—Earth Dam under Progress.



Ramanadhi Project—Earth Dam Upstream View.



Ramanadhi Project—Surplus Course Upstream view.