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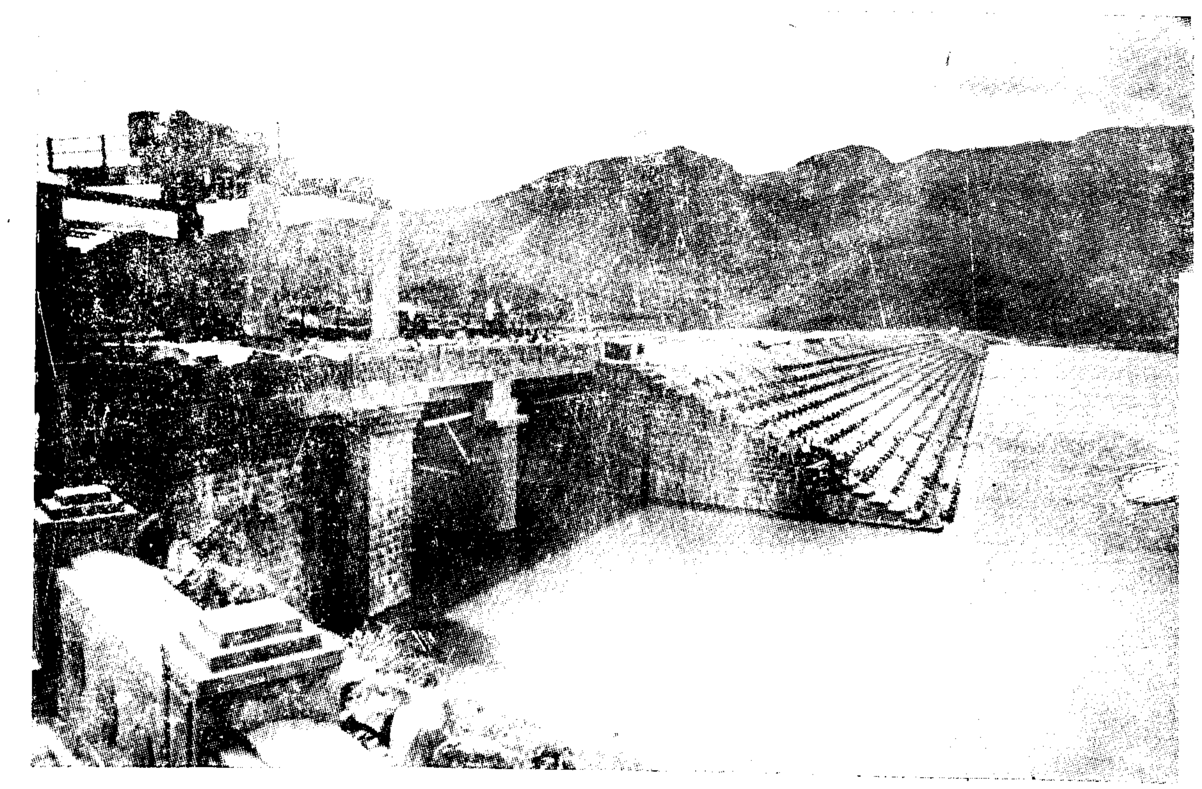
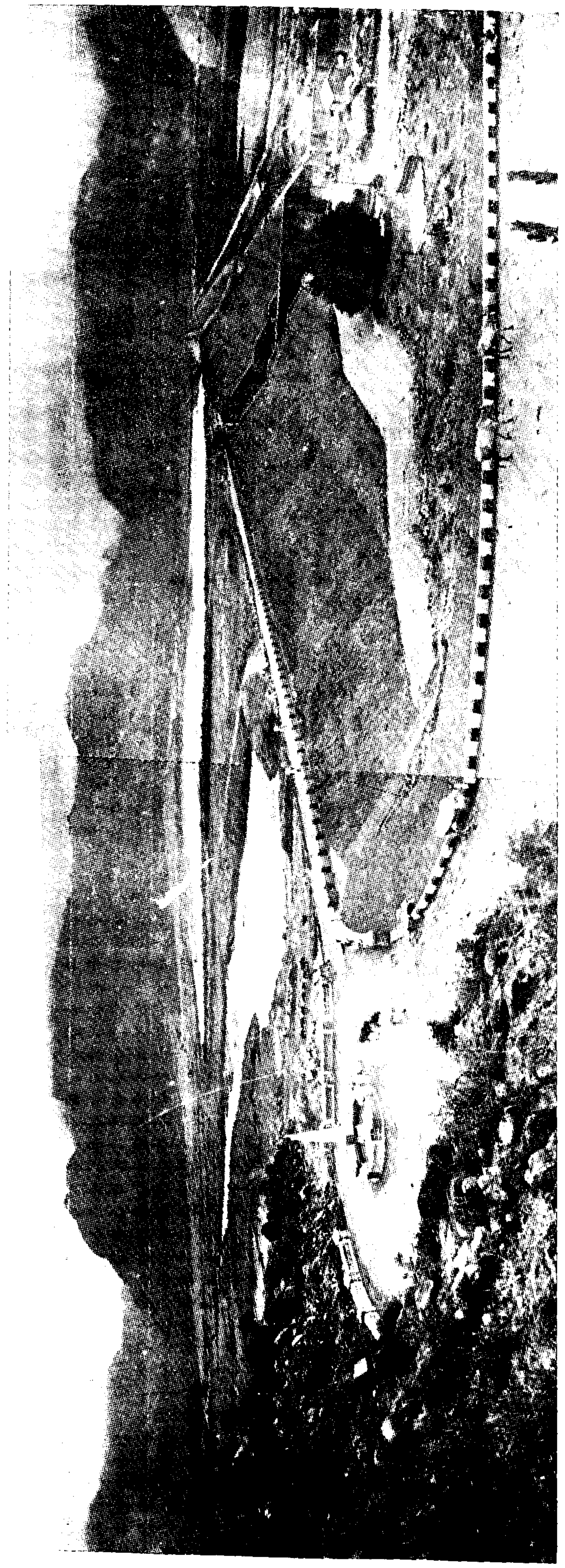


Front view of Karuppanadhi Project



A Panoramic view of Palar—Porandalar Project.

The Editorial Board of new Irrigation Era of Tamil Nadu Public Works Department accepts no responsibility for the views expressed by the authors.

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NEW IRRIGATION ERA XV - JULY 1977.

EDITORIAL.

In the first article under the topic "Scope for increasing the water resources for irrigation in Tamil Nadu" Thiru R. K. Sivanappan discusses the possibility of bringing west flowing river waters of Kerala to Tamil Nadu and thereby increasing the irrigated area and food production to feed the growing population of the State.

Under the caption "A note on use of Araldite epoxy resins for lining of water canals" by Thiru M. Balasubramanian, the various advantages that could be derived from the use of Araldite for lining the composite surface, precast composite slabs with a central manufacturing yard and steam curing instead of normal curing by water and the use of the same in the "Periyar Improvements Scheme" are suggested. The author has explained in detail as to the method of preparation of Epoxy mortar and preparation of base and its advantages and disadvantages.

Thiru K. S. Ramachandran, in the third article, viz., "work by construction equipment with special reference to earthwork by heavy earth moving machinery --Accounting by 'Use Rate' method-some suggestions" explains in detail the method of fixing the use rate that would be borne by the work for which the machinery was used. The author has described in detail as to what contributes depreciation of a machine such as whether a replacement of tyres can be included under depreciation, etc. The author has explained as to what is use rate.

In the fourth Article "An Electronic Device for settlement measurements" the author Thiru T. K. S. Ramanujam details about the three systems of detection of settlement measurements, and the principles involved in them and the fourth system developed by the Soil Mechanics and research division, P.W.D., in which a novel electronic torpedo is used, its advantages and its limitation of use.

Finally in the last article Thiru K. Ethirajan, throws light on different aspects of the prediction of the probable changes in the river dimensions and nature in a fairly scientific manner with special interest into the Engineering Point of view, the relative influence of water and sediment discharges in a river on the dimensions of river in the form of equations, formula, etc. The author concludes by saying that prediction of the future changes in the regime of a river or channel must be carefully made and considered in designing any river diversion, cross masonry or irrigation schemes.

Last but not least we request all Engineers to contribute articles for the publication of the future issues of the journal and serve a good cause.

(EDITOR.)

SCOPE FOR INCREASING THE WATER RESOURCES FOR IRRIGATION IN TAMIL NADU.

By

THIRU R. K. SIVANAPPAN*

Introduction.

Water is the most important single requirement for the growth of plant. The crops can be grown successfully if adequate quantity of water is available through rainfall or irrigation from either surface or below ground. Rainfall in most parts of the State is confined mainly for three months from October-December. In other months, the need of water by the crop is to be met by irrigation. Irrigation, the artificial supply of water to the crop, is as old as civilization in India and it is needed not only in the low rainfall areas of Coimbatore, Dharmapuri and Ramanathapuram Districts, but also in high rainfall areas of Thanjavur District. Research findings have high-lighted the importance of adequate soil moisture during the crucial stages of plant growth and hence the necessity for adequate irrigation facilities. In olden days, water resources were plentiful in relation to the man's needs. The irrigation works in existence at the beginning of the 19th century included numerous wells all over the country, a large number of tanks in Tamil Nadu, like the Viranarayana and Gangai Konda Cholapuram tanks which were constructed as early as the 10th century. The Grand anicut and Upper anicut built in the 2nd century AD was by far the greatest engineering feat of ancient India.

The development of irrigation has been taken in a big way only after independence. As far as 1903, there were only about 20 irrigation projects in operation irrigating 0.55 m.ha. From 1903-1951, the following projects were executed; 1. Toludur project, 2. Cauvery Mettur project, 3. Kattalai project. In addition, substantial improvements were carried out to regulate floods. By 1951, a total of 24 major and medium projects were there for irrigating a total area of 0.85 m.ha.

During the First Five-Year Plan, nine irrigation projects were taken up to benefit a total area of 0.22 m.ha. Five schemes were taken up during the Second Plan irrigating 0.12 m.ha. Another 12 major and medium works to benefit 0.135 m.ha. were taken up in the Third Plan. In the Fourth Plan, 10 projects were taken up to irrigate 0.028 m.ha. and another eight projects are proposed to be taken up in the Fifth Plan period.

The number of wells in operation in 1953-55 were only 7,91,215 irrigating 0.454 m.ha. of land and the demand of water is so much, the total number of wells at present have been increased to 1.40 million irrigating 1.10 mh. There are about 38,000 tanks in the State irrigating about 0.90 mh.

2. *Water, Land Resources of Tamil Nadu.*

The average annual rainfall of the State is 946 mm. This amounts to 12.3 mhm of water. But the rain water is lost by evaporation before and after reaching the surface from soil or water surface and the available water is calculated as 6.07 mhm and the utilisable surface flow is calculated as 2.486 mhm by Sakthivadivel (9). The irrigation commission has estimated that the total available surface water is estimated as 1.97 mhm of which 1.56 mhm have been utilised before 1951 (6). The new projects taken up since then would utilise an additional 0.16 mhm leaving only 0.24 mhm for further development.

(*b*) *Ground water.*—The task force on ground water, Planning Commission, New Delhi has calculated the ground water potential in the State as 1.40 mhm (7). Out of this, about 1.0 mhm has been tapped through 1.4 million wells in the State. In addition, this State is getting about 1.5 mhm of water from neighbouring basins (state) (9).

(*c*) *Land resources.*—The geographical area of the State is 13.0 M.ha. of which about 2.005 m.ha. is under forest and only about 6.1176 m.ha. is used for cultivation. The gross cultivated area comes to 7.65 m.ha. The net and gross irrigated areas are 2.82 m.ha. and 3.68 m.ha. respectively. The National Commission on agriculture indicated that the ultimate irrigation potential of the State is only 4 m.ha. of which 2.5 m.ha. of paddy which is same as the present area of cultivation, but the irrigated area under cotton is given as 0.55 m.ha. though the present area is only about 0.1 m.ha. The gross cultivation area has been noted as 9.5 m.ha. but this may go even up to 10.0 m.ha. and not more than that at any cost (6).

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The area irrigated and the total water required for irrigation and for other purposes as at present and in the future (say 2000 A.D.) are calculated and given below.

PRESENT AREA OF IRRIGATION AND WATER REQUIREMENTS.

Crops.	Area in m.ha.	Total water required in cm. (ow).	Water available from rain fall.	Net amount required as irrigation in cm.	Total quantity required m·ha.
(1)	(2)	(3)	(4)	(5)	(6)
Paddy ..	2·50	160	40	120	3·00
Millets ..	0·33	60	10	50	0·17
Groundnut and Cotton	0·46	75	15	60	0·25
Sugarcane Banana.	0·39	225	50	175	0·70
					4·12
Drinking water and for industries ..					0·52
Total ...					4·64 or 4·70 m.hm.

The sources from which this is obtained are as follows—

Surface water	2·50 m.hm.
Imported water from outside the State.. ..	1·50 m.hm.
	4·00 m·hm.
90 per cent of this is used	3·80 m.hm.
Ground water used	0·90 m.hm.
Total water used	4·70 m.hm.

AREA IRRIGATED IN 2000 A.D. AND WATER REQUIREMENTS.

Crops.	Area irrigated in m·ha.	Amount of water required excluding rain in m·hm.
(1)	(2)	(3)
Paddy	2·50	$2{\cdot}50 \times \frac{120}{100} = 3{\cdot}00$
Millets, Groundnut and Cotton.	1·10	$1{\cdot}10 \times \frac{50}{100} = 0{\cdot}55$
Sugarcane, Banana ..	0·40	$0{\cdot}40 \times \frac{175}{100} = 0{\cdot}70$
Total area ..	4·00 m.h.	

Drinking at 170 litre/day	0·45
Industries	0·80
Total ..	5·50 mhm.

The sources from which this is obtained are as follows—

Surface	2·50 mhm.
Imported from outside the State. ..	1·50 mhm.
Ground water	1·50 mhm.
	5·50 mhm.

From the figures given, it is observed that with the available water, only about 4 m.ha. can be irrigated which may be about 40 per cent of the cultivated area at that time. The percentage of irrigation for the entire country would be increased from the present 23 per cent to 54 per cent and in Kerala, the figures will be from 20 per cent and 82 per cent. This indicates that Tamil Nadu will lag behind in terms of irrigation facilities and in turn the food production may not be sufficient for feeding the growing population at that time though it is more or less self-sufficient at present. Then the question will be how to meet the increasing demand of water for the future in the State. The following ways and means can be attempted.

(a) Desalinisation of sea water.

(*b*) Cloud seeding.

(*c*) Introducing improved water management techniques.

(*d*) Practising the advanced methods of irrigation.

(*e*) Reuse of waste water wastage and industrial waste water.

(*f*) Diverting the water from North and West flowing rivers (Imported water).

Among the above six, the last item namely diverting the river water which is flowing in the west in Kerala State will be a very good proposition and the same is discussed in detail in this paper. However, we will consider the other methods also.

(*a*) *Desalinisation of sea water.*—One source of usable water is found in the saline waters of the world which is abundant. This is possible for this State since the eastern boundry is the Bay of Bengal. Scientists have developed techniques of removing the salt from sea water. But the cost is not conducive to convert the water for the use of the community. There are more than 300 units installed throughout the world for conversion. The rate of conversion for 1,000 gallon has been brought down from $ 5.00 in 1950 to 50 cents in 1970. The engineers are confident in bringing down the cost to 10 cents|1,000 gallons which is equivalent to $ 2.2|acre inch or ha. cm. The cost of well water in Coimbatore considering the cost of well, pumpsets, etc., comes to Rs. 15-20 acre-inch. Though there is a scope for conversion its utility is limited in the coastal areas for drinking and industry. This cannot be utilised for irrigation areas which are in the interior and at higher

elevations. Again the sea water has to be pumped and conveyed through pipe lines for irrigation and hence the chance of conversion will be less for irrigation needs.

(*b*) *Cloud seeding.*—One of the interesting developments in man's search for additional water supplies is cloud seeding. In this process, silver iodide and dry ice particles are introduced into the air to initiate formation of drops. When it is examined and questioned whether cloud seeding really works, the answers are different.

In Israel, seeding clouds with silver idoide from aircraft has indicated that the percentage of additional rainfall varies season to season, but was increased to 18-19 percentage on the average for the entire experiment. The data suggested that seeding may have occasionaly very strong effects and little or no effects on most days. The experinment conducted at White top, California has indicated that the estimated average loss of rain within the whole region of about 100,000 sq. mile was 21 per cent of what would have fallen without seeding. When a 5 year experiment, expected to produce a 5-10 percentage increase, shows a 20 percentage decrease in rainfall. The relevant technology does not appear reliable enough for practical use. Even if it is successful the economic feasibility is to be taken into consideration. However, considerable effort is being devoted towards improving techniques of control and measurement. The cloud seeding is practised in U.S.A. Australia, Israel and other countries. This method may be adopted only if the experiment is proved sucessful. Hence there is not much scope for this at persent.

(*c*) *Introducing improved water management techniques.*—In India, much attention is given by our engineers towards construction of dams, canals, but not on the quantitative and qualitative aspects of water use on the farm. The traditional system of irrigation is being followed without any change in spite of the latest techniques found in irrigation for high yielding varieties and multiple cropping techniques. Large quantity of water diverted from canals and pumped from wells are lost by seepage and evaporation. The loss from field water course alone is estimated to be about 15-per cent of water delivered at the canal outlets. Further inadequately or improperly designed field irrigation system and unscientific water application methods are the causes for losses of water. The losses often create problems of drainage and salt accumulation. Therefore efficient water management should be essential feature of our irrigation planning. Integrated development of water resources by a conjuctive use, efficient methods of conveyance and distribution of water on the farm, judicious methods of water application, proper soil management practices and cropping pattern of high water use efficiency, selection of suitable irrigation method according to the persent need and the removal of excess water are the important requirement for better water management on the farm.

(*d*) *Practising the advanced methods of Irrigation.*—The method of irrigation followed at present is still the same old system adopted thousands of years ago by our forefathers. Though man has walked on the moon, the irrigation method has not yet changed. Further it is difficult to convince the farmers to change the method in order to economise the available water. Even surface method, by providing suitable basin sizes and introducing skip furrow and alternative furrow irrigation, it is possible to reduce the irrigation water.

The sprinkler method which is practised all over the world will be an advanced method of irrigation and this can be practised in areas where it is economical and advantageous. One of the recent methods of irrigation is the drip or trickle method which can be used for vegetable crops, firuit crops and other cash crops which are grown in rows. In this method, water is given to each plant to its requirements at the root-zone and hence the saving is about 60-80 per cent. By introducing the above method of irrigation, it is possible to save larger quantity of water which in turn can be used to bring more area under irrigation. However, the requirement of water for drinking and household purposes and for industries cannot be brought down, but will be increased in the years to come.

(*e*) *Reuse of water.*—The effluent waste water has been used for agricultural and recreational purposes in California, New Mexico, Texas in U.S.A. and in Africa. The use of sewage water for domestic recyeling is well known in South Africa and Los Angeles in U.S.A. In Israel 18.5 m. cum|year of municipal waste water effluent has been used for irrigation and 37 m.cum year for industrial purposes. As a potential water conservation method, some cities in Japan have built large industrial water reclamation plants using waste water effluents as source . The sewage and waste water from the industries can be reclaimed and used for irrigation and other purposes.

As stated above about 0.52 mhm. of water is used for drinking, household and industries. However, it may be difficult to reclaim and reuse the entire water as many towns have not yet been provided with drainage facilities. However there are large sewage schemes in operation in Tamil Nadu. The total outflow form the towns where the collection facility is available amount to about 234 mld. excluding Madras which generates about 254 mld. of sewage (10). In addition, large quantity of water from the industry waste water could also be collected and reused. If the available (collected in the drain) sewage is utilised properly about 50,000 ha. of land can be brought under irrigation. Further if all the waste water is collected in all the places including industries and reclaimed, the quantity will be enormous. Action may be taken in this direction in order to increase the water source of the State.

The sewage effluent normally contains all the nutrients needed for plant growth. By taking certain precautions in selecting crops to be grown and following proper agronomical management, the sewage water can be used profitably. Further this water can be used for recharging the ground water in areas over pumping taking place.

(*g*) *Diverting the water from North and from West flowing river.*—Although water is available in adquate amount in India, the spatial, temporal and regional basis is severe. The availability of water in Tamil Nadu is very limited and the same has been fully harnessed as stated in the previous paragraphs. But when the irrigation resources of the entire country is taken into account only one third of the total water resources has been harnessed. The details of surface and ground water availability in the country is given below:—

(*i*) *Surface water resources.*—The Central Water and Power Commission has assessed the country's water resources. As a rough estimate, the annual rainfall over the whole country is about 400 mhm., of this about 125 mhm. is lost by evaporation, and another 80 mhm. by seepage into the soil, thus leaving about 195 mhm. as surface flow into the river system. However, all this flow cannot be utilised because of the limitations imposed by topography, climate, soil conditions, etc. It has been estimated that only 76 mhm. can be utilised from various river systems without inter basin transfers (5). If it is transported from one basin to the other, there is great possibility of utilising more water from the river basins, since substantial quantity is in the northern part of the country.

(*ii*) *Ground water resources.*—Out of 80 mhm. of water that seeps into soil, about 43 mhm. remains in the top layer and is available as soil moisture which is used by plants. The remaining 37 mhm. percolates down into the porous strata and represents the annual ground water recharge. However, it is possible to extract only about 26 mhm. economically. Again the maximum resources are only in the northern regions of the country.

Of the utilisable quantity of 67 mhm. of surface water only about 25 mhm. has been utilised so far and out of 26 mhm. of ground water only about 11 mhm. has been harnessed. This indicates that there is great potential to use the available water in this country.

The water resources both surface and ground water in each basin of the country show that large unused potential is available in the nothern rivers and basins (2). Therefore the water which is not used in the nothern rivers can be diverted to Tamil Nadu which is very badly in need of water for its agriculture and for other purposes.

The world bank experts who studied the feasibility of connecting Ganges to Cauvery have reported that the scheme is technically and economically feasible one, but the scheme will involve about Rs. 20,000 crores and take many years to complete. Hence action should be taken to divert the excess water from north to the scarcity areas like Tamil Nadu without losing further time.

There is great scope of diverting western flowing river of Kerala to Tamil Nadu. Already Periyar Parambikulam river waters are diverted to east by providing tunnels in the western ghats. Of course, only the surplus water after meeting Kerala's requirements, has to be diverted. In order to know whether there is any surplus water available to divert, it is necessary to know the water resources and its utilisation for agriculture and other purposes in Kerala.

(4) *WATER AND LAND RESOURCES OF KERALA* :—

(*i*) *Surface water resources.*—The total runoff of all the 44 rivers in Kerala State amounts to 7.80 mhm. of which 7.03 mhm. is the contribution from Kerala's catchment, the contribution from Tamil Nadu and Karnataka together being 0.77 mhm. (4,11). But all the waters that flow down the rivers cannot be utilised for several practical reasons. It is calculated that the total utilisable water resources is about 4,277 mhm. (11) large quantity goes as waste to the Arabian sea.

(*ii*) *Ground water resource.*—It is estimated that the ground water potential in that State is about 0.7 mhm. of which only 0.04 mhm. has been harnessed so far (7). Hence there is larger underground water supply which can be tapped for the requirement.

(*iii*) *Land resources.*—The total geographical area is 3.859 m.ha. of which 2.173 m.ha. of lands is utilised for agriculture. The gross cultivated area is 2,933 m.h.a. The area of irrigation at persent is 0.6 m.ha. and the entire area is irrigated from surface source only. The National Agriculture Commission has indicated that total cropped area (gros) will be about 3.2 m.h.a. in the year 2025 and the gross irrigated area will be about 2.6 m.ha. According to a publication of the Kerala Government the cultivated extent of wet land (Irrigated) and Garden land will be about 0.6997 m.ha. and 1.60 m.ha. respectively.

(*iv*) *Present water use.*—The gross irrigated area as on 70-71 was 0.60 m.ha. Even if Paddy is grown in the entire area, the water used will be less than 1 m.hm.

(*v*) *Future water requirement.*—According to the calculations made for the future requirements of water for irrigation, the report of the Government of Kerala has indicated that the total requirement will be about 2.88 mhm. However, the requirement is worked out as follows :—

a) Water needed for 0.6997 m. ha. of land for 3 crops of Paddy.

1. Total water for 3 crops .. .. 450 cm.
2. Average annual rainfall .. .. .. 308 cm.

Taking 50 percent of the rainfail will be usable in the year. i. e., 154 c.m.

Water requirements .. .. $= \frac{0.6997 \times (450-154)}{100}$

$= 2{,}10$ mhm.

b) Water needed for 50 per cent of the 1.6 m.ha. of garden land. $= \frac{1.60 \times 60}{2} = 0.48$ mhm.

Therefore total for irrigation .. $= 2.58$ mhm. or 2.60 mhm.

2. Water requirement of during in 2021 at the rate of 160 lit/day/person for 52·26 m. .. = 0·32 mhm.
3. Requirement of industries in another 50 years. .. = 3·43 mhm.

Total .. = 3·35 mhm.

4. Water required for Salinity control (as indicated in the report.) .. = 0·71 mhm.
5. Water required for removal of toxicity etc. (as indicated in the report.) .. = 0·50 mhm.

Grand Total .. = 4·56 mhm.

The totol utilisable quantity = surface water of 4·92 mhm. + ground water of 0·70 mhm.

= 5·62 mhm.

Therefore the surplus available is about 5.61—4.56 1.05 mhm. even taking the requirements for salinity control and removal of toxicity, etc., which however, may not require so much of water. Hence it is possible to divert atleast 1 mhm. of water from west to east so that about 1.50 mh. of dry lands in adjoining districts of Coimbatore, Madurai, Ramanathapuram and Tirunelveli can be brought under irrigation. If this quantity is obtained from the west flowing rivers, the percentage of irrigation can be increased from 40 to 55 per cent in Tamil Nadu which will be the average irrigated area in India in another 40-50 years. The irrigation Commission in their report has also suggested that Tamil Nadu Government can negotiate to get the surplus water from Kerala.

Tamil Nadu can offer to Kerala Government supply of atleast 50 per cent of the food produced from the water drawn from Kerala. This will facilitate to get water from Kerala and at the same time, the dry tracts of the neighbouring districts will get water for irrigation. Other arrangements like power generation and places of diversion can easily be worked out if only the Kerala Government agrees to divert water which is beneficial for both the States.

Summary :

The demand for water in Tamil Nadu is increasing day by day especially when the entire surface water and more than 60 per cent of the ground water have been harnessed for irrigation and other purposes. The area irrigated is only 3.6 m.ha. and it can at the most be increased to 4.0 m.ha. and the irrigated area will be only 40-42 per cent of the cultivated area at that time. The food production from the irrigated and dry area may not be sufficient to feed the growing population unless more area is brought under irrigation. This is possible only by diverting the Ganges water to Cauvery and also bringing west flowing river waters of Kerala to Tamil Nadu. Since the above two propositions are favourable from the data furnished above, the chance of getting water quickly and economically from Kerala State has to be looked into seriously. Since Kerala is having more water than its requirements, there is possibility to get the same through negotiation with suitable agreements on reciprocal basis. The authorities concerned can take up the matter with Kerala so that the unutilised and wasted water can be profitably used in this State.

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USE OF ARALDITE EPOXY RESINS FOR LINING OF WATER CANALS.

by Thiru M. Balasubramanian, B.E. (Hons).

1. *Introduction* :

For several years, now plastics have been finding ever increasing use in the building Industry. Recently, special importance has been attached to the use of epoxy resins in the building industry.

Epoxy Resins.—The epoxy resins used in the building industry are usually liquid resins obtained by the reaction of Disphenol A with Epichlorohydin. They set at room temparature when mixed with suitable hardeners to sol'd infusible products.

Hardeners.—Various types of hardeners may be used with epoxy resins. These are mainly amines, Polyamides, and Polysulphides.

Both the curing characteristics of the mixtures, and the mechanical and chemical properties of the end products, depend to a very large extent on the type of hardeners used.

Fillers and Aggregates.—Quartz sand is one of the most suitable aggregates and is in widest use. It confers outstanding mechanical properties and excellant chemical resistence on the cured resins.

2. *Epoxy Mortar* :

Araldite Resins when cured with suitable hardeners and in combination with quartz sand, form Epoxy Mortar and this mortar possesses the following properties :—

1. Excellent adhesion to most substratas.
2. High compressive and tensile strength.
3. Very good chemical resistance.
4. Impermeability to water.
5. Exceptional abrasion resistance.
6. Minimum shrinkage of curing.

A comparative statement based on the results of tests made on a typical Epoxy mortar and concrete, is given below for reference.

	Mortar based on Araldite.	*Concrete PC. 300.*
Unit weight ..	2·1 Tonne/M³	2·4 Tonnes/M³
Compressive strenth	1000 Kg./CM²	400 Kg/CM²
Tensile strenth in bending ..	400 Kg/CM²	60 Kg/CM²
Modulus of Elasticity	16,000 Kg/CM²	3,00,000 Kg/CM²
Co-efficient of Thermal Expansion	$20\text{-}30 \times 10^{-6}$	5.5×10^{-6}

From the above, it can be seen that the epoxy mortar possesses very suitable properties and can be advantageously used for lining of canal to ensure a permanent and impermeable surface.

3. *Epoxy Mortar for Lining* :—

The usual formulation for the Epoxy Mortar is as follows :—

Araldite Gy. 257	100 Parts by weight
Hardener Hy 843	45 Parts by weight
Hardener Hy 960	3 Parts by weight
Quartz sand mix No 10	900 Parts by weight
Pot life of mortar	1 Hour at 30· C

The above ingredients are very costly ones. and the lining work exclusively with epoxy mortar will become prohibitively costly.

Hence it will be highly desirable to adopt a suitable modified lining surface combining the conventional concrete with epoxy mortar, and at the same time ensuring best results commensurate with the cost of such work.

This modified surface will consist of a normal concrete substarata of nominal thickness, with a protective coat over it with araldite epoxy mortar, to a thickness of about 5—6. mm.

4. *Advantages of adoption of composite surface of lining.*—

1. For conventional type of lining surface, concrete of rich mix of 1:3:6 or even 1:2:4 of large thickness ranging from 3" to 6", is adopted, depending upon the site condition.

However in the case of composite surface, leaner mix of 1:4:8 or 1:5.10 of lesser thickness ranging from 1½ to 2 can be adopted, since the effect of strength of rich and thicker concrete surface is ensured by the epoxy mortar coated over it.

2. The extra cost involved in the provision of protective coat with epoxy mortar will be more than offset by the savings in cost of concrete due to reduction in thickness and adoption of leaner mix.

3.1 Experience has shown that even lining done with rich and thick concrete surface does not ensure 100 per cent impermeability. Laying of Polythelene sheet under-neath the concrete surface is resorted to for ensuring 100 per cent, impermeability.

2. Experience has also shown that lin'ng done with ordinary concrete is subject to large scale pitting and erosion due to running water, and the lined surface gets damaged easily and quickly depending upon the strength of the plastered surface on top of concrete.

4. However in the case of composite surface, the epoxy mortar coat ensures 100 per cent impermeability and offers exceptional abrasive resistance.

5. The very smooth, but hard surface obtained by the epoxy mortar coat made up of fine quartzite sand of mix 10, will ensure keeping of the velocity of flow, without increasing the co-efficient of rugosity.

**Executive Engineer, P.W.D. Upper Anicut Division, Tiruchirappalli.*

6. The deterioration of plastered surface due to ageing will not occur in this composite surface in view of the very good chemical resistance of epoxy mortar coat.

5. *Method of Execution* :

Lining of canals is normally done in two ways, i.e., (1) Insitu concrete Lining and (2) Lining with precast slab. The adoption of the new type of lining with composite surface is applicable for both the cases eventhough it is more preferable to go in for the latter method for the reasons explained later.

I. Insitu Lining with Composite surface (Sketch No. I.) :

1.1. The substrata for this lining is done in a similar way as of ordinary cement concrete lining for canal. However a leaner mix of 1:3:6 or 1:4:8, with nominal thickness of about 1-1|2 inches to 2 inches is adopted, with the top surface finished smooth with extra mortar. This substrata concrete is cured, properly to develop its full strength, in the normal way. After proper curing, the base concrete surface is subjected to pretreatment, before application of the epoxy mortar over it, to form the composite surface.

The pretreatment consists of two operations, namely preparation of surface and coating with primer.

I.1 (1).—*Preparation of surface.*—In order to obtain a clean and sound surface to ensure good adhesion, the surface is to be prepared well to receive the primer coat and then Epoxy mortar.

This preparation can be carried out either by chemical treatment or by mechanical method. The Mechanical method consists of either grinding, abrading, planning or sand blasting, etc. The dust and loose particles resulting from the above mechanical operations, should be removed by vacuum cleaning or oil-free air blast. Then the surface is ready to receive Primer coat.

Where mechanical method is not practicable (i.e. where sand blasting drum, etc. is not available) chemical treatment may be given.

For this purpose, a 15 per cent hydro-chloric acid solution is used. It is better to have the solution prepared in advance since inaccurate concentrations of acid prepared on the spot may lead to failures.

The acid solution is then brushed into the surface with the help of a stiff street broom until the surface is wet all over.

The hydrochloric acid reacts with the excess lime of the concrete surface and causes the formulation of bubbles lasting a few minutes. The stiff broom should be still worked over the surface, until they disappear. The bubbles last about 10 to 15 minutes.

The surface should then be thoroughly cleaned with water jet, until all the slush is removed. The treatment is completed by checking with Litmus paper, whether all acid has been removed. If some, remains the surface may be given another rinse or neutralised with one per cent ammonia solution. It is then sprayed again with a jet.

The surface is then allowed to dry thoroughly. Now the surface is ready to receive primer coat.

I. 1 (2) *Primer coat.*—When the substrata surface has been prepared as detailed above, then the primer coat is applied.

The Primer coat consists of the following formulations :—

Araldite Gy. 257	100 Parts by weight.
Hardener Hy. 840	50 Parts by weight.

The Araldite resin and hardner should be mixed thoroughly, and then this mix is applied over the surface with the help of a stiff nylon bristle brushes, or by hard rubber rollers. The coating should as far as possible be of uniform thickness and the surface should be thoroughly wetted with the primer coat.

1.2. *Epoxy Mortar* :

1.2.1. *Application of Epoxy mortar.*—Now after the completion of the Pretreatment, the surface is ready to receive the protective coat with epoxy mortar. The epoxy mortar should be applied to the surface within 15—30 minutes after the application of primer coat. This period is called "open time", i.e., maximum period of time allowable between application of primer coat and application of epoxy mortar.

The formulation for the epoxy mortar has been given and is as follows :—

Araldite Gy. 257	100 Parts by weight
Hardener Hy. 840	45 Parts by weight
Hardener Hy. 960	3 Parts by weight
Quartz sand mix No. 10	900 Parts by weight.

The epoxy mortar is prepared as follows:—

The resins and hardener are mixed thoroughly and then the dry filler (i.e. quartz sand mix No. 10) is added to this solution, and thoroughly stirred and mixed. The mixed ready-to-use mortar is the resultant product. The mortar should not contain lumps of unwetted filler and should be of a uniform colour.

For small quantity of mortar, (i.e.) up to 1 k.g. or less, hand mixing would be sufficient, and for larger quantities in excess of 1 Kg. of epoxy mortar, the use of mechanical mixer is advisiable.

The ready-to-use epoxy mortar is then applied over the primer coated surface and is levelled up with mason's trovels and floats to obtain a uniform coated surface.

Now the composite concrete surface is complete, and is left to cure for at least 24 hours at normal temperature. The composite surface is then ready for allowing water.

1.2.2. *Pot life.*—The ready-to-use epoxy mortar has got certain time limit within which it should be applied. This is called "POT LIFE". After this period, epoxy mortar cannot longer be worked, and would have begun to set in the container. The pot life depends upon the temperature prevalent at the time of mix, and is given below.

Mix. Temperature.	*Pot life in minutes.*
25 deg. C	90
30 deg. C	60
35 deg. C	45

The above figure is applicable for small quantities of mix.

In view of the above facts, care must be taken not to mix or cast large quantities of mortar at a time, as considerable heat is generated by the exothermic reaction which takes place and results in a very short "POT LIFE".

1.3. *Coverages* :

1.3.1. *Primer coat.*—One kilogram of the resin hardener mix (Primer coat) covers an area of about 4 to 5 Square metre per coat. However depending upon the finish of the concrete, this coverage may vary.

1.3.2. *Epoxy mortar.*—One square metre of the surface requires approximately 10 Kg. of the epoxy mortar when laid to a thickness of about 5 to 6 mm.

Based on this data, the cost of protective coat with epoxy mortar can be worked out after obtaining the local market rate of the in-gradients, namely resins, hardeners and quartz sand mix 10.

1.4. *Cleaning and precautions* :

1.4.1. *Cleaning and maintenance of equipment.*—Tools and Mixing equipment used for preparation of Primer coat and epoxy mortar should be cleaned immediately after use, since once cured, mortar and resins are extremely difficult to remove.

Mixing drums are cleaned with sand, by running the mixing machine for a short time, during which the resin is absorbed by the sand and is then easy to remove. Any resin that remains, is scraped off with a metal spatula and the surface is cleaned with a rag soaked in non-inflammable solvents such as xylene, toluene. For this purpose, it is safer to wear rubber gloves.

1.4.2. *Handling precautions.*—Epoxy resins can cause irritation of the skin in sensitive persons if incorrectly handled. Certain safety precautions must therefore be observed and those handling the resins and hardeners should be given the following instructions :—

1. Personal cleanliness at the place of work should be maintained.

2. The resin and hardener should not be allowed to come into direct contact with the skin. For this purpose, they must wear rubber or polythene gloves.

The Polythene gloves have the advantage that they can be replaced when dirty. They are more pleasant to wear if cotton gloves are worn underneath.

3. Parts of the skin which come into contact with the resin or hardener, in spite of all the above precautions, should be washed with lukewarm water and a mild soap.

4. Spleshs on the skin should be removed immediately with a soap and lukewarm water. On no account, should a cleaning rag or solvant be used for this purpose.

1.5 *Disadvantages* :

The following disadvantages and difficulties are encountered to secure composite surface in the case of concrete substrata laid insitu.—

1. The strength of the composite surface depends on the strength of base concrete which is turn depends upon proper and effective curing. The normal method of curing of this insitu concrete is only, by keeping the entire concrete surface constantly under wet condition for about 2 to 3 weeks time. This is difficult and costly process in places where canal runs in dry region and in remote area.

2. Constant supervision of concreting and curing work, to ensure quality work is deprived off, due to long length of canal, running through difficult and inaccessible terrain.

3. The time log between the completion of insitu concrete base and commencement of protective coat with epoxy mortar is large, and base concrete gets extensively dirtied and hence needs expensive cleaning operations.

4. The pretreatment operations over the base concrete, are to be done in wide open area and hence are subject to interruptions, etc., due to change of weather conditions in addition to other attendant difficulties encountered in conveying costly and harmful chemicals and other accessories, like sand blasting and vacuum cleaning equipments, etc., from place to place and mixing them properly and accurately.

5. Application of the epoxy mortar to form the protective coat over the precoated surface within the "OPEN TIME" limit which is susceptible to variation due to change in temperature, etc., will also be very difficult in the wide open area.

All the above draw-backs are only in the nature of certain practical difficulties arising and not of technical or other impossibilities, and hence they are not serious enough to discourage the adoption of this new process.

2. *Lining with precast slabs* (*Sketch No.* 2) :

2.1. All the above draw-backs are eliminated if the other method, namely, lining with precast composite slabs is adopted, as detailed below :—

1. The base concrete slabs can be manufactured in a Central place under close and constant supervision and the best quality can be ensured for the base concrete.

2. Perfect curing of the slabs can be ensured by having a Central large curing pond and placing the slabs under water in the curing ponds for the period of two to three weeks.

In order to reduce the curing pond, steam curing can be resorted to. This process is quite feasible and it is explained later.

3. The precast base concrete slabs will be of medium size and of nominal thickness of 1½ to 2 inches. They can be easily handled.

Being of medium size, and manufactured in a central area, even with covered roof on top, the pretreatment operations can be perfectly carried out, under laboratory conditions and quality ensured to the maximum extent.

4. The base slabs which are cured in curing pond, in covered or closed area, are fresh and hence the cleaning operations are made easy, with sand blasting vacuum cleaner equipments being stationed at one Central Place.

5. The application of the epoxy mortar to form the protective coat over the pre-coated slabs will also be very easy and can be done precisely to the standard.

6. Composite slabs can be manufactured to the exact size and shape to suite the various canal and distributory sections.

2.2. *Disadvantage.*—The only disadvantage in this method is to ensure safe transport of the precast slabs from the Central Casting yard to the place of work.

But this is insignificant. The Epoxy mortar coated precast slabs are not easily subject to damages, since the epoxy coat possesses good resistance to abrasion and impact load. Hence the chances of damages due to handling will be rare.

As for the transport of slabs, it is not a problem nowadays since transport lorries are available in plenty and at competitive rates.

Even in the case of Highways Department, of late, Hot mix-bitumen plants are erected in a central place of work and the black topping work is carried on for about 20 k.m. distance on either side of this Central Location.

In a similar way, a central casting yard for every 40 to 50 k.m. length of canal, may be located, the required number of precast composite slabs may be manufactured, in this Central casting yard, transported to site of work on either side and the lining can be done easily and in a very satisfactory manner.

To prevent leakage at the joints of the slabs, chamber ends may be provided all around the slabs. After placement of the slabs, a V. Groove will be formed on the top surface, all around. This V. Groove Joints can be finished with epoxy mortar, and thus the entire lined area will be made completely impermeable.

When compared with many advantages in this method, this disadvantage becomes insignificant.

2.3. *Steam curing of precast slab.*—Very large number of slabs will have to be manufactured at one Central place, tc cater to the needs of the long length of canal. Hence the problem of casting yard, curing pond and stacking yard will arise, if the normal method of curing under water for two to three weeks is resorted to.

We have to wait for about two to three weeks to remove and then complete pretreatment and protective coating works. Hence lot of time is lost before bringing the slabs into actual use.

All these problems will be got over, if steam curing method is adopted. The process has also been made very easy.

Wester Work multifide boilers of various size, capacity are easily available. There is no need to look for coal only as fuel for boilers. Medium sized boilers using waste wood, saw dust, etc., are now available from various firms, like wester worth, Lakshmi Boders, etc. The setting up of boiler, etc., is no problem since they are medium sized ones, and knowhow is easily available since the manufacturing yard is situated at one central place, and all the technical knowhow for erection of boilers and adoption of steam curing is available, this method can be easily resorted to.

The process can be successfully implemented, by carefully planning in locating casting yard-*cum*-initial curing yard and steam curing pond for final curing.

By steam curing, the precast concrete slabs obtain their full strength within one day as against 21 days by normal curing method by keeping them under water.

This reduced period of curing time enables, the subsequent operations, namely, pretreatment and application of protective coat, to be taken up within 3 days and the composite precast slabs become ready for being transported to worksite for use.

Since the total curing period is only two or three days, the surface to be pretreated is fresh and hence the cleaning and other operations became very easy.

The initial capital outlay on this, may be considered more, but considering many advantages, it is very much desirable to resort to this method of curing.

3. *Conclusion*:—

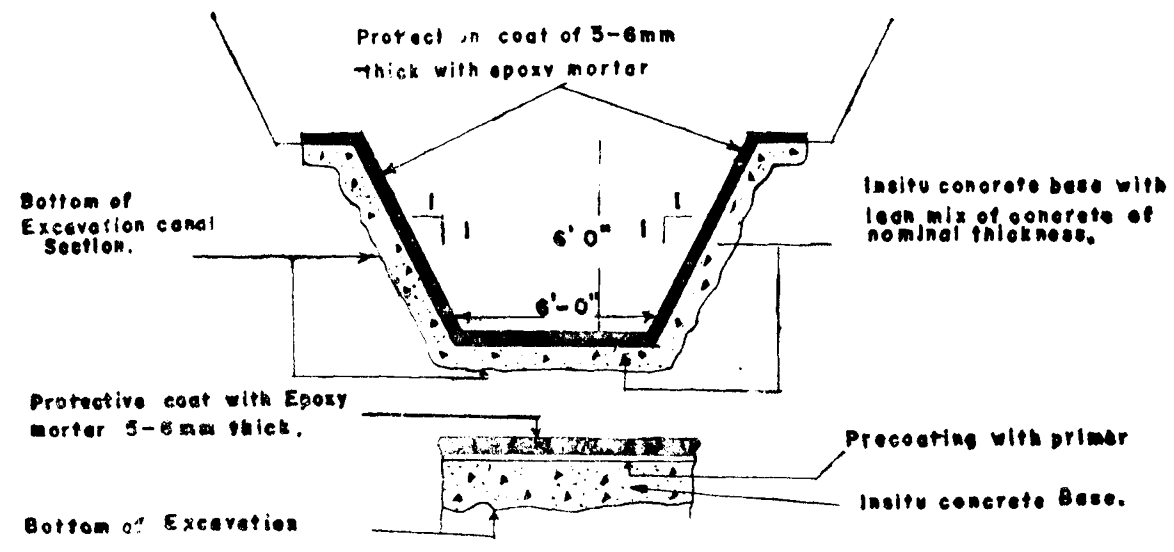
1. Considering very many advantages derived from use of Araldite for lining, it is desirable to go in for composite surface for such lining.

2. It is advantageous to go in for precast composite slabs for lining with a central manufacturing yard for such slab, instead of insitu concrete composite surface.

3. It is highly desirable to resort to steam curing of slabs instead of normal method of curing with water, since this reduces vary considerably the period of work.

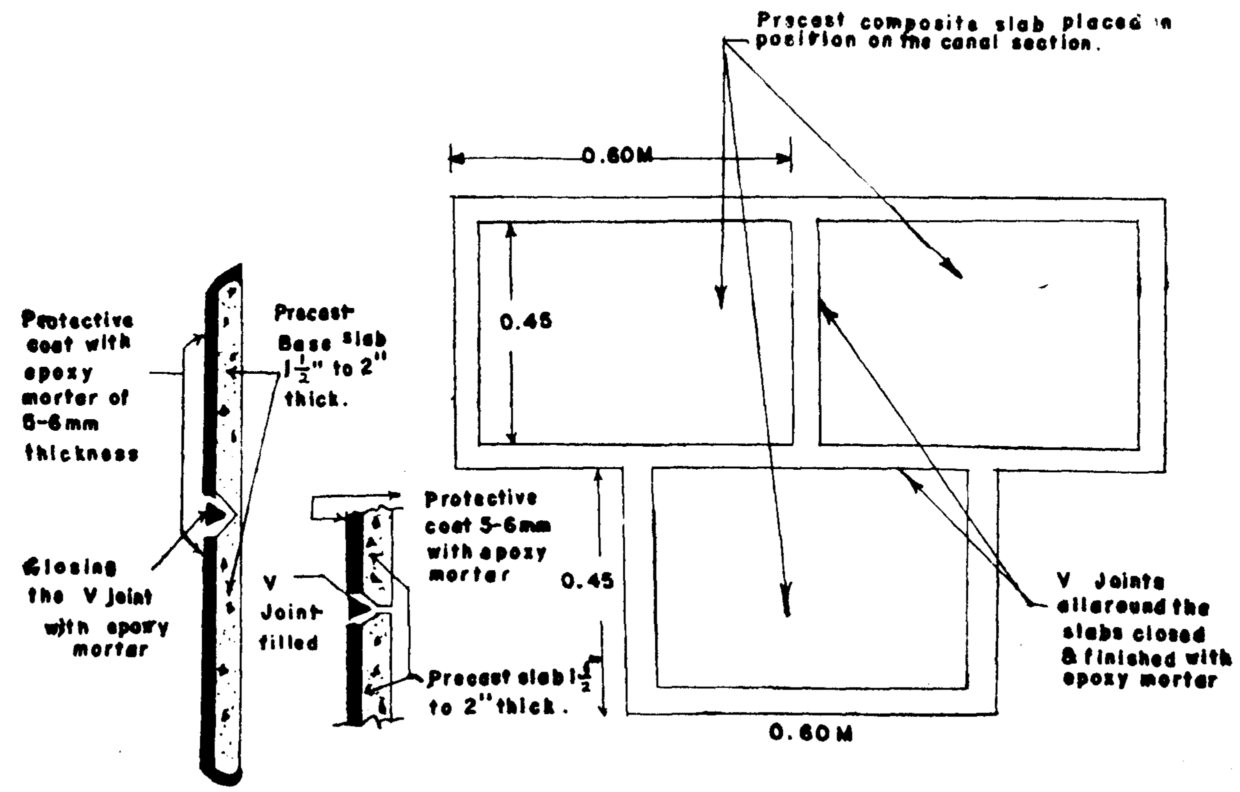
4. A beginning can be made to adopt these latest methods for lining of canals under "Periyar Improvements Scheme" where, it is understood, extensive lining work is proposed.

SKETCH NO. 1



ENLARGED SECTION

SKETCH NO. 2.



Work by Construction Equipment with Special Reference to earth work by heavy earth moving Mechinery-Accounting by "Use-Rate" Method-Rethinking required.

BY

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The work done by Machinery in our Department is accounted for by treating the machines as having been hired out to the works and collecting hire charges for the work done by machines. The hire charges are collected at "Use Rates" from the works. *The 'Use Rate' per hour is applicable to all works whether in the owning Division or any other Division. The method of fixing the "Use Rate" for machinery is enunciated in Chief Engineer (Irrigation)'s Circular No. 7117|59-A-1, dated 5th September 1959.

The "Use Rate" is being adopted by all the divisions of the Department but with a slight modification to the method illustrated in the Chief Engineer (Irrigation)'s Circular cited the modification being that depreciation of tyres which is provided for under the "I Depreciation" head in the illustration is removed from that head but added to the next head "II Major repairs and overhaul of machines". The reason for this modification is that the renewal of tyres being a "Major Repair" (which is defined as a repair which costs more than 1 per cent of the capital cost of the machine and the cost of tyres is assessed as equivalent to 1/6 the cost of the machine), the funds required for this repair have to be taken out of the Major Repair Fund and cannot be charged to the "Depreciation" head which is only a credit head. This modification is only a case of re-grouping of provisions and the total "Use Rate" remains unaltered.

The "Use Rate" system came into force actually from 1959 onwards. Inspite of the fact that it is in force for the last 15 years, I must regretfully comment, that it is being followed correctly in very few Divisions and most of the Divisions have no correct idea of the spirit behind this system and the meaning of the various provisions made in the "Use Rate". These remarks are based on my study in connection with the proposals submitted by me for the formation of Central Mechanical Organisation.

However, the aim of the present discussion is not to show out the incorrect methods followed in accounting in various Divisions of the Department or the remedial measures for the same. The aim is to show how the "Use Rate" system itself, as is followed now, is defective and how it does not represent correctly the cost of work done.

As a first step let us understand the purpose of purchasing a machine and working it. The purpose is to do work. In other words, if there is no work, there is no necessity to purchase a machine at all.

Having agreed with the purpose of purchasing the machine, what is the necessity for the various accounts such as maintenance estimate of the machine. Repair estimate, Use Rate and so on? Supposing a machine purchased is to be solely used for the specific work for which it is purchased up to the ultimate time of its condemnation and scrapping, there may be no necessity at all for an operating estimate, Repair Estimate. Use Rate, etc., as everything spent on the machine right from its purchase to its scrapping is to be borne by the work. But in practice, a machine works for several years on several different works and the expenditure incurred on the machine from the purchase to the time of scrapping has to be charged to the several works on which the machine is used. In other words each work on which it is used must share its first cost (cost of purchase), Repair charges and operating expenses. It is only for this purpose the system of "Use Rate" has been derived.

The "Use Rate" consists of 3 elements.

a. Depreciation which meets a portion of the purchase cost.

b. Provision for Major Repairs and overhauling which meets, a portion of the cost of repairs of the machine and

c. Operating cost, the actual cost of operation of machine. When the work done by machinery is charged at "Use Rate" the cost of purchase of machine, the cost of Major Repairs and operating expenses proportionate to the period the machine has worked on the work are met by the work. Summing up, the *total expenditure* incurred on the purchase of the machine, the repairs throughout its lifetime and the operating cost throughout its life time is to be shared by the various works on which a machine is deployed and proportionate to the time the machine has worked on each work.

The "Use Rate" enunciated by the Chief Engineer (Irrigation) consists of the following elements:—

1. Depreciation of the machine plus Interest on Depreciation.

2. Provision for Major Repairs and Overhaul at 75 per cent of depreciation plus cost of tyre depreciation.

3. Operating expenses consisting of

(*a*) Cost of fuel and Lubricants.

(*b*) Cost of Crew.

(*c*) Cost of minor repairs at 25 per cent of depreciation.

(*d*) Cost at 60 per cent of tyre depreciation for minor repairs and maintenance of tyres.

The provision under item (1) means that by the time a machine completes its theoretical life (fixed by the C.E.) the money invested on its purchase together with interest is realised from works.

The provision under item (2) builds up a reserve fund for carrying out Major Repairs and overhaul equivalent to 75 per cent of the cost of the machine by the end of its theoretical life, plus the cost of 5 sets of tyres (the life of tyres is taken as 3,000 hours as per Chief Engineer's Circular). This also means that the cost of all Major repairs during the entire life of the machine should be within this Reserve Fund, the money the works have paid.

The provision under item (3) represents operating cost. This is a variable factor because even in the case of two similar machines the operating costs are bound to be different because of the condition of the machines, operating conditions and method of operation of the two machines resulting in different fuel consumption, etc. Also the crew charges may be different the operator of one machine may be senior drawing more pay compared to the other and so on. However the expenditure on operating cost is completely recoverd from the work by comparing the operating cost portion of the hire charges recovered at the end of each year with the expenditure incurred on operation (i.e. maintenance estimate of the machine) and (debiting or crediting the difference called Residual balance) to the work at the end of each financial year.

In the application of this system of accounting, the most defective provision of the Use Rate is the provision for Major Repairs and overhaul. When the provisions expects that the total repair charges throughout its life have to be limited to 75 per cent of the first cost, it may be possible, if the cost of spare parts and labour constituting all the major repairs remain, throughout the life of the machine, more or less the same, as at the time of purchase of the machine. If the cost of spare parts and labour go up, it is not possible to keep the cost of repairs within the limit fixed as per this method.

In support of the argument, I am furnishing below the cost of a few spare parts used in machinery and labour charges over the last few years.

Name of the machine.	Name of spare part.	Cost.	
(1)	(2)	(3)	
Cat. D-8. 13-A	One set of Truck rollers (6 SP + 6 DF.)	14,000	(1960)
		35,000	(1974)
TD 25.	Cylinder liner + Piston Assembly 1 Set of 6.	3,750	(1964)
		8,400	(1973)
Do.	One set of Track Rollers (6 SF + 8 DF)	18,000	(1964)
		53,000	
Do.	Crank shaft	7,507·52	(1964)
		15,463	(1973)
Tournapull 'C' Scraper	Ring gear and Pinion Set.	3,626·63	(1964)
		13,210·21	(1973)
Do.	Roller Winding and Brush	6,639·38	(1964)
		21,617·64	(1973)
Do.	Motor and Shaft Assembly.	1,970·45	(1964)
		3,850·18	(1973)
	21·00×25, 24 Ply Tyres.	4,000	(1960)
		8,500	(1974)
	24·00×25, Ply tube less tyres.	6,500	(1965)
		21·500	(1974)
	Wire rope 1/2" Dia.	3·30/m	(1967)
		6/m	(1973)

Cost of Labour.

Chargeman	Rs.	170·50	(1964)	393·50	(1974)
Mechanic	Rs.	130·50	(1964)	344·50	(1974)
Fitter.	Rs.	102·50	(1964)	307·40	(1974)

It is seen that the cost of spares have increased 2 1/2 to 3 times and the labour also more or less in the same proportion in the last 10-15 years and the trend is one of increase only. Especially most of the parts used in the machines are imported items, mainly from U.S.A. and with the two devaluations of the rupee in the last 20 years and other causes the prices of to-day stand no comparison to the prices 10-15 years book.

When such is the case, is it reasonable to expect the total value of repairs of a machine to be limited to 75 per cent of its cost when the machines in our Department are continued to be worked for 10, 15 or even 20 years, in most of the cases will beyond their theoretical lives ?

Let us take the case Cat. D8, 13A Series bull dozer in our Department. Most of them were purchased in 1954 or so at a cost of Rs. 1.25 lakhs. A reconditioning of only the *undercarriage system*, not the engine, not the clutch and transmission or final drive—only undercarriage system costs in 1974 as follows:—

(*a*)	Cost of renewal of one set track rollers	35,000
(*b*)	Cost of one pair of Sprocket rings.	4,000
(*c*)	Cost of one pair of track chains with grouser shoes	35,000
(*d*)	Cost of reconditioning of idler wheels with necessary spare parts.	3,000
(*e*)	Cost of reconditioning of track carrier rollers (4 Nos.) ..	1,000
	Labour charges for dismantling fitting, etc.	1,000
		79,000

We have quite a number of these D8s still working in Department. We are to spend on under-carriage repairs to day as much as Rs. 79,000 for a machine which was purchased (new) for Rs. 1.25 lakhs.

In the same way, in the case of TD. 25 tractors which were purchased in 1964 at Rs. 2.55 lakhs each, the cost of reconditioning of under-carriage only costs to-day as much as about Rs. 1.25 lakhs. Same is the case with repairs of the machine is going off scot free without final drive, etc.

From the above, it may be seen that it is impossible to accommodate the repair cost in the Reserve Fund built up by the machine by the "Use Rate" system. Apart from this, one great mistake that is being committed by adopting the "Use Rate" system as *it exists* to-day is that the work which has to pay for the cost of repairs of the machine is going off scot free without doing so. In other words, the expenditure on work or the cost of work is not being exhibited properly.

The effect of this on work may be different in different cases. For example in a big project, the expenditure incurred on special repairs which is badly disproportionate to the recovery in the hire charges shows the earth work itself as having been done at a much lower rate than the real rate but the cost of repairs over and above what has been built up in the Reserve Fund still forms part and partial of the total expenditure on the project, having been accounted for under IV Special Tools and Plant head. It may be only a case of good chit for earth work and a bad chit for the IV Special Tools and Plant head but it still figures in the total expenditure of the Project.

But in the case of organisations like D.C.R. Divisions, Irrigation Reserve Stock (Periyakulam Division) which hire out the machines for works of other Divisions, it is a case of passing on less debit to work than should have logically been done and keeping back a substantial portion of the expenditure which should have been debited to work, under the IV Special Tools and Plant head itself. It may be a case of bringing credit to work at the same time discrediting machines.

The summary of what has been stated in the preceding paragraphs, is as follows:—

1. The work on which a machine is used has to bear (*a*) the cost of purchase of the machine; (*b*) the interest on the investment on the machine till the whole amount invested is realised. (*c*) the cost of operation and (*d*) the cost of repairs of the major repairs.

2. With the present Use Rate method, item 1(*a*), 1(*b*) and 1(*c*) are being borne by the work but not (*d*). Only a part of 1(*d*) is borne by the work.

3. The reason for 1 (*d*) not being borne by the work in full is the defective method of working out its provision in "Use Rate".

The solution, I beg to suggest, is as follows:

The first cost of the machine (cost of the new machine) and the cost of tyres should be assessed each year and the provision for major repairs and overhauls should be fixed at 75 per cent of this assessed cost of each year.

This means that item "II Major Repairs and overhaul" which is a constant in the "Use Rate" at present must also be made a variable.

AN ELECTRONIC DEVICE FOR SETTLEMENT MEASUREMENTS.

BY

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1. *Introduction* :

1.1. The objectives of instrumentation in so far as they relate to earth work engineering are: (i) to detect signs of impending danger, (ii) to furnish vital information during construction (iii) to furnish data for improving methods of construction (iv) to accumulate data on local experiences and (v) to enable the checking of various theories proposed to explain the behaviour of soil masses. The Government of India recognising the importance of the study of such instrumentation installed in dams, retaining walls. etc., constituted a committee in 1961 to review the instrumentation done so far in the country and also to make recommendations for adoption in the future. After detailed study of the practices prevalent in other countries vis-a-vis the stage of development and conditions prevailing in our country, the committee has recommended (1) that for all earth dams over 15m (50 feet) in height, the following measurements may be considered an obligatory.

"(i) Internal vertical settlement and strain during and after construction;

(ii) Surface settlements and horizontal displacements after construction. Wherever possible these may be done during construction also;

(iii) Stand-pipes and porous tube piezometers for appraisal of seepage control measures both in the body of the dam as well as through the foundations. These must be combined with the measurement of seepage;

(iv) Hydraulic piezometers in the regions liable to development of high positive pore pressures during construction and in the upstream casing and semi pervious units of dams with large range of drawn down."

The Committee on observation of dams and models of the International Commission on large dams (2) has also stressed the need for increased use of instrumentation with the construction of increasingly higher dams.

2.1. Most of the major earth dams constructed in the State of Tamil Nadu in the past two decades have been provided with vertical settlement gauges. These are generally of the USBR pattern (3) which consists of a series of 37 mm (1½ inches) and 55 mm (2 inches) sections of pipes telescoping into one another. The 37 mm (1½ inches) section is anchord to the embankment by means of horizontal cross arms at intervals of 3m (10 feet.) For this purpose the 37 mm pipe is attached to about a metre length of 75 mm channel by means of two U bolts. The channels sections are embedded in the embankment, as the embankment rises during construction. Movements of these cross arms as the fill settles is measured by recording the changes in the elevation of the bottom tip of the attached 37 mm pipe section (This point is designated as the measuring point in the figure).

2.2. A specially designed settlement torpedo is made use of to measure the elevations of the bottom tip of the 37 mm pipe sections (Fig. 1) The torpedo is attached to a 8 mm (5|16 inches) wide steel measuring tape and is lowered into the installation. The torpedo is provided with spring loaded pawls which close when passing through the 37 mm pipe sections in the downward direction, but they spring open as soon as they clear the 37 mm pipe section. If the steel tape is now pulled up, the pawls engage the lower end of the 37 mm pipe section and by holding the tape taut from the top, it is possible to determine the depth of the measuring point with reference to any accessible fixed point at the top of the installation. By progressively lowering the measuring torpedo it is possible to have the pawls of the torpedo latch with the lower ends of successive 37 mm. pipe sections and finally when the bottom of the installation is reached a specially installed latching plate, locks the pawls of the torpedo in the closed position and thereafter it could be withdrawn from the installation. Full details for the installation and taking observations with the earth dam settlement apparatus are contained in Designation No. E. 29 vide pages 672-693 of the USBR Earth Manual, 1965

2.3. This equipment has been found to give reliable service though the procedure for its installations and for taking observations is some what cumbersome.

2.4. Many attempts at simplifying and improving this system have been made. Electro-Magnetic probes for measurement of vertical and horizontal deflections in earth dams are reported to have been used in "GEPTASCH ROCK FILL DAM" in the Kanner Valley. Horizontal movement gauges based on the principle of induction have been used in the Liyn Brianne Dam (4) wherein they have used a plastic pipe (about 75 mm. diameter) threaded through metal rings or plates placed in trench during construction. The installation extended from the central clay core to the downstream slope. At the downstream end, the month of the pipe was taken into an instrument house and a reference plate was installed, attached to the wall of the instrument house and readings were taken with reference to this plate. The probe was pulled into the plastic pipe by a duct motor driven by compressed air, a steel measuring tape and a coaxial cable for the induction coil. These were paid out from drums mounted on a frame and were guided suitably by pulleys. An inductance bridge was used to indicate when the coil was near a plate. When the coil passed a plate the indicating meter on the inductance bridge moved from 0 to 100 divisions and then back to 0 again. It was observed that the deflection was at 100th division while the probe travelled several millimetres through the centre of the plate and an accurate measurement was made by taking the average of the readings of the tape when the meter showed exactly 50 divisions while increasing and again while decreasing.

2.5. The Building Research Station U.K. (5) has developed another type of equipment which is claimed to have an accuracy of better than 0.2 mm. This system has two components — a permanent circular magnet axially magnetised which acts as a mark embedded in the ground and a reed switch which is used as a sensor. As the reed switch moves axially into the central field of the magnet it snaps close thereby activating an indicator light or buzzar. The repeatability of the closure depends on the radial position of the reed switch within the magnet and also on the orientation of the reed about its own axis. By precision guidance of the probe, accuracy of the order of 0.2 mm is easily obtained. By using special equipment it is claimed that an accuracy upto 0.02 mm. is possible.

3. *Basis of the New Method*:

3.1. In the method developed by the Soil Mechanics and Research division, P.W.D., Madras a novel electronic "Torpedo" is used to measure the displacements of steel plates embedded in the earth dam. These plates may be of size 60 cm. x 60 cm. x 6 mm. with a central hole of 60 mm. dia through which a rigid PVC pipe is run to thread all the embedded steel plates. During measurement the torpedo is lower through the PVC pipe to locate the changing position of the steel plates caused by the settlement of the dam.

3.2. The torpedo has two solenoid inductors mounted on the same axis with a spacing of about 38 mm. between the coils. The Direction of winding and direction of the flow of current are so regulated that the magnetic fields produced oppose each other in the space in between the coils. When the number of turns in the two coils are identical and when the same current passes through the two coils in series, the magnetic fields produced neutralise each other in the plane exactly equidistant from the two coils. Figure 2 gives the distribution of the magnetic field as obtained from an electrical analogy experiment simulating the introduction of a metal plate in the vicinity of the coil system. If an independent pick up coil is suitably positioned, it will be possible to detect the change in magnetic fields and thus to detect the presence of the magnetic or conducting material introduced in the vicinity of the coil system.

3.3. After extensive investigation, it was finally found that the arrangement shown in Figure 3 gives the best results in respect of sensitivity and accuracy of location of the metal plate. In this arrangement, the field across the pick up coil is balanced when the system is freely suspended in space, well away from metallic objects and the output signal from the pick up coil is zero. Bringing any metallic object near to any one of these field coils affects the magnetic field distribution and thereby the null condition at the pick up coil. When the metalic object is located exactly symmetrically between the two field coils, the disturbance for both coils being equal, the null condition is restored. This principle is made use of in determining the exact location of the burried plate as will be explained below:

4. *Final Design Adopted*: A30

4.1. In the final design the main field coils consist of 1200 turns of 36 S.W.G. super enamelled copper wire wound on a 19 mm. diameter former over a length of 25 mm. The pick up coil consists of the same wire wound on a 25 mm. x 6 mm. bobbin. The D.C. resistances of the main field coils and pick up coils were 65 ohms and 12 ohms for each coil respectively. Figure 3 shows the details of the coil assembly.

4.2. *Effect of frequency.*—A study was carried out to determine the optimum frequency to be adopted for exciting the coil system. Frequencies in the range 50 cycles|sec. to 15,000 cycles|sec. at a controlled voltage were applied to the system and various factors such as magnitude of the output signal, ability to detect and distinguish different types of materials such as steel plates and plates of other materials, etc., were studied. The studies revealed that upto about 200 cycles|sec. the output from the pick up coils were relatively low and only magnetic materials were predominately detected. The sensitivity improved from 1000 cycles|sec. to 10 Kcs|sec. In the higher ranges of frequencies above 5000 kc |sec. both magnetic materials and non-magnetic conducting materials were equally effective in affecting the pick up, showing that eddy current effects were the more predominent.

4.3. *Circuits developed and utilised.*—A single stage transistorised oscillator has been used to supply the required excitation to the coil system. Figure 6 depicts the circuit diagram of the oscillator adopted. This Oscillator functions at a frequency of 8,000 cycles|sec. and delivers an output voltage of 6.0 volts to the field coils.

4.4. Four systems of detection have been developed. In the first system the output of the search coils is amplified and then fed to a rectifier, a gain control and a micro-meter. Figure 4 furnishes the circuit diagram of the amplifier-*cum*-detector. Under steady conditions when the coil system is in free space the output of the pick up coil is NIL and 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 buried plate increases the signal as also 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 the buried 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 5 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 buried plate could be easily located correct to 1 mm. It is to be noted that all these readings are steady readings and could be read quite conveniently and does not require any relative movement for taking observation as in the B.R.S. system (5).

4.5. The second type of measurement developed makes use of the principle of phase change detection. Figure 6 gives the circuit diagram adopted. The phase of the signal received from the pick up coil is compared with the phase of the input signal. 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 1 or coil 2. 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 the null position where only the maximum sensitivity is necessary. Changes of even 0.5 m. from the central position produces a measureable 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 the probe itself. Only the indicating meter is placed at ground level. A steel measuring tap is used for determining the levels with respect to the top reference point. Figure 7 gives the details of the assembly.

4.6. The above devices require 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 connecting wires. A suitable receiver with an output meter is located at the surface to receive the signals. A similar device has been used in the U.S.A. (6) but full details regarding this are not available.

4.7. A fourth system, the principle of which does not appear to have been utilised in any commercial instrument has been tried. As developed at present, the system works successfully in locations free from ground water. Further studies are under way to overcome this deficiency also.

In this system the steel measuring tape acts also as lead wire for transmitting the signals to the ground based meter. By this improvement the cumbersomeness of trailing lead wires is eliminated.

5. *Acknowledgments*:

5.1.The above work was carried out under a research project financed by the C.B.I.P. The C.B.I.P. awarded a certificate of merit to the Research Officers Thiruvalargal R. Rajaraman, and T. K. S. Ramanujam, who developed the instrument.

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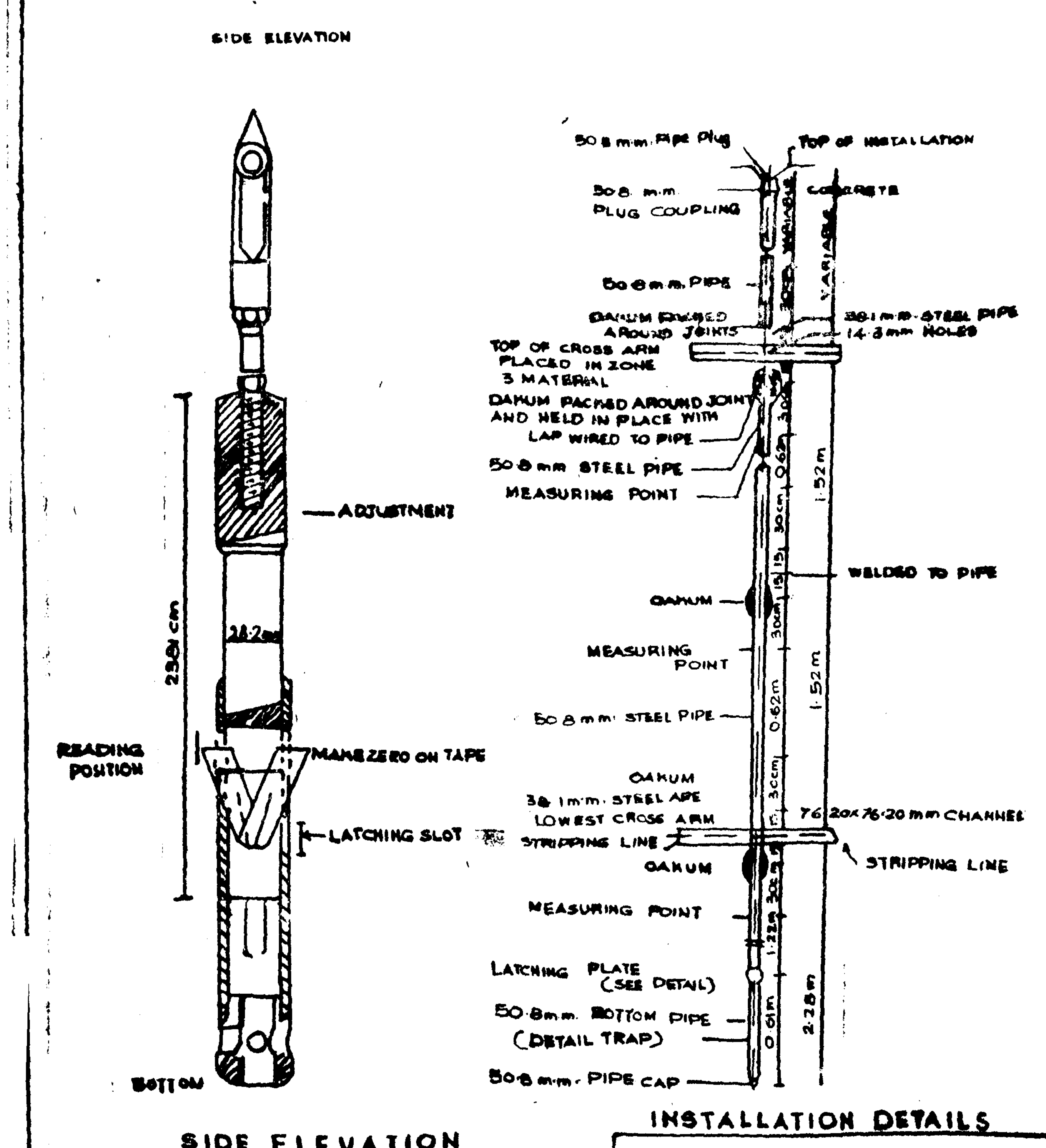
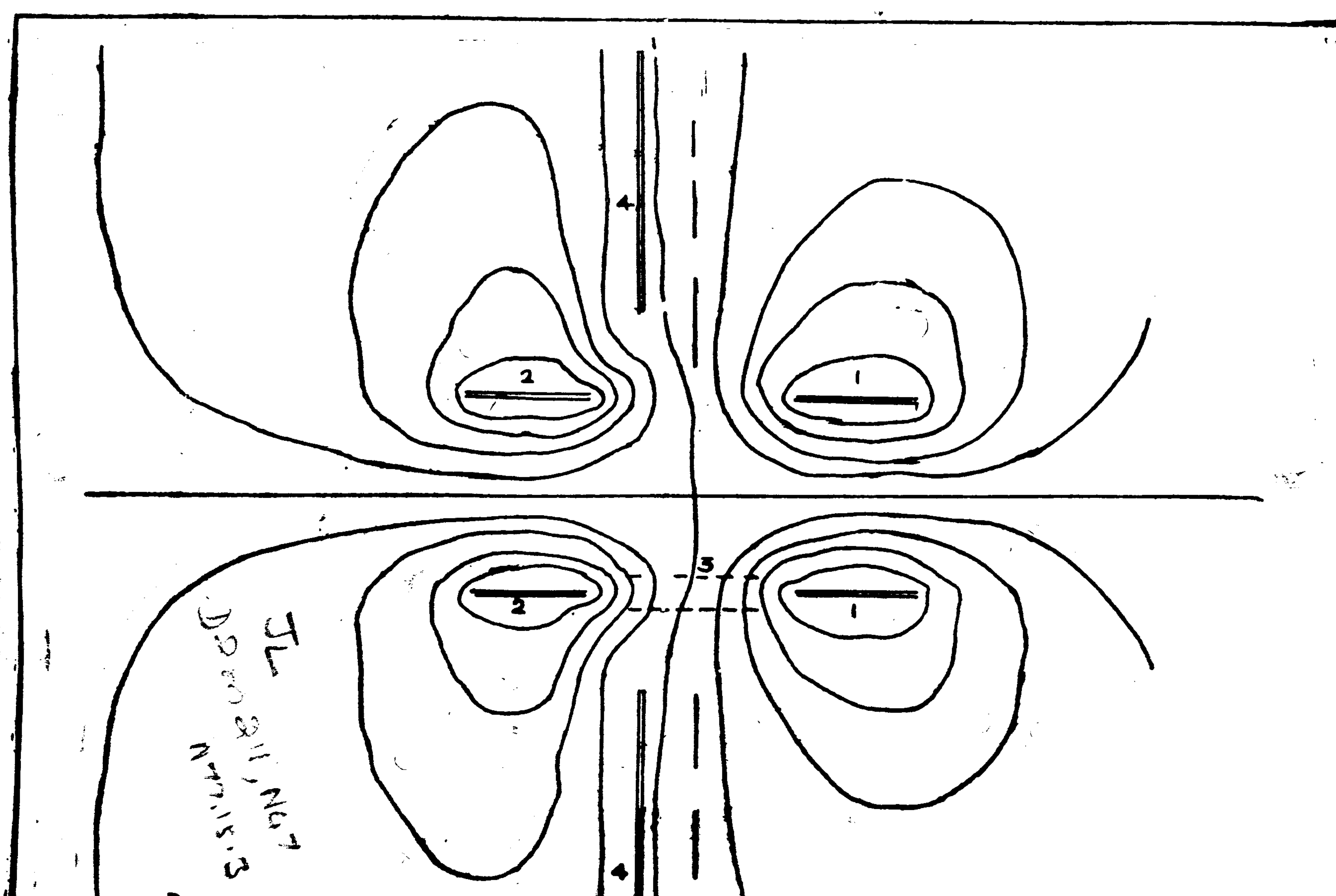
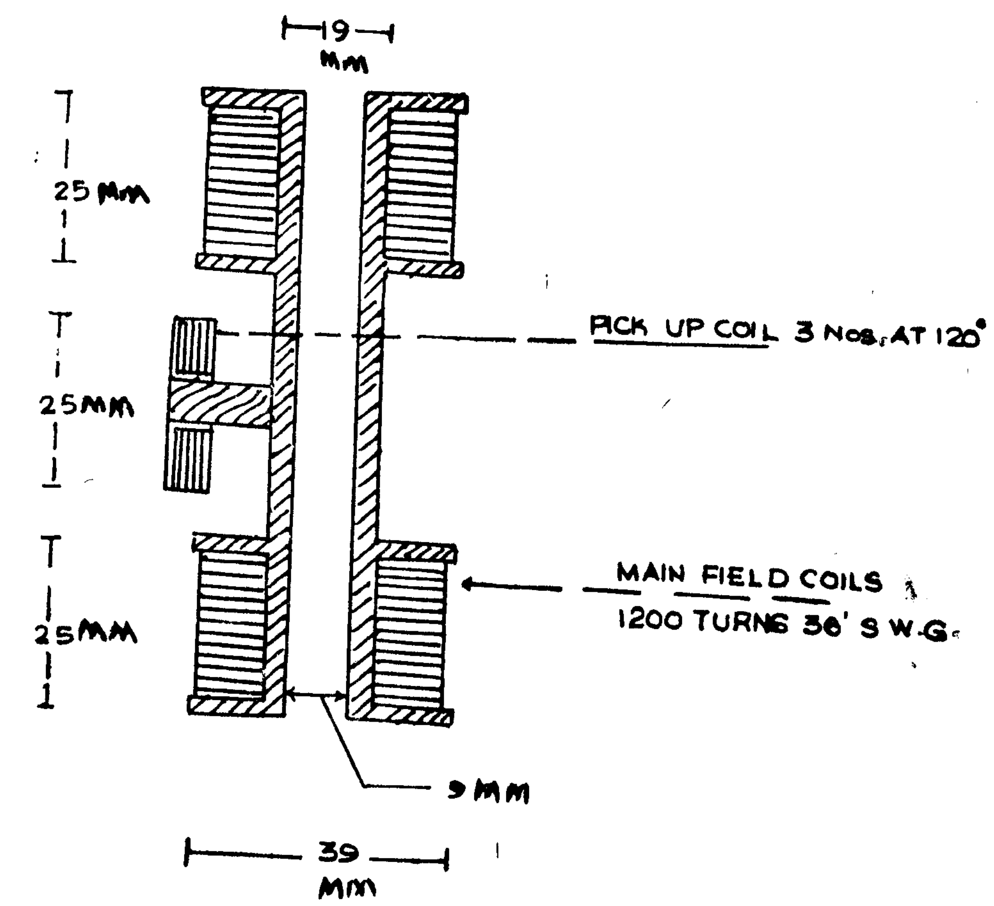


TORPEDO FOR MEASURING EMBANKMENT SETTLEMENT

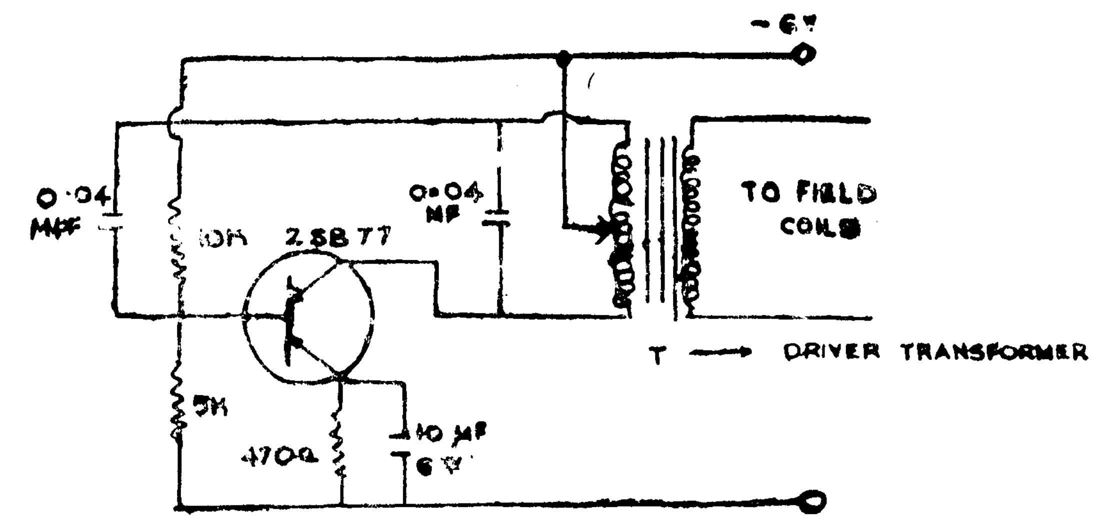
FIG.1



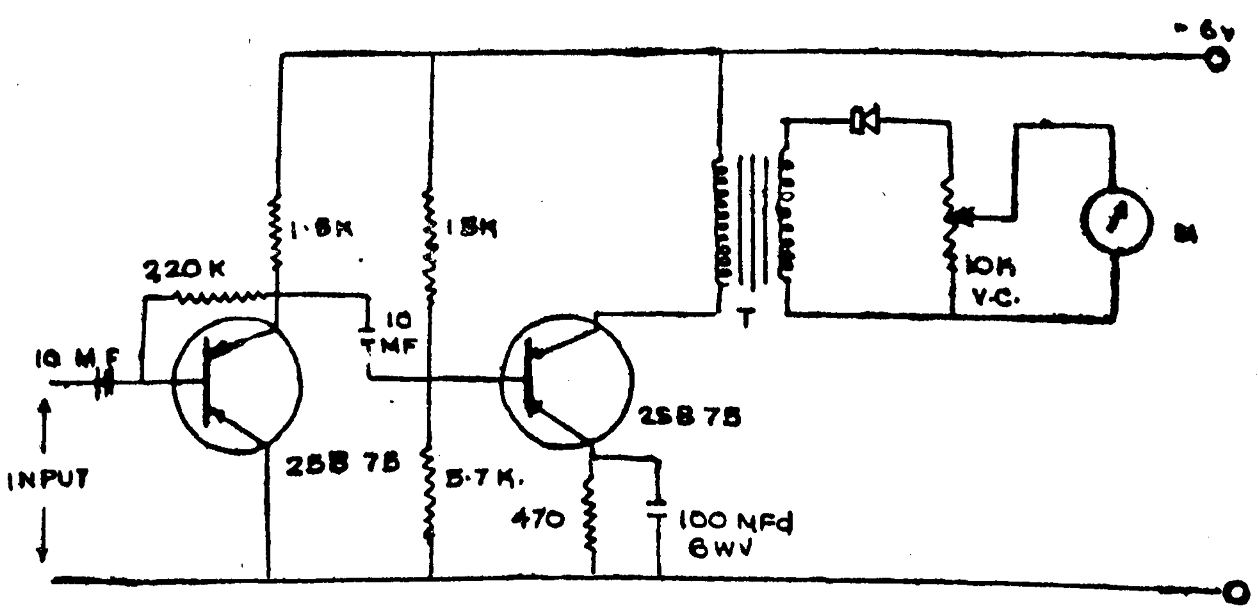
LINES OF FORCE
AFFECTED BY METAL PLATE
FIG 2



DETAILS OF
COIL ASSEMBLY
FIG.3

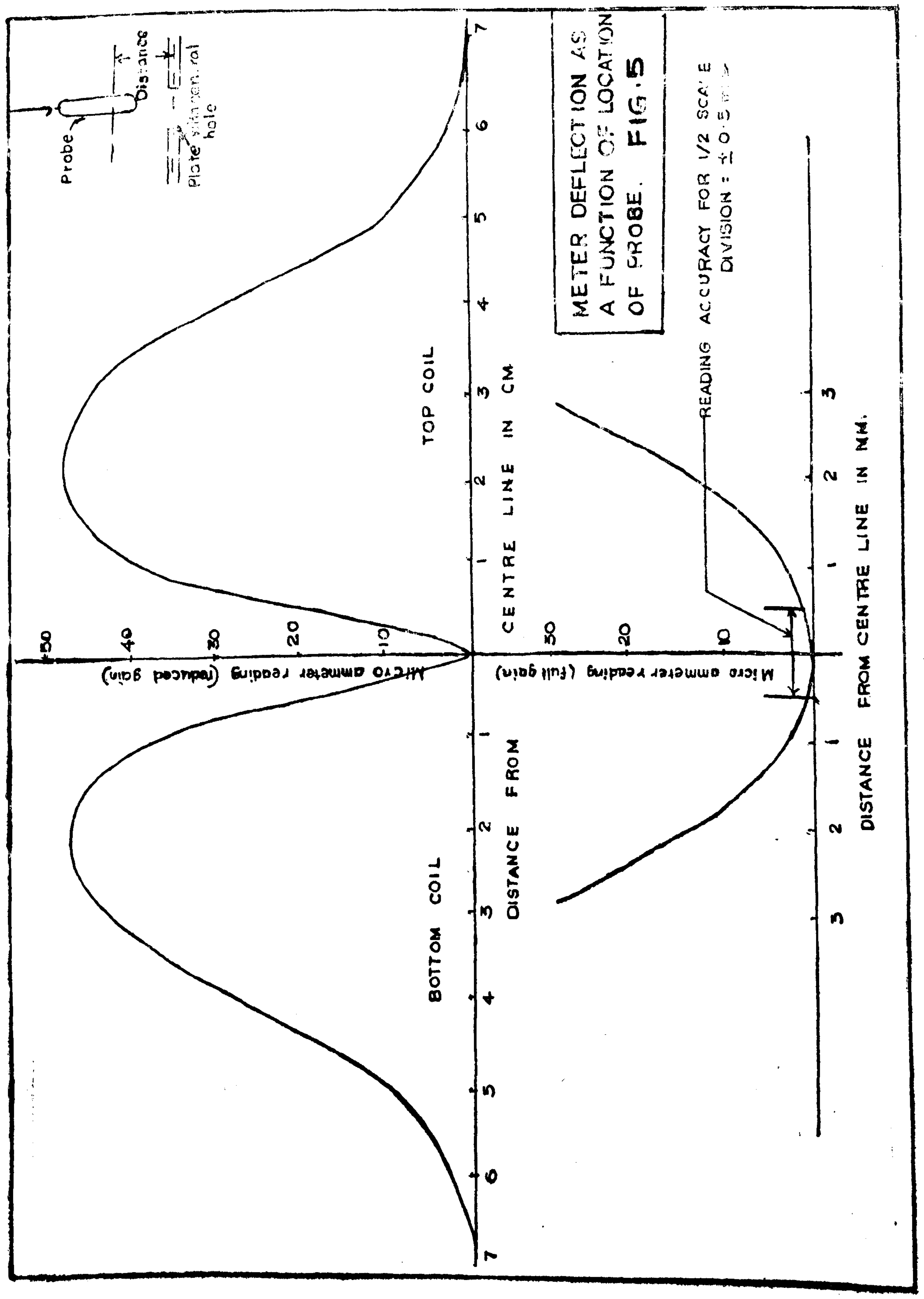


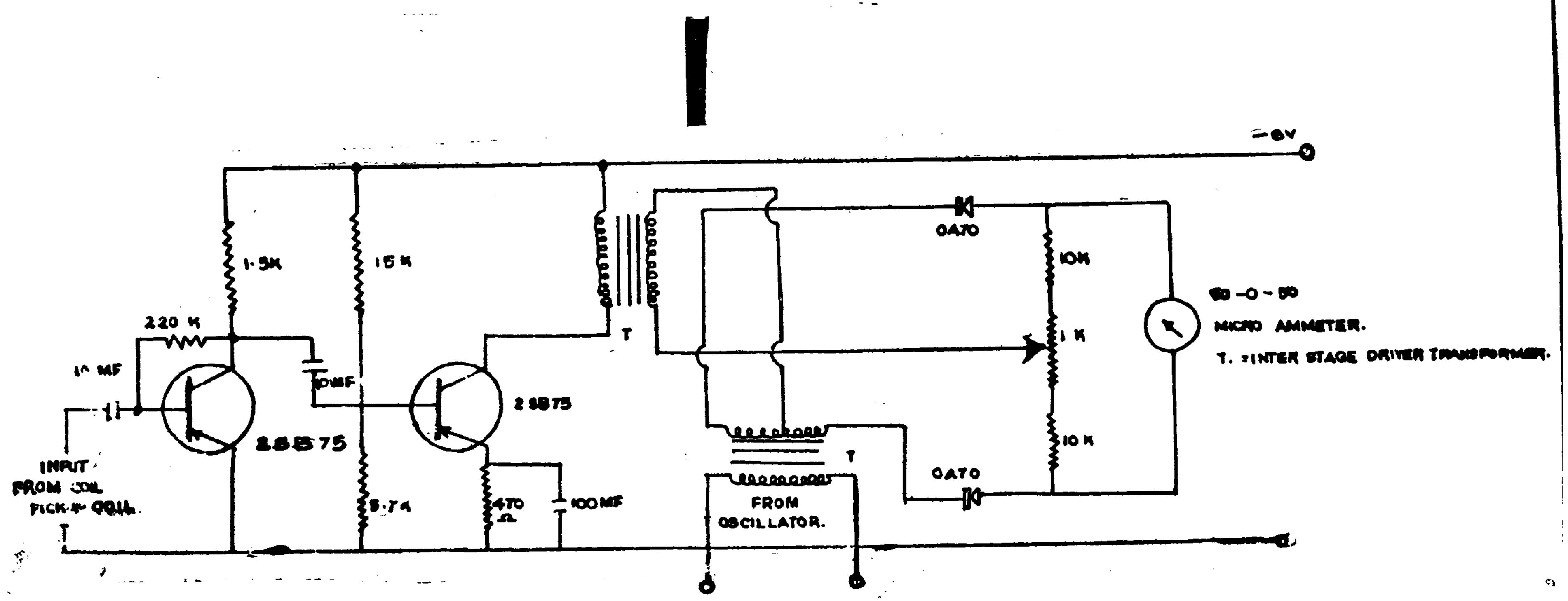
CIRCUIT DIAGRAM
OF OSCILLATOR.



T = INTER STAGE DRIVER TRANSFORMER.
M = MICRO AMMETER 50 µA FULLSCALE

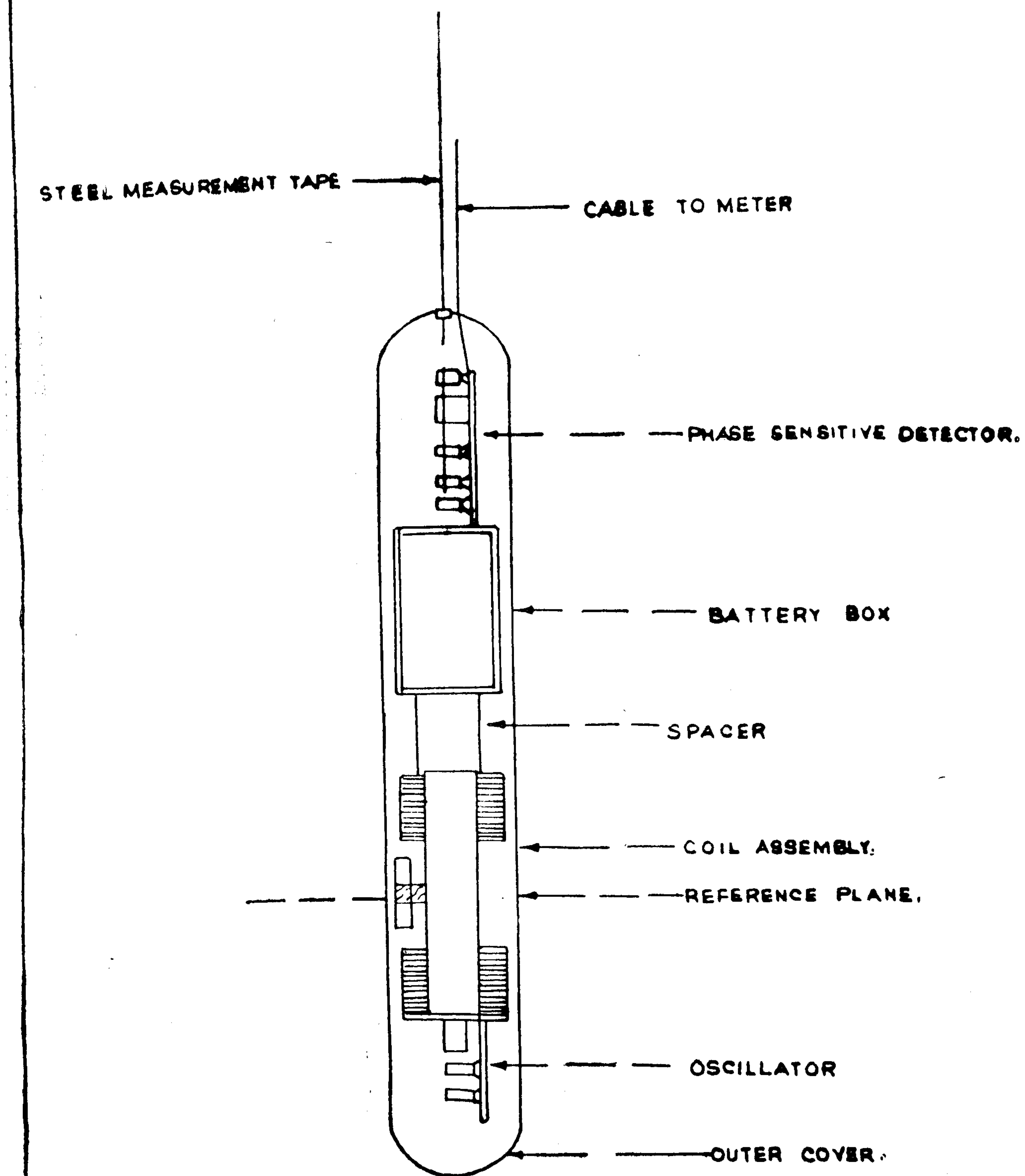
CIRCUIT DIAGRAM OF
AMPLIFIER — DETECTOR
FIG·4


METER DEFLECTION AS A FUNCTION OF LOCATION OF PROBE. FIG. 5
READING ACCURACY FOR 1/2 SCALE DIVISION ± 0.5
Probe
Distance
Plate with central hole
TOP COIL
BOTTOM COIL
DISTANCE FROM CENTRE LINE IN CM
Micro ammeter reading (reduced gain)
Micro ammeter reading (full gain)
DISTANCE FROM CENTRE LINE IN MM.



CIRCUIT DIAGRAM OF PHASE SENSITIVE DETECTOR.

FIG. 6



DETAIL OF ASSEMBLY

INSIDE PROBE

FIG.7

PREDICATION OF CHANGES IN REGIME OF RIVERS

By

THIRU *K. ETHIRAJAN, B.E., Assistant, Engineer, P.W.D.,* I.H.H. POONDI.

Scope.—Almost all the rivers are naturally formed by the geographic and geologic changes. All their dimensions, viz., breadth, depth, meandering, slope, etc., are naturally decided according to the topography and the soil nature of the terrain in which each river is formed. The effects of any flood in a river are generally accomodated within the capacity of that river to adjust itself, to be in dynamic equilibrium at all conditions of the flood.

But, due to the interferences or disturbances by the environmental changes by the mankind to utilise the land and rivers for their betterment, the dynamic equilibrium of the river is completely changed or disturbed, with the result that the naturally formed and settled river looses its original dimensions. Consequently, the new dimensions of the river, so created due to the changes in the environment will also be unstable, as there would be frequent and different changes in the environment; The changes in the environment of a river by the mankind may be Reclamation of the land, cultivation practices, clearing of the forest lands or their plantations, Diversion works and construction of Reservior accross a river, etc., in the watershed of a river basin.

From Engineering point of view, it becomes the responsibility of any design Engineer of an Irrigation Scheme across a river to visualise or predict the probable changes in the river course and its environment which can occur in an Engineering period of the scheme to prove the efficiency, economy and accuracy of the design. Otherwise, his design becomes unfit to the field of Execution of the Scheme. It is the main object of this paper to run a glance through the different aspects of the prediction of the probable changes in the river dimensions and nature in a fairly scientific manner, with special interest into the Engineering point of view.

Introduction.—In predicting or visualising the probable changes in the river dimensions, a thorough knowledge over the identification of the different variables, both dependent and independent, that can act on the change of dimensions of a river with reference to the Engineering time (10 to 100 years), if not to the geologic or others is necessary. The known, independent variables are water and sediment discharge in a river, the water discharge being the flood discharge and the sediment discharge being the wash and bed load movements in a river with the flood. The dependent variables are the breadth, depth, velocity, meandering. bed material and slope, etc., of the river, which are dependent on the independent variables, viz., water and sediment discharges in the river. Hence the study on the relative influence of the dependent variables on the independent hydraulic variables, viz., the water and sediment discharges becomes necessary. All the inferences and results of this study must be generalised in the form of equations, formulae and graphs which can reveal the required knowledge of the relations between the different variables referred above.

Relative influence of the variables.—The relative influence or effect of the different variables on the independent variables i.e., water-sediment discharges may be studied with the help of any one of the available hydraulic equations which are already established. Of those available, Einstein's modified bed load function, Colby's bed load relations, Lecey's equations and Mannings formula are some. The Einstein's modified bed load functions and Colby's relations are too difficult to elaborate for this purpose and hence it is attempted to assume their basic concept and adopt it here to start with. But from all the above functions and relations, it becomes clear that they are related to the variables under study. Hence any one of these relations may be conveniently adopted to determine the direction of change of hydraulic variables. These relations deal with the width, depth and energy slope, etc., of flow instead of those of the river or channel, and hence there may also be considerable discrepancy in the prediction of the changes in the effect of the variables.

The basic data for the study may be had or collected by direct measurements of the variables at a control section or gauging site in a river course for certain specific period. These data can also be had from flume studies and other model studies. Then, the relative influence or effect of the dependant variables on the independent variables (water sediment discharges) may be studied by keeping any one variable as varying while all the others are constant; thus the individual effect of each variable may be studied and measured and the equations and graphs pertaining to their relations may be generalised for the predictions of their effect or influence in the change of the dimensions of a river course, in due course of time. The generalised and established equations and graphs will be the ready reckoners to visualise the future changes that can take place in a river course. For very accurate and reliable results the whole course of river may be divided into different reaches according to their speciality and peculiarity and the study be made for each reach separately and the results generalised.

To understand the basic theory of the study in formulating the generalised equations and graphs, the manning's equation is analysed here for simplicity.

As per mannings, $V=\frac{1.486}{n} R^{2/3} S^{1/2}$ for wide rivers.

Where 'V' is the velocity in ft|sec, 'n' the co-efficient of rugosity, 'R' the mean hydraulic radius and 'S' the bed slope of the river reach.

$$\therefore \quad Q=AV=bd\times\frac{1.486}{n}\times\left(\frac{bd}{b+2d}\right)^{2/3}\times S^{\frac{1}{2}}$$

$$\simeq \frac{1.486}{n} bd^{5/3} S^{1/2}$$

$$\therefore \quad d=\left[\frac{Q\times n}{1.486\ b\ S^{1/2}}\right]^{3/5}$$

$$\therefore \quad d \propto \left[\frac{1}{b^{3/5}}\right], \text{ others being constant.}$$

and $V \propto d^{2/3}$

$$\therefore \quad V \propto \frac{1}{b^{2/5}}$$

Also, as per Einstein and Colby, relations, of bed load, the total sediment load $Q_s \sim V6$

$$Q \propto \frac{1}{b^{12/5}} \text{ or } b^{12/5}$$

$$Q \propto b\times b^{-12/5} = \propto b^{-7/5}$$

Where 'Q' is the total flow, 'b' the breadth of river and 'd' the depth of flow of river.

From these relations, we understand that the dependent variable 'b' (breadth) varies with reference to the independant variables, the water and sediment discharges, i.e., equal variations in Qw & Qs will tend to the same effect on the width of a river at any reach $\therefore \ b \propto [Q_w \ Q_s]$ Where Q_w is the water discharge and Q_s is the total sediment discharge. Similarly, the relations between the other variables can also be determined from the established hydraulic formulae, for any possible combination of the variations of the Qw and Qs which are independant variables. The possible combinations are,

1. An increase in the water discharge and the total bed material load with reference to the original conditions may cause either a decrease (—), or an increase (+) in the energy slope of the river at any reach

(i.e.) $Q_w+Q_s \propto S\pm$ ....(Slope variation).

(The magnitude and direction of the charges in the variables will be determined from the generalised equations and graphs which would have been already evoled for the purpose) vide (graphs 1 to 3. An increase in the Qw and Q_s may also be obtained by either increasing or decreasing the bed material size, say D_{65} to D_{50}

(i.e.) $Q_w+Q_s \propto S\pm D_{50}\pm$ (slope bed material variation).

An increase in the Q_w and Q_s can be achieved by either increasing or decreasing the depth of flow 'd', the direction of charge depending on the relative magnitude of the increase in Q_w and Q_s and also the quality of the bed material; a smaller increase in Q_w will create an increase in Q while a relatively large increase in the Q_s than Q_w will produce a decrease in the 'd'

$\therefore \quad Q_w+Q_s+\sim S\pm D_{50}\pm d\pm$ (slope, material size and depth variations.)

considering the width of the river or stream, an increase in Qw and Q_s can increase the width 'b'

$\therefore \quad Q_w+Q_s+\sim S\pm D_{50}\pm d+b+$ —(slope, material size and depths and width variations.)

2. Generally, a dam across a river will cause a decrease in the Q_w and Q_s in the downstream reaches of river. The effect of this on the other variables can be represented as below, by similar analysis.

$$Q_w-Q_s-\sim S\pm D_{50}\pm d\pm b-$$

3. In any diversion or offtake of a channel from the main river, an increase in the water discharge Q_w with a reduction in sediment load is expected. Its effect on the variable may be seen from,

$$Q_w+Q_s-\sim S-d+b\pm$$

But, from practical point of view, the changes for a decrease in width 'b' will be nil or negligible and hence the equation may be

$$Q_w+Q_s-\sim S-d+b+$$

4. Considering the effects of land use, cultivation and climate changes, etc., they can cause an increase in s and decrease in Qw and the equation will be

$$Q_w-Q_s+\sim S+d-b+$$

To decide the direction of variation of depth of flow and energy slope for conditions 1 and 2 above, the magnitude of the changes in Qw and Qs must be known and also any of the geomorphic equations can be used, assuming that the 'b', 'd' and 's' of the flow are the same as those of the channel, i.e., the channel sinuosity and width—depth ratio are necessary. According to "schemm", the width—depth ratio

$$\frac{b}{d}=56\frac{Qm^{0.10}}{M^{0.74}} \text{ (and the sinuosity}$$

$$P=0.94\ M^{0.25} \text{ and } M=\frac{55}{Q_{ss}}$$

Where 'Qm' is the average Annual flow, 'p' is the sinuosity and 'Q s' is the percentage of total bed material load.

$\therefore P\sim 1/Q_s$ and $b/d \sim Qm, Q_{ss}$,

Since the sinuosity is inversely varying to the percentage of total bed material load, any increase in Q_w and Q_s will cause a decrease in the channel sinuosity. This decrease in 'p' will straighten the channel. The b/d is directly proportional to the water discharge Q_w and the Q_s, and so any increase in Q_w and Q_w will cause an increase in b/d which will in turn cause a decrease or no change in the 'd' conversely, $Q_s\ Q_w \sim P+$ and this will cause the slope to become smaller. The b/d will decrease, as $Q_s\ Q_w\ (b/d)-$, $w\ (b/d)-$, the 'd' will be either increased or constant. Thus any other additional equations can also be obtained from all the graphs drawn from the data collected by direct measurements in the river or channel at different reaches. For, instance, considering a diversion of flow from one river to another which increases the 'Qw' 'Qs' being constant,

$Q_w+Q_s\sim S-d+b+$ will be the equation regarding the changes in the off-take river and

$Q_w-Q_s\propto S+d-b-$ will be that for the main river.

If, by any reason, Q_s is increased (by operation of scour vents, etc.); then $Q_s+Q_w\sim S+d-b+$ becomes the equation. Again, when a reservoir is across any river, it may decrease the Q_s, but not the Q_w

$$\therefore \quad Q_s-Q_w \propto S-d+b- \text{ will be}$$

the equation for the condition.

In all the above equations, the channel or river width can be decreased only if the stream transports a significant quantity of fine material. The effects on the variation of size of the bed materials can also be arrived at by postulating the changes in the characteristics of the bed material discharge.

Effects of vegetation on the flow in rivers.—The vegetation can be mainly classified as (1) Tall vegetation like trees and (2) short vegetation like grass.

The short vegetation.—Will act as any boundary roughness which retards the flow in the river, both as rigid as well as flexible roughness. Regarding the change or retardation in Q_w by the friction created by the short vegetation, the friction co-efficient 'f' can be determined for the various types and the relative changes in the 'Qw' and 'Qs' may be studied. Certain emphirical formulae are available for different boundary conditions, for this purpose.

1. For any hydraulically smooth boundary,

$$\frac{1}{\sqrt{f}}=2.0\log_{10} N_R\sqrt{f}-0.8, \text{ where } 'N_R'$$

is the Reynold's No.

2. For h hydraulically rough boundary,

$$\frac{1}{\sqrt{f}}=2.0\log_{10}\frac{2R}{K_s}+1.14, \text{ where } K_s \text{ is a}$$

known representative roughness and R is the hydraulic mean radious.

If Chezy's Co-efficient is adopted,

$$\text{then} \quad \frac{1}{\sqrt{f}}=\frac{'C'}{\sqrt{89}}$$

if the meaning's 'n' is used, the formula is

$$\frac{1}{\sqrt{f}}=\frac{1.48}{\sqrt{8g}}\ \frac{R^{1/6}}{n}.$$

The tall vegetations.—Will act as cylinders inserted in an open channel which will complicate the flow pattern by forming eddies and vortices around them in the downstream side. Depending on the type of the cylinders and the flow conditions, these vortices may be classified as 1. Horse shoe type, 2. Wake vortex type and 3. Trailing vortex type in any two dimentional flow. Any vortex system is an integral part of the flow pattern and it affects mainly the vertical componant of the velocity in the neighbourhood of the cylinder. The *horse shoe type* of vortex is formed by the concentration of the vortex filaments transverse to the river flow in a two dimensional undistributed velocity field, by the presence of the cylinder; the geometry of the cylinder controls the strength of the horse shoe. The *wake type* is formed by the rolling up of the unstable shear layers generated at the surface of the cylinder. The strength of the vortex is generated by the cylinder itself. This system is related to the so called "*Up flow*". The *Trailing System* actually occurs only on completely sub-merged cylinders and is composed of one or more discrete vortices attached to the top of the cylinder and extending D|S. The study of these systems lead to more of mathematical representations and it is also out of interest to elaborate this study for the purpose of this paper. But it is better to understand the effect of these systems in retarding the flow. The following are the inferences arrived by the study on the effects of tall vegetations in a flow.

1. Different groupings of tall vegetations have a significant effect in reducing the flow ratio and sediment yields.

2. The reduction in the flow rate due to the tall vegetation stumps (height equal to the depth of flow) can be estimated, provided that the spacing between trees is 6' dia. in the downstream and 3' dia. in the lateral side.

3. Tall vegetations grouped into staggered patterns are more effective in reducing flow rate, than any other pattern.

4. In any existing forest of tall vegetations, staggered pattern of cutting is difficult and hence it is better to harvest them in rows lr to the flow.

Application of the equations.—With the basic knowledge of the theory and the equations so formulated by understanding the relative influence of the variables on the water-sediment discharges, any hydraulic variable can be predicted prior to its occurrence, by considering the river by reaches and sub reaches. For instance, prediction of stage (depth of flow) for a certain recurrence interval discharge can be done by the following steps:—

1. The totol discharge of sand 'Qs' is computed by Colbys relations for each sub reach (graph 4 enclosed).

2. The equation of continuity for sediment is applied throughout each sub reach to obtain the bed elevation variation for certain time interval.

3. The velocity of flow is computed using the affected depth of flow.

4. From the flow velocity and energy slope with that value of stream power is computed.

5. The mannings 'n' is obtained from graph 5 with that value of stream power (graph 5 enclosed).

6. The final depth of flow is computed using the 'n' and the energy slope obtained above.

7. The stage for each sub reach is computed, adding the bed elevation with the variation in the elevation of bed.

8. Water discharge Qw is increased gradually step by step as per the hydrograph of the reach and the velocity of flow is computed using the depth of flow arrived at.

From the above steps of the equations, it is understood that a knowledge of future flow conditions is inevitable to predict the future changes or "*Regimes*", as it is known, of the rivers. The prediction of future flow conditions must be based on the past data and evaluation of the effects of present and future man made disturbances to the river. The prediction and study on the Regime of rivers and channels will certainly guide in overcoming certain difficulties in designing and improving the rivers and channels and also for flood control and protection work across them. Thus the efficiency of the Engineer's works improves better.

Prediction of long term River changes :—

1. *Basics.*—The salient features in the action of any river or channel are enumerated here for guidance. The origin of sediment in a river is its catchment erosion. The finer sediments tend to deposit on the flood plains and the coarsest are found in the deep bed during floods. The mode of their motion in a bed are various. The finer sediment, not found on bed of the river, but washed and rolled along the bed is called "Wash or suspended load"; this can be measured by "sampler's processes". The coarser sediment found on the bed which can be measured by "Traps" laid on the bed is called "Bed load". The behaviour of migrating sinuosities of a river is called its "Meandering". The initial reaches of any river may be called "Young", as there will be only bed scour which affects the water sediment ratio to a large extent due to its intensive action. The middle reaches are called "matured", as there will be scour on the sides and not the bed; the action of the earlier reach is pacified. Then the river becomes "old" by giving rise to deltas and deposition of sediment load.

2. *River Regime and equilibrium.*—Any river is said to be in equilibrium, when there is no effect on its breadth, depth, slope and meander pattern, due to any external forces during flood flows or change in flows, for a specific period. This stage of equilibrium of the river for a period is said to be the particular "*Regime*" of the river.

During a particular regime, the river will adjust by itself for the effects of the changes in water-sediment loads in a period of time, without much of changes in its geometrical form. This regime of any river may be different from one another with respect to the water sediment load changes over a period The known regimes of any open channel or river are 1. Sub. critical-laminar, 2. Supercritical-laminar 3. Super-critical-turbulant and 4. Subcritical-turbulant. To realise the sub or super critical and laminar or turbulant flow natures, the variations in the Froude No and Reynolds No are compared, as these numbers are quantitative representations of the nature of flow that is governed by gravity and viscosity respectively. For a critical flow, the Froude No is unity and it is less than unity for sub-critical and greater than unity for super critical flows. For a laminar flow, the Reynolds No is limited upto 500 for a mixed flow, it is between 500 to 2,000 and for a turbulant flow, it is beyond 2,000. It is to be understood that for a flow to be sub or super critical the gravity is the criterion and for a flow to be laminor or turbulant the viscosity is the criterion, as they are the controlling factors of the flow.

3. *Regime Changes indicators.*—All the river gauging stations and their records of specific discharge or flow will indicate the changes in Regime of a river. The gauging records of different discharges and the rising and falling stages can reveal any entrapment of sediment by a barrage or Regulator, by the drop of downstrem gauage reading etc. The downstream river reach will suffer less discharge due to obstruction of water by canals and increase bed load due to sediment exclusion from a canal etc.

Of all the possible variables, *viz.*, water, sediment loads, breadth, width, slope of the river and the grain size of bed material, water discharge 'Qw' is the one which can directly and easily be measured than the other variables. From the records of field data, different, graphs and formulae are obtained which can indicate or aid to estimate the changes that will develop in breadth, depth, slope and meander etc., of rivers, either

due to the hydraulic or man made interference or disturbance with the regime of rivers. The results of the prediction of the regime changes of a river reach with the help of those graphs and formulae will be of much useful to Ecologists, Engineers, geographers, geologists and hydrologists in their works. For instance, by knowing and interpretating the available graphs and formulae for a river behaviour, a project or design Engineer can predetermine the probable course of action of the river in an Engineering time to suit his design or execution of any irrigation project in accordance with the natural changes of the river by which the efficiency and economy of the project is increased.

4. *Simple Regime Relations.*—The regime relations consist of the meander length 'M_L' Meander breadth 'M_B' river width 'b' depth 'd' and its bed slop 's' on one side and the total discharge 'Q' on the other side; it is assumed that the water-sediment complex and the self adjusting sides are fixed.

The discharge formula.—Assuming a long, straight, horizontal channel, with a steady water-sediment discharges 'Q_w' and 'Q_s' and with a non-cohesive bed formation due to 'Q_s' the sides being either erodible or depositable, and the irregularities of sides and meandering are prevented by maintainance, the channel will get equilibrium values of 'b', 'd' and 's' depending on the (the sum of Q^w and Q_s) Q, in course of time. If this experiment is repeated for different Values of 'Q' others being constant, then the b, d, and s will be functions of Q, i.e. f (Q) =f (b,d,s). If new set of experiments are conducted allowing the full meandering of the channel, others being constant, the M^L and M_B will also be f (Q)=f(M_L M_B).

If further experiments are conducted with fluctuating, but average, steady 'Q' assuming the same functional relations in terms of specific averages, different co-efficients will be evolved. Thus, some functional relations are formed by repeated studies which are given below.

1. For river and canals—'b' varies as $Q^{1/2}$

2. Duned sand bed rivers and canals— $d \sim Q^{1/3}$ and $S \sim \overline{Q}^{1/6}$

3. For gravel rivers—$d \sim Q^{2/5}$ and $s \sim \overline{Q}^{2/5}$.

4. All rivers—M_L, $M_B \sim Q^{1/2}$

5. For any intermediate case, the power of Q will vary accordingly. Hence problems can be solved assuming that change in a formula with a fixed power to the corresponding one with another is discontinuous. The reason for the various powers is that moving beds may be flat or covered with dunes of various forms.

The Meander formulaes.—As per 'Inglis' $M_L \sim Q^{1/2}$ and $M_B \sim Q^{1/2}$ Hence $M_L \sim M_B \sim b$.

Inglis has established these formulae by his studies on the rivers in the alluvial plains of India. Here, the co-efficient in $M_L \propto Q^{1/2}$ does not seem to depend on meander pattern, but the ratio M_B/M_L varies from about 0.5 to 1.5, according to whether the fully developed pattern is sinusoidal or serpentine. Geologists also arrived the equalion $M_L = 10b$ and $M_B \propto b$. for discharges from models up to a maximum discharge.

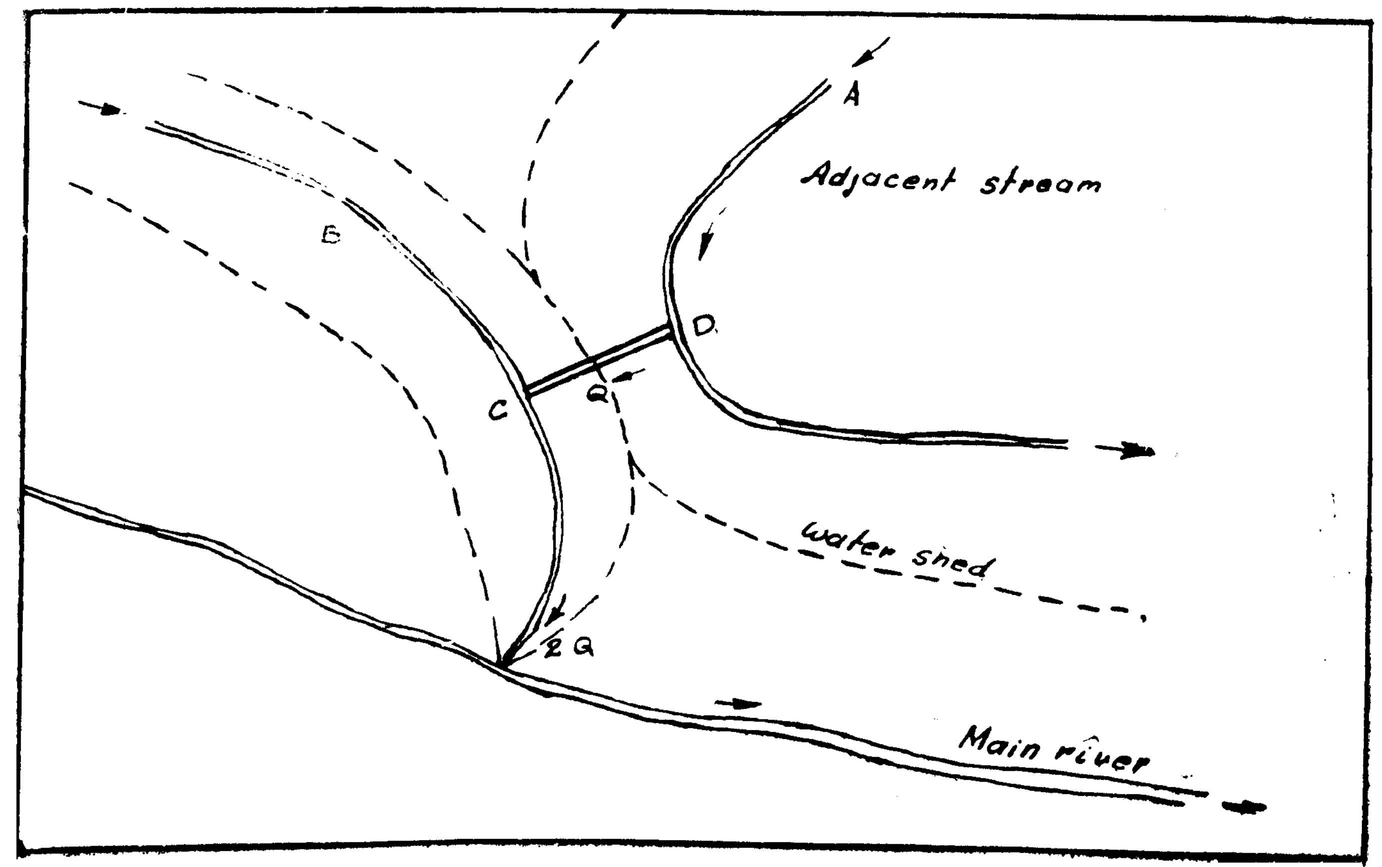
The breadth formula.—For channels formed in alluvium (both sides and bed), $b = C Q^{1/2}$ Where 'Q' is average discharge and 'C' is a constant for the same properties of channel for all discharges. This has been arrived at by 'G.Lacey' by studying eight river systems in which one was an irrigation system of canals in Madras State. The co-efficient 'C' will be considered as the ratio between the action that keeps the bed in equilibrium to that which keeps the sides in equilibrium.

$\therefore b = F_b/F_s \times (Q^{1/2})$ – where F_b is the bed factor and 'F_s' is the side factor.

The meander and breadth relations is of much importance in deciding the waterway of a bridge to be executed across the channel and locating the Intakes, docks, etc. at any reach of the channel, keeping in mind the future regime changes in due course, with changing water-sediment discharges. This is on the practical engineering aspect.

An Illustration.—This illustration is an attempt to explain the prediction of regime change and its effects, of a river system from the knowledge of the graphs and equations considered so far. This can aid in visualising the possible damages with years before its final regime is attained. The sketch below represents the river system under consideration; 'A' is the adjacent river or stream and 'B' a tributory to the Main river. The Tributory carries a total discharge 'Q'.

Sketch—


A
Adjacent stream
B
D
C
Q
water shed
2Q
Main river

Streams 'A' and 'B' are assumed to be similar in water sediment carrying capacity and in their flood plain characteristics. 'B' meanders in a fairly cultivated flood plain; Any high flood will deposit light loads of fine sand, clay and silt over the plains. The stream bed is of course sand.

Now, it is decided by the planning Engineers to divert water from 'A' along a channel cut 'DC' into 'B', as indicated in the sketch, to increase the irrigation potential along the main river. This diversion increases the discharge after the point 'C' as twice that of 'B'. For the final regime of the river.
$b = C\ Q)^{1/2} = \ 4\ 4CQ^{1/2}$ This means that for doubling the discharge, the 'b' should be increased by 41 per cent with no change in the constant 'C' Here comes the importance and use of the graphs previously drawn for the river and stream. From the graph No. 1 to 4 enclosed, (Qvs s, d and v), We can find the b and d required for the discharge known. The graphs can also indicate that 'b' is increased by 41 per cent and hence the meander dimensions M_L and M_B.

Effect of the Diversions.—Due to the diversion of 'Q' from 'A' into 'B' thro the 10 miles long channel cut, there may be violent bank and bed erosions with high flood levels, more of meandering with cut offs. The farmers in the flood plain will experience more nuisance on their lands and crops disturbed either by erosion or wash off or by deposit of coarse sediments over their lands. Their dwellings on and around the banks of the river may also be ruined due to the 41 per cent wider breath formed. In the absence of the "knowledge" and "know how" of the regime changes, these happenings may be considered as the "Act of god" even in a court of law.

Depth formula.—This can be understood by the inference made by "Lacey" that the Froude No. 'F' is fixed when the nature of the water-sediment complex is Fixed. i.e. $F = \frac{V}{\sqrt{gd}} + Q$ a Q s a constant irrespective of the breadth of the channel. Hence, for any channel with *Duned bed* (sand bed) and erodible sides, the depth 'd' will be $CQ^{1/3}$ where 'C' is a constant. When 'g' is ignored in the Froudes' formula, then the bed factor 'F_b' may be introduced which may be equated as $F_b = \frac{V^2}{d} = \frac{q^2}{d^3}$ since

$q = \frac{Q}{b} = Vd$. This 'F_b' is a function of the bed load charge 'C' and mean dia. of the bed material 'D' gravity; viscosity, density and slope of the bed material, etc.

From $F_b = \frac{q^2}{d^3}$, we have $d = \frac{q^{2/3}}{F_b^{1/3}}$.

Already $b = CQ^{1/2}$

$\therefore q = \frac{Q}{b} = \frac{Q}{CQ^{1/2}} = C^{-1}\ Q^{1/2}$

$\therefore 'd' = \frac{Q^{2/3}}{F_b^{1/3}} = \frac{(C^{-1}Q^{1/2})^{2/3}}{F_b^{\ 1/3}} = \left(\frac{C^{-2}}{F_b^{\ 1/3}}\right) Q^{1/3} = C\ Q^{1/3}$

For No dunes (Gravel bed), since there will be only a small bed load charge due to the bigger size of the gravel and its slope, the bed factor may be $F_{bo}(D/d)^{1/2}$ where F_{bo} is the zero bed factor, 'D' is the grain size dia and 'd' is the depth of flow. This means that the bed factor no langer depends on the nature of water sediment complex. However, if this is inserted in the depth formula, it becomes as

$$d \propto Q^{.5} / (C\ D)^{1/5}$$

For any other intermediate cases, the powers may alter. The depth formula is of use in estimating the scour depths of river training works, i.e., it can indicate whether the bed scour will be violent or not for a particular discharge in a particular period.

Now, in the illustrative problem taken, the river will hold water level to the normal so that the extra 60 per cent of depth caused by the doubling of discharge will be taken by the scour, as

$$d = \frac{2^{2/3}\ q^{2/3}}{F_b^{1/3}} = 1.60\ \frac{q^{2/3}}{F_b^{1/3}}$$

Further, the upstream water level for the doubled discharge will be greater than that of the original discharge so that the potential drop in the bed would be less. The calculation is good enough to give creditability to the farmers—statements that the interference with the river bed caused unprecedented quantities of bed materials to be whipped into suspension and dumped on their land.

Slope formula.—As per "Lacey", the slope formula is S 6 where "C" is a constant depending on the nature of the water sediment complex and the sides. This constant can be arrived at from the fundamental relation R ½ S' is a constant for any constant water-sediment complex and fixed erodible side nature. The basic difficulties with all the available slope formulae for any kind of mobile boundary are, (1) The slope has to depend on bed and side roughness which is different in genesis and operation and there is no way to separate the effects of these two points of the boundary. (2) the river meandering has a major effect on slope. Hence, for practical engineering applications of this formula, a new constant 'K' known as the meander correction co-efficient may be introduced to avoid enormous errors.

For no deures, the river data are of no use for producing a formula for this case, but "Leopold" and "Wolman" have produced a graph of 'S' against 'Q' for a large range of rivers in different systems, from which it is deduced that $S \propto D^{6/5}\ Q^{.25}$

Again, coming to the illustration, in accordance with the slope formulae, considering the change in slope of reaches 'CE' and 'DC' from their original undisturbed and designed states, the 'CE' reach is to take 2Q while 'Q' is allowed through 'DC' reach by division. So the ultimate 'S' will be $2^{-7/6} \simeq 1.8$ times the original and the ultimate 'b' will be increased to $\sqrt{2}$ times the original. If the original slope of 'CE' is 2'|mile and that of 'DC' is 6'|mile (designed) then 'CE' reach will have 30' drop and 'DC' 60' drop.

Then the river at 'C' will be [illegible] lower than its original level after the 2Q flow. The reach 'DC' will experience and acquire the original meandering, dimensions and slope as per 'CE' reach as it had Q from 'B' and it will get a drop of 30' instead of its original designed drop of 60' its slope being 2'|mile and possibly a winding length of about 15 miles. Its tail being the head of 'CE' will be 4' lower than its original one which makes its head 34' lower than designed. Hence its head regulator will certainly need a lot of remodelling during the decades. The effect of this change is regional of "DC" is as follows: When designing the "DC" reach, generally, the bed is assumed to be the same as that of 'CE' and the bed slope of 'DC' is arrived with its straight alignment. Due to the deep slopy bed and straight alignment, there will be enormous bed scour and if there is side scour there will be meandering of the 'DC' reach in accordance with the soil nature. In turn, the 'CE' reach will also suffer from misdesign due to the change in the regime of 'DC', is the sediment will enter 'CE' and might dump an alluvial pan As the sediment advances, it will steepen the head reach of 'CE'. Apart from this aggradation of 'CE' and degradation of 'DC', the main river and 'B' also will suffer from abnormalities which will affect downstream irrigation, land use, Highways, etc., and cause public disaster. Hence prediction of the future changes in the regime of a river or channel must be carefully made and considered in designing any river diversion, across masonry or Irrigation schemes.

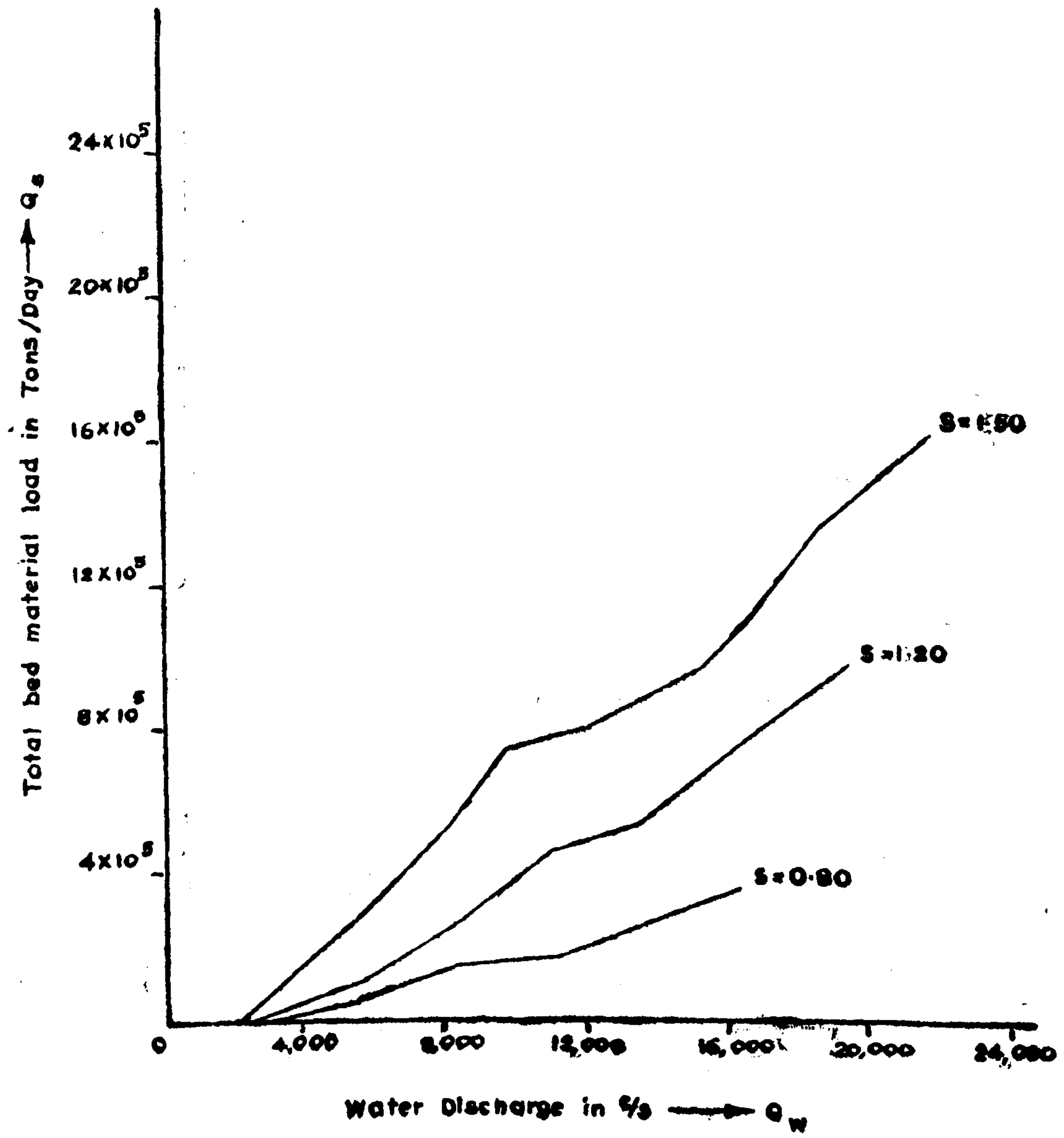
— K. ETHIRAJAN.

Reference Books—

1. Hand Book of Applied Hydrology by—Ven Te Chow.
2. Open Channel Hydraulics by—Ven To Chow.
3. Hand Book of Applied Hydraulics by—C.V. Davis.
4. River mechanics by—H.W. Shen.
5. Environmental Impact on Rivers by—H.W. Shen.

FIG. : I. VARIATION OF BED SLOPE 'S'

(Developed from Fig (1·4) of Book Environmental impact on Rivers By — H. W. Shen.)



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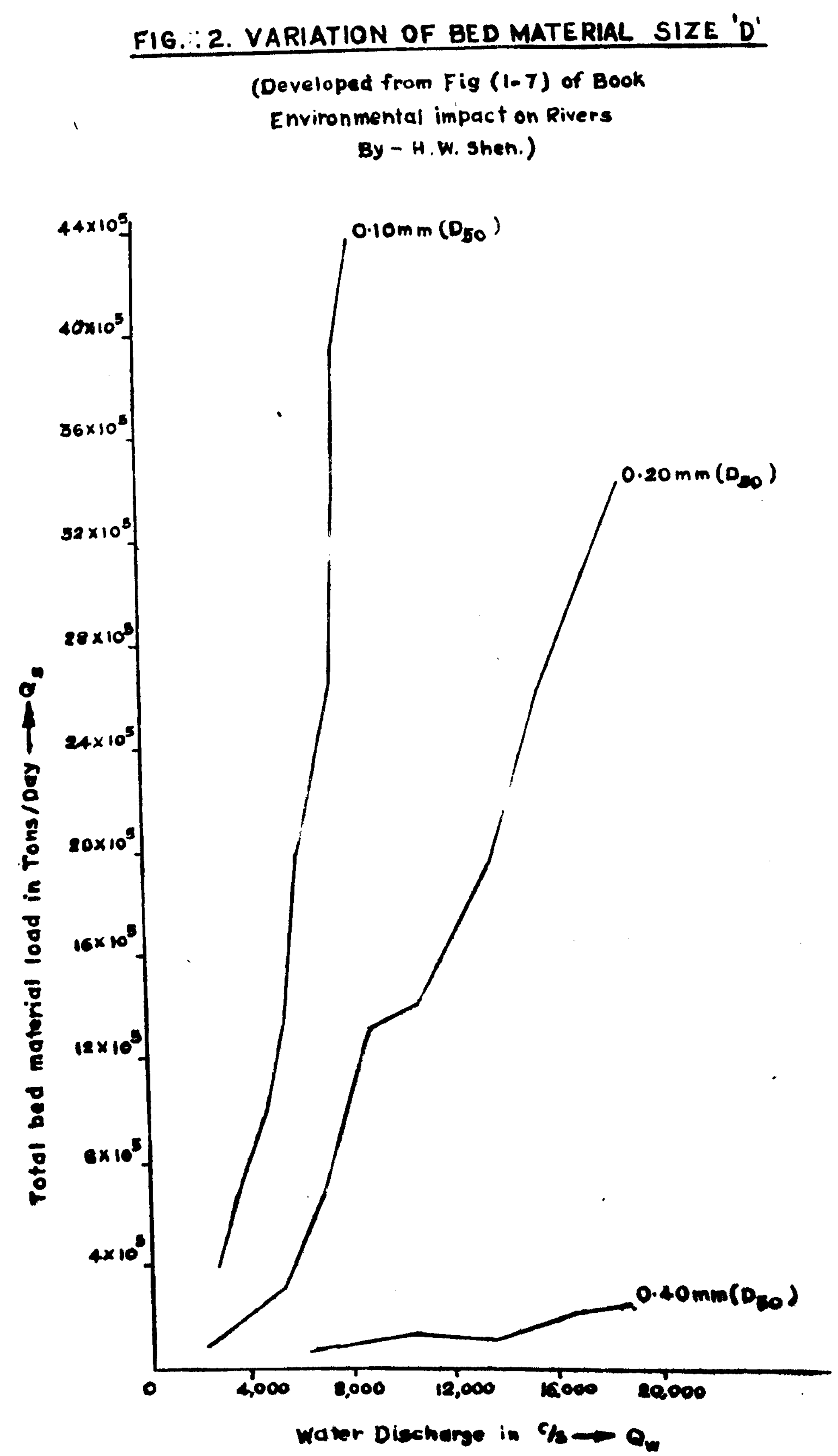

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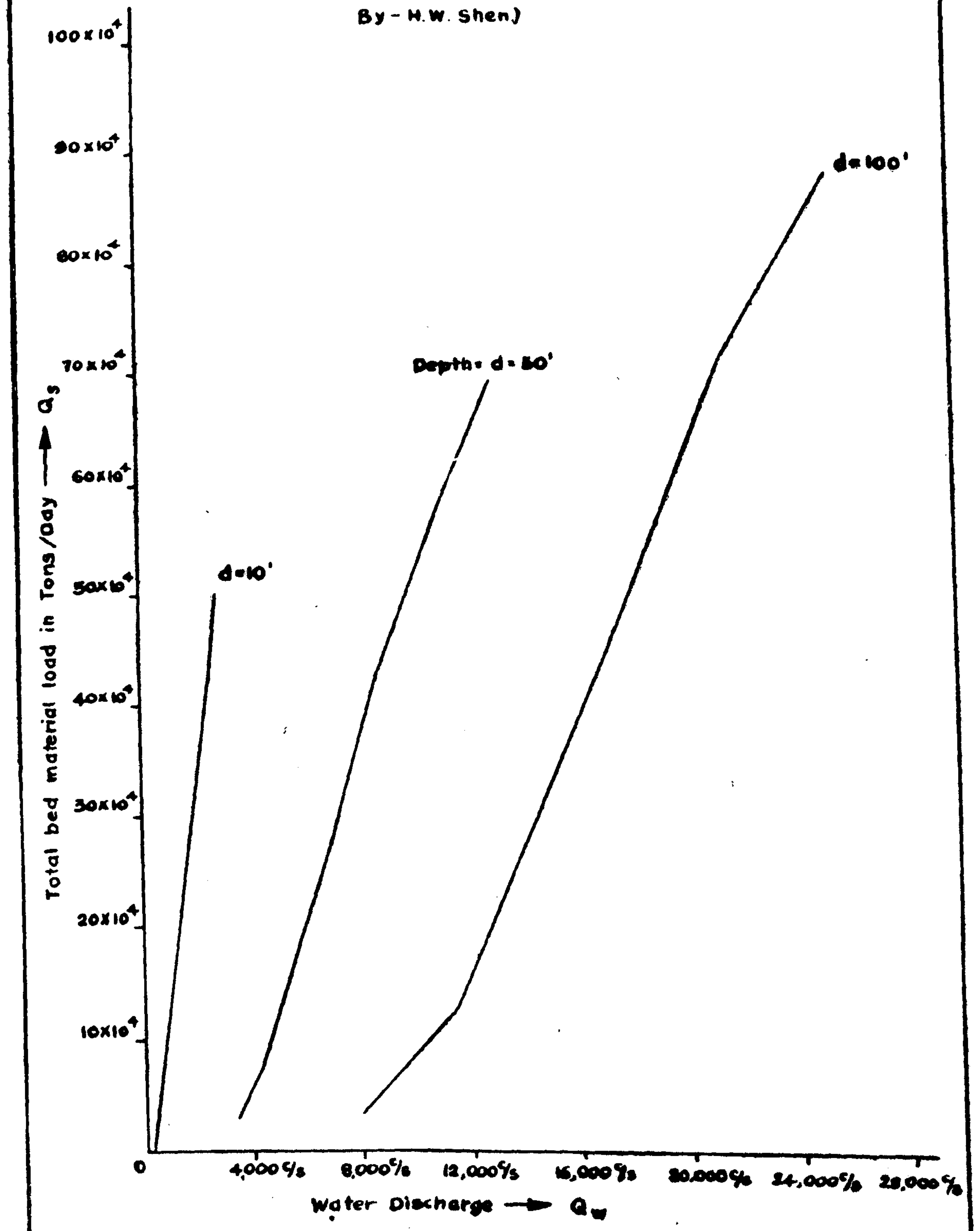
FIG. 3. VARIATION OF DEPTH WITH DISCHARGE

(Developed from Fig. (1-10) of Book
Environmental Impact on Rivers
By - H.W. Shen)



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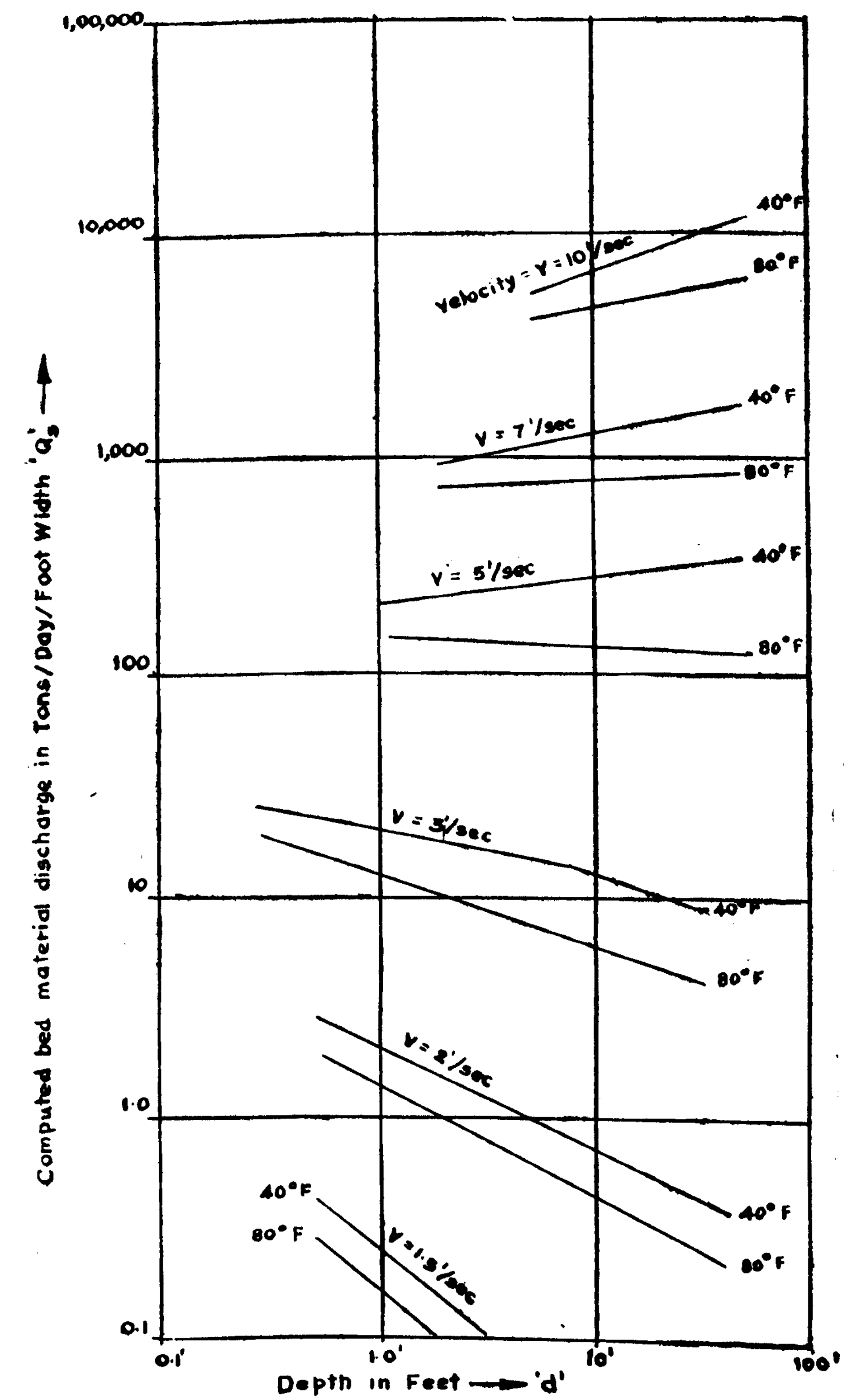

FIG: 4. Effects of Depth on the Colboy's relations between mean velocity and Bed load (0·4 mm ø)

(Developed from Fig (7-13) of Hand Book of Applied Hydrology, by Ven Te chow.)

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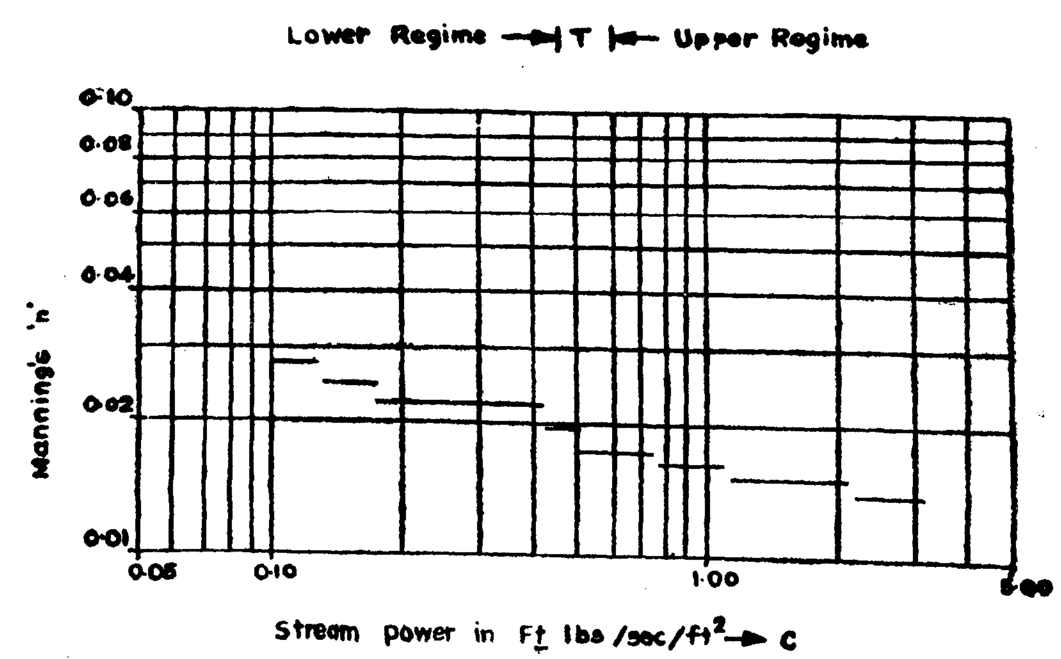
FIG. 5 VARIATION OF MANNING'S 'n' WITH STREAM POWER

(Extract from Fig. (1-12) of Book
Environmental impact on Rivers
By – H. W. Shen)



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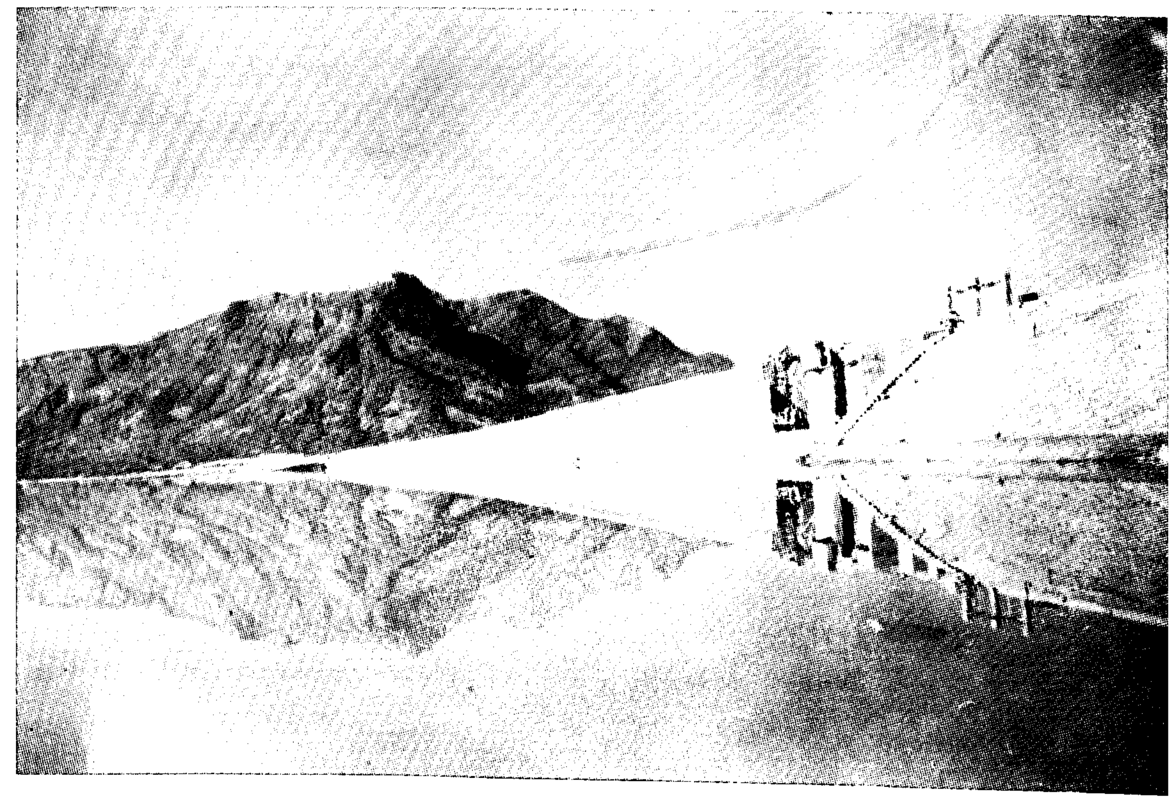

Another view of Palar—Porandalar Project—(Reflected view is also seen).

Karuppanadhi Project —Another view.

(1)	(2)	(1)	(2)