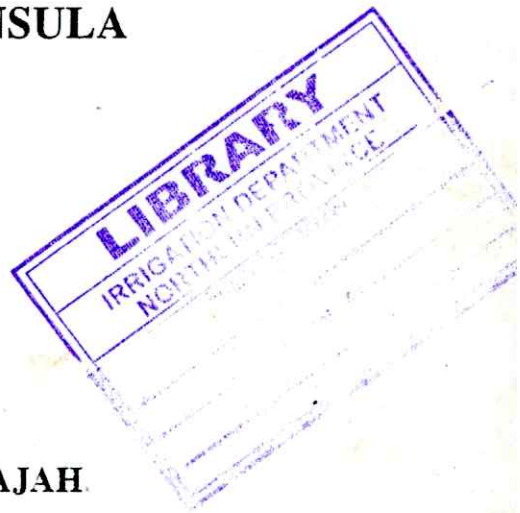
With compliments
from
K. Shanmugarajah

WATER RESOURCES DEVELOPMENT

JAFFNA PENINSULA



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FOREWORD

The Water Resources of the Jaffna Peninsula has been a subject of great interest and much concern. The Peninsula, unlike other parts of the Island, depends for its water on the rainfall which percolates and is retained annually by its sub-soil limestone aquifer.

The Hydrological cycle of the Peninsula is somewhat like operating a Current Account in a Bank. The rainy season makes underground deposit, annually: that is drawn out from the wells during the dry months. A limit for the drawing is imposed by the amount put in. Over drawing spells disaster - salt water intrudes.

Aware of this constriction, the ancestors evolved a remarkable system of ponds interlinked by waterways. These conserved the precipitation, detaining it for increased percolation. Unfortunately the demands of a growing population have fast obliterated the ponds and the waterways have since become lanes and Roadways. Therefore other methods have now to be devised for ensuring this detention.

Valuable suggestions have been made and proposals mooted in the recent past. Mr K. Shanmugarajah who has made a considerable study of these lays out detail plans for their practical accomplishment, in this work.

London
June 1991

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KILINOCHCHI RANGE

FOREWORD

Ground water has been the "Life blood" of the Jaffna Peninsula. Shallow open wells with the traditional well sweeps had been used for centuries for domestic as well as farm irrigation. Introduction of heavy duty pumps, for undertaking large scale and or more frequent irrigation has brought about problems of salt water intrusion and attendant environmental problems.

The irrigation Department commenced intensive investigations on ground water levels, water quality, soil salinity and other related environmental conditions. Coupled to this study, was the investigation to convert the Jaffna Lagoon into a fresh water lake.

Recent political conflict in the North & East has set back the programme of development that was envisaged. When stable conditions return to Jaffna, it would be very necessary to embark on planning of the Water Resources Development for the benefit of the peninsula.

Mr K. Shanmugarajah was associated, along with other Officials of the Irrigation Department, in the investigations and planning for the development of the Water Resources. In his characteristic manner, he had maintained and collated the data made available from these investigations. He has already presented summarised data at meetings of professional associations in Sri Lanka. We are grateful to him for compiling this book "Water Resources Development of Jaffna Peninsula" for the benefit of future planners and development authorities.

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Sri Lanka

1991

DEDICATION

This book is dedicated to my late Parents
Mr. Sinnappu Kanagasabapathy and
Mrs. Ponnammah Kanagasabapathy

I am grateful to late Professor A. Thurairajah Vice Chancellor of Jaffna University for having reviewed the manuscript.

ACRONYMS

JP	Jaffna Peninsula
JL	Jaffna Lagoon
EPL	Elephant Pass Lagoon
VL	Vadamarachchi Lagoon
UL	Upparu Lagoon
ID	Irrigation Department
GA	Government Agent
NP	Northern Province
D.I.E.	Divisional Irrigation Engineer
T.C.E.O.	Territorial Civil Engineering Organization

FIG - I

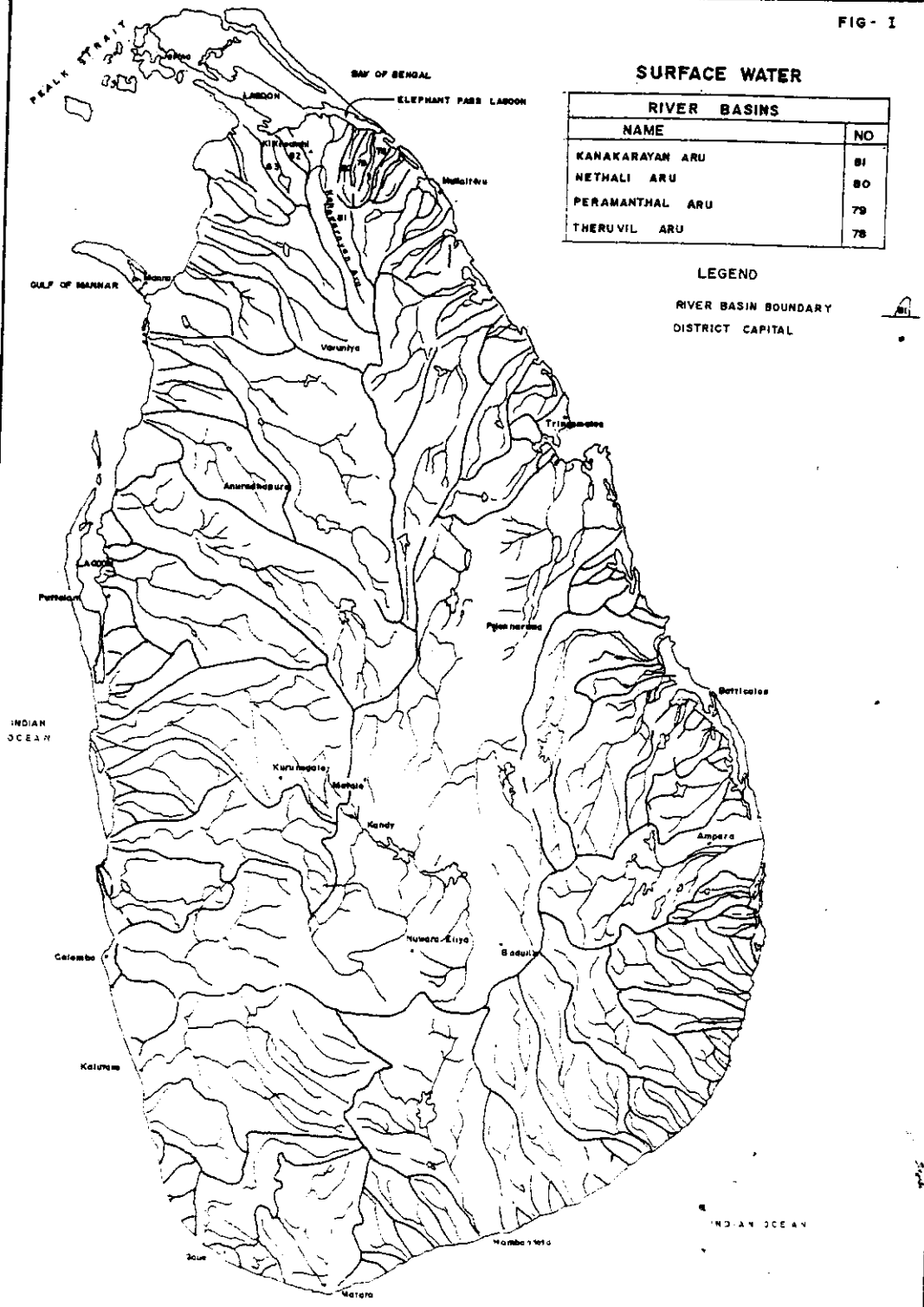
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FIG - I

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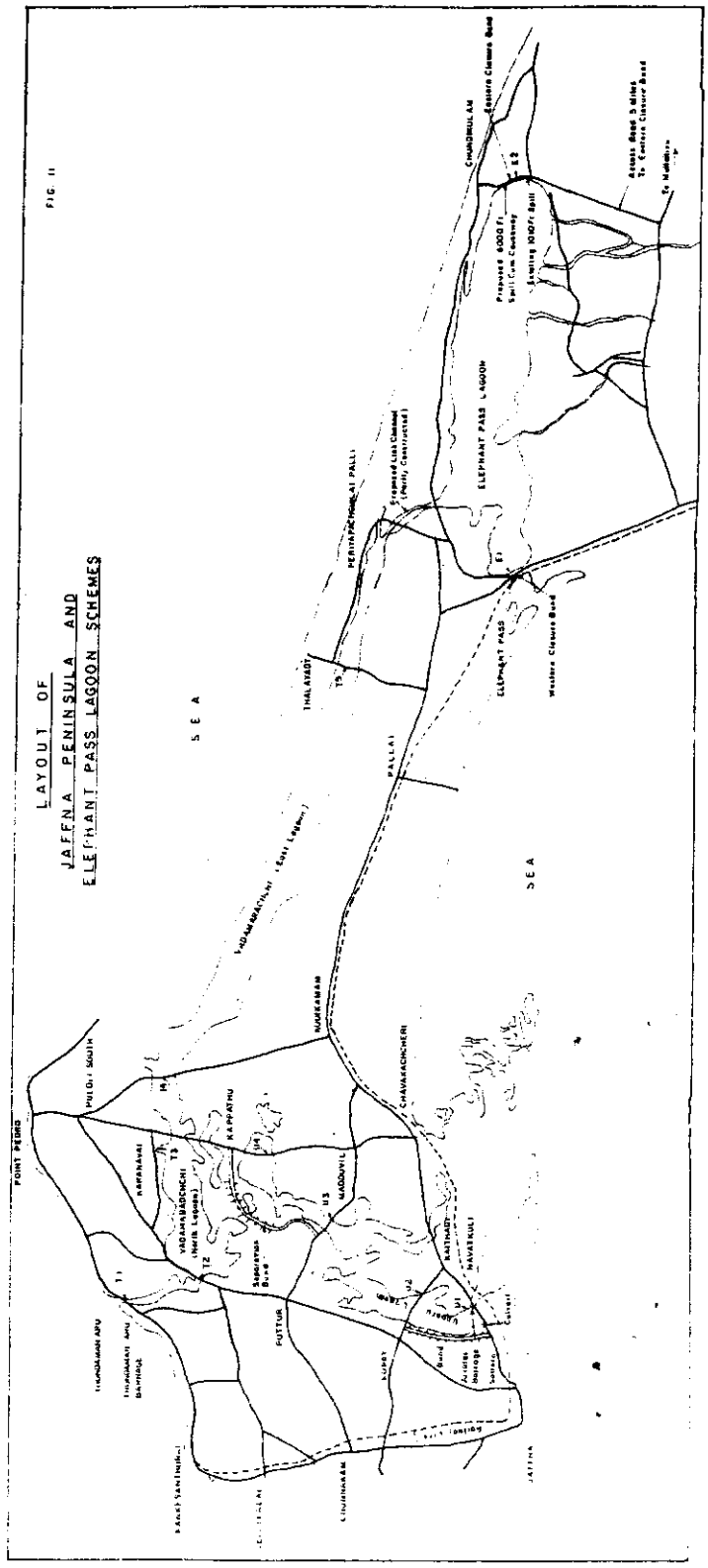

PREFACE

There are no streams and rivers in Jaffna peninsula due to the flatness of the land and the topography does not permit the construction of reservoirs. Jaffna peninsula limestone with fissures, cracks and joints and with its porous characteristics permits percolation of fresh water to be stored underground. Ground water is the potential for water resources development of Jaffna peninsula.

There are over thousand ponds scattered all over the peninsula and conserve the precipitation to provide water for cultivation of small extents around the ponds and to recharge the aquifer.

The ponds are badly silted due to many years of usage and the capacities are reduced. A program to rehabilitate, improve and desilt the ponds will increase the water resources potential of the peninsula.

From 1879 onwards, proposals were framed to convert the internal lagoons to fresh water lakes. These lagoons are connected to the sea and water in the lagoons are brine due to ingress of sea water.

The proposals were to construct barrages at the entrances to prevent the ingress of sea water. Rainfall in lagoon beds and their catchment within the peninsula is the only source of water supply to the lagoons.

During rainy season, flood run-off will leach out the brine water and the salt impregnated in the top soil of the lagoon bed. Leaching out process of the soil can be facilitated by disturbing (ploughing) the soil before the rains.

In few years time, lagoons can be converted to fresh water lakes which will serve to irrigate the lands, along the fringe of the lagoons. In addition they can be served to recharge the underground aquifer. A pilot project covering a small area of the north lagoon, from 1920 to 1923 was successful. The extension of this pilot project to cover the entire area of the lagoons, with the construction of two barrages was undertaken in the early fifties. The desired benefits were not derived due to:

- Run-off from the local catchments within the peninsula was not sufficient for the leaching out process.

- Management (operation and maintenance) was not carried out successfully.

Hence in the fifties, investigations were carried out to identify water resources in the mainland to augment the internal lagoons via Elephant Pass Lagoon for leaching out process. Elephant Pass Lagoon (EPL) will also serve as primary reservoir to feed the internal lagoons after they are converted to fresh water lakes. Due to various problems, this proposal was not implemented successfully.

This book presents, actions taken from 1879 by Twyneham the then Government Agent of the Northern Province, who originated the idea and subsequently by Horseburg in 1916 the then G.A/N.P., Balasingam Member of Legislative Council in 1930, F.R.G. Webb Divisional Irrigation Engineer N.P. in 1930 through forties with valuable proposals for the two internal lagoons, and S. Arumugam D.I.E/N.P from 1940. Arumugam presented a proposal in early fifties to augment the internal lagoons from the mainland via E.P.

Finally in 1976 extensive and intensive investigations, proposals, designs, construction drawings, cost estimates and economic analysis were carried out by a team of Engineers and supporting staff of the Irrigation Department, led by the author of this book, who as the then Chief Engineer was in charge of the project.

The project proposals were submitted to the planning committee to include in the budget for 1976. Though the project was technically sound and economically feasible, was not included in the budget for reasons best known to them.

The book presents actions taken from 1879 by individuals, and institutions in identifying water resources potential and problems and framing proposals for implementation.

The works carried by Irrigation Department I.D. in 1976 is presented in detail, with documents require for implementation.

In the North zone of the peninsula where intensive study carried out during the period 1973-1976 in an area of 55 sq. miles, indicate that about 30% of the wells were becoming brine. The present underground storage is limited and with the increased demand for domestic and agriculture use, the possibility of saline intrusion to the underground fresh water will be great and reach of a critical stage. Hence implementation of this project is a must for the existence of the people of the area whose prime occupation is agriculture. The final proposal presented in this book serves this purpose.

Fishing is mainly for sea prawns and confined to the areas close to the barrages. There is a fear that the change to fresh water lake would affect the livelihood of the fishing community. Sea prawns and fresh water prawns are expensive commodities. Hence during the last two decades tremendous technological advances have been made to culture these in man made structures. Hatchery can operated economically to supply all the required young larvae of the prawns in Vadamarachchi and Upparu Lagoons and get a harvest which would be several times more than what was obtained from the lagoon recently or at any time before.

Below a certain salinity level sea prawns cannot survive. At this stage fresh water prawns can be introduced which can tolerate lower salinity levels. After the lagoon is complete fresh water lake, fresh water prawns can continue to be cultured in the lake.

I have been trying my best to get this project implemented while working in the Irrigation Department and even after I retired from the Department in 1980, through other resources. I have failed in my endeavour. Hence I am documenting all the available data related to the project - Historical, problems, requirements, proposals, designs, drawing, cost estimates, economic analysis etc. in this book with the hope that it will serve as a good guideline for future planners and development authorities to benefit the people of the area

I am not sure when the auspicious time will come for implementation. But it must come before a critical stage is reached, when most of the area will be faced with shortage of fresh water for the domestic use and agricultural purpose.

1993
K. Shanmugarajah

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SUMMARY

INTRODUCTION

The Jaffna cultivator is extremely industrious and hard working and takes full advantage of every thing that nature, rather sparsely, provides in his district. Jaffna Peninsula is an area where nature is not over generous and where assiduous zeal and drudgery are the necessary concomitants of a bare living. Whereas in other parts of Sir Lanka, having similar rainfall, similarly distributed the paddy grower requires it to be supplemented by stored water to raise a successful rainy season crop, the Jaffna man some how manages with rainfall alone, there being no facilities for creating reservoirs in such a flat country. Ground water is the only source for supplementary irrigation and its potential is limited, and overdrawing results in saline intrusion.

One feels that such industry as is here exhibited warrants every consideration and deserves every assistance and encouragement it is possible to provide. If any means of reducing the hazard attached to the present cultivation or of increasing the productivity of the soil or rendering the now uncultivable lands fertile can be devised and provided, there is every reason to justify full investigations and exploitation.

The purpose of this exercise is to analyse the requirements, potential and problems and provide some guidelines to achieve the goal.

UNDERGROUND STORAGE

The recharge to the ground water in the peninsula is almost entirely from rainfall percolation. Ground water is the prime source for agricultural development in the peninsula. The subject came to prominence in the early sixties due to the incidence of saline infiltration in wells that have never been saline before. Dr. Arnon Arad, Hydrogeological Expert from Israel advised a systematic survey to ascertain the quantity and quality of the ground water resources in the peninsula, for use in Agricultural development.

Accordingly surveys and investigations were carried out from 1966 and substantial data and information are available, but more investigations, study etc. are required to have a through knowledge of what is happening. Number of constraints have been impeding the work, study etc. i.e.: political, financial etc. The study already carried out revealed that with the increase in agricultural production and domestic use, the excessive drawing of water has resulted in the saline intrusion.

A preliminary report by S. Arumugam in 1968 deals on the ground water potential of the entire peninsula from the data collected from selected 411 shallow wells.

INVESTIGATIONS CARRIED OUT IN THE NORTH-WEST ZONE OF THE PENINSULA

Intensive studies were done by the Irrigation Dept: since 1973 in the North-west Zone of the peninsula covering an area of 55 square miles. Substantial and relevant data and information in water table fluctuations and salinity intrusion are available from the studies. The primary purpose was to establish as accurately as possible the state of balance between ground water replenishment and abstraction practices in this area to provide basis for future management. Some idea of the geological and hydraulic character of the aquifer of the zone has been identified. The seepage flow along the North coast was also identified in the study.

Permanent drilling of deep bore holes on a grid system was recommended for monitoring of:

- Ground water resources.
- Seasonal and long term movement of saline water found along the coast.
- Fluctuations of the interface and to assess the actual storage.

The study in this region revealed that about 30% of the wells are becoming brackish.

SUPPLY SOURCE

The supply of adequate fresh water has been a perennial problem of the people of the peninsula. Though considerable research has been done on the subject the problem was largely neglected by successive governments, and is now considered as one of the factors leading to lack of development of the Tamil speaking areas.

Studies have already shown that due to over-exploitation of the aquifer in the Jaffna peninsula, most wells in the region have become brackish, and the importance of a supply source to replenish the wells to meet the increased demand is considered to be of paramount importance.

The proposal to convert the two internal salt water lagoons Vadamarachchi, and Upparu, and the external lagoon (Elephant Pass) to fresh water lakes was expected to improve the water resources of the peninsula, both in recharging the underground storage with additional surface storage and desalinating the lands fringing the lagoons and making suitable for cultivation.

Annually about 91,000 Acre feet of fresh water from an area of 363 square miles of the mainland and 30 square miles of the Elephant Pass Lagoon bed, flow as waste to the sea through the Eastern opening of this lagoon while the people of the peninsula are starving for their domestic use and agricultural purposes.

Elephant Pass lagoon will be the primary reservoir. A bund cum spill across the east end at Chundikulam would seal the entry of sea water into this lagoon, thus transforming it into a fresh water primary reservoir. From this reservoir the water would be led by a link canal, 2 miles long to Vadamarachchi lagoon, which then becomes the secondary reservoir. Vandamarachchi lagoon feeds Upparu lagoon with an outlet to the sea at Thondamannaru. Upparu lagoon has an outlet to the sea at Ariyalai.

HISTORICAL

The efforts to provide the peninsula with adequate supplies of fresh water have had an interesting and chequered history. The idea originated as far back as 1879 when the then Government Agent of Northern Provice, Twyneham reported on the feasibility of such a project. In 1916 Horseburg the Government Agent of the day considered implementing part of the project on an experimental basis. In 1920 the implementation of this project commenced with a sum of Rs. 5,000 and the scheme is reported to have functioned efficiently until 1923.

After the success of the 4 year experimental operation and with the public acceptance of the experimental project, the late Balasingham proposed the implementation of the full scheme.

In 1930 F.R.G. Webb together with Balasingham issued "The Balasingham Webb Report", which suggested that barrages to be built to prevent salt water intrusion into the inland lagoons to convert them into fresh water lakes, reclaim uncultivable land, and increase the yield of the lands already cultivated.

Balasingham's idea of diverting Mahaweli water to Jaffna has not materialised. As per prevailing situation in the country it is a blessing in disguise.

WORKS UNDER TAKEN BY THE IRRIGATION DEPARTMENT

WEBB PROPOSALS

In 1942 Webb, Divisional Irrigation Engineer studied and sifted all the available data, records, and endeavoured to extract, adapt and utilise all the useful matter. He prepared the report "Jaffna peninsula lagoon Scheme", which is an important guideline of the scheme. Webb's analysis and reports conclude a number of important findings in support of the following.

If sea is kept out of the lagoons and the past accumulation of salt washed out effectively there is every chance of improving:

(i) The quality of the soil and water, and
(ii) Agricultural prospects of the reclaimed land using lagoon water for irrigation.

Regarding the reclamation of the land it is suggested that the area to be deep ploughed and a system of internal drainage laid down to accelerate the leaching process. In addition to this, a saline resisting leguminous crop to be planted successively, to be ploughed in, to improve the texture of the soil. This will as anticipated by the chemist, reduce the period required to sweeten the soil, and by the time the cultivation has spread to the extreme marginal lands much of the alkaline or salt impregnated area may have improved sufficiently to enable economic crops to be cultivated.

In 1945 Webb brought up his proposals and designs for the two barrages across Thondamannaru and Upparu. The sites were selected after considerable investigations including sub soil.

After further investigations some amendments were made to Webb's original proposals. In 1947 final plans for Thondamannaru barrage was drawn and estimates were sanctioned.

Construction of the Thondamannaru barrage commenced in 1947. A separation bund between the Vadamarachchi lagoon and Upparu lagoon was also constructed along a saddle between the two lagoons. Subsequently Upparu lagoon was incorporated into the scheme by the construction of a semi-circular spill at its outlet at Ariyalai. Thondamannaru barrage was completed in 1953 and Ariyalai barrage in 1955.

The leaching action of the lagoons will be slow process on account of the limited catchment area draining into the internal lagoons.

ARUMUGAM'S PLAN

S. Arumugam proposed that Elephant Pass Lagoon be the Primary Reservoir which will be fed from catchment area of 363 sq.miles. A bund cum spill across the east end at Chundikulam and another bund where the railway and motor bridges are at Elephant Pass would seal the entry of sea water into this lagoon, thus transforming it into a fresh water

lake. Water from this reservoir would be led by a link canal to Vadamarachchi lagoon. This will serve to accelerate the leaching out process and augment the internal lagoons.

Construction of the Elephant Pass Lagoon scheme commenced in 1962. When completed it received two major set backs. At the Western end sea water was seeping in considerable quantity through the P.W.D. road into the lagoon. Preventive measures taken subsequently was successful. The second set back was the damage to the eastern closure bund. Due probably to the settlement of the sub soil below the bund, the bund had settled and has been overtopped and breached during one of the floods.

LATEST PROPOSALS BY IRRIGATION DEPARTMENT IN 1976

After a long lapse of time the project was revived in 1976 by the Irrigation Dept. by a team of Engineers headed by the author. Fresh investigations were carried out resulting in a feasibility report, proposals, designs, cost estimates, economic analyses, construction drawings etc. The project is technically sound and economically feasible.

However when the scheme was presented for inclusion in the budget for 1976 the planning committee, perhaps following the path of political expediency (it was the final year of SLFP Government) turned the proposals down.

After the UNP came to power, the scheme was put forward again in 1978, and was accepted by the planning committee and a token vote was passed by the parliament to implement the scheme. However the scheme went into abeyance once again. In both circumstances the net result is same, only the approach is different.

In 1976, investigations and studies were carried out to assess the cause of the failure of the scheme and the conditions of the components of the project ie: Thondamannaru barrage, Ariyalai barrage, separation bund, flood bunds, link canal, Elephant Pass lagoon, eastern closure bund at Chundikulam etc. Sub soil investigations for the Elephant Pass Lagoon-spill cum causeway and closure bud at the eastern end was carried out in detail to design a suitable structure. This was one of the important aspects of the investigation in view of the earlier failure of the closure bund.

PROPOSALS

a) Elephant Pass Lagoon - provide a closure bund of 4700 feet with a spill cum causeway of 7000 feet along the eastern end of the lagoon. The access road to the spill, a length of 6 miles to be improved.

b) Link canal 2.5 miles long and already constructed for a length of 2.25 miles is badly damaged and silted, as it runs in a sandy material. The canal section is now re-designed after detail soil investigations and the present proposal is to recondition the existing canal as per new design, excavate the balance length, provide an inlet regulator-cum-bridge and provide a roadway along the link canal.

c) Vadamarachchi lagoon: all the perished and decayed gates in the Thondamannaru barrage are to be replaced and the missing and damaged parts of the lifting devices to be replaced and repaired.

d) Upparu lagoon: The planked bays in the Ariyalai barrage to be replaced by screw operated gates, the missing and damaged parts of the lifting devices to be replaced and repaired and the passerells, widened to 2' 0' with hand rails for easy operation of the gates. The culverts to be provided with screw operated gates.

The separation bund between the lagoons to be improved according to new design.

Improvement to bund, isolating the saltern and paddy field from this lagoon.

Economic Analysis

The scheme is technically sound and economically feasible. In addition to benefit for agricultural development, there will be employment opportunities, growth of secondary industries, and other indirect benefits would result in substantial improvement in the living conditions. In the economic analysis recharging of the underground storage thereby, benefiting the brackish wells and the possibility of suppressing the interface of the fresh and salt water below the existing levels, and increasing the storage potential of the ground water to meet the increased demand for irrigation and domestic use has not been considered.

The scheme is therefore strongly recommended for immediate implementation.

Anticipated benefits:-

(a) Gradual conversion of the lagoons to fresh water lakes.

(b) Under-ground storage will be recharged thereby benefiting the brackish wells. There is a possibility of suppressing the fresh water - salt water interface thereby increasing the storage potential of ground water to meet the increased demand for irrigation and domestic consumption.

(c) Reclaiming 11,000 acres of non-arable land by having salt leached out. From the results of present cultivation on small extents in partially reclaimed areas, it is evident that red onion, chillies, yams, cashew, grape wines, etc. can be cultivated in this land. However, a land use survey will help to select the suitable crops.

(d) Supplement the 20,000 acres of presently cultivated land (rain fed) along the fringe during the period of drought and during the tail end of the cultivation by pumping from newly created fresh water storage in the 25,000 acres of the lagoon area. Due to lack of water, cultivation of paddy in this 20,000 acres has been a total failure during most of the years.

(e) Cultivation in the lake bed will be possible when the lake full of fresh water draws down during dry season. The bed may also be used for cattle grazing during the dry season.

PONDS IN JAFFNA PENINSULA

Over one thousand ponds scattered all over the peninsula benefit the people of the area substantially and also helps to recharge the underground aquifer. The ponds require improvement and desilting.

PROPOSED CHANGE TO FRESH WATER LAKE AND DEVELOPMENT OF ITS FISHERIES

Fishing is mainly for sea prawns and confined to areas close to the barrages. There is a fear that the change to fresh water lake would affect the livelihood of the present fishing community. In order to understand the change, the life history of the sea prawns is given in the text.

Sea prawns and fresh water prawns are expensive commodities, hence during the last [illegible] decades tremendous technological advances have been made to culture these organisms [illegible] man made structures. It is now common practice to grow several generations of bo[illegible] varieties within man made structures, without having to depend on natural supplies of praw[illegible] larvae. Hatchery can be operated economically to supply all the required young larvae of t[illegible] prawns to stock the Thondamannaru lagoon and get a prawn harvest from an area whi[illegible] would be several times more that what was obtained from the lagoon recently or at any tim[illegible] before.

Below a certain salinity level the sea prawn cannot survive. At this stage the fresh wa[illegible] prawn can be introduced which can tolerate lower salinity levels. After the lagoon is[illegible] complete fresh water lake, the fresh water prawns can continue to be cultured in the lake.

Generally it can assured that with proper management not only the total catches would b[illegible] higher, but at the same time employment opportunities would also be proportionately greate[illegible]

CONCLUSION

It is very essential that the entire Jaffna Lagoon Scheme, North, South and Elephant Pas[illegible] should be controlled by one body for efficient management, maintenance, operation[illegible] investigation, tests, studies etc. Benefits from this scheme cannot be derived, no sooner th[illegible] construction works is over. Benefits depend entirely on efficient operation and manipulatio[illegible] of the gates, maintenance, good under-standing and proper co-ordination of personne[illegible] manning Elephant Pass and internal lagoons, processing of test results, initiating action fo[illegible] necessary investigations on results of tests, etc. Efficient control by one body with definit[illegible] instructions regarding the manipulation of gates of the barrages, regulators in the Link Cana[illegible] and flood bunds with regards to tide levels, heavy rains and water levels in the Lagoon is[illegible] must if any benefits are to be derived. A standing order should be issued and followed b[illegible] re-same. These are more important especially in the transition period when the salinity of th[illegible] water in Lagoon is approaching a limit below which the water can be considered suitable fo[illegible] irrigation and domestic use.

In recent years studies, tests, research, etc. have been carried out for scheme of this nature al[illegible] over the world and great advances have been achieved. The results and know-how hav[illegible] been incorporated in the Improvements to Jaffna Lagoon Scheme, to accelerate the proces[illegible] and derive benefits early.

Urgent and immediate action is a must to tide over the danger of salt water intrusion in well[illegible] and to provide the much needed fresh water in the lagoon for cultivation and domestic use.

After 1978, no further action was taken to implement the project. In January 1983 Prof[illegible] H.W. Thambiah Q.C., S. Arumugam and K. Shanmugarajah submitted a report to hi[illegible] Excellency J. R. Jayawardana President of Sri Lanka, with an appeal to implement th[illegible] scheme. This team met his Excellency on 4th May 1983 in his office, to explain the schem[illegible] to him. This was followed by a meeting to discuss and explain the scheme to His Excellenc[illegible] the President and Senior members of the cabinet and officials. It was decided at this meetin[illegible] to implement the scheme, but so far nothing materialised. (Annex.5)

The main constraint to implement the scheme is political, which has to be removed to achiev[illegible] the goal.

CHAPTER 1

INTRODUCTION

GENERAL

The Jaffna cultivator is extremely industrious and hard working and takes full advantage of everything that nature, rather sparsely, provides his district. He has been brought up in an area where nature is not over-generous and where assiduous zeal and drudgery are the necessary concomitants of a bare living. Whereas in other part of Sri Lanka, having similar rainfall, similarly distributed, the paddy grower requires it to be supplemented by stored water to enable to raise a successful rainy season crop, the Jaffna man somehow manages with rainfall alone, there being no facilities for creating reservoirs in such a flat country. During the dry weather he continues his husbandry by growing numerous kinds of crops, having to lift the necessary water. In the earlier days this was done either by his own manual effort or with the aid of animals. Now water pumps are used for this purpose.

Paddy fields are ploughed two to three months before the commencement of the cultivation. All kinds of vegetable matter are being collected and buried into the soil, not even dead palmyra fronds and worn out cadjans being despised, cattle are carefully herded in covered "Kraals" during the nights so that their dung can be easily gathered and spread over the fields and there is not a vestige of growing weeds to be seen.

As one approaches the lagoon area, low scrub and sparse pasture cover the land. Along the fringe of the lagoon the land in completely bare and the soil is salt impregnated. Further away from the lagoon in the residential area subsidiary food crops such as chillies, onions, potatoes, tobacco, vegetables etc. are cultivated in the well drained soil with water laboriously lifted from the underground source.

One feels that such industry as is here exhibited warrants every consideration and deserves every assistance and encouragement possible to provide. If any means of reducing the hazard attached to the present cultivation or of increasing the productivity of the soil or of rendering the now uncultivable lands fertile, can be devised and provided, there is every reason to justify full investigation and exploitation.

PRE-HISTORICAL

It would appear that lagoons in the Jaffna peninsula owe their formations, to subsidence following subterranean dissolution in the calcareous deposits of which the peninsula in composed. The whole mass of this land is organic in origin, being made up of almost entirely of the fossilized remains of sea creatures which lived and died in, and sank to the bottom of a shallow sea. According to generally accepted geological theory, this process having gone on for millions of years, was followed by a similar period during which the sea bottom arose above the water level and became dry land.

Then came another epoch when rain fell on the land and soaked through the interstices, carrying with it acids, which gradually eroded away less resistible parts, leaving hollow undergrounds. As this continued underground passages formed, along which there would be regular flows of acidulated water which would widen and deepen the corridors, eventually creating vast subterranean caverns. Finally after further millions of years the unsupported ceiling of these caverns collapsed and fell in, leaving on the surface these large hollows with their bottom below sea level. Incidentally, this is the most likely explanation of the mystery of the celebrated Nilavarai well at Puttur, some nine miles North East of Jaffna Town. Although 5 miles from the sea, the water rises and falls with the daily tide, is reputed to be

inexhaustible and is nearly 150 feet deep, the top 15 feet being fresh and the re seemingly indicating that there exists an underground passage joining the well with the

GEOLOGY

Jaffna peninsula is mainly underlain by miocene limestone. Limestones are exposed North Central Part, extending in a NNW to SSE direction from Urumpirai to P Bordering this on the Western side are patches of red earth formations. Encompassing two formations are found the brown sand formation which occupy a larger area o western side than the eastern side. Enclosing these along the western coast and in the l areas are found lagoonal deposits. The area east of the lagoon are occupied mainly by l sandy loams in the south and sand dunes in the north along the eastern coast o peninsula, stretching from Thumpalai to Nagarkovil and beyond. Recent coralline ree found along the northern coast of the peninsula.

The Jaffna limestone belongs to the lower miocene period. It is almost flat bedded and vertical thickness of at least several hundred feet. From a drill hole put down at Palai, i found to be 270 feet thick there, and was underlain by a thick sandstone formation abo precambrian basement.

The Jaffna limestone is a creamy coloured hard compact, indistinctly bedded, p crystalline rock. It is massive in parts but some layers are richly fossiliferous and we into a honey combed mass. In places it is well jointed and has a marked rectangular pa of closely spaced joints running NW - SE and NE - SW. The easily dissoluble lime also gives rise to a number of underground solution caverns.

From the Gondwana period till the miocene period, Sri Lanka and India were togethe remained above the sea. About 20 million years ago, an arm of the Tethys sea encroache the peneplaned land mass between India and Sir Lanka and for the first time convertin Lanka into an Island submerging the entire area of the Jaffna peninsula under sea. In relatively shallow seas grew extensive coral reefs rich in fauna and several hundred fe limestones, calcareous clays and sands were accumulated on the sea floor. The ter period throughout the earth was marked by great mountain building movements. Sri La was however far from these intense movements and the miocene rocks were hardly affe by them. There was only a slight warping of the surfaces and a continuous uplifting o sea floor whereby the limestone beds were brought above the sea to form the penins During the quartenary period, the peninsula had minor upliftment and the subsidence wh gave rise to the residual, lacustrine and lagoonal deposits.

RAINFALL AND HYDROLOGY

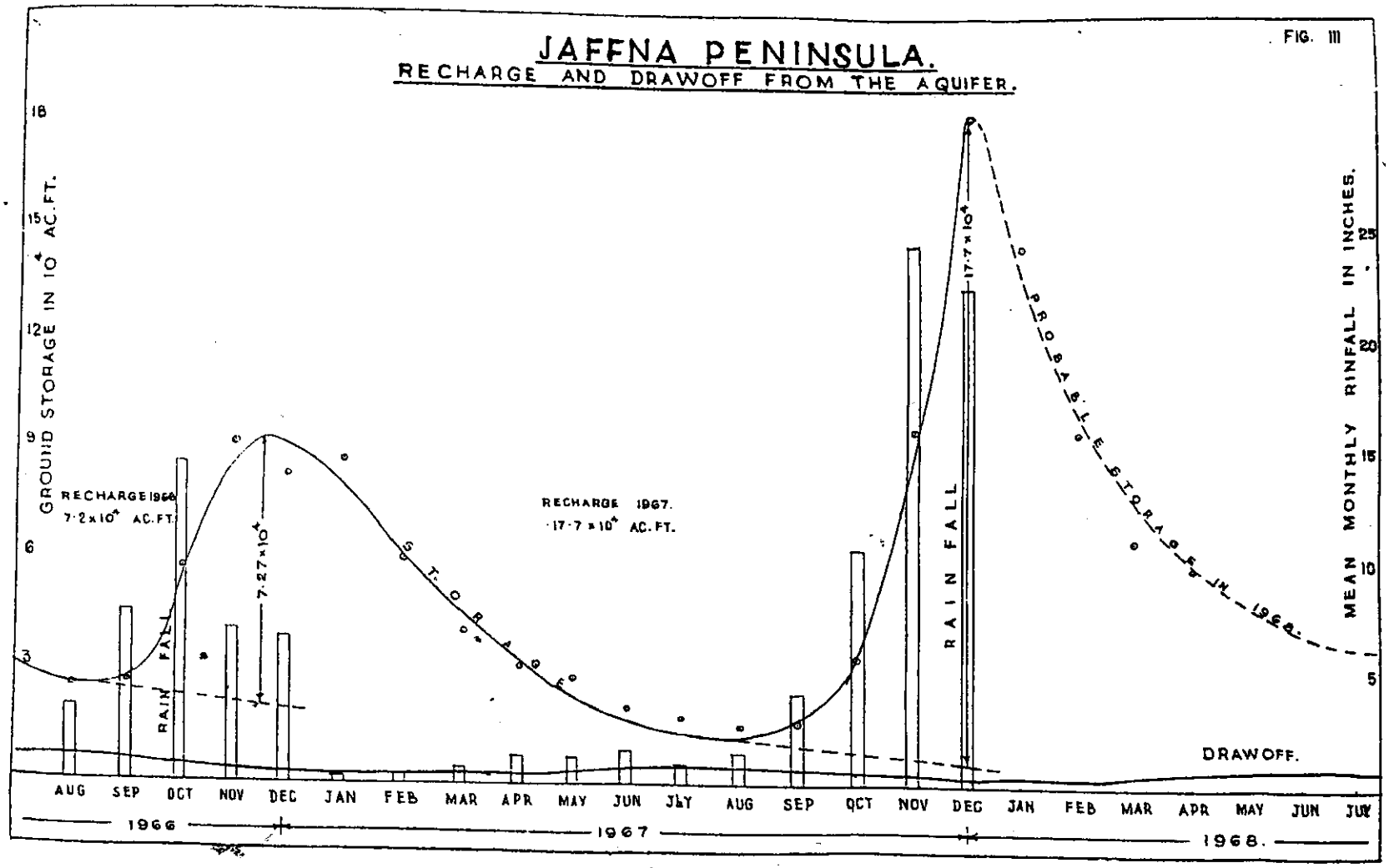
Rainfall records are available from fourteen rainfall stations in the peninsula, recording o 20 to 120 years. Jaffna Town itself has rainfall records commencing from as far back 1871. The annual average as appearing in the report of the Colombo Observatory is inches. North East monsoon rainfall in the Peninsula, 45 inches forms 87% of the to annual rainfall.

While the seasonal rainfall exhibits a definite rhythmic pattern, there is however considera variation in it from year to year. This variability of rainfall has always been a major haz for agricultural development. At the end of August, water table is general at their lowest a the salinity of water at it highest.

FIG. III

JAFFNA PENINSULA.

RECHARGE AND DRAWOFF FROM THE AQUIFER.



Run off - due to the relatively flat topographical nature of the area and its geolog structure, the surface drainage of the peninsula under normal rainfall is meagre. Heavy r off and flooding however takes place after heavy and abnormal rains, through the drain courses.

RECHARGE FROM RAINFALL

The recharge to the ground water in the peninsula is almost entirely from rainfall percolati 411 wells were studied during the period 1965 to 1967 covering the peninsula - annex Table I gives the location of the observation wells. Data pertaining to some selected wells given in Tables II, III and IV, of annex 1.

Table II - Water in the wells in feet.
Table III - Elevation of water surface in the wells, - M S L Datum.
Table IV - Salinity from samples of water found at the bottom of the wells (chloride ions in parts per million)

The behaviour of ground water table, during the years 1965, 1966 to December 1967 enabl us to compute the increase in ground storage, above sea level, as a result of rainfall recharg each year. These contours enable the computation of the volume of water stored in th aquifer, by integrating the incremental layers of the saturated aquifer each month an assuming a storage coefficient (effective porosity) of 0.15. The porosity of Jaffna limeston has been found to vary between 4.5% to 27% with a mean value of 15%. We thus get th following.

TABLE V - RAINFALL AND RECHARGE

PERIOD	RAINFALL (INCHES)	RECHARGE IN ACRE. FEET
Sept. 64 - Jan. 65	22	50,000 (Estimated)
Sept. 65 - Jan. 66	40	90,000 " "
Sept. 66 - Jan. 67	36	73,000 " "
Sept. 67 - Jan. 68	62	177,000 " "

TOPOGRAPHY AND DRAINAGE

The Jaffna peninsula with a land mass of 400 sq.miles has two internal lagoons - Vadamarachchi (North & West lagoons) and Upparu (South) lagoon. The Islands of Mandaitivu, Karainagar, Kayts, Eluvaitivvu, Analaitivu, Punkudutivu, Nainativu and Delft lie to the West of the peninsula. The peninsula is separated from the mainland in the south by Elephant Pass lagoon covering an area of 30 sq.miles.

The two drainage outlets are controlled and regulated at Thondamannaru in the north and Ariyalai in the south, for prevention of sea water ingress. Apart from Thondamannaru and Upparu which drain to the north and south respectively, a small stream called Valukai Aru from the centre commencing at an elevation of 35 ft MSL runs for about 8 miles, through Alaveddi, Uduvil and Manipay conveying drainage from south western areas.

Apart from these natural drainage courses, a few excavated short length canals eg: one from Nanthavil flowing through Jaffna Town, another from Palali through Myliddy etc. are serving as drainage outlets.

GROUND WATER EXPLOITATION AND UTILIZATION

Ground water is the prime source for agricultural development in the Jaffna peninsula. The subject came to prominence in early sixties due to the incidents of saline infiltration in wells that have never been saline before. Dr. Arnon Arad, Hydrological expert from Israel advised a systematic survey to be carried out. The object was to ascertain the quantity and quality of the ground water resources in the peninsula, for use in Agricultural Development.

The survey was expected to reveal indications of the following:-

- Quantity of rain water that percolates annually into the ground water source of the peninsula.
- Quantity of ground water seeping to sea.
- Quantity of ground water available for agriculture.
- The extent of salinity that tends to infiltrate into the aquifer.
- The direction, duration and source of saline infiltration.

A census of all domestic and agricultural wells in the peninsula was made in 1966/67 with the assistance of the census and statistic section of the Jaffna Katcheri and there were in all over 84,000 wells in the area. Of these about 66,000 are domestic wells where water is drawn for domestic purposes only and the balance are agricultural wells. At present the number of wells may be over 100,000. In 1968 the total quantity of water drawn for agriculture was computed by the Agricultural department to be 28,000 acre feet per year mostly from 18,000 agricultural wells. The annual draw off from each well was about 1.5 acre feet. The present demand has increased considerably with the increase in area that is being cultivated.

SALINE INTRUSION

Every sample of the water obtained from each of the 411 observation wells were chemically analysed to determine ions etc. in it. On the basis of the results obtained from such analysis, isochlor maps have been prepared. These maps show the distribution of chlorides, in parts per million, as found in the well waters of the peninsula at the end of the month of August during each of the years 1965, 1966 and 1967.

A combination of the three maps enables us to delineate the areas or zones where salinity prevailed during the period 1965 - 1967.

This is shown in the salinity map fig. IV showing:-

- Areas free from salinity (less than 500 ppm)
- Areas moderately free from salinity (500 to 1000 ppm)
- Areas moderately fee from salinity but liable to salinity with slight increase in draw off (1000 to 1500 ppm)
- Areas liable to salinity in the dry seasons (1500 to 2000 ppm)
- Saline areas (above 2000 ppm)
- Direction of salinity trend

Wherever possible, the directional trend along which salinity in likely to percolate inland, is indicated by arrows; the distribution of salinity and its trend appear to be controlled by recharge from rainfall, withdrawal from limestone aquifer.

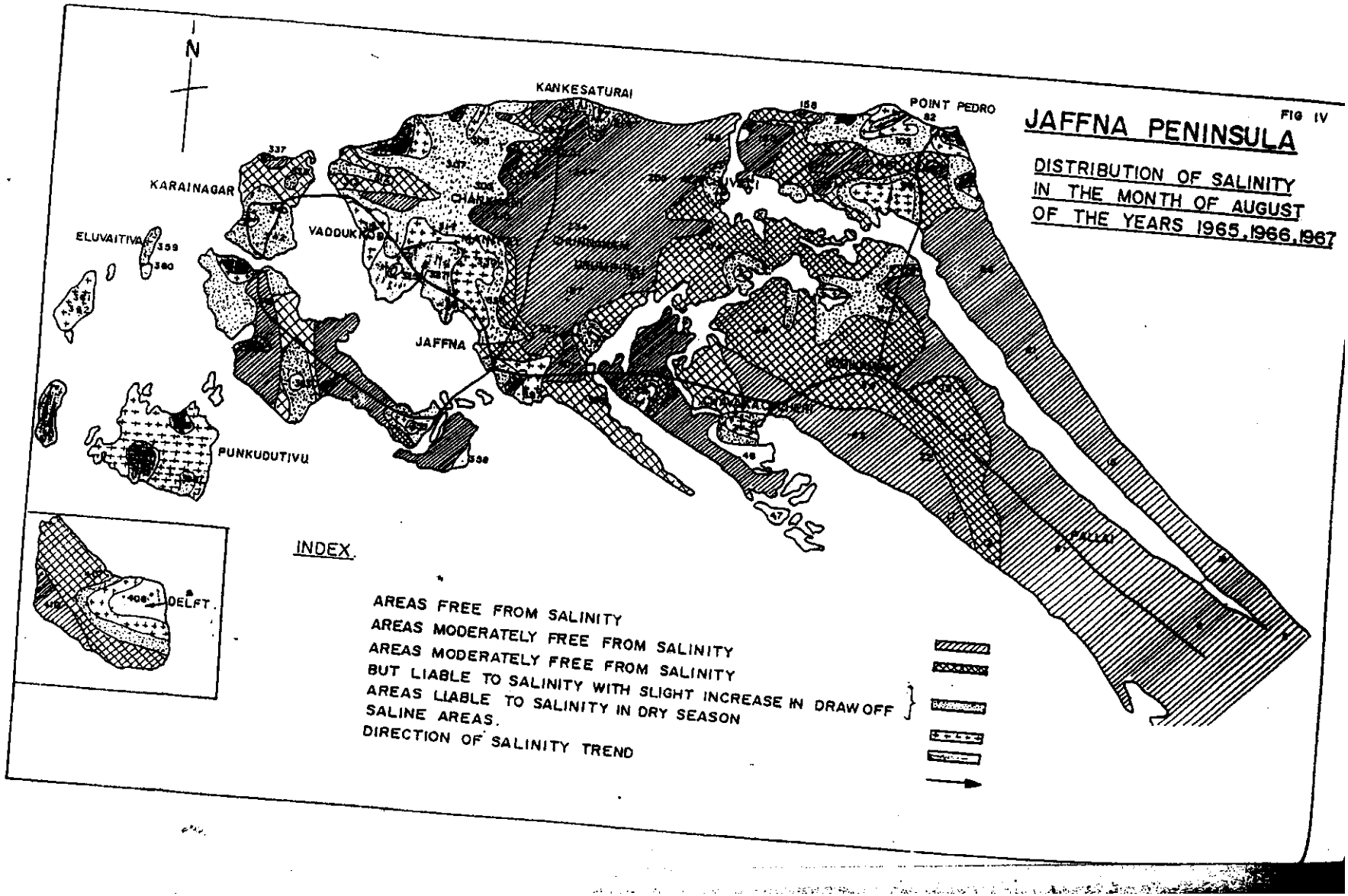


FIG IV
JAFFNA PENINSULA
DISTRIBUTION OF SALINITY
IN THE MONTH OF AUGUST
OF THE YEARS 1965, 1966, 1967
N
KANKESATURAI
POINT PEDRO
KARAINAGAR
ELUVAITIVU
VADDUKODDAI
JAFFNA
PUNKUDUTIVU
DELFT
INDEX.
AREAS FREE FROM SALINITY
AREAS MODERATELY FREE FROM SALINITY
AREAS MODERATELY FREE FROM SALINITY
BUT LIABLE TO SALINITY WITH SLIGHT INCREASE IN DRAW OFF
AREAS LIABLE TO SALINITY IN DRY SEASON
SALINE AREAS.
DIRECTION OF SALINITY TREND

VERTICAL INTRUSION OF SALINITY

The vertical distribution of salinity has been under observation from October 1964 in the bore holes at Kondavil and Kankesanthurai. These show that the general pattern of change is indicated by the improvement in the quality of the water at all levels, during and after each wet season and by deterioration of quality of water during the dry period.

CHAPTER 2

INVESTIGATIONS CARRIED OUT IN THE NORTH - WEST ZONE OF THE PENINSULA

GENERAL

Investigations were carried out by the Irrigation Department since 1973 in a particular zone of the peninsula for detailed study and scrutinization. The analysis of the data obtained from the investigations re-examines the state of ground water resources in the particular zone. A preliminary report by S. Arumugam in 1968 deals on the ground water potentials of the entire peninsula from the data collected from selected 411 shallow wells.

A general evaluation of the monthly ground water storage above the mean sea level and the extent of certain coastal areas susceptible to sea water intrusion were determined from the studies. In 1973 Irrigation Department carried out a study of the water table fluctuation and salinity intrusion in a particular zone (North - Western Region), using available shallow wells and a few deep wells. This zone is characterised with numerous fresh water springs and saline water intrusion fronts. Report from investigations carried out from 1961 to 1972 revealed that salinity areas, areas moderately free from salinity but liable to salinity with slight increase in draw off and areas liable to salinity in dry season are concentrated in this zone.

This region is approximately defined by boundary through Moolai, Chankanai, Sandilipay, Chunnakam, Navakkiri, Thondamannaru and the North coast and covers an extent of 55 sq.miles. Data collected from 725 wells on a grid system of 16 wells per square mile.

The primary purpose was to establish as accurately as possible the state of balance between ground water replenishment and abstraction practices in this area to provide basis for future management, in addition to explore the possibilities to arrest or retard the depletion of fresh water from aquifer to the sea.

The constraints encountered for the investigations were:

- Few bore holes drilled for the conductivity logging and depths were non-effective, except three or four holes, as the balance had collapsed or had been tampered with by the public. This curtailed the study of the behaviour of the interface in the aquifer, to determine precisely its location and the movement through a time sequence under hydrologic conditions.

- Abstraction figures were obtained from the owners of private wells through field surveys of the entire area. Data obtained cannot be considered as reasonably accurate and satisfactory.

It is important that these discrepancies have to be rectified.

GEOLOGICAL AND HYDRAULIC CHARACTERISTICS OF THE AQUIFER STRATIGRAPHY AND STRUCTURE

The land mass is entirely underlain by the sedimentary limestone formation. This intensive area comprises a varying sequence of highly decomposed and highly compact white limestone with a maximum vertical depth of 400 feet, distinctly bedded and well jointed, often extensively karstic in the region of 2 to 4 feet above mean sea level. While there are some vertical variations in the physical property of the limestone (as observed from the four deep bore holes logs), both weathering and presence of secondary structures may have induced modifications.

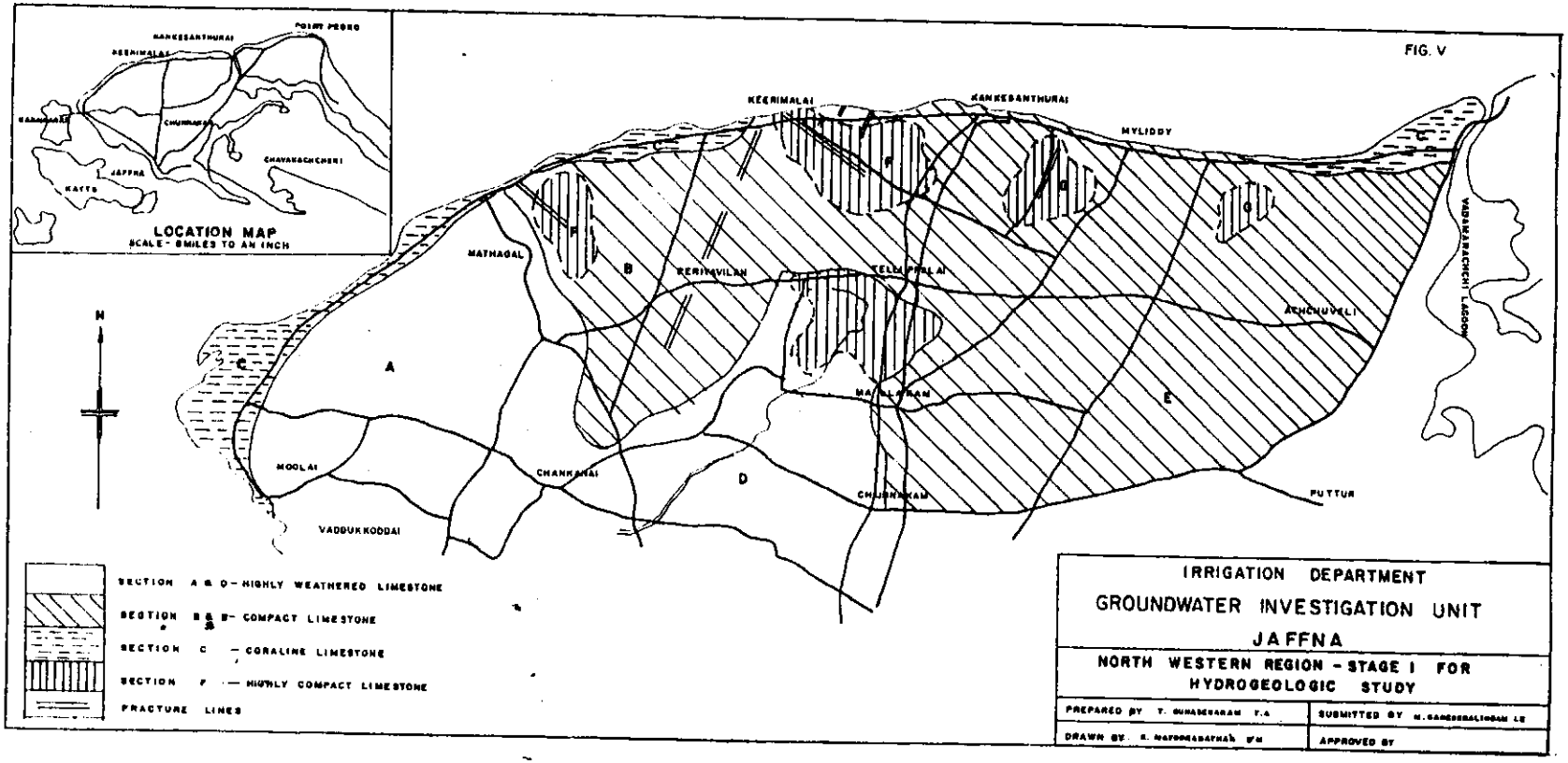


FIG. V
KEERIMALAI
KANKESANTHURAI
MYLIDDY
MATHAGAL
KERIMVILAN
TELLIPPALAI
ATCHUVELI
VADAMARACHCHI LAGOON
MALLAKAM
MOOLAI
CHANKANAI
CHUNNAKAM
PUTTUR
VADDUKKODDAI
A
B
C
D
E
F
G
LOCATION MAP
SCALE- 8MILES TO AN INCH
POINT PEDRO
CHAVAKACHCHERI
JAFFNA
KAYTS
N
SECTION A & D - HIGHLY WEATHERED LIMESTONE
SECTION B & B' - COMPACT LIMESTONE
SECTION C - CORALINE LIMESTONE
SECTION F - HIGHLY COMPACT LIMESTONE
FRACTURE LINES
IRRIGATION DEPARTMENT
GROUNDWATER INVESTIGATION UNIT
JAFFNA
NORTH WESTERN REGION - STAGE I FOR HYDROGEOLOGIC STUDY
PREPARED BY T. GUNASEKARAM T.A
SUBMITTED BY N. GANESHALINGAM I.E
DRAWN BY S. NAGENDRARAJAH D'M
APPROVED BY

The extensive karst topography of the aquifer possess very high porosity than its stratigraphic equivalents in the Manner and Vanathavillu formations. Both flow and storage of ground water in the saturated zone must be a factor of physical discontinuities of the limestone mass, with fracture and karst enlarged locally by soluation. Data collected from topography, limestone structure in the shallow wells in the area, core samples of a few deep bore holes and the monthly water table maps, a general geological structure of the limestone in the intensive area had been evaluated, subject to confirmation with core sample drilling. There appears to be an evident disparity in the limestone structure in the intensive area. The east of the area appears to be of fine to course grained white limestone, highly compact, with high permeability, high specific yield with may fissures and karst, usually 2 to 3 feet above mean sea level. West of the area appears to be composed of weathered and highly weathered limestone when compared to the limestone of the east. Fig V shows the compaction of the limestone strata.

In Section F of the limestone there appears to be a horizontal bedding plane at 4 to 6 feet MSL approximately through which some of the ground water storage is lost. There appears to be a definite fracture along Maviddapuram - Keerimalai Road (45 degrees North West direction) termination at Keerimalai and possibly with no lateral fractures in the direction of north. The escarpment of the North coast from Keerimalai to Sadaiammah Madam shows clear bedding planes and karst permitting spring flow. Detailed investigations are necessary to establish these facts with core drilling.

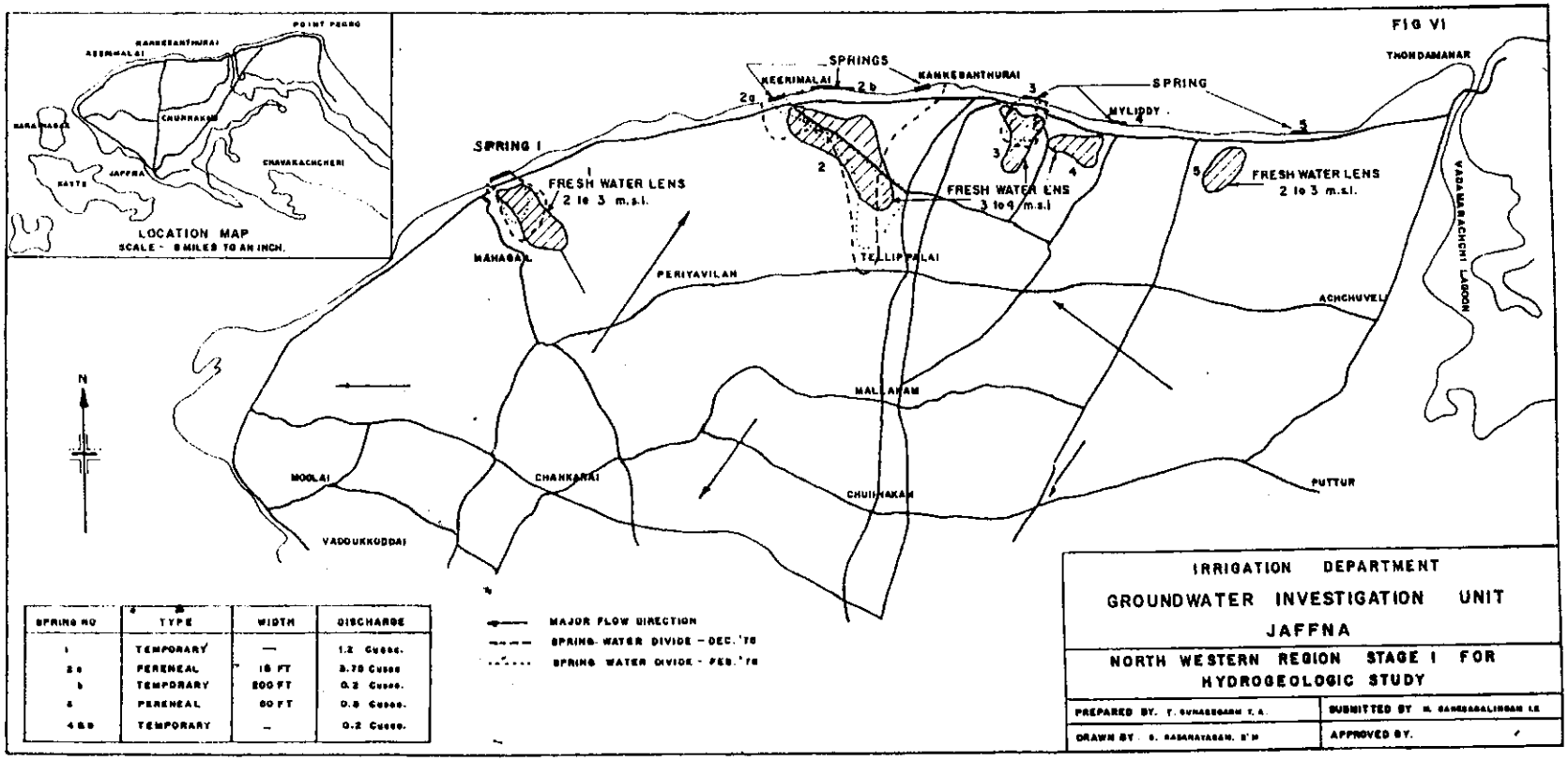
The fracture pattern and karst in the east section of the limestone appears to be in the direction of South East to North West and in the Western area appears to be from South West to North East (Section B) and East to West in Section A.

The porosity of the Jaffna limestone was found to vary from 4.5% to 27%. The transmissivity value derived from the few tests vary from 40,000 to 90,000 g.p.d/ft (C.H.L. Sirimonne). These values indicate a storage coefficient of 15% or 0.15.

HYDRAULIC CHARACTER, WATER TABLE AQUIFER

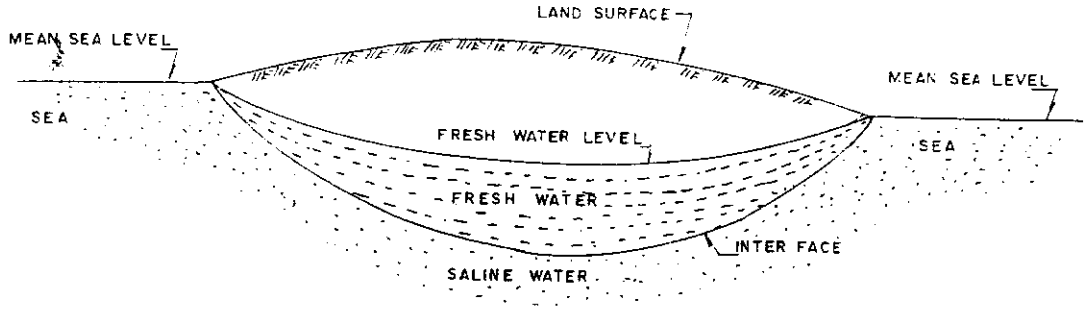
Water table fluctuations were observed monthly on the 1st and 15th of each month from the selected 725 shallow dug wells of this intensive area commencing from August 1973 to 1976.
The occurrence of only a few scattered lenses of fresh water above MSL in the whole intensive area during drought (Fig VI) gives a clear indication of the hydraulic nature of the aquifer, its compaction and boundary parameters. The saturation and general recharge of the aquifer are, during the period of October to January (NE monsoon) by way of precipitation, with a slight recharge during the month of April, when the area experiences a very low rainfall.

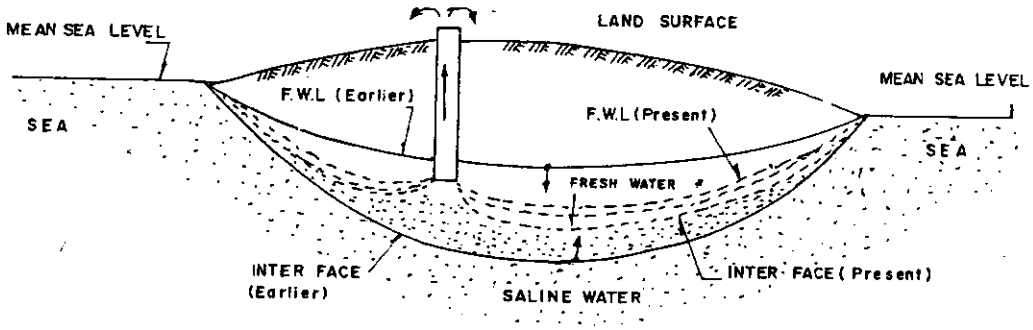
The fresh ground water is derived from precipitation, which infiltrates into the water table. Because of its low density, this fresh water will float upon the underlain saline ground water, forming a lense shaped body, (Fig VII) through the radial movement of fresh water towards the coast. The thickness of the fresh water lens at any location is a function of recharge, the distance from the coast and permeability of the aquifer. It is also possible that poorly permeable beach or lagoon deposits may locally act as a cap rock and increase the thickness and the areal extent of the lens. The variation in aquifer permiabilities are probably more important, than other parameters in controlling the lens thickness.

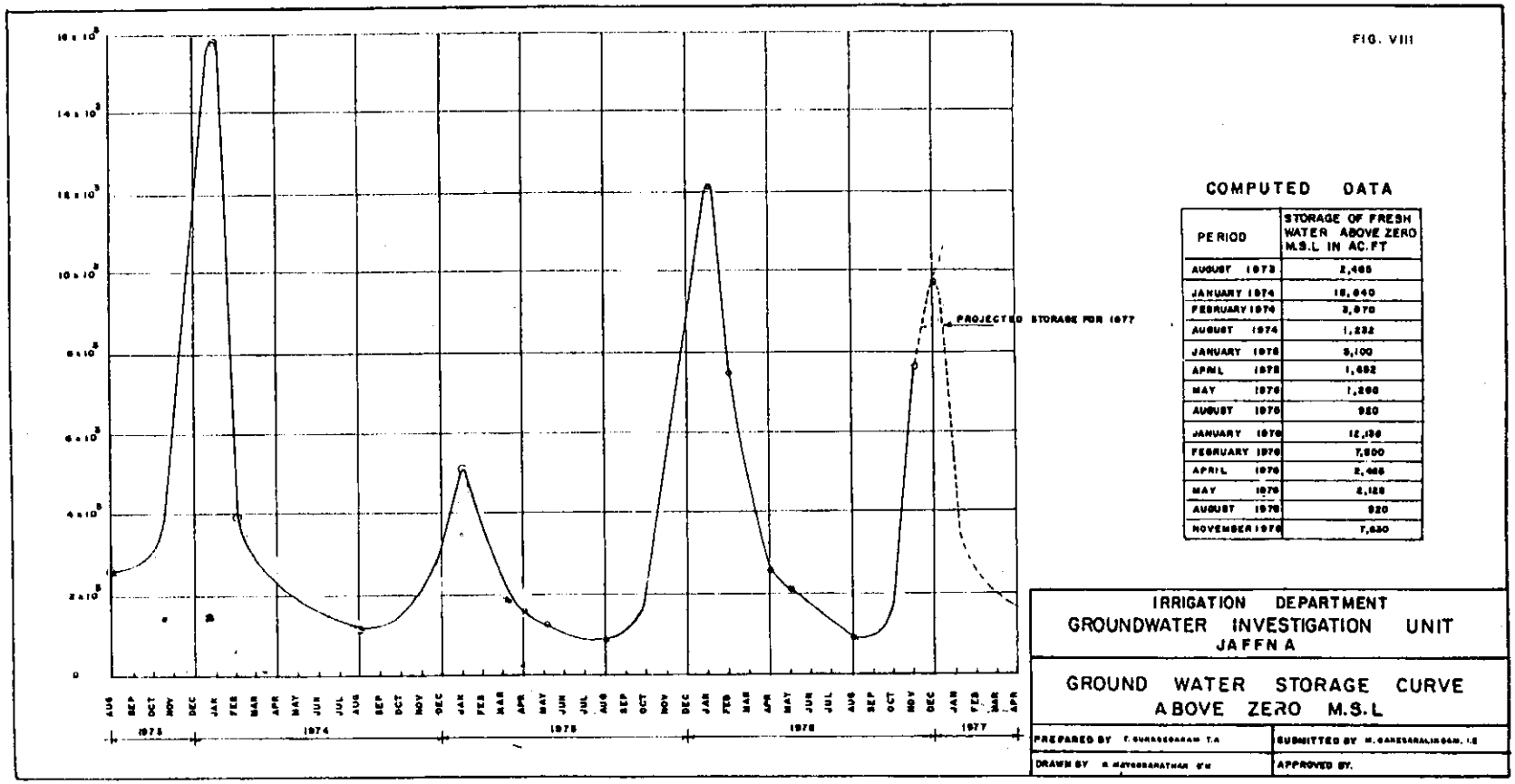


SPRING NO	TYPE	WIDTH	DISCHARGE
1	TEMPORARY	—	1.2 Cusec.
2a	PERENEAL	15 FT	3.75 Cusec
b	TEMPORARY	200 FT	0.2 Cusec.
3	PERENEAL	60 FT	0.8 Cusec.
4 & 5	TEMPORARY	—	0.2 Cusec.

FIG VII


LAND SURFACE
MEAN SEA LEVEL
SEA
FRESH WATER LEVEL
FRESH WATER
INTER FACE
SALINE WATER
MEAN SEA LEVEL
SEA


MEAN SEA LEVEL
LAND SURFACE
SEA
F.W.L (Earlier)
F.W.L (Present)
MEAN SEA LEVEL
SEA
FRESH WATER
INTER FACE
(Earlier)
SALINE WATER
INTER FACE (Present)



COMPUTED DATA

PERIOD	STORAGE OF FRESH WATER ABOVE ZERO M.S.L IN AC.FT
AUGUST 1973	2,485
JANUARY 1974	18,040
FEBRUARY 1974	3,970
AUGUST 1974	1,232
JANUARY 1975	5,100
APRIL 1975	1,682
MAY 1975	1,266
AUGUST 1975	920
JANUARY 1976	12,136
FEBRUARY 1976	7,500
APRIL 1976	2,485
MAY 1976	2,128
AUGUST 1976	920
NOVEMBER 1976	7,630

IRRIGATION DEPARTMENT
GROUNDWATER INVESTIGATION UNIT
JAFFNA

GROUND WATER STORAGE CURVE
ABOVE ZERO M.S.L

PREPARED BY T. SUBASEGARAM T.A	SUBMITTED BY M. GANESARALINGAM, I.E
DRAWN BY M. MAYOORANATHAN D'M	APPROVED BY.

The east and west of the aquifer appears to have different permeability co-efficients. The eas of the area gets saturated up to 2 to 3 feet MSL, whereas the west of the aquifer get saturated up to 6 to 8 MSL. There is an evident disparity in the saturation zone of the aquife in the intensive area.

Under natural conditions, the limestone aquifer appears to have been discharging in numerous sizeable springs all along the northern coast. It is most likely that there could be some off shore springs at shallow depth of the sea bed, which cold contribute to the depletion of the ground water during and immediately after the monsoon. It was observed during the investigation along the north coast during and immediately after the NE monsoonal rains innumerable springs were seen along a certain stretch of the north coast, discharging from one foot below MSL to 4 feet above MSL.

From November to January, springs at a level of 4 feet above MSL could be seen to discharge fresh water between a stretch of one and half mile distance from Keerimalai to Kankesanthurai. However these springs disappear by mid January except the spring at Keerimalai, which is at an elevation of 1 or 2 feet below MSL. Between KKS and Myliddy, fresh water could be seen bubbling up from the sea bed at an elevation of one foot below MSL even during dry months. Only places where a perennial springs could be observed are at Keerimalai and Myliddy. The rest disappear with monsoon.

THE REGIONAL HYDROLOGICAL SYSTEM, ASSESSMENT OF GROUND WATER RECHARGE

The assessment of the rate of ground water recharge is of critical importance in an area of heavy development of ground water resources and there are numerous problems in assessing it. Ground water recharge in the peninsula is from the infiltrating rain water. The average annual rainfall is about 50 inches, with minor seasonal differences.

The water table oscillations of the limestone aquifer, in relation to the rainfall and its depletion during the dry season has been analysed from the ground water table contour maps of this particular zone. The behaviour of the ground water table during the years 1973, 1974, 1975 and 1976 enables the computation of the ground water storage above MSL and to study the variation of storage in relation to regional rainfall during each year of investigation. A long term average recharge of the entire peninsula in relation to rainfall had been evaluated by S. Arumugam (1968) and M.W.P. Wijesinghe (1972). The storage figures arrived then was for the volume of water above MSL. But the fact remains that all ground water storage above MSL is not fresh water (below 1000 PPM is considered fresh water) and all ground water below MSL is not salt water. The computation (Fig VIII) for this 55 sq.miles of the aquifer had been evaluated for fresh water above MSL only. All saline water above MSL had been omitted from the storage. The storage co-efficient was assumed as 15%. Maximum storage is during January and minimum during August/September.

GROUND WATER ABSTRACTION, AVAILABILITY AND RELIABILITY OF DATA

In satisfactory assessment of the state of development of ground water resources, it is essential to have accurate data on ground water abstraction. For the specific purpose of an assessment of any possible overdraft and of the variation in extent of saline intrusion, an accurate picture of the changes in the magnitude and distribution of actual abstraction is required.

A comprehensive survey of all domestic and agricultural wells, acreage cultivated, rate of average recuperation of wells, types of crops cultivated, total number of saline wells and fresh water wells were carried out in the intensive area to access the actual quantities of abstraction done during a cycle of 12 months. Total quantity of fresh water abstracted in this area is about 46,000 Ac. ft; during the period of 9 months. This appears to be an overdraft when compared to the storage above MSL. The overdraft is definitily from the storage below MSL. This abstraction figure were obtained in 1976.

TABLE VI

Data obtained from intensive study area - N.W.Zone
The survey revealed the following:-

Intensive study area	35,000	Acres.
Agricultural land cultivated	9,000	Acres.
Saline wells	6,143	Nos.
Fresh water wells	13,862	Nos.
Total wells	20,005	Nos.
Intensity of wells per square mile	333	Nos.
Percentage of saline wells	30	
Total annual domestic and Agricultural abstraction	46,000	Ac.ft.
Average abstraction per well	2.30	Ac.ft

RECOMMENDATIONS

An urgent requirement for the improved management of the ground water resources of the peninsula is the permanent drilling of deep bore holes on a grid system, principally for the monitoring of :-

- the ground water resources.
- the seasonal and long term movement of the saline water front along the coasts.
- the fluctuations of the interface and to assess the actual storage.

The bore holes for monitoring the ground water conditions are necessary as long as ground water is being used in the peninsula. Proper study of ground water conditions could only be well established by the way of deep bore holes investigations, than with the aid of shallow wells. The water levels in the shallow wells cannot be the actual water table as most of the wells are under heavy pumping and at times the possibility of recording the water levels during the recuperation period cannot be ruled out. Some shallow wells have been deep drilled within and they act as freak wells when compared to many other shallow wells.

POSSIBLE SOLUTION TO PREVENT WATER FROM THE AQUIFER ESCAPING TO THE SEA

Observations were carried out immediately before and after the monsoon along the north coast through which much of the water from the aquifer is escaping to the sea. It was observed that only a particular stretch of the coast was discharging the water from the aquifer for a particular period immediately after the monsoonal rains. Investigations to be carried out to explore the possibilities of sealing the karst region with a cut off wall to a particular depth and height to keep the water in the aquifer from causing undue hydraulic gradients and water logging of low areas. Some relevant data may be obtained from the water table map, for the design of cut-off walls. Cut-off wall construction may be taken up as a research pilot project on a particular stretch of the North cost. The stretch of about one and a half miles from Keerimalai to Sadaiammah madam, where heavy spring discharge is taking place, is ideally suited for this purpose.

CHAPTER 3

AUGMENTATION OF THE PENINSULA WATER RESOURCES FROM EXTERNAL SOURCES (MAINLAND) AND INTERNAL SOURCES

GENERAL

The main feeder stream to the Elephant Pass lagoon is Kanagarayan Aru and it has its origin in Vavuniya. The other streams draining into this lagoon are Nethali Aru, Piramanthal Aru and Theravil Aru. The catchment area is 363 sq.miles excluding the lagoon bed which is 30 sq.miles. The net yield is 91,000 Acre feet.

Elephant Pass lagoon will be the primary reservoir. A bund cum spill across the east end at Chundikulam would seal the entry of sea water into the Elephant Pass lagoon, thus transforming it into a fresh water primary reservoir. From this reservoir the water would be led by a canal called the "Mulliyan canal" link canal to the Vadamarachchi lagoon which then becomes the secondary reservoir. Vadamarachchi lagoon feeds Upparu lagoon.

The inland salt lagoons within the peninsula comprising the Northern section called Vadamarachchi lagoon, covering an area of about 30 sq.miles with outlet to the sea at Thondamannaru and Southern section called Upparu lagoon covering an area of about 10 sq.miles, with an outlet to the sea through the bridge near 195th mile post on the Kandy - Jaffna road at Ariyalai, are referred to as the "Jaffna peninsula lagoon". The portion of the lagoon lying between the peninsula and the main land and to the east of the railway line at Elephant Pass covering an area of about 30 sq.miles is referred to as the "Elephant Pass lagoon". All these three lagoons form the "Jaffna lagoon scheme".

The proposal to convert the salt lagoons to fresh water lakes was expected to improve the water resources of the peninsula, both in recharging the underground storage with additional surface storage and desalinating the lands fringing the lagoons and making suitable for cultivation.

HISTORICAL

History does not speak of ancient irrigation works in the Jaffna peninsula, but according to tradition a large tract of land was under cultivation many centuries ago. For some unknown reasons the dams that have kept out the salt water was removed and the sea water allowed to run in forming a vast lagoon, extending from Thondamannaru on the North to Ariyalai on the South and from Vallai bridge on the East to Periyapachchilaippalai on the West.

The supply of adequate fresh water has been a perennial problem of the people of the peninsula. Though considerable investigations, research and proposals have been finalised, the implementation was neglected by successive governments, and is now considered as one of the factors leading to the lack of development of Tamil speaking areas.

Studies have already shown that due to over exploitation of the aquifer in the peninsula most wells in the region have become brackish, and the importance of a supply source to replenish the wells in order to meet increased demand is considered to be a paramount importance.

This project is both feasible and pragmatic, in that it could supply the peninsula with fresh water without tapping the resources of the Mahaveli Ganga.

Technical aspects of the scheme envisages utilising the following resources:-

(1) The yield from a catchment of 363 sq.miles of the main land and 30 sq.miles of the Elephant Pass lagoon area which drains into the sea via Chundikulam, at the eastern end of the Elephant Pass lagoon and

(2) The yield from the local catchment of about 200 sq.miles of the two internal lagoons Vadamarachchi and Upparu.

TWYNEHAM REPORT

The efforts to provide the Jaffna peninsula with adequate supplies of fresh water have had an interesting and chequered history. The idea originated as far back as 1879 when the then Government Agent of the Northern Province, Twyneham reported on the feasibility of such a scheme.

The "Twyneham Report" foresaw the possibility of damming the sea water from entering the inland lagoons and reclaiming the fringe lands for cultivations. However in 1884, the peninsula experienced a disastrous flood of such magnitude that it made the G.A. turn away the original proposals as he feared that the whole peninsula may be inundated by the floods once their outlets to the sea were blocked. The scheme was again taken up in 1913, when Fesling, Government Agent, Northern Province took up the Project, but the following year he wrote that he did not require the matter to be investigated further. He did not give any reason for his decision.

HORSEBURG REPORT

In 1916 G.A. of the day Horseburg, considered the implementation of the proposals, but he feared that the salt manufacture in the area, which fills the coffers of the state, would be affected. However he took up an experimental arrangement of isolating the east lagoon from the rest by constructing temporary bunds coupled with insertion of planks in the existing PWD culverts in the roads as a precautionary preliminary measure before commencing permanent works. This recommendation received the consideration of the colonial secretary in London, the same year.

The main suggestions of Horseburg Report were that:

1) 8500 Acres of crown land and 3000 Acres of private holdings could be developed.

2) The culvert across the Point Pedro - Chavakachcheri road could be blocked by wooden gates and opened to release excess water during the rainy season.

Later in 1920 the Vadamarachchi lagoon scheme began with a sum of Rs. 5000 and the scheme is reported to have functioned efficiently till 1923.

After the success of the 4 year experimental operation, the views of the people of the area were sought by means of a vote on the scheme. The people voted in favour of continuing and expanding scheme.

The support of the people was not surprising as Karaveddi East and Thunnalai, once saline tracts, had been reclaimed for cultivation with the addition of plenty of water for domestic consumption.

Following the wide public acceptance of the experimental project. the late Balasingham proposed the implementation of the full scheme.

BALASINGHAM AND WEBB REPORT

In 1930 the Divisional Irrigation Engineer Northern Province F.R.G. Webb together with Balasingham issued "The Balasingham Webb Report" which suggested that barrages be built to prevent salt water intrusion into the inland lagoons to convert them into fresh water lakes, reclaim uncultivable land, and increase the yields of the lands already cultivated.

Some of the interesting points from their report are:-

1) The area of the lagoons
   a) Vadamarachchi - 30 sq.miles.
   b) Upparu - 10 sq.miles.

2) Uncultivable lands along the fringe of the lagoons are 17.5 sq.miles (11,000 Acres).

3) About 20,000 Acres of paddy lands (rain fed) had poor yields.

BALASINGHAM'S PROPOSAL

Diverting Mahaveli to irrigate the dry zone in the North central and Northern Provinces and finally to Jaffna peninsula via Kanangarayan aru is the idea of Balasingham, member of the legislative council. The lagoons in the peninsula to serve as reservoirs for the peninsula.

Mahaveli project as today has taken a different turn with no possibility of the dry zone in the North including Jaffna peninsula being benefited. As per prevailing situation in the country it is a blessing in disguise.

The net flow in Kanagarayan Aru and three other minor rivers is sufficient to supplement the water resources in the peninsula, if diverted to the peninsula via the Elephant Pass lagoon.

Quoting the exhortation of the great Parakrama Bahu that "not a drop of water should be allowed to flow into the ocean without profiting man", K. Balasingham, drew the attention to the utilization of lagoons by converting them into fresh water lakes, in a series of articles ito the "Ceylon Daily News", in the Thirties. The conversion of the Elephant Pass lagoon is referred in these articles as being of great potential value.

In 1936 W.A. Guthree, who subsequently retired as Director of Irrigation, mentioned in his inspection notes that the possibility of diverting the Iranamadu Reservoir's spill stream (Kanagarayan Aru via Iranamadu reservoir) Via Elephant Pass lagoon to Vadamarachchi lagoon in the peninsula may considered. This will expedite leaching out salt deposits and will result in bringing a river to the Jaffna peninsula.

PREVIOUS INVESTIGATIONS, RECORDS DATA ETC.

Proposals for the conversion of all or some parts of the lagoon areas into fresh water lakes have been under consideration for more than one hundred years. During part of this period, investigations and experiments have been carried out. As a result there exists an accumulated mass of documents and figures. To begin with the scheme is unique in many respects. Nothing like it has been attempted in Sri Lanka before. It will not only affect agricultural interests but also domestic conditions, livelihood and comfort and possibly the health of thousands of the local inhabitants.

In 1942 F.R.G. Webb Divisional Irrigation Engineer studied and sifted all the available data, records, and endeavoured to extract, adapt and utilise all the useful matter.

He prepared the report "Jaffna Peninsula lagoon Scheme". Since then it has remained an important guideline of this scheme. He says that it would be temerarious for anyone who aims at producing a full report on the scheme, to disdain any of these considered opinions, they and the information that is available, and the suggestions, hopes and fears put forward, must at least, be set out, analysed and commented on. Subsequent to his report substantial amount of work has been done though more to be done to make it a success.

Webb's report analyses the following aspects:-

- History of the scheme, the various proposals, investigations and trials and to consolidate the many weeks of labour recently spent in collecting, studying, sifting, and collating several thousands of sheets of correspondence, minutes, memoranda, observation, gauge readings etc. into comprehensive epitome of the useful portions, thereby serving future inquiries, a repetition of such works and enabling them to grasp the fundamental features in a couple of hours instead of only after weeks of arduous toil.

- Secondly it describes and analyses many aspects of the problem and various methods of solving it, it explains why he considers his proposed solution the best one, it weighs up the benefits and disadvantages which can be expected to flow from the proposals and endeavours to forecast, as well as it is possible to do so, the effects it will have on the areas affected.

- Thirdly, being in mind the prejudice which exists in some quarters against the scheme, the opposition it is likely to encounter and that its acceptance hinges not so much on Engineering Technicalities as on overcoming the fears so deeply rooted in some minds, the report deals lengthy with this aspect and attempts to meet all the objections which have been or may be raised and to meet in language which can be understood by those primarily concerned.

- Finally, it presents and analyses the hydrographical and other Technical data, it put forward concrete proposals for effecting the suggested transformation and his opinion and recommendations.

About the time Webb's report was written a wide range of observations regarding the salinity of lagoon waters and soils were undertaken in collaboration with the agricultural chemist of the Department of Agriculture. These observation were carried over one complete cycle covering both lagoon areas, via Vadamarachchi and Upparu. These observations were divided into two seasons - September to March and April to August, wet and dry periods respectively.

As a result of these observations the general conclusions aimed at are:

(a) Highest concentration of salt corresponds generally to the months of low water level - August and September.

(b) Lowest concentration of salt corresponds generally to the months of high water level - December and January.

(c) There does not seem to be any seepage flow from the sea to the lagoons. Hence it is quite possible that the salinity in the soils and water in the lagoons are solely due to ingress of the sea water into the lagoons via the mouths.

(d) If the sea is kept out of the lagoons and the past accumulation of the salt washed out effectively there is every chance of improving:-

(i) The quality of the soil and water, and

(ii) Agricultural prospects of the reclaimed land using lagoon water for irrigation.

Regarding the reclamation of the land it is suggested the area to be deep ploughed and a system of internal drainage laid down to accelerate the leaching process. In addition to this a saline resisting leguminous crop should be planted successively for ploughing in to improve the texture of the soil. This will as anticipated by the chemist, reduce the period required to sweeten the soil. and by the time the cultivation has spread to extreme marginal lands, much of the alkaline or salt impregnated area may have improved sufficiently to enable economic crops to be cultivated.

A SUMMARY OF ACTION TAKEN BY THE IRRIGATION DEPARTMENT FROM 1941 TO 1970 - STUDIES, PROPOSALS, DESIGNS, CONSTRUCTION ETC.

The scheme was put up as an item for preliminary investigation in the Jaffna District Agricultural Committee by the Divisional Irrigation Engineer, Northern Division in 1941 and was dropped. In the later part of 1941 Webb, Divisional Irrigation Engineer inspected the various areas coming under the scheme and made a study of them. He commenced gauge readings, salinity tests, etc. in the Vadamarachchi lagoon and he brought up his proposals in his report on the scheme which was published in 1945.

WEBB'S PROPOSALS

The design allows for two barrages across Thondamannaru and Upparu. Each must satisfy three main requirements viz. complete prevention of ingress of sea water, adequate provision for rapid and safe discharge of rainfall and for accruing out salt impregnated water, and the ordinary engineering requirements for stability under all conditions of loading.

SELECTION OF SITE

Examination of the Upparu from Kopay road to the railway bridge, indicates beyond doubt the most suitable site for the Southern barrage is at Ariyalai bridge. The foundations are the best here and a barrage here would enable the Chemmani salt pans to continue to function with only a slight alteration and that the saline supply would have to be led in entirely by way of channel from the south of the road through the road culvert. After taking soundings up stream and down stream of the Ariyalai bridge it was found that the foundation condition up stream of the bridge was better than the down stream. Therefore the site up stream of the bridge was selected.

For the Northern barrage the Vallai bridge site and the Thondamannaru bridge site were first investigated. The former site had geological formations and would involve deep and costly foundations. Further the spread area of the flood waters is so large that it may not have enough head to open the then proposed flap gates.

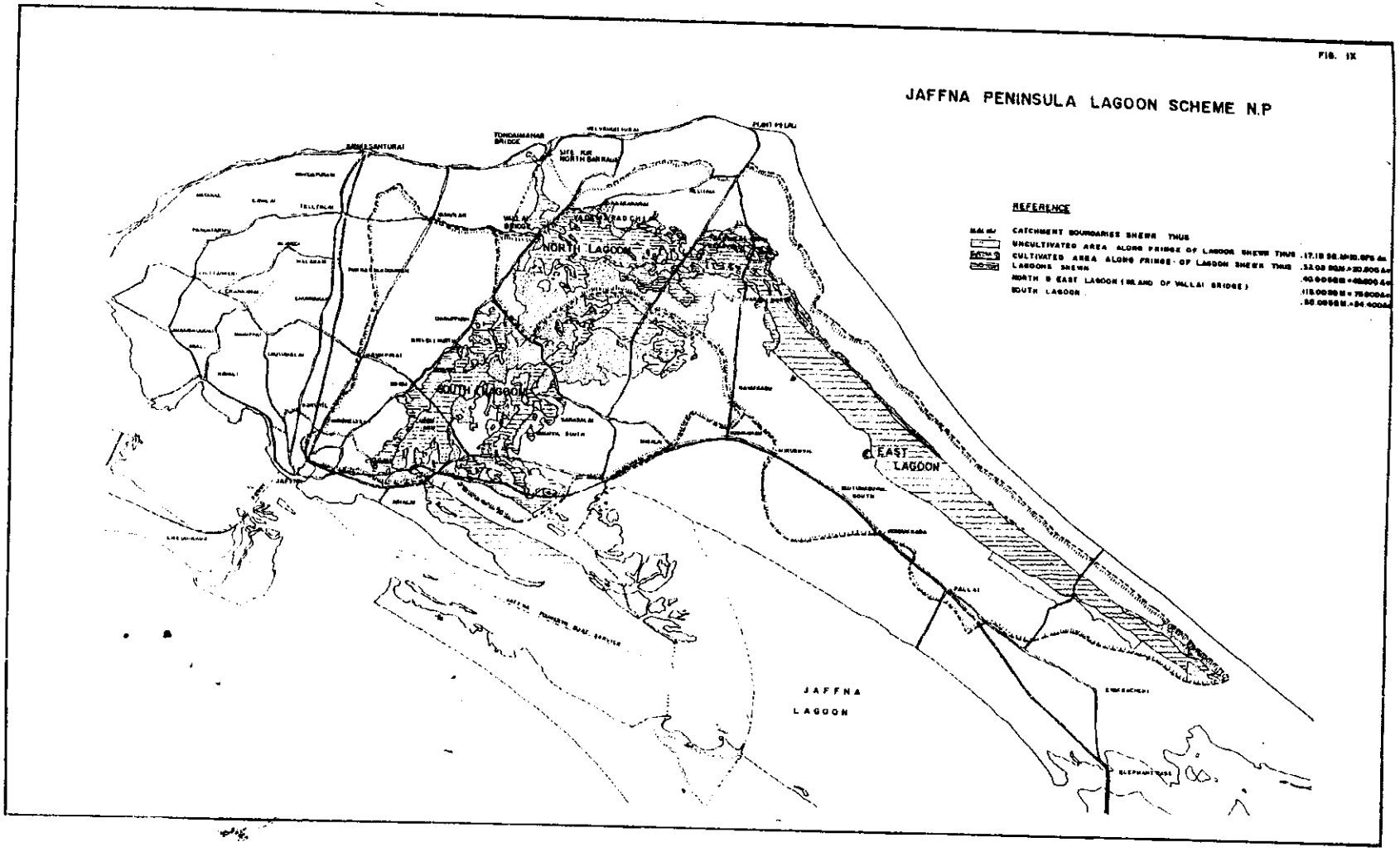


FIG. IX
JAFFNA PENINSULA LAGOON SCHEME N.P
REFERENCE
CATCHMENT BOUNDARIES SHEWN THUS
UNCULTIVATED AREA ALONG FRINGE OF LAGOON SHEWN THUS
CULTIVATED AREA ALONG FRINGE OF LAGOON SHEWN THUS
LAGOONS SHEWN
NORTH & EAST LAGOON (ISLAND OF VALLAI BRIDGE)
SOUTH LAGOON
NORTH LAGOON
SOUTH LAGOON
EAST LAGOON
JAFFNA LAGOON

The most serious objection for this site is the vicinity of a thickly congested residential area. Then the various points in between the bridges were investigated and it was finally determined that the site close to the Temple and across the minor road was the most suitable one.

CATCHMENT AREA, RAINFALL, TIDAL LEVELS AND RUN OFF

The catchment area of North lagoon is 115 sq.miles and the catchment area of South lagoon is 85 sq.miles.

The area of North lagoon is 30 sq.miles.
The area of South lagoon is 10 sq.miles.

The uncultivated lands, immediately adjoining the lagoons and shown in dotted patches 17.15 sq.miles or 10,976 acres. The cultivated lands inside the catchment area shown horizontally hatched patches 32.03 sq.miles or 20,500 acres. (Fig IX)

TABLE VII

Average Rainfall (in inches)

	Jaffna	Chavak.	Pallai.	Pt.Pedro	Average
September	3.12	3.36	2.01	2.52	2.75
October	9.63	9.93	9.67	11.71	10.23
November	16.32	18.27	16.84	16.99	17.10
December	9.46	10.37	10.31	8.95	9.77
January	4.39	4.18	4.33	4.30	4.30
February	1.18	1.15	0.83	0.96	1.03
Total N.E.	44.1	47.26	43.99	45.43	45.19
March	1.86	1.74	2.30	1.49	1.85
April	1.49	1.80	1.01	0.90	1.30
May	1.66	1.50	1.58	1.27	1.50
June	0.36	0.36	0.34	0.50	0.39
July	0.61	0.42	0.51	0.73	0.57
August	1.08	1.37	1.24	1.75	1.36
Total S.W.	7.07	7.19	6.98	6.64	6.97

TABLE VIII

Record November Rainfall (in inches)

	Jaffna	Chavak.	Pallai.	Pt.Pedro	Average
Nov. 1918	34.02	-	19.12	17.62	23.06
Nov. 1920	36.80	-	48.69	47.32	44.30
Nov. 1939	35.35	41.69	26.91	27.24	32.80

TABLE IX

Tide Levels (in feet)

	Jaffna	Thondamanaru
Dec. 1941	2.06	2.68
	0.35	0.65
May 1942	1.05	1.25
	0.50	0.90

TABLE X

Yield of Catchments

	Area Sq. Mls.	Area Acs.	Cross Yield Ac. Ft.	Nat. Yield Ac. Ft.
North East Lagoons	115	73600	276000	69000
South Lagoon	85	54400	204000	51000
Total	200	128000	480000	120000

Area & Capacity

M.S.L.	1	2	3	4.7
North East Lagoons				
Area	19200	26100	34600	73000
Mean Area	22650	30350	53800	
Layer Depth	1	1	1.7	
Layer Capacity	22650	30350	91460	
Total Capacity	22650	53000	144460	
Say	22500	53000	144500	
South Lagoon				
Area	6400	10500	22500	54000
Mean Area	8450	16500	38250	
Layer Depth	1	1	1.7	
Layer Capacity	8450	16500	65025	
Total Capacity	8450	24950	89975	
Say	8500	25000	90000	

Gross & Net Yield

Catchment	Gross Ac. ft.	Net from Strange curve Ac. ft.	Net from Weir curve Ac. Ft.
North & East Lagoon	276000	60400	81600
South Lagoon	204000	44600	37600

Maximum Flood Run-off by Dicken's Formula

	Catchment sq. miles	C = 650 cusecs	C = 750 cusecs	C. = 1000 cusecs
North & East Lagoons	115	22600	26300	35100
South Lagoon	85	18000	21000	28000

South Lagoon (Upparu)

The collected information of heavy floods. etc., indicated that Ariyalai bridge in conjunction with the railway bridge discharged about 5,500 cusecs when the flood level is 3.75 MSL and is capable of discharging well over 6,000 cusecs, before the level goes up to 5.0 MSL., at which point it begins to lose control of the run-off and passes on the surfaces to the roads and other outlets.

The rainfall examination showed that quite an exceptionally heavy rainfall period produces a discharge of 5,500 cusecs. This is not a cyclonic rainfall but one which may raise the flood level to 3.75 MSL

North and East Lagoons (Vadamarachchi)

The results obtained from the only flood behaviour information available indicated when flood water stands at 3.75 MSL, Thondamannaru bridge is discharging at a rate of about 9,000 cusecs, and is certainly capable of discharging well over 10,000 cusecs before 5.00 MSL. is reached and the surplus is passed on to the high flood outlets from the East lagoon and over road surfaces.

An exceptionally heavy rainfall period, not approaching cyclonic intensity but which is likely to bring up the flood level to about 3.75 MSL. produces a run-off of 7,500 cusecs.

Taking the water level at 2.75 the equivalent openings in the Vallai and Thondamannaru bridges indicated that the maximum barrage openings required as 1,524 sq. feet.

WEBB'S PROPOSALS FOR THE BARRAGES

Southern barrage

Length of Barrage	- 325 ft
Crest of Barrage	- 3.0 MSL.
Number of flap gates	- 40
Size of gate openings	- 5 ft. x 4 ft.
Lock gates width	- 15 ft.
Sill of lock gate	- -3.0 ft. MSL.
Geometry of Structure	- semi circular arc
Sill of flap gates	- -4.8 MSL.
Ceiling level of openings	- -0.8 MSL.

Northern barrage

Length of Barrage	- 400 ft.
Crest of Barrage	- 3.0 MSL.
Number of flap gates	- 50
Size of gate openings	- 5 ft. x 4 ft.
Lock gates width	- 15 ft.
Sill of lock gate	- -3.0 ft. MSL.
Sill of flap gates	- -4.8 MSL.
Ceiling level of openings	- -0.8 MSL.
Geometry of Structure	- straight line.

The foundations of both the barrages were proposed as "raft" type, mounted on continuous timber piles driven down to good rock. He suggested steel piles also to be driven in

between. The dam structure to be either in mass concrete or reinforced concrete. However he finally states the dam to be of mass concrete structure, with a raft foundation and built on two continuous walls of timber sheet piling.

Also, he estimates the total costs then (1943) to be Rs. 65,000/=.

AMENDMENTS TO WEBB'S PROPOSALS

After 1945, further studies were made by the Irrigation Department and amendments were made to Webb's proposals. However, in 1947 final plans for the Northern barrage were drawn up and estimates were sanctioned.

(i) Final Proposal for Northern Barrages. (Vadamarachchi)

1.	Catchment area	115 sq.miles.
2.	Lagoon water spread	30 sq.miles.
3.	Maximum tidal levels	
	(1) at sea	+2.68 ft. MSL.
	(2) at Thondamannaru bridge	+2.27 ft. MSL.
4.	Spill way	
	(I) Main spans	18 Nos. 20 ft. wide separated by 3ft. 6 ins. wide piers. sill at -3.5ft. MSL.
	(II) Controls gates	Two vertical lift gates each 4 ft. high.
	(III) Subsidiary spans	16 Nos. 10 ft. wide, with 2 ft. thick piers controlled by planks.
5.	Effective width of the down stream channel	600 ft.

The road way bridge down stream at Vallai is expected to cause afflux of about 0.75 ft.

Maximum inflow discharge in the lagoon

The Dicken's formula with C = 1,000 gives an inflow of 25,100 cusecs. It may be mentioned as the length of catchment is about 25 miles it modifies this maximum inflow that will last for not more than 5 hours. There are also natural constrictions in the lagoon water way like one at Karaveddi. However, when floods approach +5.00 ft. MSL. overflow to the sea begins at several places along the North - East of the East lagoon and at its Southern extremity into the Elephant Pass Lagoon. These conditions will further modify the spillway capacity requirements. It is, therefore presumed that the actual maximum inflow on which the spillway capacity is to be based is considerably less and may be of the order of 20,000 cusecs.

Spillway capacity of the Thondamannaru Gates

The main gate controlled block has a total waterway of 360 ft. with sill at - 3.5 ft. MSL. The block on the left flank has a total waterway of 160 ft. with sill at +2.5 ft. MSL. Discharges with up stream water levels varying between +4.0 ft. MSL. and +5.0 ft. MSL. and down stream water levels varying from say + 3.0 ft. MSL. to + 4.0 ft. MSL. were worked out. (similar calculation is illustrated in the case of Ariyalai barrage). Thus for lagoon water levels at +4.0 ft. and 4.5 ft. MSL. and with down stream water levels at +3 ft. MSL. the discharges with all spans open are 13250 cusecs and 16,800 cusecs respectively. If however, only the bottom gates are lifted by 4 ft. together with 16 subsidiary spans full operating, the discharges passing will be 7,500 cusecs and 9,800 cusecs respectively.

(ii) Final Proposal for Southern lagoon

(1)	Catchment area	85 sq. miles.
(2)	Lagoon area	10 sq. miles.
(3)	Spill way	
i)	Length of spill way semi circular arc R - 150 ft. & 2 areas of 50 ft. each	571 ft.
ii)	Openings in the spillway operated by control gates 5 ft. wide.	18 Nos with sill at -1.0 MSL.
iii)	Openings in the spillway controlled by wooden planks each 5 ft. wide.	34 Nos with sill at -1.0 MSL.

The openings are separated by piers 2 ft. thick with triangular shaped cut waters. The top of the piers and the remaining length of the spillway has top level +4.0 and affective length of 337 ft. Crest is 2 ft. wide.

(4)	Tide level Nov. - Dec. period	+2.06ft. MSL. (max.) +0.35 ft. MSL. (min.)
(5)	Effective width of lagoon down stream of the Ariyalai barrage	700 ft.

The spill way capacity of the structure as constructed depends on:

(1) The water levels down stream due to tidal effects.

(2) Any modification in these levels because of quantity of outward flow and the effect of S.W. strong winds, that may boost up the down stream level.

Observed Maximum level in the lagoons.

On the bridge on Kopay - Kaithady road, maximum water level was +5.5 MSL. when 13.69" rainfall occurred in a day of 15th November, 1939. In order to find out the discharging capacity under adverse conditions of the tide, water levels are assumed down stream of the Ariyalai barrage.

(i) +5.0 ft. (ii) +4.0 ft. (iii) +3.0 ft. MSL.

The table below gives the discharges for up stream water levels of +6.5, +5.5 & +5.0 ft. MSL. when all the 42 gates in the control structure are assumed to be open. In calculating the total discharge, the part of the discharge passing as overflow, over the effective length of 337 ft. was calculated on the basis of

$$Q1 = C.LD^{3/2}$$

a suitable C value was adopted for overflow with different submergence ratio,
C varying from 2.9 to 3.3
D = up stream depth of flow
L = 337 ft.

For the flow in the gated portion, the following submerged weir formula was used.

$Q2 = 3.1L \{(H - h_a)^{3/2} - h_a^{3/2}\} - 8\ c.d\ (H - h_a)^{1/2}$

where

H = Difference of up-stream & down-stream water levels

ha = head due to velocity of approach (assumed negligible)

L = total length 42 x 5 = 210 ft.

effective length = 205 ft. (5' for end contraction)

c = co-efficient taken 0.6

d = depth of water down-stream over the sill level (-1.0 MSL) due to down-stream water level under consideration.

TABLE XI

Spill discharge for various up-stream and down-stream water levels

	U/S Water Level	+6.5	+6.0	+5.5	+5.0
		Q	Q	Q	Q
D/S	+5	12,390	9,640	5,930	-
Water	+4	14,680	11,870	9,120	6,600
Level	+3	16,050	13,410	10,710	7,520

(iii) Maximum inflow intensity.

The catchment area of the lagoon is 85 square miles.

Adopting Dicken's formula for maximum run off.

$Q = CA^{3/4}$ Max

When C = 750, Q = 21,000 cusecs.

C = 1,000, Q = 28,000 cusecs.

C = co-efficient of maximum run off.

A = catchment area in square miles.

Taking 28,000 cusecs as maximum inflow and imposing the appropriate flood hydrograph on the lagoon, would give us by step method the maximum outflow and the corresponding lagoon water level. A high tidal level in the down-stream channel is expected to prevail for two hours preceding and also succeeding the high water slack in the tidal cycle. It is pertinent to point out however that, for high discharges water level in the channel down-stream of the structure is probably governed more by the out flow volume and the depth of flow required to carry the discharge under the prevailing channel shape and slope, rather than by the tidal level as in the worst case tidal level is only 2.05 ft MSL. Assuming an average width of the channel of 700 ft. and the average slope of say 0.5 ft. per mile, the depth of flow required is 3.5 to 4.0 ft. for discharge of the order of 10,000 cusecs. It is for this reason that the discharging capacity of the structure has been calculated for the down-stream water levels of +3.0, +4.0 and +5.0 ft. MSL. The hypothesis can be checked from recorded highest water levels both up-stream and down stream of the structure, when it happened to coincide with high and low tidal levels.

Completed Works

Thondamannaru and Arivalai Barrages and Separation Bund

The construction of the Thondamannaru barrage commenced in 1947 incorporating the final proposals mentioned earlier. The estimated cost of this scheme was Rs. 1,500,000/=. A separation bund between Vadamarachchi lagoon and Upparu lagoon was also constructed

along a saddle between the two lagoons. It was subsequently decided to incorporate th Upparu lagoon into the scheme by the construction of semi circular spill at its outlet a Ariyalai. The estimated cost of this spill and flank bunds, etc. was Rs. 200,000/=. Th Thondamannaru barrage was completed in the year 1953 and the Ariyalai barrage wa completed in the year 1955.

Arumugam's plan

Elephant Pass lagoon scheme

When the works to convert Jaffna peninsula lagoon into fresh water lake was nearing completion, it was recognised that a plentiful supply of rain would be required over the years to leach out the salt encrusted lagoon bed. The leaching action would be naturally slow on account of the limited catchment area draining into the Jaffna peninsula lagoon. Attention was therefore directed towards converting the Elephant Pass lagoon into a fresh water lake and discharging the excess water into Jaffna peninsula lagoon to expedite the process of leaching.

It may be interesting to note that in November 1920, Walter C. Price, the then Public Works Dept. Provincial Engineer, Northern Province observed the rainfall and the corresponding rise and fall of flood levels in the lagoon from hour to hour. He worked out the catchment capacities, yields and discharges and the capabilities of the road and railway bridges for dealing with these discharges. All these he did when he was marooned in the rest-house by torrential rains and floods.

A new fillip was given to this much talked of Elephant Pass lagoon scheme when S. Arumugam published an article in the "Observer" of October 1954. S. Arumugam the then Divisional Irrigation Engineer Northern Division mentioned that Elephant Pass lagoon with a water spread of 30 sq.miles fed by the inflowing Kanagarayan Aru, Nethali Aru, Piramantal Aru and Theravil Aru be the primary reservoir in the scheme. These streams drain from a catchment area of 363 sq. miles. According to Arumugam's study a bund cum spill across the east at Chundikulam and another bund where the railway and motor bridges are, at Elephant Pass would seal the entry of sea water into Elephant pass lagoon, thus transforming it into a fresh water primary reservoir.

From this reservoir, the water would be led by a channel called the Mulliyan channel to Vadamarachchi lagoon which then becomes the secondary reservoir. This is what he suggested for the agricultural upliftment of the peninsula.

A report was prepared by S.J. Bocks, Irrigation Engineer, Hydrology Division and his proposals were:-

a) A semi-elliptical 600 ft. spill whose crest is at 4.0 MSL. This was to be built on the western end of the lagoon in order that the discharge will pass through the then existed 120 ft. long PWD. bridge.

b) Two jetties, each 40 ft. long, connecting the ends of the spill to the north and sough embankments, leading to the 120 ft. road bridge; the crest of the jetties were to be at 5.4 MSL.

c) Two sluices, one at each end of the spills. Each sluice to have 2 gates; each gate to be 4 ft. wide and 6 ft. high. The sill to be at -0.50 MSL.

Further investigations revealed that there is discharge through the sand bar which forms the boundary of the lagoon and the sea at the eastern end.

As Elephant Pass lagoon receives plentiful supply of water from the run-off from the catchment of Kanagarayan Aru, Pulithi Aru, Nethali Aru, and other small streams, proposals were made to seal off the connection to the sea on the east by a bund at Chundikulam and to close the opening of the road and railway bridges on the West at Elephant Pass. It was also decided to incorporate the spillway with the eastern closure bund. The main advantage in this new proposal is that it helped protecting the salt pans west of the railway line from the large volume of flood water, which normally dilute the brine in the salt pans.

Final Proposals of Elephant lagoon

I.	(1)	Catchment area	363 sq.miles.
	(2)	Length of catchment	40 miles.
	(3)	Length of spillway	1,010 ft. consisting of 119 bays of 7' width separated by 18" thick piers. Spill level +3.0 MSL.
	(4)	Top level of piers	+4.5 MSL.
	(5)	Water spread area of lagoon	34 sq.miles at +300 MSL.

II. Maximum Inflow Intensity.

Adopting a coefficient of 1,000 in the Dicken's formula the maximum inflow comes to 92,050 cusecs. With C = 750, ti comes to 69,750 cusecs. Even allowing for the moderation due to absorption, the maximum discharging capacity that may have to be provided at the spill way its large. This is specially so as the Elephant Pass spill has now been bunded.

III. Discharging Capacity of the Structure.

The spill channel is wide and shallow and the outfall is affected by sand bar formation which further restricts the channel capacity to carry discharge.

Water level in	Depth of flow	The spillway discharge under free flow conditions	Remark
+ 4.0	1.0	2,160	C.D. assumed
+ 5.0	2.0	6,310	varying
+ 6.0	3.0	11,980	from
+ 7.0	4.0	19,000	2.6 - 2.9

These figures will get modified depending on the submergence due to water level down-stream which is expected to reduce the discharging capacity further.

Completed work of Elephant Pass lagoon Scheme.

The construction of the Elephant Pass lagoon scheme, commenced in the year 1962, incorporating the final proposals mentioned above. The estimated cost of the scheme was Rs. 2,000000. Due to various difficulties the progress was rather slow, when it was eventually completed, it received two major set backs. It was noted, that salt water was seeping in considerable quantity through the PWD. road into the lagoon. Prevention measures were subsequently taken to seal the seepage. The second set back was the damage

to the Eastern closure bund. Due probably to the settlement of the sub-soil below and bund, the bund had settled and has been overtopped and breached during one of the floods that occurred subsequently.

The hydrology analysis carried subsequently in 1976 showed that the spilling accommodation provided at the eastern end was not sufficient. The empirical formula ($Q - C M^{3/4}$) was not adequate.

CHAPTER 4

INVESTIGATIONS, PROPOSAL, DESIGNS, ECONOMIC ANALYSES ETC. CARRIED OUT IN 1976

GENERAL

After a long lapse of time, the project was revived in the Seventies. In 1976, the completion of the scheme received serious consideration and fresh investigations were carried out by the Irrigation Department resulting in a feasibility report, design, Construction Drawings etc. The Author, then Chief Engineer Irrigation Department was in charge of the project.

However, when the scheme was presented for inclusion in the budget for 1976 the planning committee, perhaps following the path of political expediency, (it was the final year of the SLFP Government) turned the proposal down.

However shortly after UNP Government came to power the scheme was put forward again in 1978, and was accepted by the planning committee and a token vote was passed by Parliament to implement the scheme. However the scheme went into abeyance once again. In both circumstances the net result is the same only the approach is different.

Jaffna peninsula comprises a total area of 400 sq.miles and nearly 40 sq.miles of this extent is covered by two internal lagoons namely the North (Vadamarachchi) and South (Upparu) lagoons. An external lagoon of water spread area of 30 sq.miles called the Elephant Pass lagoon lies between the main land and the peninsula. These lagoons are not inter connected. The first one starting from Periyapachilaipalli as its eastern boundary enters the sea at Thondamannaru. The south lagoon originates from the lower plains of Kapathu Paddy lands, spreads abutting Sarasalai, Madduvil, Kaithadi and Navatkuly on the Left, Puttur, Kopay, Irupalai, and Chiviyatheru on the right and links the sea at Ariyalai in the outskirts of Jaffna Town. The Elephant Pass lagoon is the portion lying between the peninsula and the mainland and enters the sea at Chundikulam on its eastern side and is isolated from the sea on the Western side by Kandy - Jaffna road.

Purpose of the Scheme

The major problems facing Sri Lanka are the increasing foreign exchange requirements and unemployment. As considerable amount of valuable foreign exchange is being spent for the import of food items, stepping up cultivation of rice and subsidiary food crops is a major objective. This will also increase the employment opportunities among the educated youth. The people of this area have been constantly agitating to convert this lagoon to a fresh water lake for domestic purposes, cultivation and to replenish the ground water resource. Due to over-exploitation of the aquifer, most of the wells have become brackish and it is of paramount importance to have a supply source to replenish the wells in order to meet the increased demands.

Proposals for the Scheme

(a) **Elephant Pass Lagoon:** This will be used as a supply source for the internal (North and South) lagoons in addition to improving the conditions along the fringes of this lagoon.

The present proposal is to provide a total spilling accommodation of 7.000 feet length along the eastern closure with an earthen dam for a length of 4,700 ft. The spill has to cater for the run-off from a catchment of 363sq.miles. In addition. the highest flood

level is controlled by the Kandy - Jaffna road, and the inundation of the developed land along the periphery. High-tide levels etc. are also taken into consideration in deciding on the spill length.

(b) **Link canal:** This connects Elephant Pass lagoon with North (Vandamarachchi) lagoon and is 2.5 miles long. The canal already constructed for a length of 2.25 miles is badly damaged and silted, as it runs in sandy material.

The channel section is now re-designed after detail soil investigations and the present proposal is to re-condition the existing channel as per new design, excavate the balance length, provide an inlet regulator cum bridge and provide a roadway along the link canal.

North and East (Vadamarachchi) Lagoon.

This project consists of barrage across the outfall to the sea at Thondamannaru main gate. There are 18 bays of 20 feet wide consisting of lower and upper gates. The gates are 20'0" wide x 4'0" high and made of steel subsidiary gates.

There are 16 No. subsidiary spans.

These are wooden gates 10'0" wide. The sill is at +2.50 MSL. and crest level at +4.00 MSL.

All the perished and decayed gates are to be replaced and the missing and damaged parts of the lifting devices are to be replaced and repaired.

South (Upparu) lagoon

This project consists of barrage which is located across the sea outfall at Ariyalai between 195 and 196 mile post along Kandy - Jaffna road, two culverts 196/2 and 196/3 on Kandy - Jaffna road and a separation bund 2.75 miles isolating the lagoon from Chemmani Salterns and Paddy fields. The barrage consists of a series of controlled bays, flanked on both sides by two clear overfall gravity sections. Controlled bays are 42 in number out of which, 18 are fitted with screw operated wooden gates each 5'6" in width and 5'0" in height. The balance 24 bays are centrally situated and are controlled by planks each of width 5'6" raising to a height of 5'0".

The planked bays are to be replaced by screw operated gates, the missing and damaged parts of the lifting devices to be replace and repaired, and passerelles widened to 2'0" with hand-rails for easy operation of the gates. The culverts are to be provided with screw operated gates.

The separation bund will be improved according to new design determined after investigation of the soils available in the area.

1. Anticipated benefits

(a) To recharge the underground storage thereby benefiting the brackish wells along the fringe of the lagoons. There may be a possibility of suppressing the interface of fresh and salt water below the existing level and thereby increasing the storage potential of ground water.

(b) Reclaiming 11,000 acres of non - arable land by having salt leached out. It was observed during the last inspection that in certain places along the fringe cultivation in being done by providing suitable layer of borrowed earth. This shows the demand for

cultivable land and the perseverance of the people. This may be extended to obtain immediate benefits but the availability of suitable earth for borrowing at convenient distance is limited.

(c) Supplement the 20,000 acres of presently cultivated (rain fed) land along the fringe during periods of drought, during the tail end of the cultivation by pumping from the newly created fresh water storage in the 25,000 acres of the lagoon area.

(d) Cultivation in the lake bed will be possible when the lake full of fresh water, draws down during dry season. The bed may also be used for cattle grazing during dry season.

2. Existing Condition in 1976

(a) Vadamarachchi Lagoon

i) Negligence of maintenance and operation had caused upper gates of the Thondamannaru barrage to perish and the operating system is not functioning. Territorial Civil Engineering Organization (T.C.E.O) has just stared to replace the upper gates by locally manufactured wooden gates.

ii) Almost all hand rails are corroded and certain devices missing.

iii) Coffer dam provided during the construction of the barrage has not been removed and hinders the flow.

Some lands fringing the lagoon in Thunnalai, Karaveddi south, Varani north and Karanavai areas are being cultivated during October - March, season. Shallow wells have been sunk and used for supplementary irrigation. This shows that inspite of the barrages not functioning efficiently, there had been some improvements and benefits though less than anticipated. If the scheme had been properly maintained and operated, the anticipated benefits could have been derived which would have been a great asset to the district.

This lagoon can ben taken up independently or as a complex with the Elephant Pass lagoon. Even without Thondamannaru barrage functioning efficiently and a study of the data collected indicates that there had been a graded change in the quality of the water in the lagoon. This change has enabled the cultivation of small percentage of land along the fringe of the lagoon and further away from the barrage which were not suitable. The work to be done is mainly on the barrage. The TECO is doing some work at present, but it may be necessary to assess the present condition of the barrage, gates etc. in detail in order to frame proposals to bring back this barrage to working condition.

(b) Upparu lagoon

The concrete structure of the barrage is in a fairly good condition but the operating devices of some of the gates have to be repaired or replaced. Only 6 out 18 screw operated gates are in working order and it appears that the planks in the 32 bays are not removed as and when required. During the November 1975 heavy rains, when it was essential that all the gates should have been fully opened and the planks removed, only 6 gates were opened fully and another 5 partially opened and the planks in the other bays were not removed. About 2500 ft. of the bund between Chemmani saltern and the lagoon breached during this season, flooding the saltern and inundating the adjoining fields. Non operation of the gates and planks were mainly due to the failure of the lifting devices and the difficulty in removing the planks. The culvert across Kandy -

Jaffna road near the barrage which was permanently closed with concrete planks w forced open to drain the water in the lagoon.

(c) **Separation Bund**

The bund separating Upparu Lagoon from Vadamarachchi lagoon is in a very ba condition. During the November 1975 heavy rains, the bund was overtopped.

(d) **Chemmani Saltern**

The bund blocking the saltern and the paddy fields from the lagoon was breache during November 1975. The annual production is about 70,000 cwts of salt an providing employment to about 300 people from April to September. The breaching o the 2500 feet of the bund has flooded the saltern and the paddy fields, and the breac has to be closed.

(e) **Elephant Pass Lagoon and Link channel and Access Road**

The eastern closure bund had breached soon after it was constructed due to settlement and overtopping of the bund. It appears that the sub-soil investigation carried out and empirical formula used for hydrology analysis were not adequate.

The link channel connecting the Elephant Pass lagoon and the Vadamarachchi lagoon, th ough constructed has never functioned, and the channel has been damaged and silted up. The channel has to be re-conditioned.

The access road to Eastern closure bund, 6 miles long is now in poor condition and provision should be made in the proposal to improve this road.

3. Investigations Carried out

(a) Upparu Lagoon

1) Details of the existing condition of the gates and lifting devices to replace and repair as required.

2) Details of the planked bays to provide screw operated gates.

3) Details of the culvert between the barrage and Chemmani Saltern to provide screw operated gates.

4) Longitudinal and cross-section of the bund between the lagoon and Chemmani saltern.

5) Longitudinal and cross-section of the separation bund between the Upparu lagoon and Vadamarachchi lagoon.

(b) Vadamarachchi Lagoon

1) Details of the present condition of the barrage including the gates, lifting devices etc.

2) Longitudinal and cross-sections of the coffer dam provided during construction, to ascertain the quantity of material to be removed.

(c) Elephant Pass Lagoon

1) Detail investigations along the eastern closure bund site to ascertain the sub terrain features.

2) Topographical survey of the area - L.S & C.SS, site survey etc.

3) L.S. & C. SS of the 6 miles access road to eastern closure bund.

4) Type of material available at site for the construction of closure bund and spill.

5) If suitable materials are not available at site to locate places where such material can be borrowed.

(d) Link Channel

1) L.S & C.SS of the channel.

2) Type of soil in the channel to re-design the section.

5. CONCLUSION

The people living along the fringe of Vadamarachchi and Upparu lagoons are also of the opinion that if the two barrages function properly the scheme will be a success. They say that they need not and will not wait till the water in the lagoons become absolutely fresh to start cultivation, as certain types of crops with some tolerance for water with low salinity can be cultivated. Also in certain areas along the fringe shallow wells have been sunk recently to irrigate grape vines and the plants are coming up satisfactorily. The water requirement for this plant is not high and they are able to draw out water from shallow wells at such a rate without saline water coming up. In areas where the people have provided a suitable layer of borrowed earth, the extent of high-land crop cultivated under one well is limited in extent to the availability of fresh water.

This indicates that with reasonable improvements of the scheme, the people will make a start with suitable crops, and expand their cultivation activities as conditions improve.

TABLE XII

Existing Condition

Description	Vadamarachchi lagoon (1) North & East	Upparu lagoon (2) South	Elephant Pass lag (3)
Catchment Sq. mls	115	85	
Water spread sq. mls	30	10	
Rainfall Average inch	49.6	49.6	5
Net Yield Ac.ft	56000	41500	91
Tide Levels			
Dec Max	2.68	2.06	Not Known
Min	0.68	0.35	Not Known
May Max	1.25	1.5	Not Known
Min	0.9	0.5	Not Known
Feeder streams			Kanagarayan Aru Neththall Aru Piramanthal Aru Theravil Aru
Bund			Length of Western bund 2M 3740 ft. Eastern bund (Chundikulam) 1M 4700 ft. BTL 7.0 MSL
Link Channel			2,5 miles connecting 1&3
Spill	Thondamanaru 1)18 Nos. 20ft. wide bays. Sill at -3.5 MSL with 2 vertical gates 4 ft. high crest at 4 MSL 2) 16 Nos subsidiary spans each 10 ft wide sill +2.5 MSL crest +4 MSL	Arialai Length 540 ft. Semicircular arc 150ft. radius comprising 18 Nos 5' by $5^1/_2$' lifting gates and 24 Nos 5' by $5^1/_2$' openings controlled by wooden planks Sill -1 MSL Crest +4 MSL	Elephant Pass Length 1010ft comprising 119 bays of 7ft. width sill + 3 MSL crest +4.5 MSL

SUBSOIL INVESTIGATIONS FOR JAFFNA LAGOONS SCHEME

1. **Authority** - Authority was granted by D.I.'s No. WG/13/4 of 1975.12.31 to conduct the above investigations.

2. **Purpose** - The purpose of the investigations is to a study the soil characteristics and recommend:

   i. Suitable side slopes for the link channel,
   ii. Side slopes for the reconstruction of the Chundikulam bund.
   iii. Suitable foundation for the spill at chundikulam

3. **Description of the investigations** - Field investigations conducted consists of :

   i. Hand augering along the axis of the link channel.
   ii. Hand augering along the axis of the Chundikulam bund, and spill
   iii. Hand augering and excavation of test pits in selected borrow areas near Chundikulam bund.

   The laboratory investigations consisted of the following tests on samples obtained from the borrow areas:-

   i. Specific gravity.
   ii. Atterberg limits.
   iii. Mechanical Analysis.
   iv. Proctor compaction.

Recommendations -

The following recommendations are made:

i. The link canal is to have side slopes of 1 on 2.5
ii. The Chundikulam bund to be zoned embankment as shown in the drawing, having an upstream slope of 1 on 3 and down-stream slope of 1 on 2.5.
iii. The proposed spill of 7000 ft. be provided in 2 parts, namely a spill of 3,000 ft. commencing at 20 chains followed by an earthen embankment of 2,000 ft. which is then to be followed by a spill of 4,000 ft.

General:

The location of the borrow areas is indicated in the drawing.

sgd./-I.E.Soils

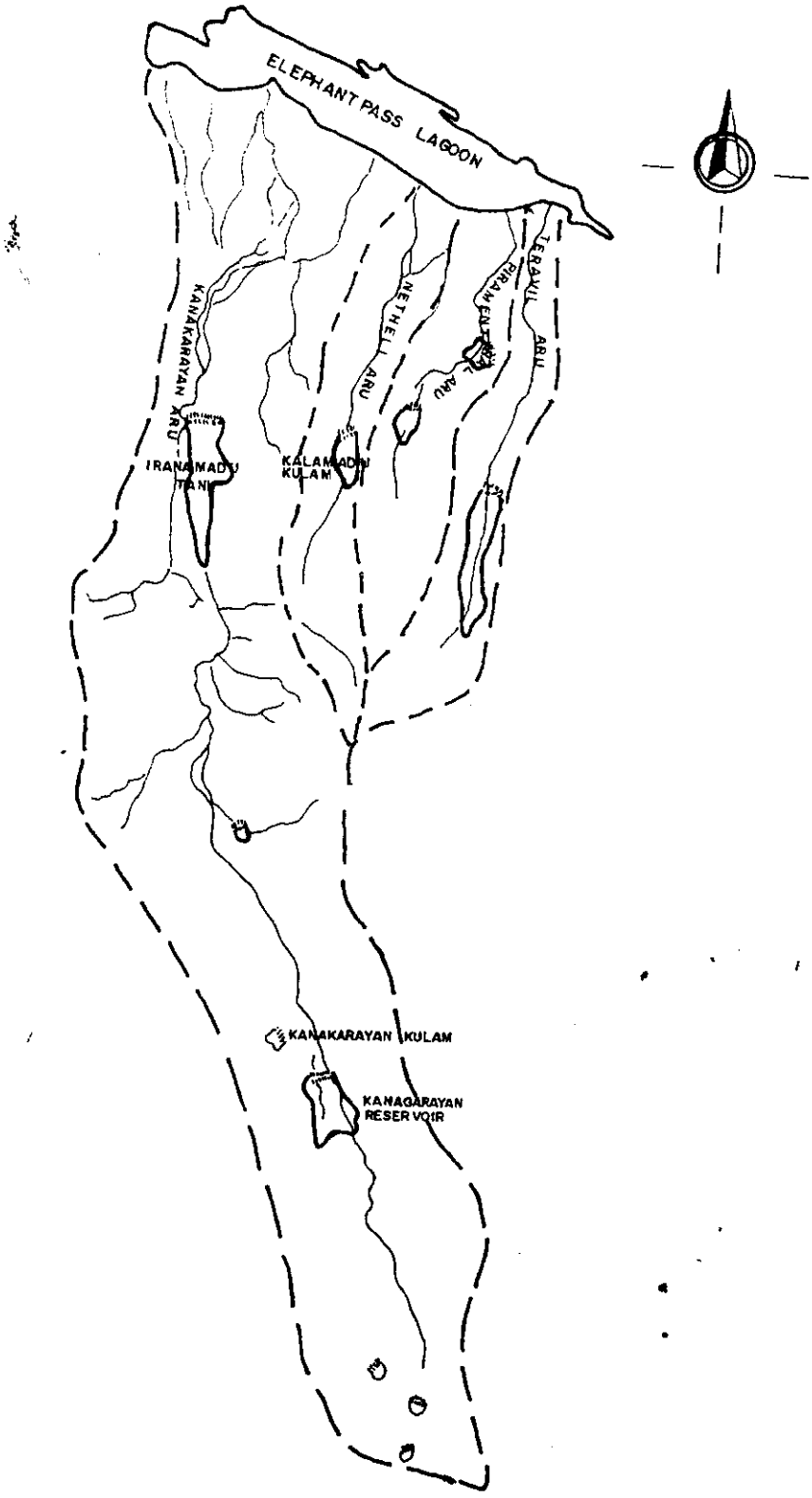
sgd./-D.I.E. (Eng. Materials).

Note: Recommendation (iii) to be amended as follows:-

The proposed spill of 7000 ft. be provided in two parts - a spill of 3500 ft from 14.7 chains to 49.7 chains, an earthen embankment from 49.7 chains to 1M 15.5 chains and the balance spill length of 3500 ft. from 1M 15.5 chains.

FIG. X

CATCHMENT OF ELEPHANTPASS LAGOON



HYDROLOGY AND HYDRAULIC STUDIES AND STRUCTURAL DESIGN OF SPILL CUM CAUSEWAY OF ELEPHANT PASS LAGOON

RUN OFF PROCESS

Phase (1) Rainless period just prior to the beginning of rainfall and after an extended dry period. The ground water is low and its elevation continues to decrease gradually.

Phase (ii) Initial period of rain

Rain starts

(a) Precipitation
(b) Interception by Vegetation
(c) Infiltration into the soil

Gradual increase of water in the zone of aeration after natural storage is satisfied.

(d) Temporary retention in surface depression

Phase (iii) Continuation of rainfall at a variable intensity

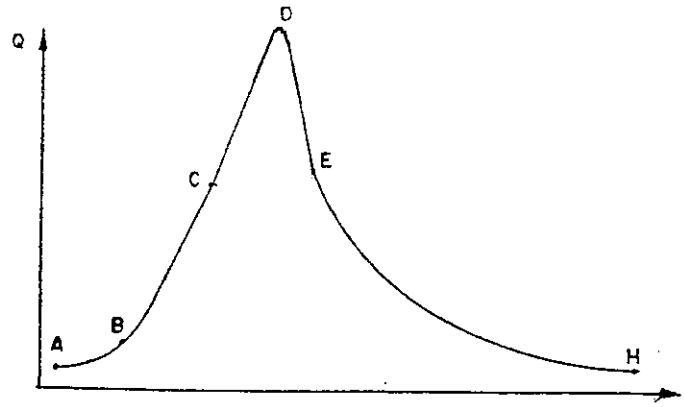
The capacities of vegetable interception and retention of surface of depressions are reached and the excess rain becomes a source of run off and detention storage on land surface and channel. Overflow over land occurs when net rate of rain exceeds the infiltration rate. The infiltrated water will saturate the upper part of the land of aeration. If the rain continues water table will rise and the ground water contribution to the streamflow will increase. As the zone of aeration is saturated, sub surface run off may also contribute to the stream flow. If the storage of flow in the channels rises rapidly and becomes higher than the rising of ground water table, the stream changes from **Effluent stream** to **Influent stream**, contributing to the ground water and developing bank storage water. Due to this storage, evaporation and transpiration are also slow.

Phase (iv) Continuation of rainfall until all natural storage has been satisfied.

The infiltration rate will approach the rate of water transmission through the zone of aeration to both ground water table and sub-surface run off. As the rain continues the water table rises constantly until the ground water run-off balances the rate of recharge possible and all additional rain results in direct increment to run of.

Phase (v) Period between the termination of rain and the time when phase (i) is to be reached evaporation and transpiration are active and infiltration continues. Water in the zone of aeration is reaching water table or the stream level, surface flow and ground water is low.

HYDROGRAPH
A GRAPH SHOWING STORAGE (WATER TABLE), Q, V AND OTHER PROPERTIES OF WATER FLOW WITH RESPECT TO TIME



AB - Approach limb
BD - Rising limb
DH - Recession limb

The lower portion of the DH ie. EH shows the ground water depletion curve which show the decreasing rate of ground water inflow. Peak 'D' occurs at certain time after the rain h stopped and the time depends on the aerial distribution of rainfall. Multiple peaks may occ on a hydrograph. If a hydrograph shows double or treble peaks, fairly regularly the reaso may be due to either non synchronization of the run off contribution from several tributarie to the main stream or kidney like shape of the drainage basin.

DESIGN FLOOD

Maximum flood flow that could be passed without damage or serious threat to the stability o the engineering structure. It is the peak discharge adopted for the design of a particula project or any of its structure.

METHOD OF ESTIMATION OF DESIGN FLOOD

i) Application of safety factors to the observed maximum historical flood.
ii) Emperical flood formulae.
iii) Enveloping curves.
iv) Flood frequency analysis.
v) Rational method involving unit hydrograph, hydrometerological studies.
vi) Regression analysis.

HYDROLOGY AND HYDRAULIC STUDIES

(a) Elephant Pass Lagoon

Under this studies it is proposed to study the provision of a spill cum causeway for EPL and to check the adequacy of the existing barrage at Thondamannaru. The main feeder stream to the lagoon, Kanagarayan Aru has its origin in Vavuniya. The other streams draining into this lagoon are Pulthai Aru, Nethali Aru, Piramanthal Aru and Theruvil Aru. Puluthai Aru drains downstream of the spill cum causeway alignment.

Catchment Area	= 363 sq.miles.
Spreaded Area	= 30 sq.miles. at 2.0 MSL.
Average rainfall	= 55.5 inches

Net yield

Basin	Runoff	Detention	Capacity of Reservoir
Theruvil	23,550	6,500	
Piramanthal Aru	21,190	21,190	11,000
Nethali Aru	25,910	9,150	
Kanagarayan Aru	**196,070**	**196,070**	106,000
	266,720	232,910	
	232,910		
Yield	33,810		33,810
15% Drainage of detention			34,937
25% of gross yield in lagoon (30 sq.miles) 1/4 x 30 x 640 x 55/12			**22,000**
			90,747
			say **91,000 Ac.ft.**

(b) **Vadamarachchi Lagoon (North and East Lagoon)**

Catchment Area = 115 sq.miles.
Spreaded Area = 30 sq.miles.
Average rainfall = 49.6 inches.
N. E. Monsoon rainfall = 45.0 inches.

Net Yield

(a) 25% of gross yield
= 1/4 x 115 x 640 x 45/12 = 69,000 Ac.ft.

(b) Using the specific yield factor of 489 ac. ft. per sq.mile
Net yield = 115 x 489 = 56,000 Ac.ft.

(c) **Upparu Lagoon (South Lagoon)**

Catchment Area = 85 sq.miles
Spreaded Area = 10 sq.miles.
Average rainfall = 49.6 inches.
N.E. Monsoon rainfall = 45.0 inches.

Net yield

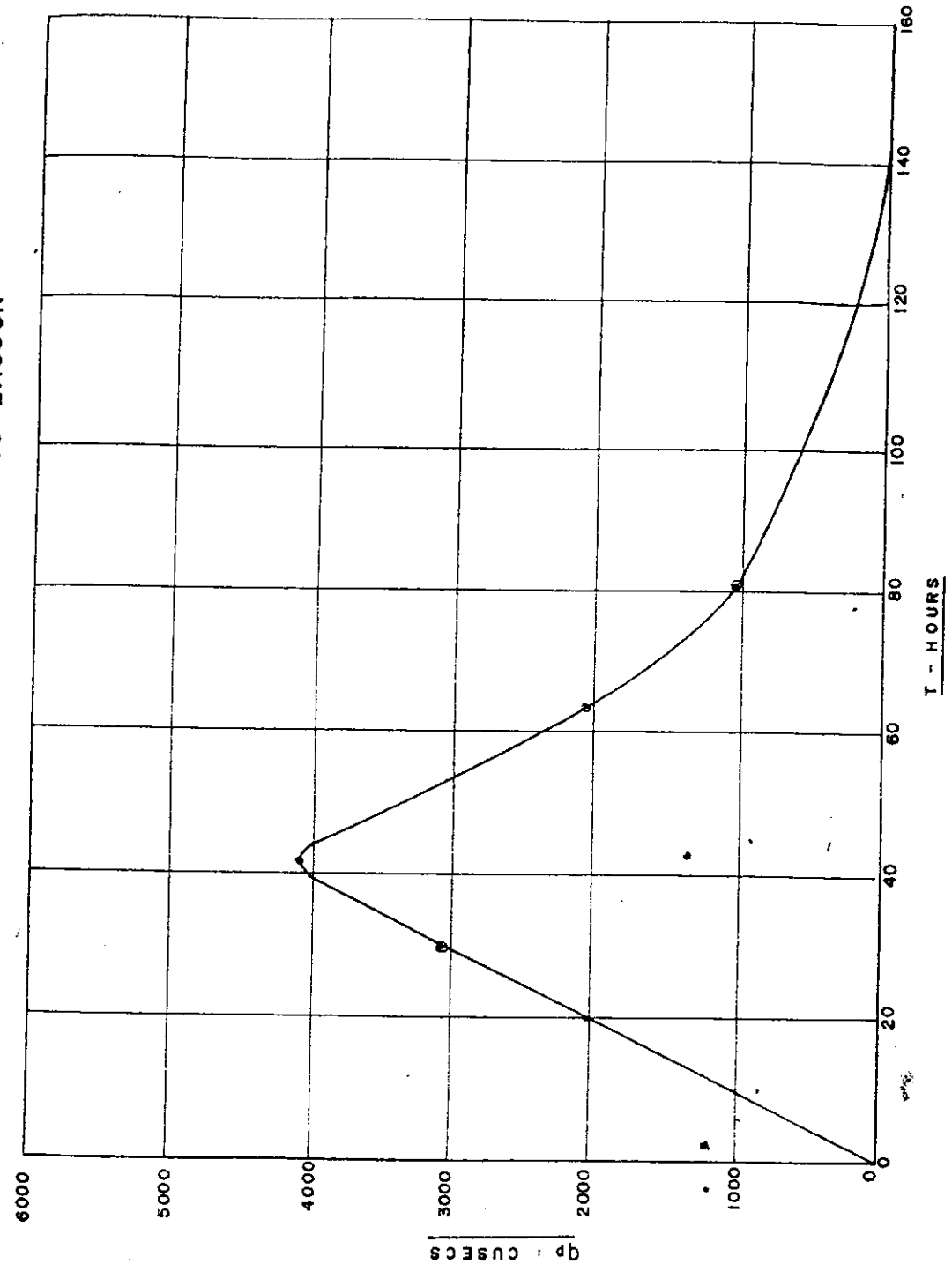
(a) 25% of gross yield
= 1/4 x 85 x 640 x 45/12 = 51,000 Ac.ft.

(b) Using the specific yield factor of 489 ac.ft. per sq.mile
Net yield = 85 x 489 = 41.500 Ac. ft.

DERIVATION OF UNIT HYDROGRAPH BY SNYDER'S TECHNIQUE
ELEPHANT PASS LAGOON

Catchment Area - A.	=	363 sq.miles
Length of longest water course from point of interest to water shed divide in miles (L)	=	56 miles
Length of water course from point of interest to centroid of the catchment (Lc)	=	21 miles

FIG. XI


UNIT HYDROGRAPH - ELEPHANT PASS LAGOON
qp : cusecs
6000
5000
4000
3000
2000
1000
0
0
20
40
60
80
100
120
140
160
T - HOURS

C_p and C_t values

The catchment resembles the adjacent Malwatha Oya catchment-Kapachchi

For Kapachchi $C_t = 4.42$ and $C_p = 0.87$

Considering the flatness of the land in Kanagarayan Aru Basin, consider slightly hi value for Ct(5.0) and slightly lower value for Cp(0.75)

$t_p = C_t (LXL_c)^{0.3} = 5.0 (56 \times 21)^{0.3} = 41.69$ say 42 hrs.

Unit duration of rainfall excess = $t_p/5.5 = 7.6$ hrs.

$$q_p = \frac{640 \times A \times C_p}{t_p} = \frac{640 \times 363 \times 0.75}{42} = 4149 \text{ cusecs}$$

say 4100 cusecs

$T = B + C (t_p/24) = 0.77 + 2.92 (42/24) = 5.88$ days $= 141$ hrs.

$W_{25} = A_{25}(q_p/A)^{-1} = 850 (4149/363)^{-1} = 74$ hrs.

$W_{50} = A_{50}(q_p/A)^{-1} = 500 (4149/363)^{-1} = 44$ hrs.

$W_{75} = A_{75} (q_p/A)^{-1} = 270 (4149/363)^{-1} = 24$ hrs.

TABLE XIII

100 YEAR DESIGN STORM PATTERN OF ELEPHANT PASS LAGOO

MEAN OF KKS AND VAVUNIA

Hours	6	12	18	2
Depth in ins. - average of KKS & Vavunia	9.40	12.40	14.40	16.
Incremental depth in ins.	9.40	3.00	2.00	1.
Areal distribution (factor 0.827)	7.77	2.40	1.65	1.
Loss 0.05 ins/hr	7.47	2.11	1.35	1.
Storm pattern (re arranged)	2.11	7.47	1.35	1.

ORDINATE FROM UNIT HYDROGRAPH

Hrs	Cusecs	Hrs	Cusecs	Hrs	Cusecs	Hrs	Cuse
0	0	36	3600	72	1420	108	480
6	700	42	4149	78	1180	114	370
12	1300	48	3600	84	950	120	270
18	1800	54	3050	90	820	126	200
24	2400	60	2400	96	700	132	110
30	3050	66	1800	102	580	138	10

TABLE XIV

100 Year Flood Hydrograph for Elephant Pass Lagoon - Computation

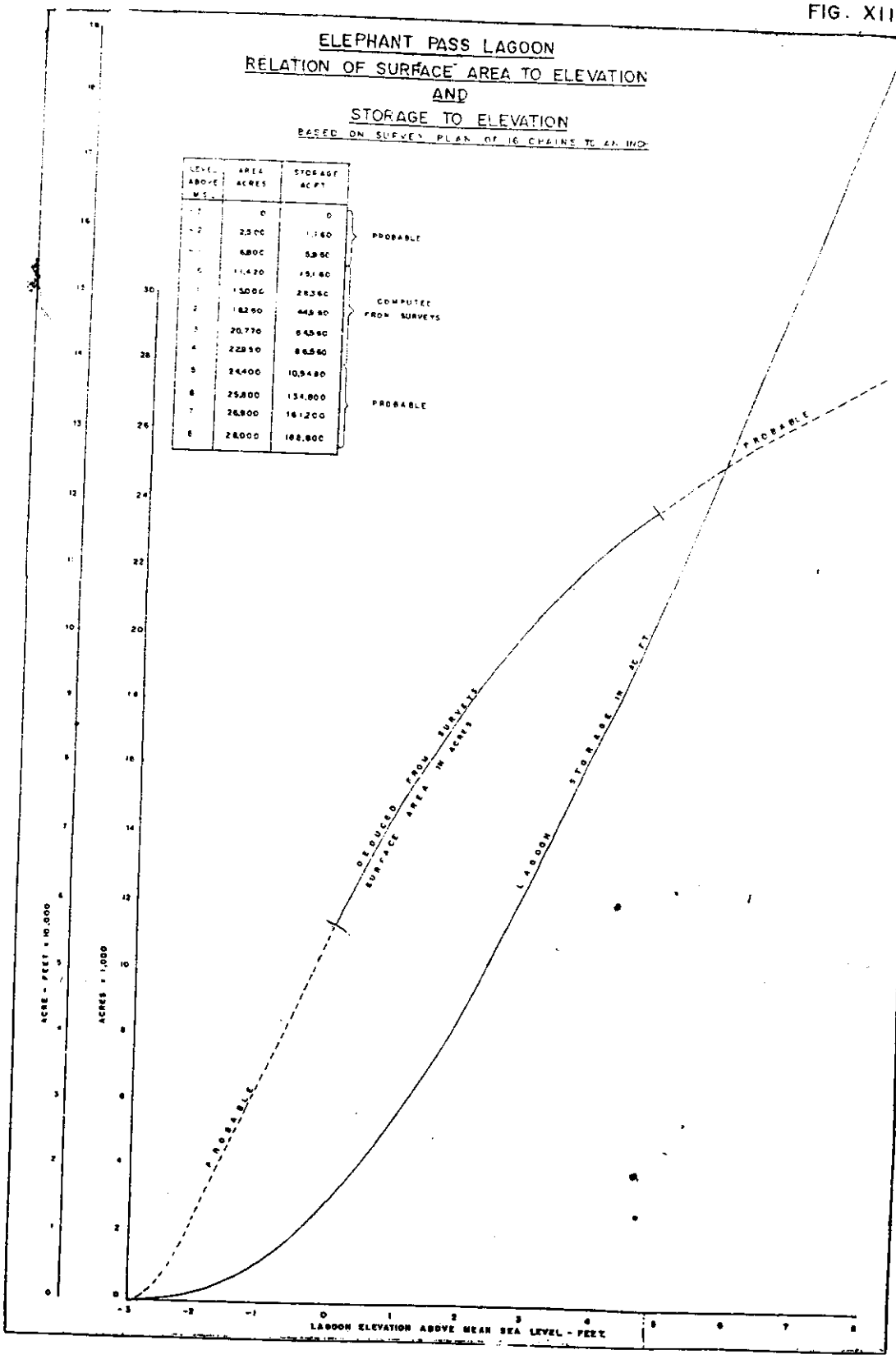
Hrs		6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126	132	139	
Time	S.P.																								
Hrs		700	1300	1800	2400	3050	3600	4100	3600	3050	2400	1800	1420	1180	950	820	700	580	480	370	270	200	120	60	Total
0	0	0																							0
6	2.11	1477	0																						1477
12	7.47	5229	2743	0																					7972
18	1.35	945	9711	3798	0																				14454
24	1.1	770	1755	13446	5064	0																			21035
30			1430	2430	17928	6435	0																		28223
36				1980	3240	22783	7596	0																	35599
42					2640	4117	26892	8651	0																42300
48						3355	4860	30627	7596	0															46438
54							3960	5535	26892	6435	0														42822
60								4510	4860	22783	5064	0													37217
66									3960	4117	17928	3798	0												29803
72										3355	3240	13446	2996	0											23037
78											2640	2430	10607	2489	0										18166
84												1980	1917	8814	2004	0									14715
90													1562	1593	7096	1730	0								11981
96														1298	1282	6125	1477	0							10182
102															1045	1107	5227	1223	0						8602
108																902	945	4332	1012	0					7191
114																	770	783	3585	780	0				5918
120																		638	648	2764	570	0			4620
126																			528	500	2016	422	0		3466
132																				407	364	1494	253	0	2518
138																					297	270	896	127	1590
144																						220	162	448	830
148																							132	81	213
																								66	66

FIG. XII

ELEPHANT PASS LAGOON
RELATION OF SURFACE AREA TO ELEVATION
AND
STORAGE TO ELEVATION

BASED ON SURVEY PLAN OF 16 CHAINS TO AN INCH

LEVEL ABOVE M.S.	AREA ACRES	STORAGE AC.FT.	
-3	0	0	
-2	2,500	1,160	PROBABLE
-1	6,800	5,960	
0	11,420	15,160	
1	15,000	28,360	COMPUTED FROM SURVEYS
2	18,260	44,980	
3	20,770	64,560	
4	22,950	86,560	
5	24,400	109,480	
6	25,800	134,800	PROBABLE
7	26,800	161,200	
8	28,000	188,800	



ELEPHANT PASS LAGOON - STORAGE OUTFLOW RELATIONSHIP

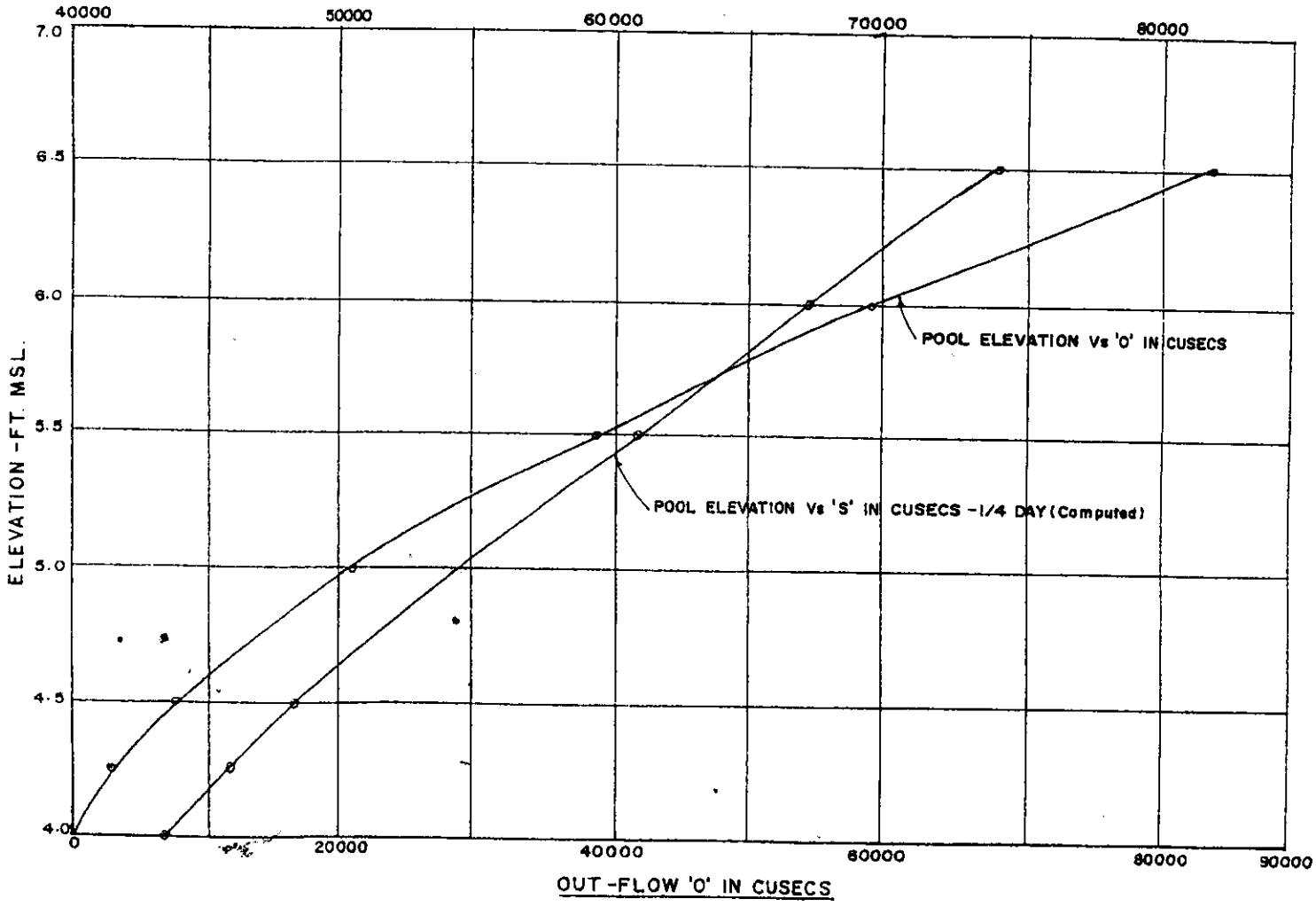


FIG. XIII

FIG. XIV

ELEPHANT PASS LAGOON

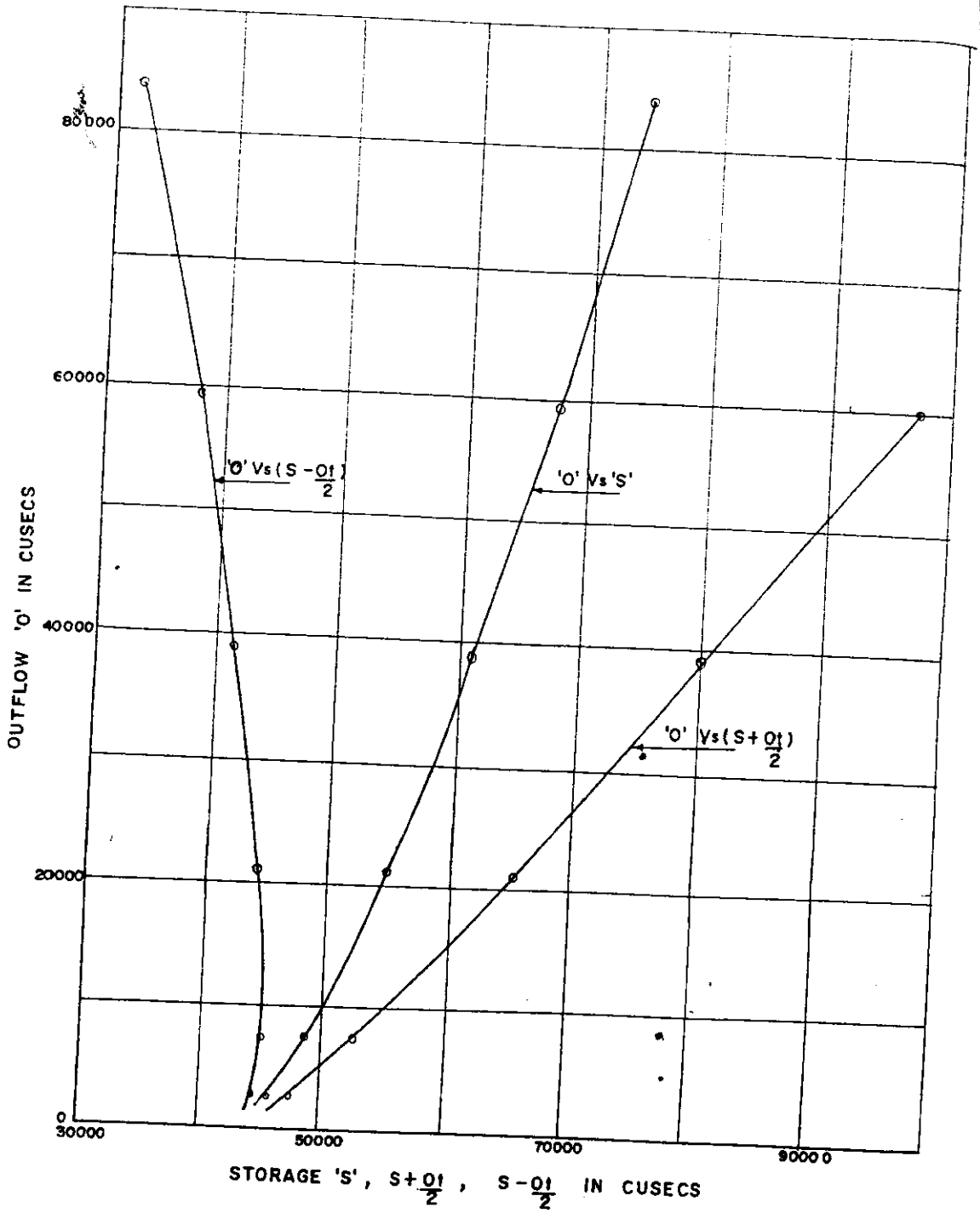


TABLE XV

ELEVATION STORAGE - (vide Fig XII)

Elevation M.S.L	Storage (S)	
	Ac.ft.	Cusecs 1/4 day
0	15160	7580
1	28360	14180
2	44960	22480
3	64560	32280
4	86560	43280
4.25	91500	45750
4.5	97500	48750
5	109480	54740
5.5	121500	60750
6	134800	67400
6.5	148000	74000

TABLE XVI

TABULATION FOR DRAWING S, S+Ot/2, S-Ot/2 CURVES FOR ROUTING THROUGH THE RESERVOIR

Pool Elev: (ft.)	Outflow O cusecs	Storage S		Computation for I.S.D method (t = 6 hr.= 1/4 day)		
		Ac.ft.	Cusecs 1/4 day	Ot/2 Cusec -1/4 day	S+Ot/e Cusecs -1/4 day	S-Ot/2 Cusecs -1/4 day
4.00 FSL	-	86560	43280	-		
4.25	2625	91500	45750	1313	47063	44437
4.5	7456	97450	48750	3728	52478	45022
5.0	21000	109480	54740	10500	65240	44240
5.5	38640	121500	60750	19320	80070	41430
6.0	59230	134800	67400	29615	97015	37785
6.5	84000	148000	74000	42000	116000	32000

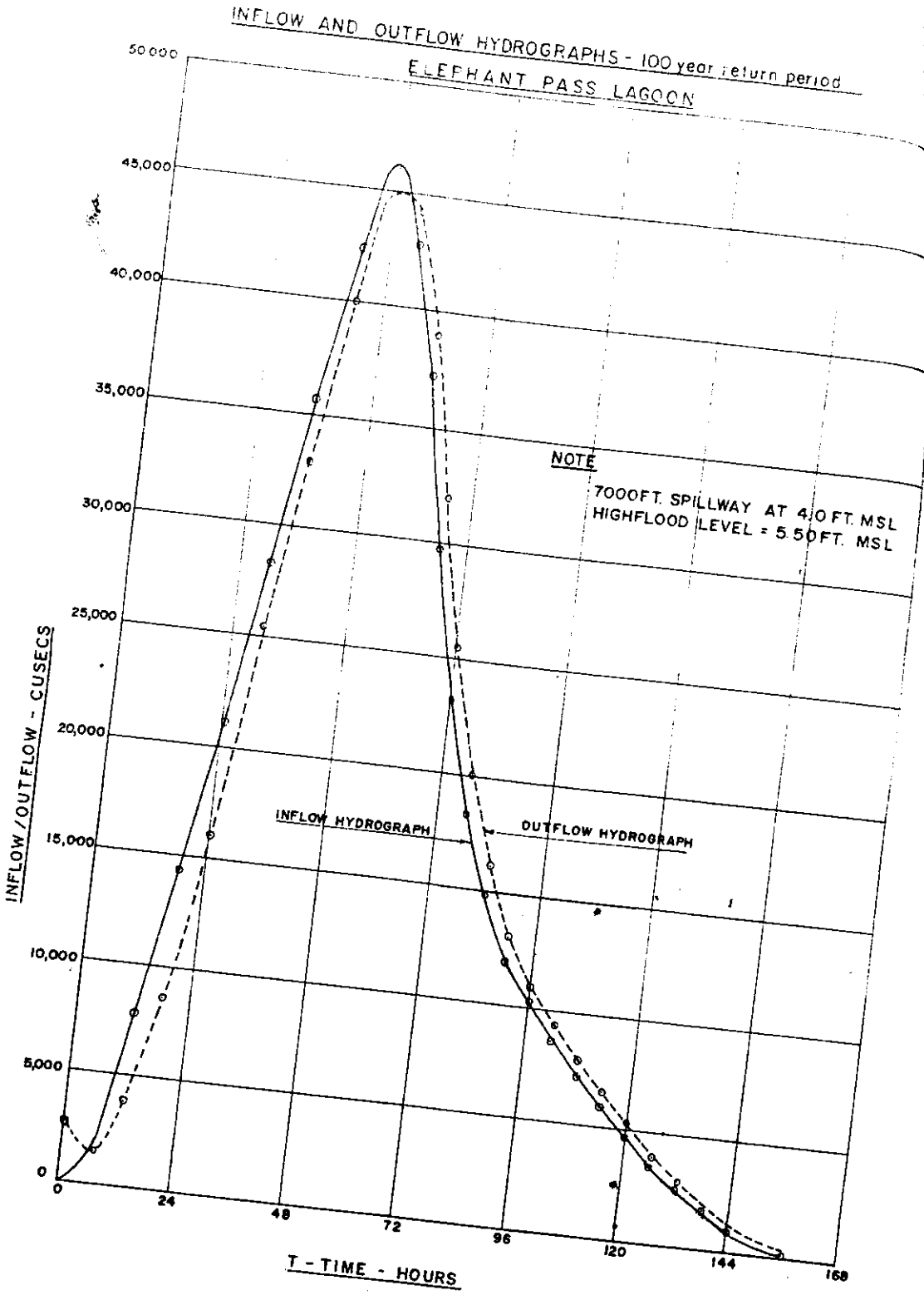
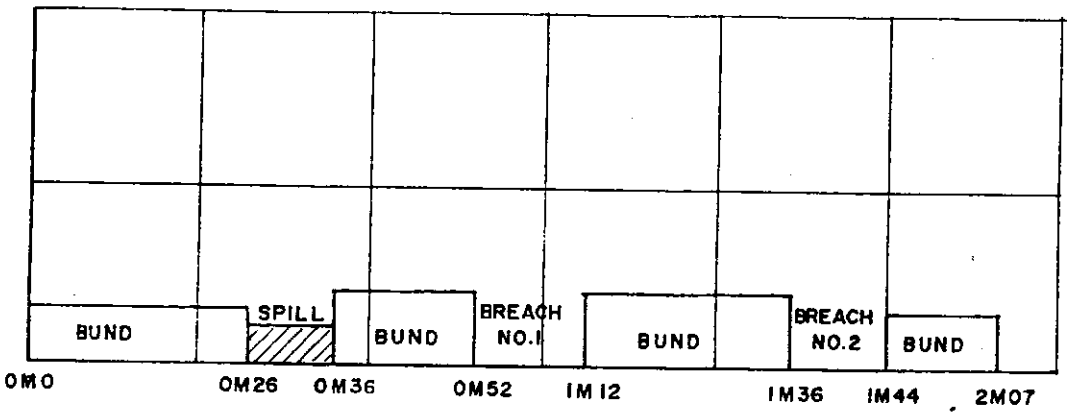

INFLOW AND OUTFLOW HYDROGRAPHS - 100 year return period
ELEPHANT PASS LAGOON
50000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
INFLOW/OUTFLOW - CUSECS
NOTE
700FT. SPILLWAY AT 4.0 FT. MSL
HIGHFLOOD LEVEL = 5.50FT. MSL
INFLOW HYDROGRAPH
OUTFLOW HYDROGRAPH
0
24
48
72
96
120
144
168
T - TIME - HOURS

FIG. XVI

L.SS. OF EXISTING & PROPOSED SPILL AND BUND AT EASTERN END ELEPHANT PASS LAGOON

EXISTING



PROPOSED

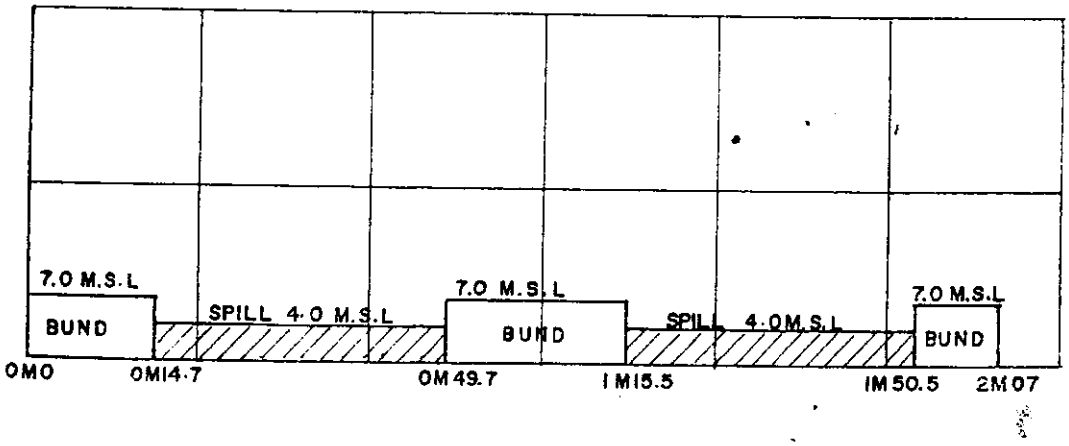


TABLE XVII

RESERVOIR ROUTING I.S.D. METHOD
E.P. LAGOON

Time hrs	Inflow I (cusecs)	(1+I2)xt (cusecs -1/4 day)	Outflow (cusecs) '0'	(S-Ot)/2 (cusecs -1/4 day)	(S+Ot)/2 (cusecs -1/4)	Pool elev. (ft.) M
0	0		2625			4.25
6	1477	739	1100	44437	45176	4.10
12	7970	4723	3800	44100	48823	4.31
18	10454	9212	8600	44700	53912	4.52
24	20985	15720	16000	45000	60720	4.65
30	28223	24604	25500	44500	69104	4.81
36	35599	31911	33000	43500	81249	4.92
42	42300	38949	40000	42300	81249	5.50
48	46438	44396	45000	41000	85369	5.57
54	42822	44630	44200	40200	84830	5.55
60	37217	40018	39000	40300	80318	5.49
66	29803	33510	32000	41200	74710	4.90
72	23037	26420	25500	41200	74710	4.81
78	18166	20601	20000	43600	64201	4.73
84	14715	16441	16000	44300	60741	4.65
90	11981	13348	13000	44500	57848	4.60
96	10182	11081	10700	44700	55781	4.55
102	8602	9392	92000	44900	54292	4.45
108	7191	7897	7800	45000	52897	4.51
114	5918	6555	6500	45000	51555	4.54
120	4620	5269	5100	44900	50169	4.38
126	3466	4043	3800	44700	48743	4.31
132	2518	2992	2800	44600	47592	4.26

SPILL LENGTH AND AFFLUX

Outflow (Q) - 45,000 cusecs.

The outlet at the eastern end (Chundikulam) can accommodate a clear overfall spill of 7000 ft. based on topographic and sub soil investigations.

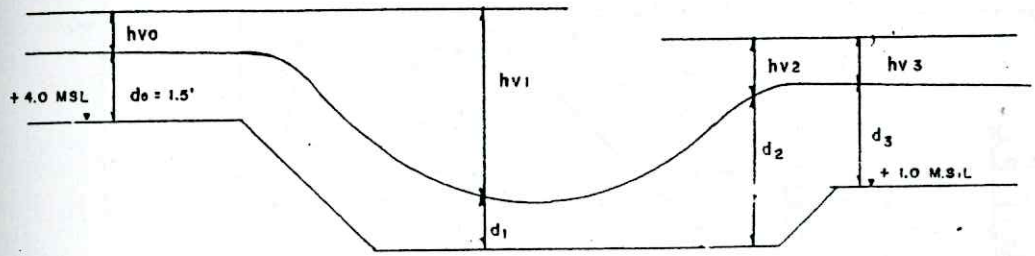
Hence adopting a spill length (L) of 7000 ft, High Flood Level (H.F.L.) derived from Inflow Storage Discharge (I.S.D) Method is 5.57 ft. MSL.

The proposals are:

Full Supply Level (F.S.L)	= 4.00 ft. MSL
Length of spill cum causeway	= 7000 ft.
High Flood Level	= 5.50 ft. MSL
Bund Top Level (B.T.L)	= 8.00 ft. MSL

HYDRAULIC DESIGN OF SPILL CUM CAUSEWAY

Stilling Basin Design



Ref; USBR Publication-Canal and Related Structures.

$q = 3.3 \times H^{1.5} = 3.3 \times 1.5^{1.5} = 6.04$ cusecs

$v_0 = 6.06/1.5 = 4.04$ ft/sec.

$h_{vo} = (4.04)^2/2x32.2 = 0.253$ ft.

$d_0 = 1.5$

$d_0 + h_{vO} = 1.5 + 0.253 = 1.753$ ft.

$d_c = \sqrt[3]{q^2/g} = 1.04$ ft.

$d_3 = 1.5$ ft. and $h_{v3} = 0.253$ ft.

$d_3 + h_{v3} = 1.5 + 0.253 = 1.753$ ft.

F = 3.0 ft. and $F/d_C = 3.0/1.04 = 2.88$ ft.

From the Table;
F/d = 2.88, corresponding values of d_2/d_1 and d_1/d_C are:
7.74 and 0.309

PROPOSED SPILL CUM CAUSEWAY E.P.L.

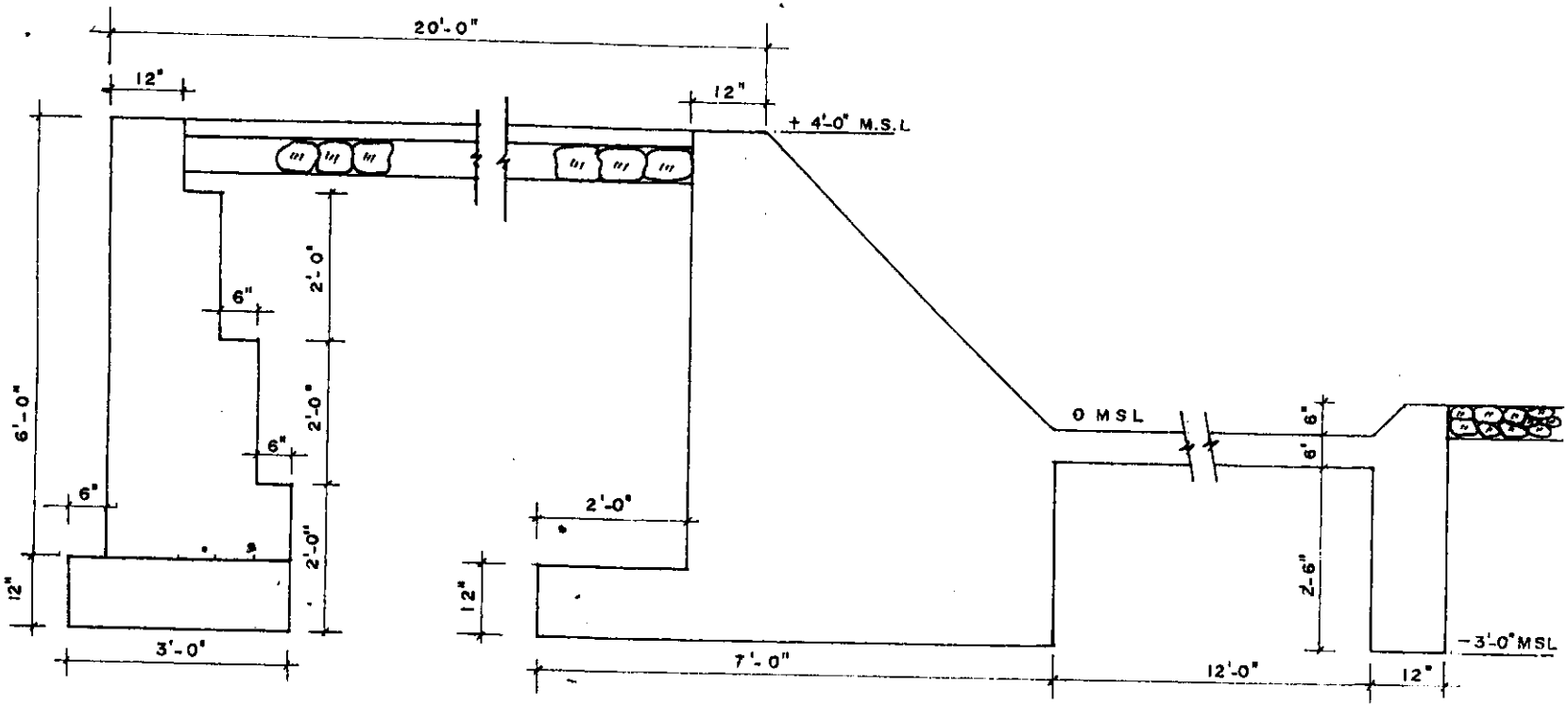
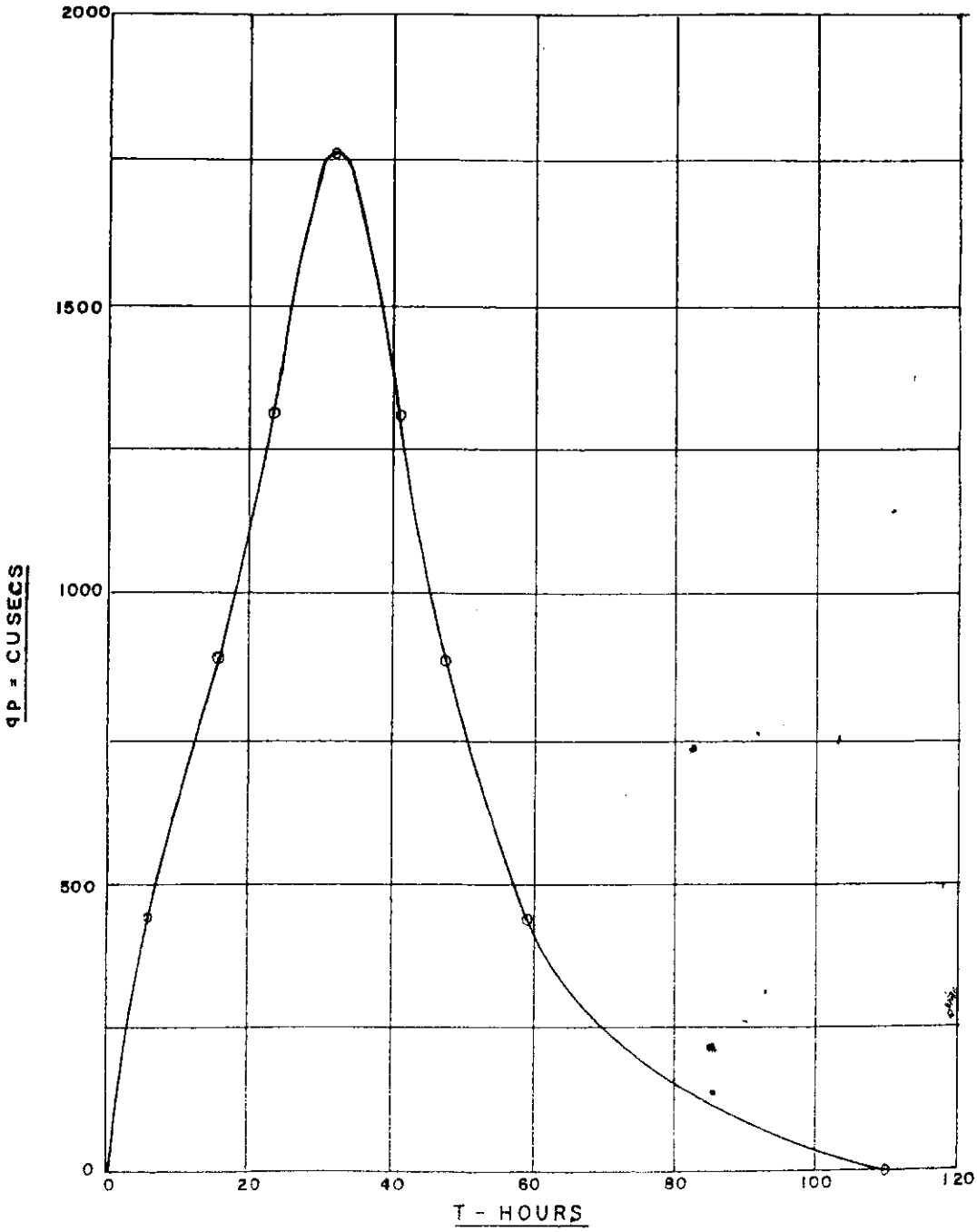


FIG. X VII

FIG. XVIII

UNIT HYDROGRAPH - VADAMARACHCHI LAGOON



$\therefore d_1 = 0.304$ ft. & $d_2 = 2.40$ ft.

$L = 4 \times d_2 = 9.6$ ft. - Assume L as 12 ft.

VADAMARACHCHI LAGOON

DERIVATION OF UNIT HYDROGRAPH BY SNYDER'S TECHNIQUE

Catchment Area (A)	= 115 sq.miles.
Spread Area	= 30 sq.miles.
(L)	= 31 miles.
(L_c)	= 14.8 miles.
Tide levels	= +2.68 MSL (maximum) and +0.65 MSL (minimum)

$C^t = 5$ and $C_p = 0.75$

$t_p = Ct(LxL_c)^{0.3} = 5(31 \times 14.8)^{0.3} = 31.4$ hrs.

$q_p = 640AC_p/t_p = 640 \times 115 \times 0.75/31.4 = 1750$ cusecs.

$T = B + C\,(t_p/24) = .77 + 2.92\,(31.4/24) = 0.77 + 3.82 = 4.59$ days
$= 110$ hrs.

$W_{25} = 850(1758/115) = 55.6$ hrs.

$W_{50} = 500(1758/115) = 32.7$ hrs.

$W_{75} = 270(1758/115) = 17.7$ hrs.

Unit duration of rainfall excess = $t_p/5.5 = 31.4/5.5 = 5.71$ hrs.

say = 6 hrs.

TABLE XVIII
100 YEAR STORM PATTERN OF KKS

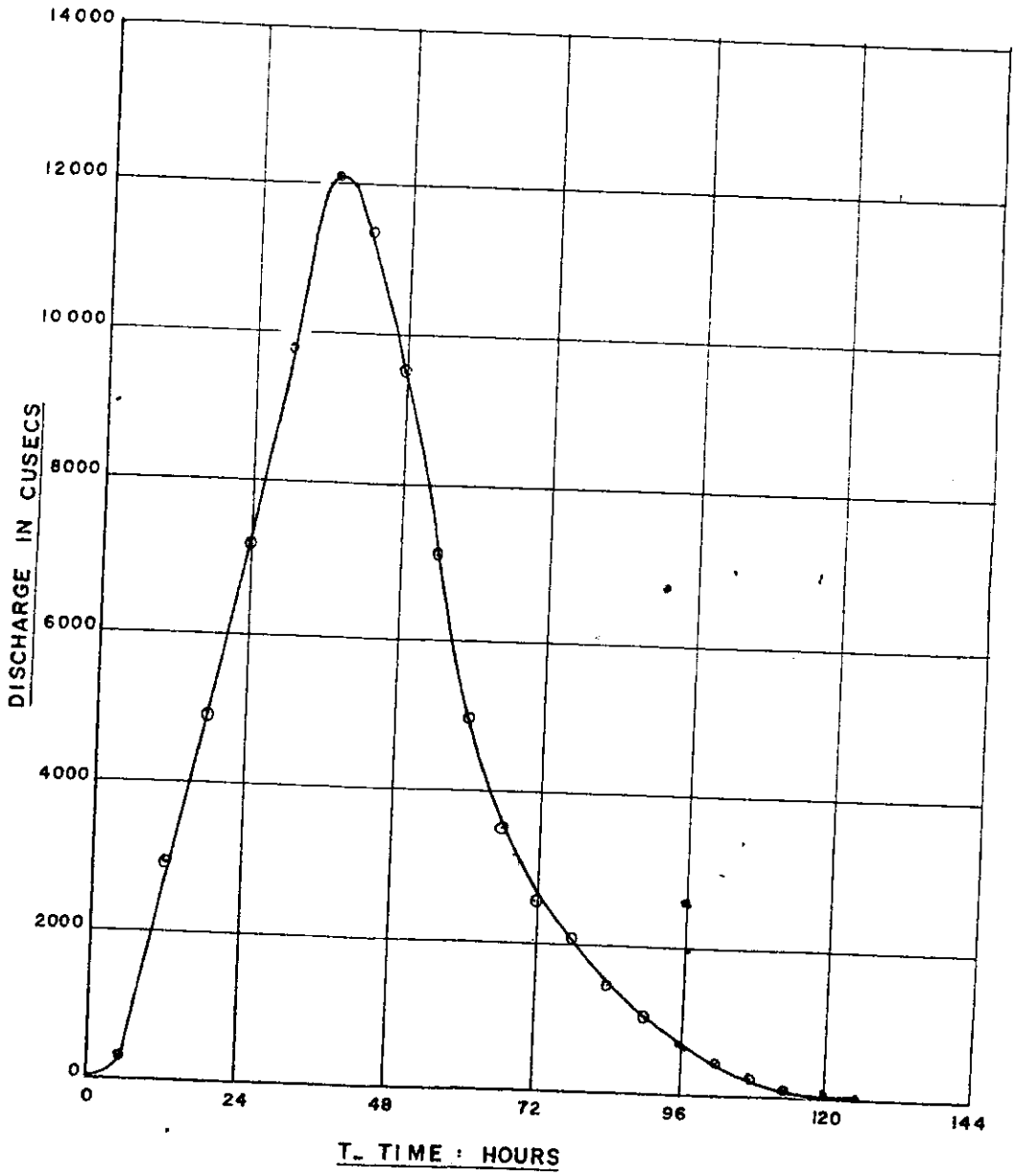
Hours	6	12	18	24
Depth in ins.	6.70	7.80	8.80	10.20
Incremental depth in ins	6.70	1.10	1.00	1.40
Areal distribution (factor 0.853)	5.72	0.93	0.85	1.19
Loss 0.05 ins./hr	5.42	0.63	0.55	0.89
Storm pattern (re arranged)	0.63	5.42	0.55	0.89

Table XIX
100 Year Hydrograph for Vadamarachchi Lagoon - Computation

Hrs Time Hrs	S.P	6 450	12 725	18 1025	24 1375	30 1750	36 1575	42 1225	48 875	54 600	60 420	66 300	72 270	78 175	84 120	90 80	96 50	102 25	108 10	Total	T Hrs
0	0	0																		0	0
6	0.63	284	0																	284	6
12	5.42	2439	457	0																2896	12
18	0.55	248	3930	646	0															4824	18
24	0.8	360	399	5555	866	0														7180	24
30			580	564	7491	1102	0													9737	30
36				820	756	9485	992	0												12053	36
42					1100	963	8537	772	0											11372	42
48						1400	866	6639	551	0										9456	48
54							1260	674	4743	378	0									7055	54
60								980	481	3252	264	0								4977	60
66									700	330	2276	189	0							3495	66
72										480	231	1626	170	0						2507	72
78											336	165	1463	110	0					2074	78
84												240	149	949	76	0				1414	84
90													216	96	650	50	0			1012	90
96														140	66	434	32	0		672	96
102															96	44	271	16	0	427	102
108																64	28	136	6	234	108
114																	40	14	54	108	114
120																		20	6	26	120
126																			8	8	126

FIG. XIX

100 YEAR FLOOD HYDROGRAPH - VADAMARACHCHI LAGOON

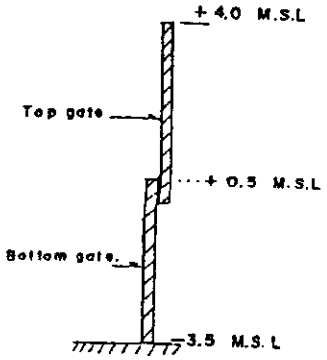


ORDINATE FROM UNIT HYDROGRAPH

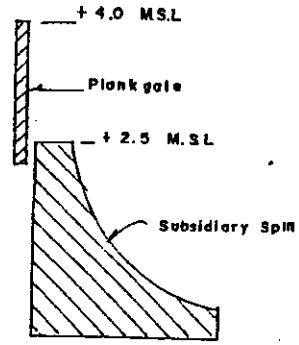
Hrs	Cusecs	Hrs	Cusecs	Hrs	Cusecs
0	0	36	1575	72	270
6	450	42	1225	78	175
12	725	48	875	84	120
18	1025	54	600	90	80
24	1375	60	420	96	50
30	1750	66	300	102	25

VADAMARACHCHI LAGOON

THONDAMANNARU BARRAGE
EXISTING STRUCTURAL DETAILS FOR FLOOD DISCHARGE

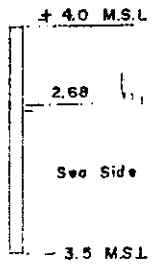


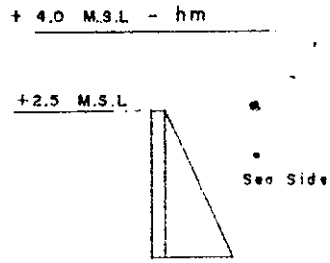
18 No / 20 ft. Span gates
Clear length = 360 ft



16 No / 10 ft Span gates
Clear Spill length = 160 ft.

WORST FLOW CONDITION ARISE WHEN THE TIDE LEVEL IS MAXIMUM

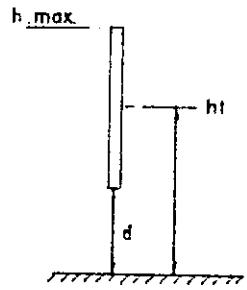




$q_2 = 3.0 (h_m - h_s)^{3/2}$

Theory

CASE (1)



When $d < h_t$

$V = \sqrt{2g(h_m - h_t)}$

Therefore $q_1 = (c_d)d\sqrt{2g(h_m - h_t)}$

Assume $c_d = 0.6$

$q_1 = 4.8 \times d\sqrt{h_m - h_t)}$

CASE (2)

When $d > h_t$

$q = q_1 + 3.0 (h_{max.} - h_t)^{1.5}$

1/3 maximum opening

$d = 7.5/3 = 2.5$ ft.

Therefore $q_1 = 4.8 \times 2.5\sqrt{4.0 - 2.68}$

$= 4.8 \times 2.5 \times 1.15$

$= 13.8$ cusec/ft.

2/3 maximum opening

$d = 5.0$ ft.

$q_1 = 27.6$ cusec/ft.

$q_2 = 3.0(1.32)^{.67}$

$= 3.0(1.21)$

$= 3.63$ cusec/ft.

$q = 31.32$ cusec/ft.

Full opening

$q = q_1 + q_2$

$= 4.8 \times 6.18 \times 1.15 + 3.0 (1.32)^{.67}$

$= 34.1 + 3.63 = 37.73$ cusec/ft.

Discharge through subsidiary gates = $Q_{ss} = 3.63 \times 160 = 580$ cusecs

Opening restricted to +1.5 MSL - (At present 4 bays are closed)

$q = 4.8 \times 2.18 \times 1.15 + 3.0 (1.32)^{.67}$

$= 12.0 + 3.63 = 15.63$ cusecs.

Case (a) - with subsidiary span gates not open

Case (b) - with subsidiary span gates open

Q_{280} = discharge through 14 No./20 ft. span, double gate opening sill -3.5 MSL

Q_{80} = discharge through 4 No./20 ft. span, single gate opening sill +0.5 MSL

Q_{160} = discharge through 16 No./10 ft. span, subsidiary span sill + 2.5 MSL

TABLE XX

Discharge through Thondamannaru Barrage For Various Openings

Opening	Case	Q_{280}	Q_{80}	Q_{160}	Total
1/3 full opening of main gates	(a)	4100	1250	0	5350
	(b)	4100	1250	580	5930
2/3 full opening of main gates	(a)	8950	1250	0	10200
	(b)	8950	1250	580	10780
Full opening of main gates	(a)	10600	1250	0	11850
	(b)	10600	1250	580	12430

Result

Existing structure details of Thondamannaru barrage:
14 No. of 20 ft. span, double gate opening, sill at -3.5 MSL
4 No. of 20 ft. span, single gate opening, sill at +0.5 MSL
16 No. of 10 ft. span, subsidiary gates, sill at +2.5 MSL

14 No./20 ft. span (q_1) flow through the gates fully opened = 10600 cusecs.
04 No./20 ft. span (q_2) flow through the gates fully opened = 1250 cusecs.
16 No./10ft/ span (q_3) flow through the gates fully opened = 580 cusecs.,
Total = 12430 cusecs.

The reduction in discharge by closing one span by concreting is:
(37.73 - 15.63) x 20 = 442 cusecs.

Peak outflow 12,053 cusecs.

Hence one more span can ben closed. But it is recommended not to close it as additional safety.

Evaporation

Rate of evaporation is comparatively high in the Peninsula. Evaporation pans to be installed at suitable locations of internal and Elephant Pass Lagoons and observations recorded to assess the rate of evaporation.

Floods and Droughts:

The peninsula has experienced the worst drought in 1918, when only 2.3 inches of rai over the 7 months period March to September. The lowest rainfall so far recorded fo last 95 years was in 1964, when there was only 24.6 inches of precipitation, whereas average is about 46 inches.
The details of maximum one day is given below.

TABLE XXI

Station	Year/date	Precipitation (inches)
Jaffna	18.11.1918	20.48
Chavakachcheri	15.11.1939	21.17
Pallai	20.12.1903	18.00

The records of floods experienced are inadequate to make a comprehensive flood study. T design hydrograph has been obtained from the Unit Hydrograph. The Unit Hydrograph been drawn synthetically, assigning appropriate values to the "Snyder's Constants", as gi in a paper by the Hydrology Division of the Irrigation Department.

The storm pattern for a 100 year storm is obtained by using the precipitation data of r gauge station - Vavuniya and Kankesanthurai. By applying this storm pattern to the U Hydrograph synthetically derived, the 100 year flood hydrograph was obtained.

Reservoir Routing by Inflow Storage Discharge (I.S.D) method for 100 year return peri gave a peak discharge of 45,000 cusecs at the eastern closure bund and spill site of Elepha Pass lagoon.

A 100 year design storm pattern for Vadamarachchi Lagoon gave a peak discharge Thondamannaru barrage as 12,000 cusecs.

Water Requirements:

Since the scheme is located in the dry zone, water requirements for various crops given below are form the results obtained from Agriculture Research Station at Maha-Illuppallama.

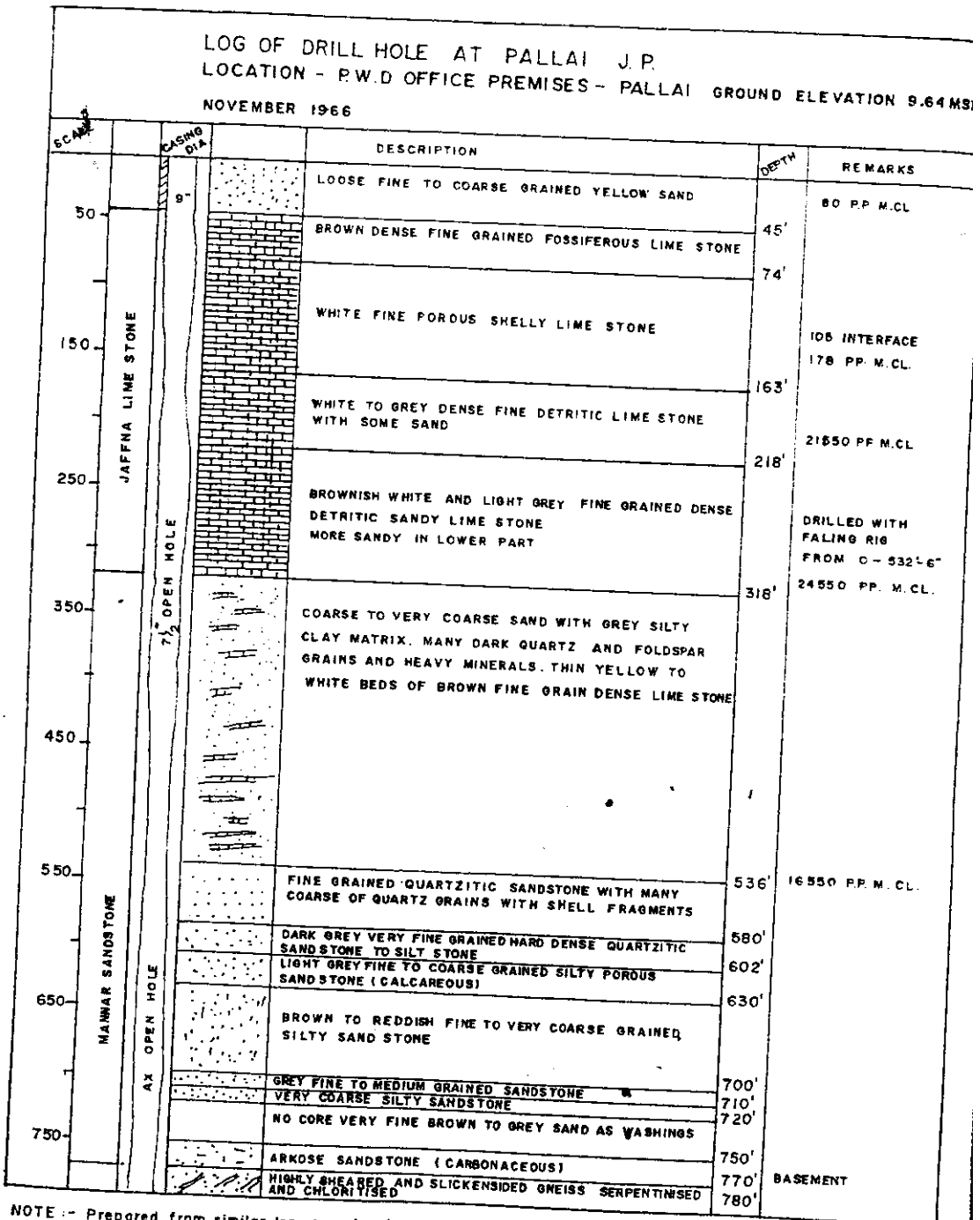
TABLE XXII

Month	Paddy	Onions	Chillies
October	0.32		
November	0.50		
December	0.63		
January	1		
February	0.52		0.65
March	0.27		1.04
April	0.67		0.76
May	1.25		0.87
June	1.11		0.68
July	1.11	0.69	
August	0.84	0.94	
September	0.32	0.29	
Total (say)	8.60	2	4

Salinity Variation

The variation of salinity with time at different locations of the lagoons is given in Table XXIII - annex-2. The locations are shown in the general layout plan of the scheme (lagoons) Fig II.

FIG. XX



NOTE :- Prepared from similar log appearing in the 1968 Transactions

Ground Water and Jaffna Aquifer

The geological formation of the sub-soil bears excellent physical character to underground storage. The replenishment solely depends on rainfall. The porous sand and lime stone sub-strata provides ample storage. The over-drawing from wells due to the increased activity in cultivation has resulted in intrusion of salt water. Table XXIV shows the population and the probable consumption of water.

TABLE XXIV

Annual Water Requirements in Million Gallons

	Population in 1976	For domestic Use 20 G.H.D.	For Home Gardens	For cultivation of dry season crops	Total
Jaffna	134000	978	9	153	1140
Valikamam, West	84000	613	2	656	1272
- do - North	101000	737	4	1933	2675
- do - East	57000	416	5	2119	2540
Thenmarachchi	97000	708	5	708	1490
Vadamarachchi	59000	431	4	640	1075
Pachchilaipalli	13000	95	1	85	231
Islands & Delfts	76000	529	3	1024	1457
Total	621500	4507	33	7328	11880

The table shows that the annual requirement is 43,300 acre feet, from a hand out from Agricultural Department sources to the Hydrological Survey Investigation Committee. (1968)

A census taken in 1958, shows that there were 84,000 wells of which 66,000 are used for domestic purposes and 18,000 are used for agricultural purposes and annually 1.5 acre feet of water is drawn from each well for agricultural uses.

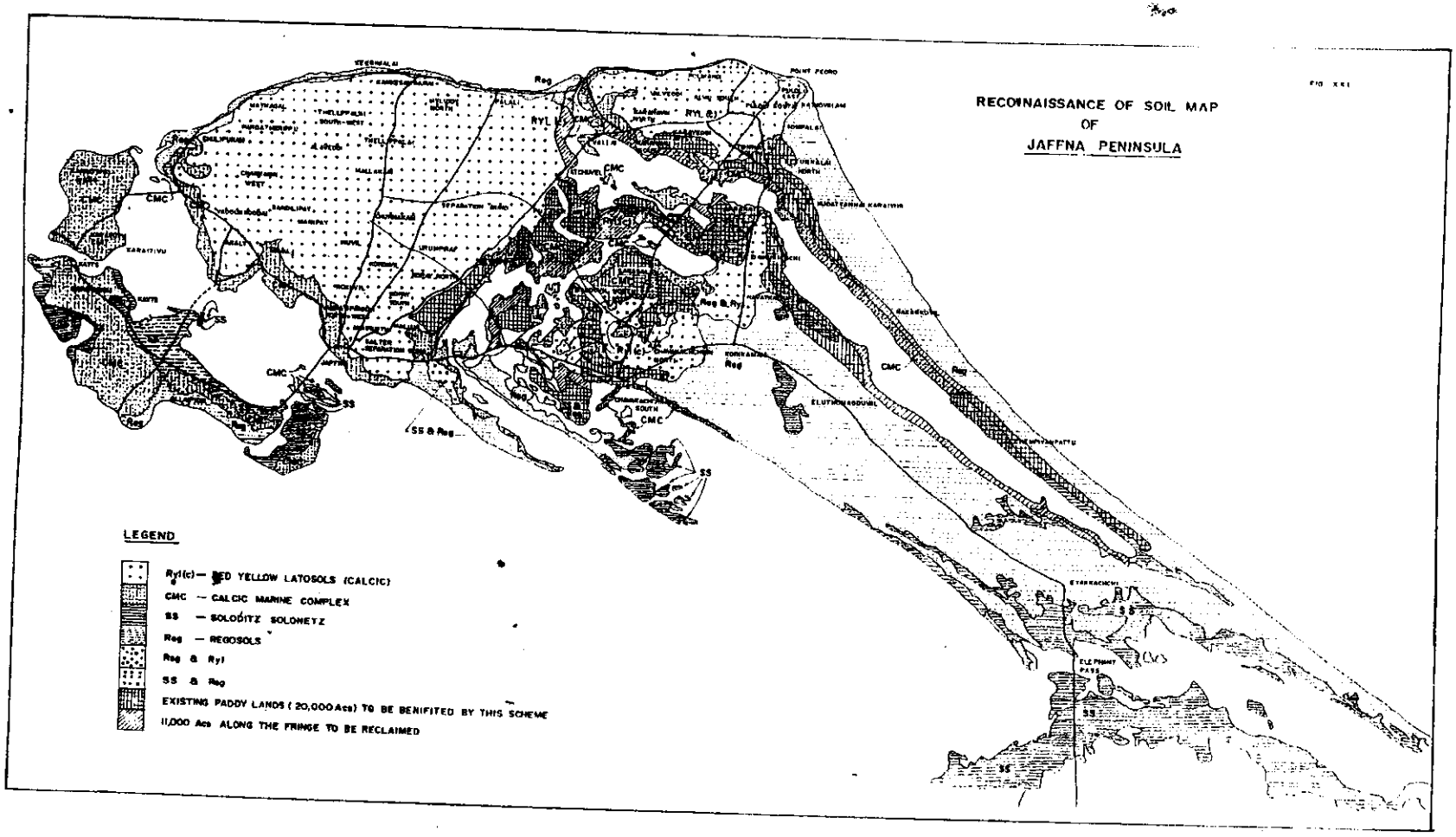
Exploration Detail

Drilling exploration showed the presence of lime stone to a depth of 200 ft. Drilling investigation carried at Kondavil, showed a massive lime stone substrata form immediately below the red soil becoming honey combed lower down. Cavities and solution caverns are found frequently. Calcarius, powdery layers are interspaced in the rock hard lime stone. The drill hole at Pallai showed that 200 feet thick lime stone was underlaid by a thick sand formation above a Precambarian basement. This log of the hole at Pallai is shown in figure XX.

Project Land and Soil Classification Project area

The peninsula comprise an area of 260,000 acres. Out of this, 157,000 acres are occupied as residence and home gardens inclusive of palmyrah etc., about 34,000 acres are cultivated with subsidiary and other food crops. Paddy is cultivated (rain fed) in 32,000 acres and the lagoons occupy about 26,000 acres. 11,000 acres of land fringing the lagoon are non-arable.

Source:- S. Arumugam - Development of Ground Water. I.E.C. Transactions for 1970.


RECONNAISSANCE OF SOIL MAP
OF
JAFFNA PENINSULA
FIG XXI
LEGEND
Ryl(c)— RED YELLOW LATOSOLS (CALCIC)
CMC — CALCIC MARINE COMPLEX
SS — SOLODITZ SOLONETZ
Reg — REGOSOLS
Reg & Ryl
SS & Reg
EXISTING PADDY LANDS (20,000 Acs) TO BE BENIFITED BY THIS SCHEME
11,000 Acs ALONG THE FRINGE TO BE RECLAIMED
POINT PEDRO
KARAITIVU
ELEPHANT PASS

Soil Classification

The soil along the fringes and mainly in the Upper reaches of Vadamarachchi lagoon consists of Calcic Marine Complex (C.M.C) with varying degrees of salinity. Nearly 40 to 50% of this land could be utilised for cultivation. The soil along the highland close to the sea is Regosols and an extent, where elevation of the water table is high enough for easy exploitation of the moisture by the root zone, can be brought under cashew plantation. Only a reconnaissance soil survey plan is available, fig XXI, and a detail survey has to be undertaken early.

The area that is being cultivated at present with subsidiary food crops are mostly of well drained reddish brown earth. This type of soil is ideally suited for chillies, onion and other subsidiary food crops and the cultivation can be extended and intensified when this scheme becomes a success.

ECONOMIC ANALYSIS

The figures arrived at in the economic analysis are as follows:
Benefit/cost ratio at 10% discount = 2.52
Internal rate of return = 49.10%

Plan of Development

The lagoon project is proposed for the replenishment of the Ground water in the Peninsula to assure the population of the area, water for both domestic and agricultural consumption, and to develop non arable land of extent 11,000 acres. This extent of 11,000 acres with the existing cultivable land of extent 20,000 acres for which water could be made available for the cultivation of paddy, chillies, onions, yams and other crops, are to be developed in the following stages:

Year	Paddy (crop acres)	Chillies (crop acres)	Onions (crop acres)	Yams & food crops (crop acres)
1	-	-	-	-
2	-	-	-	-
3	-	-	-	-
4	-	-	-	-
5	-	-	-	-
6	-	-	-	-
7	20.000	3.000	3.000	6.000
8	-	2.000	2.000	-
Total	20.000	5.000	5.000	6.000

The Cost Stream

In computing the cost to the economy, the cost of each item of expenditure was allocated Foreign component (F.C) domestic materials (DM), skilled labour (SL), and unskilled labour (UL). Transfer costs such as acquisition, interest on loans, etc. were ignored as they will be small. The opportunity cost of both foreign exchange and unskilled labour inputs were considered in the economic analysis. A factor of two was allowed for the foreign exchange component and one third was allowed for unskilled labour. The cost to the economy was thus equal to -

2 x (Foreign component) + (Domestic Materials) + (Skilled Labour) + 1/3 (Unskilled labour)

The percentage allocation of resource used in the analysis is given below.

Item	F.C.	D.M.	S.L.	U.L	Cost of economy
Bund	66	3	12	13	153
Spill	60	10	15	15	150
Link Canal	66	3	12	19	153
Access Road	35	5	20	40	109
Irrigation facilities	50	5	20	25	134
Land Development	16	28	18	38	91
Cultivation	25	25	-	50	91
Operation & Maintenance	15	10	15	60	75
Replacement	60	10	15	15	150
General charges	50	5	15	30	130

DIRECT AND INDIRECT BENEFITS

At full development, the Project will yield annually 400,000 bushels of paddy, 60,000 cwts of chillies, 500,000 cwts. of onions and 120,000 cwts. of other subsidiary food crops.

In the economic study, only the primary benefits from Agricultural production have been evaluated. The re charging of the under ground storage thereby, benefiting the brackish wells and increasing the storage potential of the ground water to meet the increased demand for irrigation and domestic use has not been considered. There will also be employment opportunities, growth of secondary industries, the increase of land values, recreational facilities, etc., as the secondary and intangible benefits. This scheme will bring immense benefits by way of economic upliftment, not only to the poor peasants of the area, but also to the entire country. The scheme is therefore, highly recommended for immediate implementation.

OUTSTANDING ISSUES

1. Detailed Land Use Surveys of the development area have to be carried out;
2. Salinity Test of the lagoons and wells along the fringe done and systematically processed;
3. Test on the salt content of sub soil of the lagoon to be carried out;
4. A Schedule and Standing Order for operation and maintenance of the barrage gates should be prepared, issued and followed;

CONCLUSION

It is very essential that the entire Jaffna lagoon Scheme, North, South and Elephant Pass should be controlled by one body for efficient management, maintenance, operation, investigation, tests, studies, etc. Benefits from this scheme cannot be derived, no sooner the construction work is over. Benefits depend entirely on efficient operation and manipulation of gates, maintenance, good understanding and proper co ordination of personnel manning Elephant Pass and internal lagoons, processing of test results, initiating action for necessary investigations on results of tests, etc. Efficient control by one body with definite instructions regarding the manipulation of gates of the barrages, regulators in the Link Canal and flood bunds with regards to tide levels, heavy rains and water levels in the lagoon is a must if any benefits are to be derived. A standing Order should be issued and follow up action is important. These are more important especially in the transition period when the salinity of the water in lagoon is approaching a limit below which the water can be considered as fresh for irrigation and domestic use.

In recent years studies, tests, research, etc. have been carried out for scheme of this nature all over the world and great advances have been achieved. The results and know-how have been incorporated in the Improvements to Jaffna Lagoon Scheme to accelerate the process and derive benefits early.

Urgent and immediate action is a must to tide over the danger of salt water intrusion in wells and to provide the much needed fresh water in the lagoons for cultivation and domestic use.

CHAPTER 5

PONDS IN JAFFNA PENINSULA

There are no streams and rivers in Jaffna Peninsula due to the flatness of the land and the topography does not permit the construction of reservoirs. Underground storage is the only source of supply water for domestic and agricultural purposes. Jaffna limestone with fissures, cracks and joints and with its porous characteristics permits percolation of rainwater to be stored underground.

There are over thousand ponds scattered all over the peninsula. The capacity of these ponds may be small but the benefit to the people of the area is substantial. Most of these were man-made to conserve the precipitation to provide water for cultivation of small extents around the ponds, drinking water by cows and other domestic animals and to recharge the underground aquifer and thereby raise the levels of water in the wells in the vicinity.

Drainage canals were constructed to direct the flood water from the rains into the ponds with necessary inlet structures. Similarly outlet structures were provided for issuing water to the fields adjoining the ponds. Ponds were provided with perimetral earthen bunds.

The ponds are badly silted due to many years of usage and the capacities are reduced. This results in increase draining of the runoff which would otherwise be stored up in the ponds for direct benefit and to recharge the underground aquifer. The collection of silt has further aggravated the seepage of fresh water into the underground storage.

In the sixties the ponds were said to be functioning satisfactorily. The net work of feeder canals serve to feed the ponds with flood waters and the drainage canals to drain the excess water into the sea, thereby preventing damage due to floods. A major drainage canal is the Valukai Aru basin which interconnects a series of minor drainage canals. Irrigation structures such as sluices, regulators and bunds were provided in this basin for regulation and issue of water for cultivation.

A program to rehabilitate, improve and desilt the ponds will improve the water resource potential of the peninsula. The cost estimate for desilting and other improvements of 892 ponds is Rs. 125,000,000.00 (Vide the report prepared by the University of Jaffna in collaboration with the Government Institutions in Jaffna at the request of the Government Agent of Jaffna.)

The author of this book was in possession of survey plans of 88 ponds with bed contours. They were handed over to Professor A. Thurairajah, Vice Chancellor of the University of Jaffna and will be available in library of the University of Jaffna for any reference. Survey plans of the balance ponds may be available in Survey Department, Colombo.

Annex.4.....a sample study of the ponds carried out gives the pond numbers, pond names, Village, lowest and highest contours related to mean sea level (MSL) datum and corresponding areas in acres, and capacities in acre feet. Sufficient data is not available in the plans to compute capacities of 12 ponds. Total capacity of the balance 76 ponds in 1152 Ac. Ft.

A similar study may be carried out for the other ponds when their survey plans are made available. If they are not available in Jaffna district level, they may be obtained from the Survey Department, Colombo. Such comprehensive study will be very useful to assess the potential of the ponds and to provide substantial data for desilting and other improvements.

CHAPTER 6

PROPOSED CHANGE OF VADAMARACHCHI AND UPPARU LAGOONS TO FRESH WATER LAKE AND DEVELOPMENT OF ITS FISHERIES

The lagoon is shallow and its bottom is quite flat. The water is brackish with the high salinity reached at the end of the dry season and with the lowest during the end of t rainy season.

Fisheries activities are generally limited to areas close to the barrages at the junction of t lagoon and the sea. Fishing is mainly for prawns. There is hardly any fishing activi towards the Centre of the lagoon away from these locations.

It is being stressed by the interested parties that the change to fresh water lake wou affect the livelihood of the present fishing community.

In order to understand the effect of the change over to fresh water conditions on th existing fishery it would be helpful to add here a note on the life history of the se prawns which are at present fished in the Thondamanaru lagoon. Essentially the popula species of sea prawns breed in the sea, the eggs hatch and the larvae float or swi towards the lagoons in their stages and then settle to the bottom, live inside the lagoo and grow up to a preadult stage when they start migrating to the sea to mature and bree to start the cycle all over again. Normally they do not breed within the lagoons.

It is at the late floating larval stage that they enter the Thondamanaru lagoon with th incoming sea water. Therefore the magnitude of the prawn catches within th Thondamanaru lagoon depends on the quantity of sea water entering the lagoon. Th lagoon's total prawn catch considering the large area of the lagoon, is very small even a times when there were no spillboard at the barrages. This is because of the very narrow entrances connecting the lagoon and the sea and very low tidal range. In any case it is being feared by the small population that depends for their livelihood probably partly and not fully on this resource that they may lose their income if the mouths of the lagoon are permanently closed and the lagoon be turned into a fresh water lake. Closing of the mouths would prevent entry of the prawn larvae and there would be no prawn catch inside the lagoon.

Prawns, both sea prawns and fresh water prawns are expensive commodities and as a result during the last two decades tremendous technological advances have been made to culture these organisms in man made structures, small and big. It is now a common practice to grow several generation one after the other of both the above varieties within man made structures, without having to depend on natural supplies of prawn larvae. Both varieties are available naturally in Sir Lanka, and without going into a detailed analysis at this stage, it can be said that a hatchery can be operated economically to supply all the required young larvae of the prawns to stock the Thondamanaru lagoon and get a prawn harvest from the entire lagoon which would be several times more than what was obtained from the lagoon recently or at any time before.

The closing of entrances would be beneficial and prevent entry of predators which would feed on the prawns and also help keep salinity levels low which would enhance production levels of sea prawn during early stages of conversion to fresh water conditions. Below a certain salinity level the sea prawn cannot survive.

At this stage the fresh water prawn can be introduced which can tolerate lower salinity levels. After the lagoon is complete fresh water lake the fresh water prawn can continue to be cultured in the lake. It is assumed that the water quality (dissolved salts etc.) would remain within acceptable limits. In addition there are also fish species that can be introduced. These species of fish are available locally. Generally it can be assured that with proper management not only the total catches would be higher than of present or ever before but at the same time employment opportunities would also be proportionately greater if the entrances can be closed and the area is managed rationally.

CHAPTER 7

COMMENTS AND SUGGESTIONS FOR FUTURE ACTION

1. **Investigations, design, proposals etc. carried out 1976**

When the project is to be taken up for implementation some of the investigations carried out in 1976 have to be repeated in view of the lapse of considerable time and further investigations to be carried out to update the proposals, designs, estimates etc.

- Barrages at Thondamanaru and Ariyalai, separation bund between Vadamarachchi and Upparu Lagoons, Separation bund between Upparu Lagoon and Ariyalai saltern, and Access Road (5 miles) off Paranthan - Mullaitivu Road to spill cum causeway at Chundikulam at the eastern end of Elephant Pass Lagoon have deteriorated due to Vandal damage and lack of maintenance. The condition of these have to be assessed. It was not possible to do so due to the prevailing situation. Hence the investigation related to the above items identified in Para 3 of Chapter 4 have to be repeated to finalise the proposals.

- Longitudinal and cross sections of the link channel to be taken in view of the lapse of considerable time after the proposals were finalised in 1976.

- In view of the failure of the Eastern closure bund in 1962 careful attention was given for the investigations, design, proposals etc. for EPL.

2. **HYDROLOGY- EPL**

Catchment area of EPL is 363 square miles. Kanagarayan Aru is the main and major one feeding EPL. This comprises about 75.0 percent of the entire catchment area.

3. **Hydraulics of Chandikulam spill - EPL**

Sand bar would have breached before EPL commences spilling, due to the water draining into the lagoon between the spill and the sand bar. While investigations were carried out in 1976 discussion with the villagers for collecting data for the proposals, revealed that just prior to the failure of the closure bund in 1962, there was sufficient water between the spill and sand bar, before the spill commenced spilling, to enable them to cut a pilot channel in the sand bar to facilitate breaching of same. In addition, considering the spill crest level, high tide level and site conditions, clear overall condition assumed in the design is valid at site.

4. **Upstream submergence- EPL:**

Investigations were carried out in 1976 to identify areas susceptible for U.S. submergence. The areas in doubt were Kanagarayan estuary and the Kandy - Jaffna road, (a stretch south of Elephant Pass Causeway up to the saltern office entrance). Investigations revealed that these areas will not be submerged. There were no paddy lands susceptible for submergence.

5. Evaporation Losses - EPL

There will not be any water in the Lagoon (EPL) during major part of heavy evaporation period. There will be some evaporation during the period when there is water in the lagoon as in all reservoirs. EPL being shallow the evaporation loss will be relatively higher than in other normal reservoirs, but substantial amount will be available for utilization. We have to make use of what is available without abandoning the limited resources to achieve the objective.

6. Structural design of Chandikulam Spill and Embankment - EPL

In view of the failure of eastern closure bund in 1962, elaborate investigation and study, including subsoil conditions were carried out in 1976 and the spill and embankment were designed to cater for the site conditions. (Vide drg no. SLW/186-1)

The soils and materials laboratory of the Irrigation Department, did the studies and tests and the designs were based on the data and suggestions provided by the laboratory.

7. Spill cum causeway - EPL

The main function is to discharge the flood run off and the use as a causeway in secondary. However quard stones are provided in the estimate, Vide annex 3 for convenience of the pedestrians and vehicles, specially when the water level is fairly full - 4.00 MSL.

8. Link channel - EPL to VL

The channel is designed for 1 on $2^1/_2$ side slope and found to be adequate as per tests and studies carried out in the soils and materials laboratory of the Irrigation Department.

9. Monitoring of ground water conditions

Drilling of deep bore holes on a grid system is necessary for monitoring of ground water resources, seasonal and long term movement of the saline water front along the coast, and the fluctuation of the interface and to assess the actual storage. Proper study of ground water conditions could only be well established by way of deep bore hole investigations, than with the aid of shallow wells.

10. Ponds in Jaffna Peninsula

Contour Survey to be carried out for all the ponds for which plans are not available. These plans are necessary to compute the capacity, data for desilting and other improvements.

- A program to desilt and improve the ponds to be prepared and implemented in stages. This will facilitate to utilise the precipitation to the maximum.

11. Proposed change to fresh water lake and development of its Fisheries:

Fresh water prawns are cultured in an extensive way in the country and substantial data is available. It is suggested to carry out further studies to incorporate culturing of fresh water prawns in this project. A pilot scheme to rare fresh water prawns

may be set up midway between the two barrages at Thondamanaru and Ariyalai where the effect of sea water intrusion will be lowest at present. The larval forms of fresh water prawns are available locally. This will go a great way in removing the fear that change to fresh water lake would effect the livelihood of the present fishing community.

12. Recharging of the underground storage

The porous characteristics of Jaffna Lime stone with joints, cracks, and fissures permit the percolation of rain water to be stored underground. The rate of percolation along the bed of the lagoons may be less than that through the lime stone strata in other areas of the Peninsula, due to silt deposits, subsoil investigation along the lagoon bed will reveal the degree of compaction and the rate of percolation. If it is necessary recharge wells may be constructed at suitable locations to increase the recharge of the aquifer. This method is being adopted in Israel and found to be effective. Water resources available for the Peninsula is limited. Hence best use must be made of the available resources and suitable techniques adopted to overcome any constraints and problems.

13. General:

Discussion with the Villagers in Chundikulam is 1976 revealed that they used to send their cattle to the mainland in the absence of pasture land in their area. But during the short period before the failure of the closure bund there was sufficient grass along the fringe of the lagoon in this area for cattle to feed on. This was a substantial help and benefit to the villagers.

- During the investigations 1976, it was observed that grape wines were cultivated on a stretch of land north of the link channel (Partly constructed). Stagnant water in the channel was used for irrigation. (Lift).

- Food and Agricultural Organization of the UNO (FAO) did prefeasibility studies in 1984 on irrigating coconut trees at the request of Coconut Cultivation Board / Ministry. The request was made because of the drought experienced in early eighties and the drop in the yield. The studies revealed that rainfall had a positive effect on the yield. The prefeasibility report suggested number of pilot projects in the country providing irrigation systems from ground and surface water (lift and gravity). The author was a member of the FAO team and handled the irrigation system. Water in the link channel and upper reaches of Vadamarachchi Lagoon will have beneficial effect on the yield of Coconut trees in the area.

The benefits from the anticipated fresh water resources created by this project are numerous. There are two ways of approaching a project. One is how to implement the project and the other is how not to implement. The first one has to be followed early as the time is running short.

The latent benefits will be an additional contribution to the efficiency of the Project. Some of these cannot be quantified in computing the efficiency of the project but have to bear in mind. Basic principles, requirements, and water resources have been carefully looked into but improvements, amendments etc. in details are always bound to arise when updating the proposals and as implementation progresses.

I am not sure when the auspicious time will come for implementation, but it must come before a critical stage is reached, when most of the area will be faced with shortage of fresh water for domestic use and agricultural purpose.

I have been trying my best to get this project implemented while working in the Irrigation Department and even after I retired from the Irrigation Department in 1980, through other sources. I have failed in my endeavour. Hence, I am documenting all the available data relating to the project - historical, problems, requirements, proposals, designs, construction drawings, cost estimates, economic analysis etc. in this book with the hope that it will serve as a guideline for the future planners and development authorities to the benefit of the people of the area.