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SEDIMENTATION PROBLEMS IN MASSANJORE RESERVOIR OF MAYURAKSHI RIVER SYSTEM, WEST BENGAL

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1993-94

PREFACE

Sedimentation of reservoir play a vital rote in the planning and design of a storage reservoir. The problem of sedimentation starts with the impounding of water in the reservoir. Various factors influence the pattern of sediment deposition. To evaluate the effect of each of these and to serve as a guide for future planning, systematic capacity surveys of reservoirs should be undertaken at regular intervals.

In the present report status of sedimentation problems in Massanjore reservoir of Mayurakshi river system, West Bengal is presented. The report attempts to discuss the methods used by investigators, remedial measures taken in the reservoir and future plans. A case study of the Massanjore reservoir is carried out using remote sensing techniques.

The report entitled " Sedimentation Problems in Massanjore Reservoir of Mayurakshi river system, west Bengal" is prepared by Sri Ramakar Jha, Scientist'B', R.K.Jaiswal, SRA and Sri A.Kumar, R.A under the guidance of Dr. K.K.S.Bhatia, scientist'F'& Tech co-ordinator. The assistance of Sri M.B.Santosh & A.K.Sivadas, Technicians are appreciated.

S.M.Seth
Director

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ABSTRACT

During the last four decades India has constructed several major/medium river valley projects involving construction of dams and creation of reservoirs for flood controls, irrigation and hydropower. As the above storages are subjected to silting, sedimentation of reservoirs is infect a matter of vital concern to all water resources development projects. The surveys conducted in some of the reservoirs have indicated that siltation not only occurs in the dead storage but also enchroaches in the live storages zone which impairs the intended benefits from the reservoir. The decrease in storage capacity impairs the functioning of the reservoir for which it has been designed.

This problem of sedimentation starts with the impounding of water in the reservoir. When the sediment laden flood water enters the reservoir the velocity of the inflow currents is reduced. Consequently nearly all the coarser particles, including sand, gravel and boulders are deposited in or near the tail end of the impoundment. The silt and clay particles remain in suspension longer and are carried forward into the water body where deposition takes place.

The following factors are responsible for reservoir sedimentation (Rao et al,1990):

a. Physical and hydrological characterstics of the catchment.
b. Trap efficiency of reservoir & method of reservoir operation.
c. Intensity of erosion in the catchment.
d. Landuse pattern in catchment.
e. Quality ,quantity and concentration of the sediment brought down by the river.
f. Growth of vegetation at the head of the reservoir.

Presently the reservoir surveys have been carried out using conventional methods. Most common conventional techniques for sedimentation quantification are (a) direct measurement of sediment deposition by hydrographic surveys and (b) indirect measurement of sediment concentration by inflow - outflow method. Both these methods are laborious, time consuming and costly and have their own limitations. The successful management of large reservoirs is possible if cheap ,efficient and accurate means for determining the instantaneous suspended sediments in large water bodies are available. Remote sensing methods can be effectively used to assess sedimentation in reservoirs. Remote sensing of reflected solar radiation can provide timely and repeated information concerning suspended sediment flow patterns in reservoirs.

For the evaluation of sedimentation problems of Massanjore reservoir of Mayurakshi basin, remote sensing has been used in

the present study. The present study provides the status of sedimentation problems in the reservoir and a clear-cut picture of the previous studies carried out in the reservoir. In the report an attempt is also made to identify and study the extent of sediment deposition and their location in the Massanjore reservoir using pre- and post-monsoon data of Indian Remote Sensing Satellite(LISS II) for the year 1989.

INTRODUCTION

Dams are constructed across the rivers and streams to create an artificial lake or reservoir behind it. Dams and reservoirs are the most important and expensive elements both in single or multipurpose river basin development. They require very careful planning, design and operation. A number of problems arise in design, construction and operation of dams and reservoirs; for example, selection of site, the relative merits of different types of dams, storage capacity, optimum yield and co-ordinate use of storage for different purpose.

The primary function of a dams/reservoir is to provide storage and their most important physical characteristic is storage capacity. The development and maintenance of storage capacity in reservoirs is a major problem due to silting/ sedimentation in the reservoir.

The sedimentation is the maligrant growth of a reservoir and it dissipates the effectiveness of reservoir for which purpose it is built. It is considered the major component in stream reservoir, estuaries and lakes. Although sedimentation is a natural process, the rate can be accelerated or decelerated by man's activity in the acquatic environment. The dissolved and sediment loads of a river are both derived from rock weathering. Subramanian (1978) estimated that at the present rate of erosion, with no compensating uplifting mechanism, river basin in India would achieve their base level of erosion in 5 million years.

The importance of the sedimentation studies is felt, when the reservoirs constructed in Egypt, India, Japan, China the United Sates, Australia and eleswhere shown a tendency to silt in varying degree depending upon a number of factors. Records show that the rate of silting in some of the reservoirs is alarming. For example, the Yamoka Reservoir on the Teuryh river in Japan having an original capacity of 176.6 million as much as 85 % or its capacity in 13 years.

The suspended material discharged by river into reservoir, transport polluntants and are the natural material that fill channel and reservoir. The input of suspended material to reservoir is variable in concentration and composition from river to river, as well as changing with time in any particular river. The variation in average concentration is related to seasonal changes in precipitation and runoff within the drainage basin of the river. The region of extreme seasonal variation in precipitation and runoff also have the widest variation in suspended material concentration and region having reasonably steady climate have the least variation in suspended material concentration. The effect of man on the increase of suspended material concentration and discharge of river has been striking.

The cutting of forest planing for formland and the multiplicity of construction project associated with man's industrial and residential expansion have markedly increased the concentration and discharge of suspended material.

The composition of the suspended material discharged by rivers into reservoirs also varies from river to river, depending on the composition of the rocks and soils in the river's drainage basin, the weathering climate to which these rocks and soils have been exposed and the energy of river to transport various sizes of material. The various mineral that make up the suspended material all have different size distribution. Sperimposed upon the inorganic fraction of the suspended material transported by river in the natural biologically produced material in the river generally amounting to only few milligram per litre of organic material. In addition to contributing natural material to rivers and reservoirs, man is responsible for permitting such suspended matter as solid sewage and industrial wastes in the form of metal, plastics, and wood etc. to enter the water.

Sedimentation of reservoirs leads to a gradual loss of the storage capacity available for re-regulation of supplies. Apart from this, it can cause operational problems created by large entry of sediments in the canals or in the turbines, as also due to jamming of hydraulic gates. Reservoir sedimentation can also cause ecological problems due to turbidity, and due to gradual delta formation at the upstream end of the reservoirs. The sedimentation damages badly a reservoir if the decreased storage capacity prrevents it from supplying the full service for which it was designed. Reservoirs of comparable size but of different service functions are not necessarily damaged, therefore, to a like degree by the same rate of sedimentation.

Conservation of water in storage reservoirs is inevitablle to meet the variables of rainfall. A reservoir begins to receive sediment the moment it is formed, its capacity gradually diminishing with years. Most of the sediment is transported by the inflowing water. Accelerated by uncontrolled deforestation, forest fires, overgrazing, improper methods of tillage and unwise agriculture practices, soil eroded from the catchment area constitutes the silt charge of the stream and settles down in the reservoir through a very small part, may escape when the spill way and outlets dispose off floods.

The measures to reduce the inflow of sediment into the reservoir consists of taking planning, design and management measures to ensure that the reservoir sedimentation does not cause unexpected problems in the usefull operation of the reservoir. Reservoir planning must include consideration of the probable rate of sedimentation in order to determine whether the useful life of the proposed reservoir will be sufficient to warrant its construction.

In this context, the silting or sedimentation rate of a reservoir is necessary to be assessed periodically for proper operation and to determine the quantum of silt deposited in the sedimentation inflow.

1.1 Criteria for Life of a Reservoir

After considerable discussions and deliberations, the water planners in India have agreed that the reservoirs do not have a single well defined life. According to the Compendium on silting of reservoirs in India, reservoir do not have, strictly speaking, a defined life which denotes two functional states 'ON' and 'OFF'. They show a gradual degradation of performance without any sudden non-functional stage. Sedimentation and consequent reduction of capacity is a gradual process, which can be classified in following phases :

<u>Phase-I</u> The reservoir shows no adverse effects and is able to deliver the full planned benefits.

<u>Phase-II</u> The reservoir delivers progressively smaller benefits, but its contiuned operation for the reduced benefits is economically beneficial.

<u>Phase-III</u> The sedimentation causes difficulties in operation such as jamming the passage of flow in canals or through turbines.

<u>Phase-IV</u> The Phase III difficulties become so serious that the operation becomes impossible.

<u>Phase-V</u> The benefit reduce to such an extent that it is no longer beneficial to operate the reservoir.

1.2 Indian Planning for Reservoir Sedimentation

The earlier assumption that sediment would settle within the dead storage was not supported by the experiences in India and other countries. The results indicating a considerable difference from the initial assumption, started becoming available by 1965. After 1965, CWC started insisting that the sediment inflow rates be based on the basis of reservoir survey data. It also brought out the need for distributing the sediment throughout the reservoir. For this purpose, the empirical area reduction method was preferred in general. At least the more important major projects had to adopt this new approach. However, no guidance was given until then about which stage off sediement should be used for the working table studies.

Around 1974, it was decided that the 50 year sedimentation position of the reservoir should be used in the simultation of working table studies. Also by this time the observed suspended sediment data from the key hydrologic network of CWC had become available in considerable volume. CWC, therefore, started insisting the use of this measured sediment transport data to firm up the assumption of the inflow rates of sediment. In 1982, the report of the working group on the guidlines for the preparation of detailed project report of Major and Medium Irrigation Projects was published. In this report, CWC had incorporated the above mentioned practices to make these mandatory on the State Governments. Also in the report the detailing of the sediment studies was linked with the expected seriousness of the sediment problem. For very serious cases, redistribution and re-estimation of trapping efficiency in 10 year block was indicated.

In 1987, CWC got this practice incorporated in the IS:12182 (1987) " Guidelines for Determination of Effects of Sediment in Planning and Performance of Reservoirs" to make this the national practices. In these guidelines the general philosophy and the concept of multiple life related terms was also spelt out. Also these guidelines indicated that the full services time for hydroelectric projects can be reduced to 25 years against notes on the need for periodic resurveys and give guidance to determine their frequency.

1.2.1 Management problems

Amongst the 44 reservoirs for which data have been prescribedby C.W.C., 43% have a serious problem, 43% have a problem which is significant but not serious and the remaining 14 % do not have a significant problem (Table 1). However, the sample, could not be considered as a representative, since the reservoirs for which there were other indirect indications of a problem would have received more attention in the research schemes. The main points to be noted were:

(1) For many reservoirs, the rate of sedimentation has been more than that assumed at the time of planning.

(2) No large reservoir in India has completed its feasible service time. Although some old reservoirs have deplited their original capacity by more than 50 percent, it is still beneficial to operate these.

(3) For many Himalayan Streams which carry very heavy loads of sediments, planning of the project with a feasible service time of 75 or 100 years becomes difficult. For hydroelectric projects in particular, it is possible to repay the development costs in few years, and a project can be planned effectively for a shorter period. In Pakistan, for example, the Tarbela project has perhaps been planned to lose most of its capacity in about 50 years. This brings us to the extra-economic considerations discussed earlier. A periodical

Table 1: Loss of annual capacity in reservoirs.

Range of Annual Loss of Capacity	Number of Reservoir Within the Range	Range of Data Length (Year)
Less than 0.1 %	6	10 to 56
0.1 % to 0.5 %	19	10 to 81
More than 0.5 %	19	6 to 73

thinking of this aspect is perhaps necessary.

(4) A large number of hydro-electric and even Irrigation Projects are planned as pondages where the capacity : inflow ratio or the detention period can be of the order of a few days to a month. For many such projects, most of the capacity is against creast gates. There is a belief amongst planning engineers that for such structures, where the gates would be kept open during the high flow - high sediment inflow period, no sedimentation would occur above the crest of the gates. Although there is enough empirical evidence to indicate that sedimentation does occur above the crest level, simple methods to indicate the new regime of the river upstream of the dam, and the 'ultimate' pondage available for reregulation in spite of sedimentation, are not available. For the Gauriganga H.E. Project in the U.P. Himalayas, for which the capacity is of the order of 5 million m^3 with a sediment inflow of 3.2 million m^3 with a sediment inflow of 3.2 million m^3/yr. A general stabilisation of the million m^3 was seen after 10 years.

1.3 Objectives of the Present Study

Realizing the problems of sedimentation in reservoirs of India, in the present report the Massanjore reservoir of Mayurakshi river system of West Bengal was selected to study the following:

1. To study the extent of sedimentation problems in the Massanjore reservoir, its history , management problems in the past and present status of the reservoir sedimentation problem, causes of sedimentation etc.

2. To locate the sediment deposition pattern using Remote sensing IRS-satellite data.

2.0 THE STUDY AREA

2.1 The River Mayurakshi

The Mayurakshi River has its origin on the slopes of Tirhut hills about 43 km (27 miles) upstream from Dumka in Bihar (Fig.1) At its origin it is known as Maithara. In its course downwards to the south-east, it takes in number of rivulets, streams and important tributaries such as Bhurburi, Dhobai, Pusaro, Tepra, Bhamri, Dauna and Sidheswari. The confluence of Sidheswari with Mayurakshi is in the downstream of Canada Dam. Tilpara Barrage on the River Mayurakshi is in downstream of the confluence of these two rivers.

Mayurakshi River is 70 km (44 river miles) in length from its origin to the dam site out of which 43 percent (30 km) lies in the reservoir waterspread area. The river has an average bed grade of 1:950 before it enters the reservoir waterspread area. The tributaries Dauna, Bhamri, Tepra and Bhurburi have bed grades of 1:260, 1:740, 1:420 and 1:370 respectively before their entry into the reservoir waterspread area.

The total basin comprises the eastern part of the Chotanagpur plateau on the west and a strip of gangetic alluvium on the east with a transition zone in between. In fact the Archaean and other formations of the plateau have gone below the alluvium. The catchment area of the river Mayurakshi above the Massanjore dam located in Bihar measures 1860 sq. km, is shaped like a leaf and is devoid of appreciable vegetal cover. Up to Tilpara barrage, located 37 km below the dam, the total catchment increases to 3212 sq. km Undulating in nature with scattered hillocks, the catchment comprises various landuses as shown in **Table 2**.

The forests constitute only 6 percent of the catchment area the vegetation is generally limited to hill tops and slopes. 44 percent of the catchment area comprises lands under paddy cultivation with field bunds subject to limited soil erosion. But rest 50 percent of the catchment area is subject to sever erosion.

The whole catchment can be studied by dividing it into seven sub-catchments. From the aerial survey maps, the soil conservation Department of the Govt. of Bihar prepared the erosion interpretation maps of the catchment.

The catchment is under various stages of erosion i.e., sheet erosion, gully erosion and ravines. Out of 50 percent of the catchment area 929.81 sq. km susceptible to heavy erosion 26 percent of it 239.58 sq. km already under various stages of erosion.

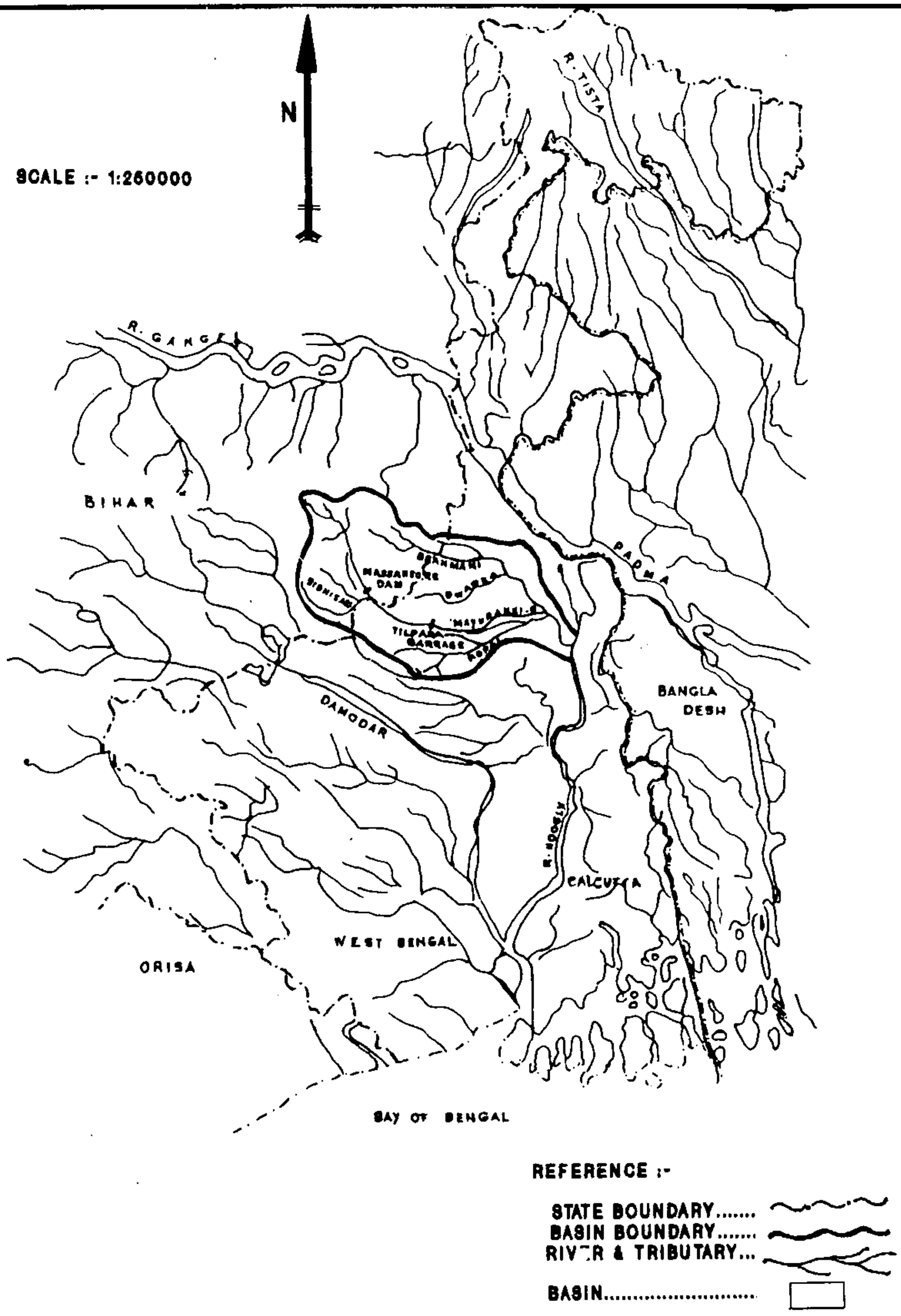

FIG 1.0 INDEX MAP OF MAYURAKSHI SUB-BASIN

Due to indiscriminate deforestation and annual forest fires the forest area is being denuded. Excessive grazing of pasture lands has contributed to their accelerated erosion. Agricultural lands other than paddy lands with poor crop-density are continuously loosing top soil (Table 2). In many places gravely and rocky substrata are exposed.

2.1.1 Topography of the area

The Mayurakshi basin in West Bengal lies in Birbhum and Murshidabad districts. Important towns in Birbhum are Suri, Rampurhat and Bolpur and Kandi in Murshidabad. The west portions of Birbhum district comprising Khoyrasol, Rajnagar, Dubrajpur, Suri Mohammed Basar and Rampurhat thanas are at the base of the heavily dissected plateau of Santhal Parganas projecting south-east. Almost the entire Birbhum district, the surface is intercepted by a succession of undulations, the general trend of which is from north west to south east. Near the western boundary of the district Birbhum, these undulations rise into high ridges, separated by valley a mile or more in width. To the south east these upland ridges and their ramifications fade out, the valleys become shallow and gradually merge into the broad alluvium plains extending into Murshidabad district (Fig. 2). However, the rapidity with which the hillocks change to ridges, ridges to ramifield undulations and undulations to level country varies considerably. The 250 ft. contour skirts the western fringes and the 60 ft. contour lies at the eastern part of the basin. However, there are quite a number of isolated highs in the western side ranging from 275 ft. to 375 ft.

2.1.2 Rivers and tributaries

The Birbhum district is well drained by a number of rivers and streams running smoothly from west to east with a slight south-easterly inclination except for Pagla and Bansloi in the northern part of the district which flow north east and is outside the Mayurakshi basin. Similarly the river Ajoy and its tributaries in the southern part belong to the Ajoy basin. The Mayurakshi basin lies in the middle of the district and includes Brahmani, Dwarka, Bakreswar and Kopai system of rivers. The combined discharge of all these rivers, joins the Bhagirathi river through a number of distributaries (Fig.3). In fact the Mayurakshi project draws some replenishment through four pick up barrage located at the crossing of the main canals on these four rivers. Apart from these, Mayurakshi has an important tributary namely Sidheswari-Noon Beel (combinations of two streams) which joins the main river upstream of the Tilpara barrage.

2.1.3 Rainfall

The basin of the Mayurakshi river may be considered to be consisting of the basins of Mayurakshi, Brahmani, Dwarka, Kopai

Table 2: Land Status of the Mayurakshi Basin

Sl.No.	Land status	Area in sq km	PC of total catchment
(1)	Cultivable waste land	443	24
(2)	Land under paddy cultivation	816	44
(3)	Other cultivated land	342	18
(4)	Forest land	114	6
(5)	Pasture land	145	8

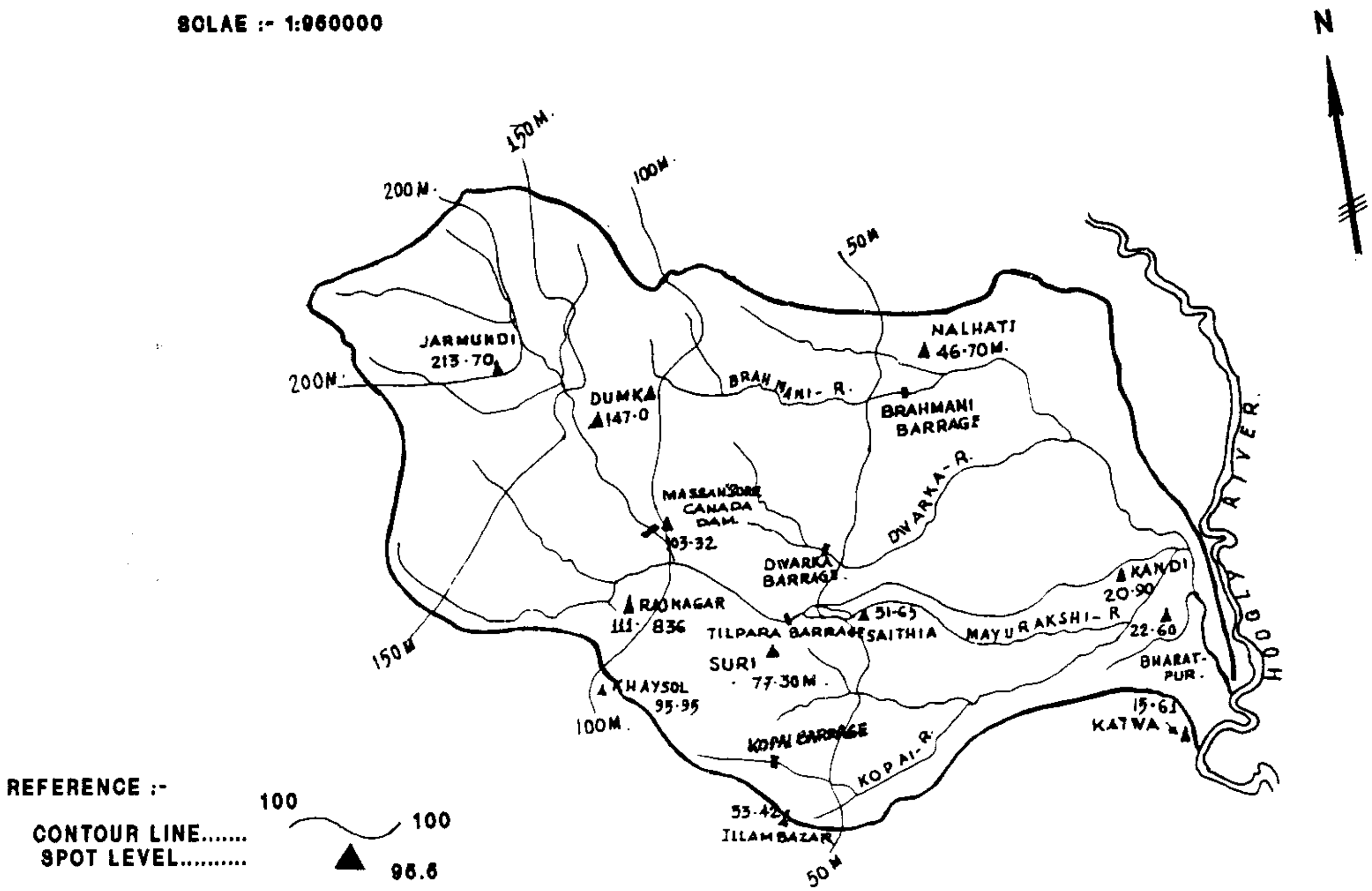

FIG 2.0 CONTOURS IN MAYURAKSHI SUB-BASIN

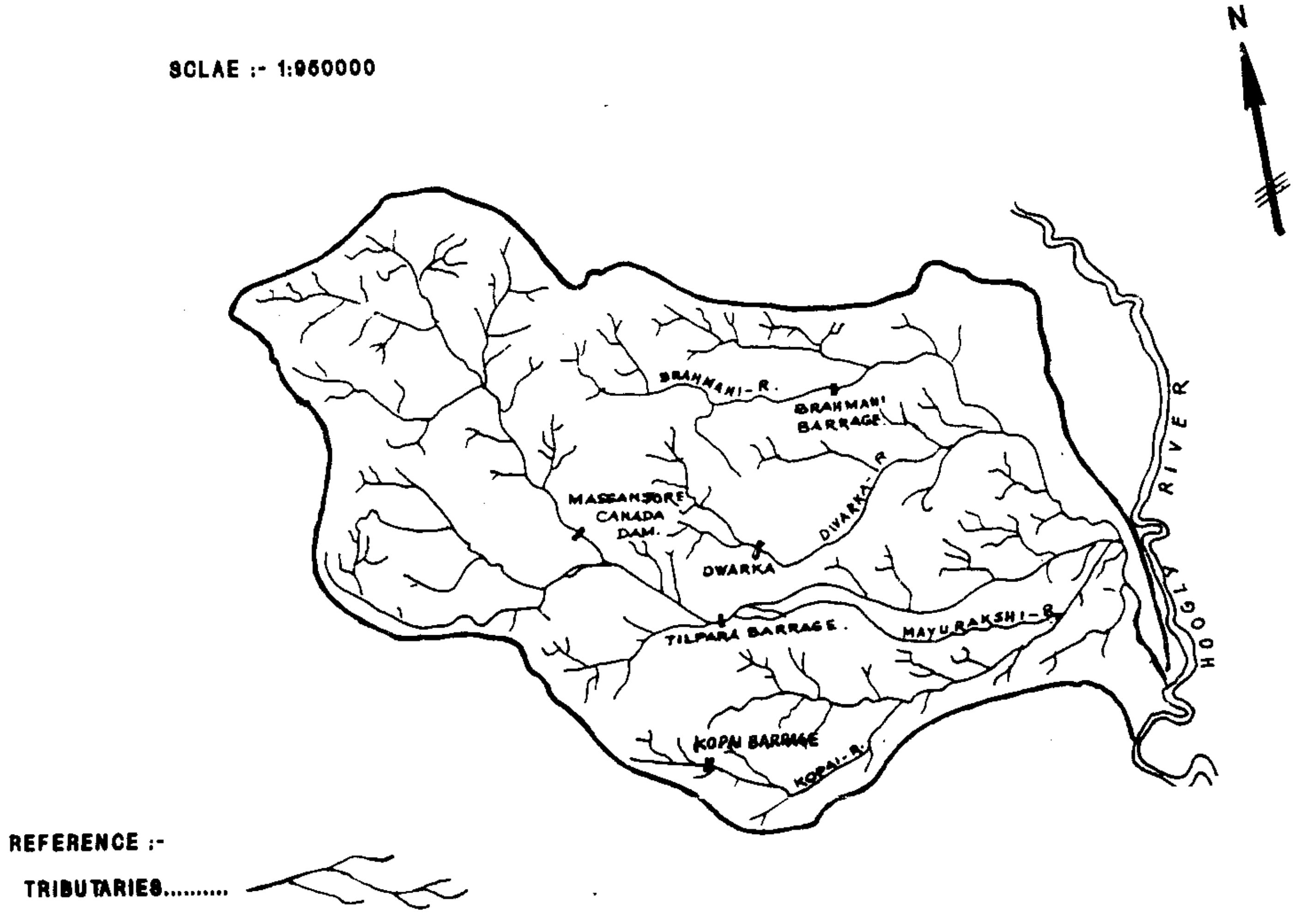

FIG 3.0 DRAINAGE MAP OF THE MAYURAKSHI SUB-BASIN SHOWING TRIBUTARIES

and Bakreswar and measures about 4873 sq.km.. Rainfall in the basin varies from 1000 mm to 1400 mm. The variation in annual rainfall ranges from 165% to 50% .

As usual in these parts, about 80% of the annual rainfall occurs during the four months of monsoon (15 th June to 15 th October). However, intensive rainfall occurs during 3/4 days period when a depression passes through the area. Isohyetal map of Mayurakshi Command area is given is **Fig. 4.**

2.1.4 Evaporation and humidity

Evaporation is a source of loss in this basin particularly during the summer months. Reservoir evaporation data has been given in **Table 3**.

The air is highly humid throughout the monsoon season. Thereafter the relative humidity decreases progressively. The driest part is the summer season with average relative humidity of about 45 % to 65 % in the mornings and 25% to 40 % in the afternoons. The figures increase as proceeding from west to east.

2.1.5 Agroclimatic zone

The Planning Commission had divided this State into three Agro-climatic zones, are given below.

(1) Eastern Himalayan,
(2) Lower Gangetic Plain,
(3) Eastern Plateau.

The Mayurakshi basin lies in lower gangetic plain zone.

2.1.6 Geological formations

Archaeans are the oldest (900 million years) rock formations in this region. These are a contribution to the east of the Peninsular Archaeans of the Chotanagpur Plateau and outcrops are exposed in the western parts of the districts. These regions were subjected to great diastrophic movements and erosion through a considerable period before the cycle of fluviatile sedimentation resulting in the subsidence of the basins, which took place from the upper carboniferous of the plaeozic era through the Mesozoic era. These long time sedimentation resulted in the formation of most characteristics system of thick fluviatile or lacustrine formation of shales and sandstones with intercalculations of coal seams belonging to the Gondwana system. During the upper Gondwana sedimentation period there was marked vulcanite, which manifested itself into outpouring of Rajmahal level flows and intrusions of numerous sills and dykes of basic and ultrabasic rocks. Outcrops of Rajmahal traps of early cretaceous (Mesozoic) period appear along the western fringe of the district in Rampurhat and Nalhati thanas. Approximately to the east of Andal Sainthia Chord

Table 3: Evaporation data for the Basin

Month	Evaporation in mm
July to November	Low
December	25
January	75
February	100
March	125
April	150
May	175
June	100

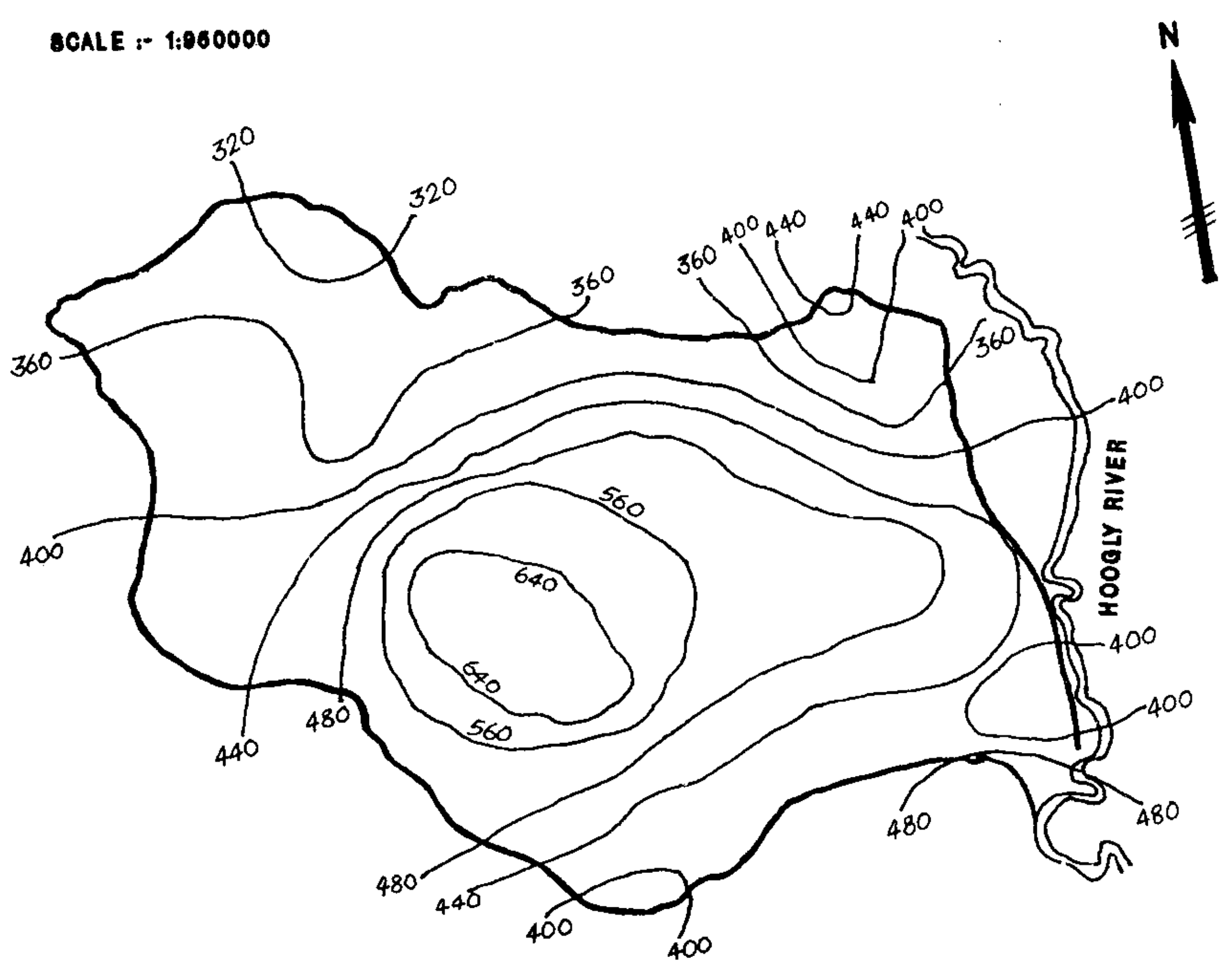

FIG 4.0 ISOHYETAL MAP FOR 1 DAY P.M.P (mm)
-MAYURAKSHI SUB-BASIN-

(Railway) and the Eastern Railway Loop Line the Archaean and tne Rajmahal traps disappear below a blanket of alluvium. Several patchy exposures of the Tertiaries sequence are found in Mahmmadbazar, Bolpur areas. This apparently indicate the presence of a continuous belt of Tertiary rocks in this part of the State. The Territory sequence overlies the Rajmahal traps but in certain parts it directly overlies the Archaeans. The alluvial deposits cover approximately four fifths of the area of the State. The older alluvium is coarse and generally of reddish colour containing disseminations of calcareous and limnotic concretions. The alluvium is probably of middle pleistocene age. The newer alluvium is of sub-recent to recent and gradually merges into the flood plains. The geological succession found in the basin is given in **Table 4**.

2.1.7 Hydrogeology

Water supply in the crystalline tracts is mainly derived from surface water. Dug wells are generally shallow. These tap only localized water bodies collected in the cracks and crevices of the impervious rocks, and from the upper weathered zones of the bed rock. The area suffers from water scarcity. The tertiary and pleistocene deposits in the Birbhum district are mostly covered by a variable thickness of laterite which sometimes overlap some portions of the peniplained and highly weathered genissic terrain. This laterite has generally claybeds at its base. In such regions, during the rainy season, the water level rises to the maximum and during summer it falls in the level of ground water is very sharp, and there is always a steady outward discharge, away from the centre of the highland. Some artesian structures have been discovered near Bolpur.

2.1.8 Soils

The major portion of command area consists of very deep, poorly drained, fine cracking soils occurring on level to nearly low lying alluvial plains with clayey surface **(Fig.5)**. Apart from this, following groups of soil occur sporadically in the command area :

(a) Very deep, moderately well drained coarse loamy soils occurring on very gently sloping active alluvial plain with loamy surface.

(b) Very deep, poorly drained, fine soils occurring on level to nearly level recent alluvial plain with clayey surface and moderate flooding (Aeric Haplaquepts).

(c) Very deep, very poorly drained, fine cracking soils occurring on level to nearly level low lying alluvial plain with clayey surface (Vertic Haplaquepts).

Table 4: Geological succession of the basin

1.	Recent	: Alluvium
2.	Tertiary (Miocene)	: Laterite and lateritic gravels with fossil wood clay beds. Ferruginous and Felspathic sand stone and clay beds.
3.	Middle to upper Jurassic	: Rajmahal Traps
4.	Upper Gondwanas (Middle Trias - Jurassic)	: Grit, ironstone, sandstone and shales with beds of fire clay and coal seams.
5.	Archaeans (Uncofmity)	: Granits (porphyritic and graphic), gnessies and schists with pegmatites and quartzy veins.

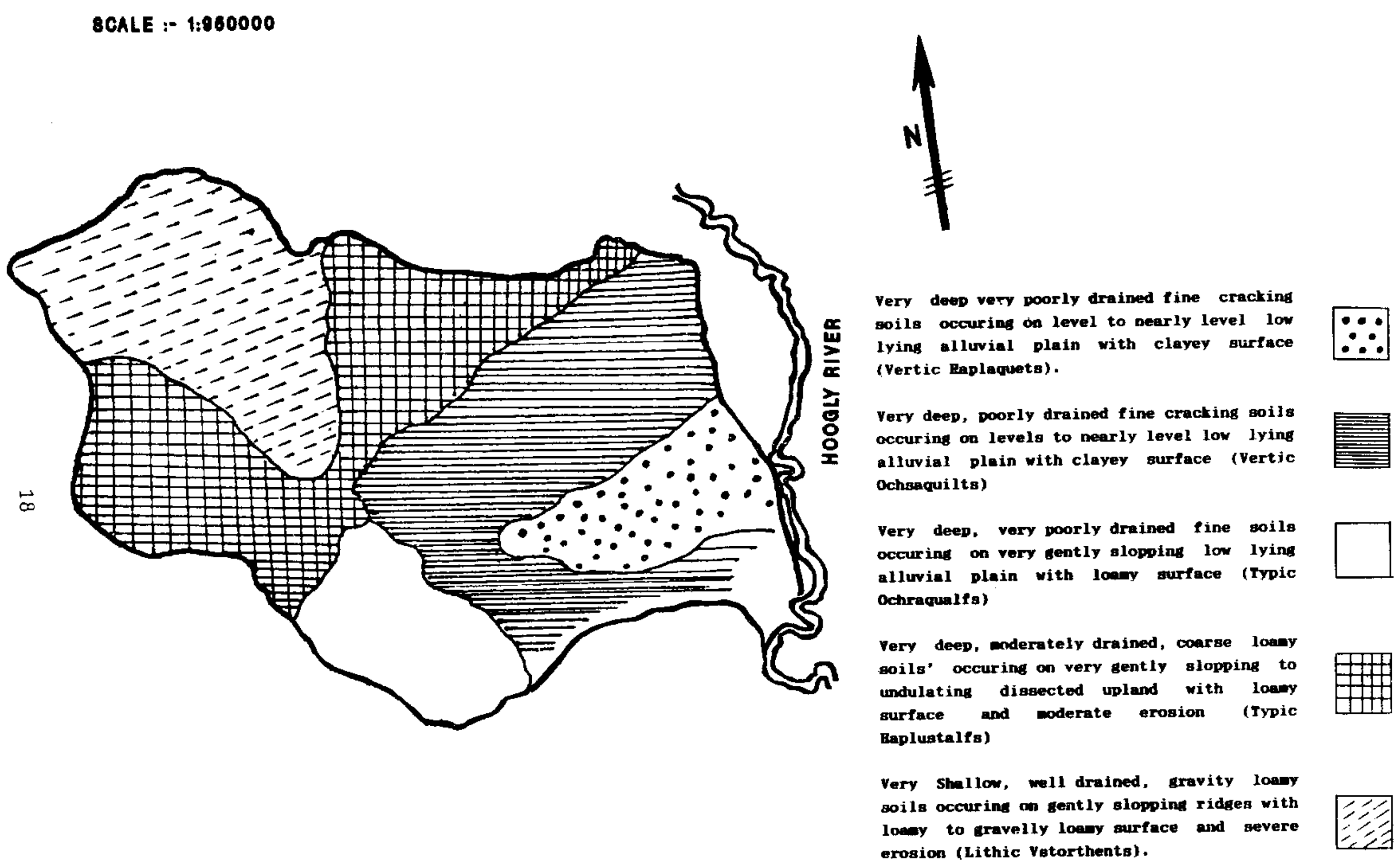

FIG 5.0 SOIL TYPE OF MAYURAKSHI SUB-BASIN

(d) Very deep, moderately drained, coarse loamy soils occurring on very gently slopping to undulating dissected upland with loamy surface and moderate erosion (Typic Haplustalls)

(e) Very deep, moderately drained, coarse loamy soils' occurring on very gently sloping to undulating dissected upland with loamy surface and moderate erosion (Ultic Plaeustalls).

(f) Shallow, somewhat excessively drained, gravelly loamy soils occurring on gently sloping subdued ridged with gravelly loamy surface and serve erosion (Lithic Ustochrepts).

2.1.9 Cropping system

The agriculture data **(Fig. 6)** are based mostly on Birbhum district which covers nearly 72 % of the command areas. However, the difference in remaining areas of the basin will be marginal, accept for the low lying areas bordering the Bhagirathi river which usually can not have the most popular crop. i.e. Aman or winter rice due to drainage problem. The cropping pattern and crop calendar usually followed in the command area are given in **Table 5.**

2.1.10 Data base

(a) Raingauge

At present there exist 47 rain gauge stations **(Fig.7)** in the basin. The IMD station is located at Suri, the others are State RF station. Suri and Sriniketan are also having hydrometeorological station **(Fig. 8)**.

(b) River discharge

The river discharge data **(Fig. 9)** are collected at Canada dam and Tilpara barrage daily at 3 hours interval during monsoon except during floods when data are collected on hourly basis. Apart from this, discharge in four main tributaries of Mayurakshi river are measured at the weir/ barrage paints across these streams.

Data are collected by project authorities with assistance of RRI. CWC in their hydrological net work program has established gauging stations in lower reaches of these four streams. Stream gauging of the outfall river of Mayurakshi system of rivers namely Bhagirathi is also done by CWC with same frequency of observations.

(c) Ground Water

The ground water data **(Fig. 10)** are collected by SWID and CGWB in their regular program of monitoring of ground water in

Table 5: The cropping pattern and crop calender usually followed in the command area are indicated below

Agro Climatic zone	Land situation	Cropping Patern & without irrigation			Crop Calender with irrigation		
		Prekharif 1st May-31st Oct.	Kharif 15th June-Dec. 30	Rabi Summer Oct.31st -April	Prekhrif 1st May-31 Oct.	Kharif 15th June-Dec.30	Rabi summer 1st Oct. -April
1	2	3	4	5	6	7	8
Lower Gangatic Plains Zone	A. High land 20 %	Follow	Aman	Fallow Rabi Pluses	Aus Paddy Maize/ Vegetables	Aman Paddy Vegetabl -es	Vegetables Wheat/Rabi Oilseeds Rabi pulses/Potato Sesamum/ groundnut
	B. Medium land (65%)	do	do	Fallow/ Rabi Pulses/ Rabi Oil seeds	do	do	do & Boro Paddy
	C. Low Land (15%)	do	do	Fallow/ Rabi Pulses	Aus Paddy	Aman Paddy	Boro Paddy summer moon sesamum

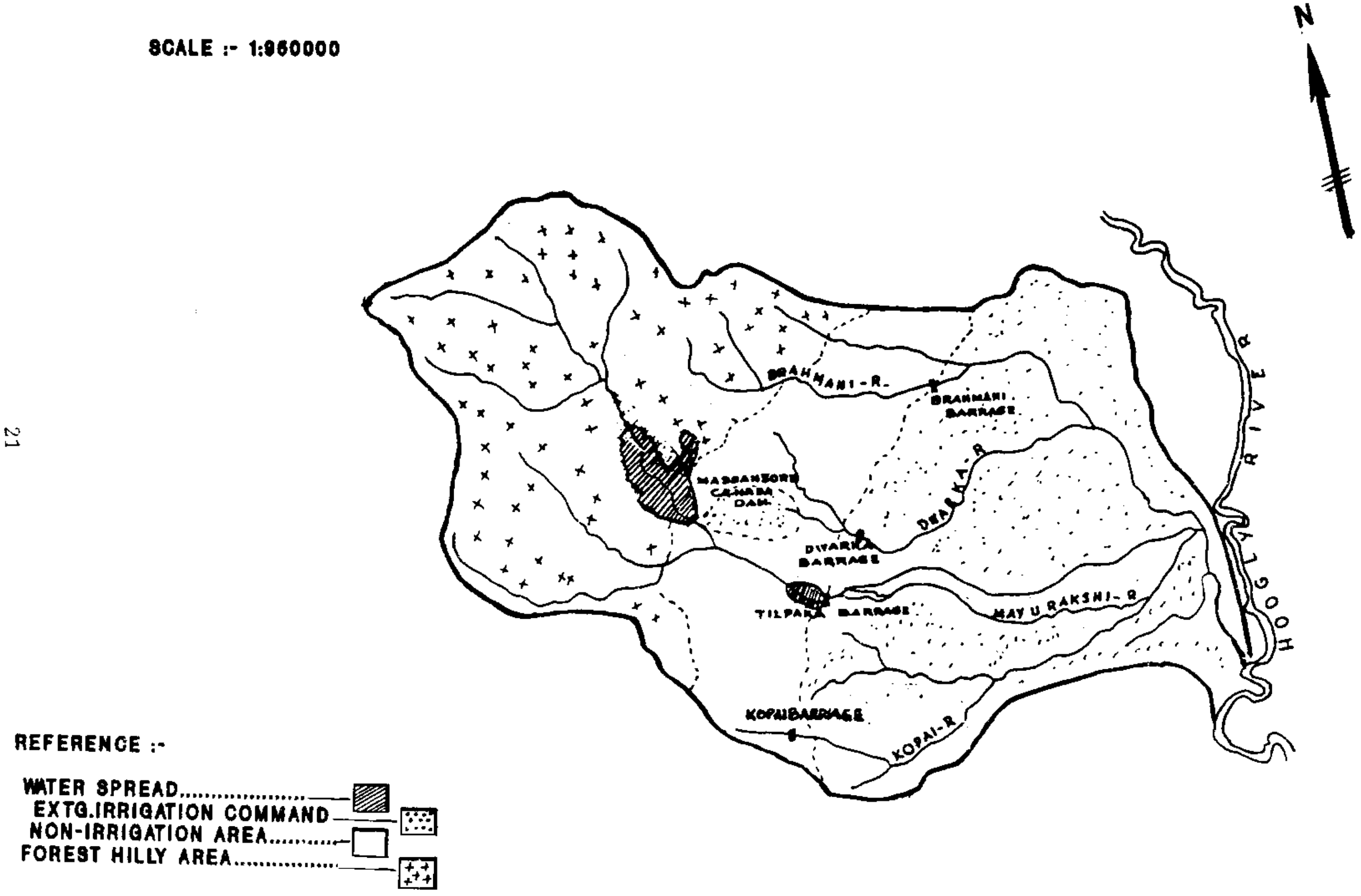

FIG 6.0 LAND USE IN MAYURAKSHI SUB-BASIN

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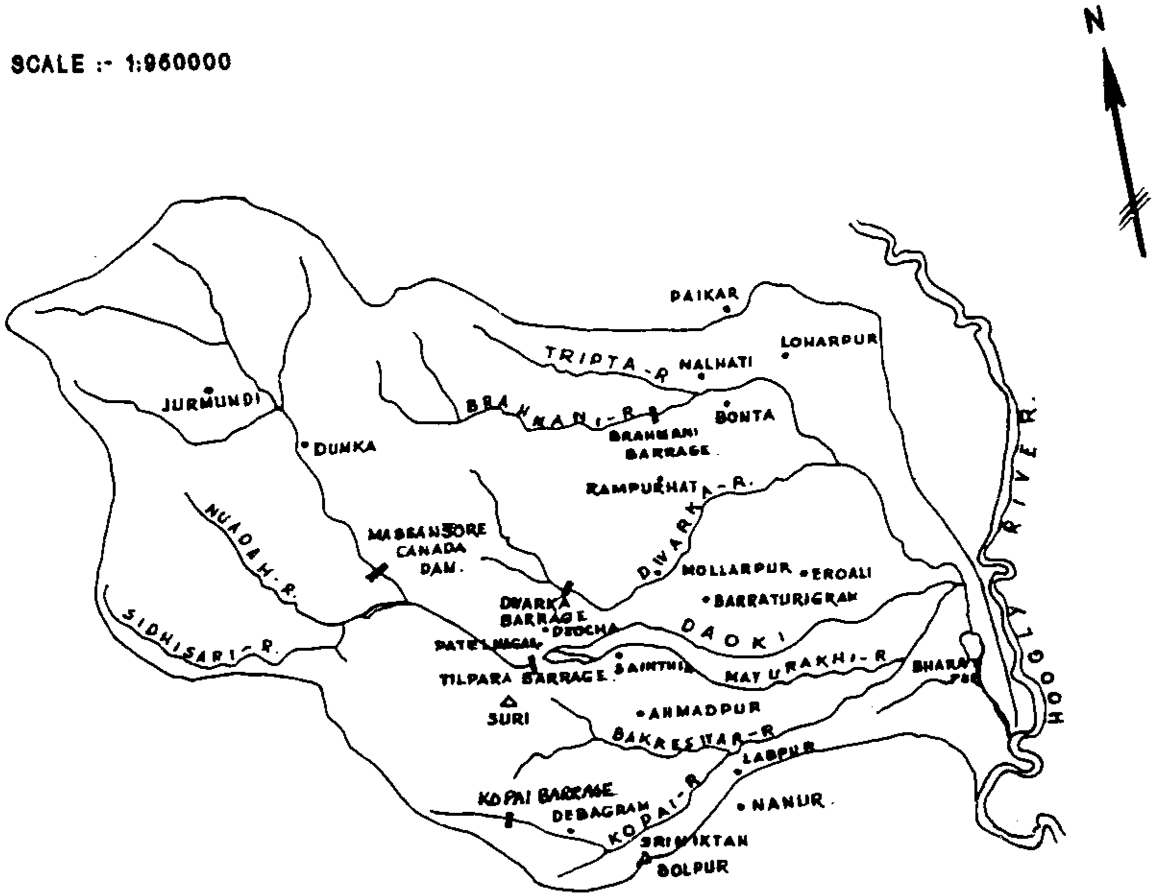

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FIG 7.0 RAINGAUGE STATIONS IN MAYURAKSHI SUB-BASIN

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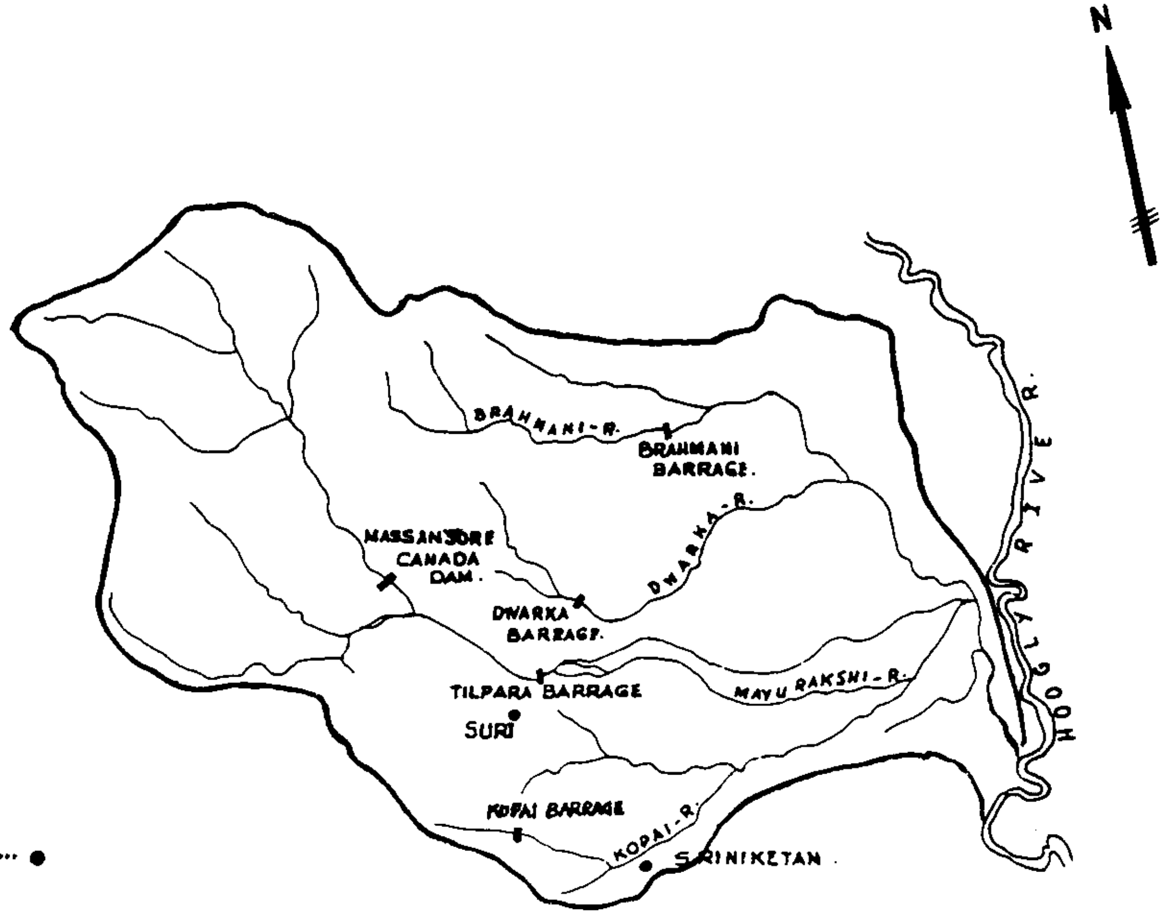

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FIG 8.0 HYDROMETEOROLOGICAL STATIONS IN MAYURAKSHI SUB-BASIN

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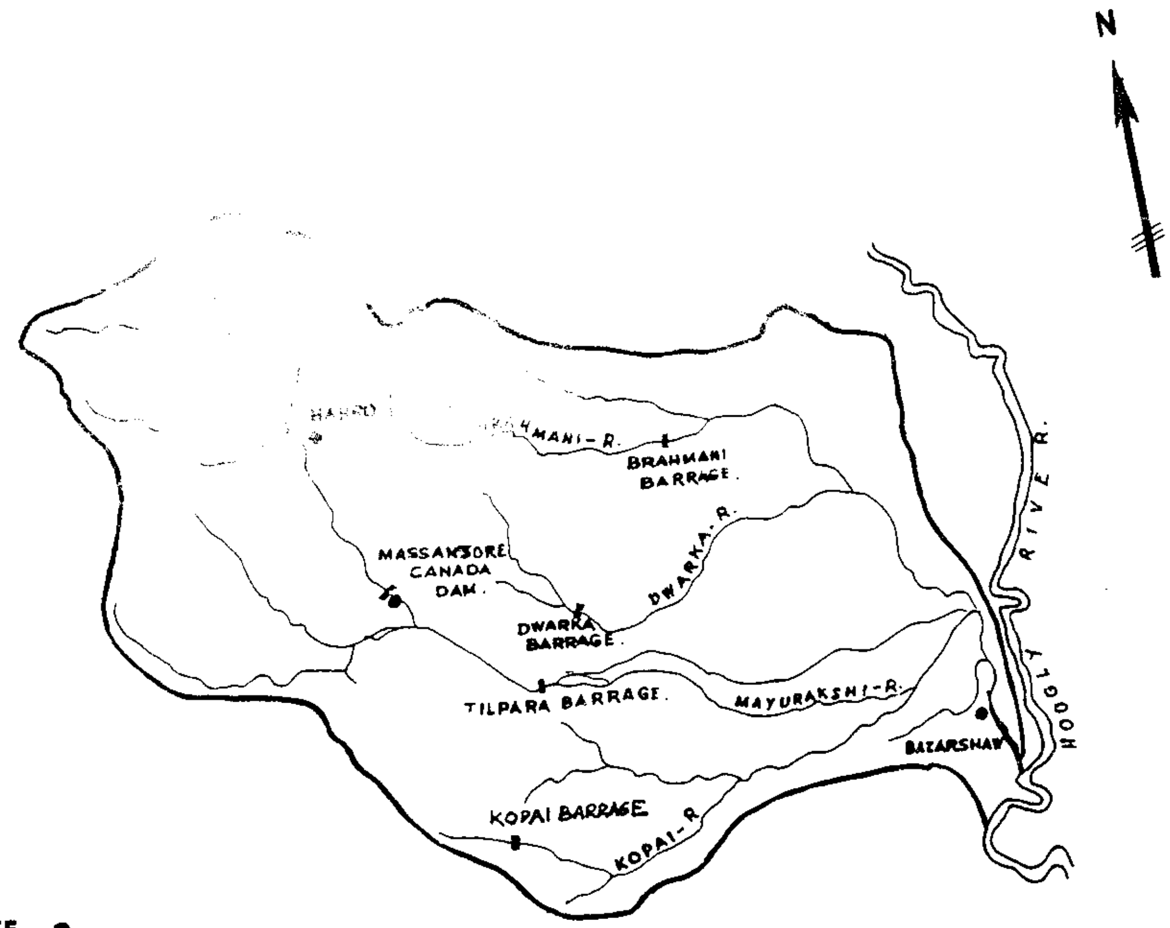

REFERENCE :-

GAUGE DISCHARGE SITE ●

FIG 9.0 GAUGE DISCHARGE SITES IN MAYURAKSHI SUB-BASIN

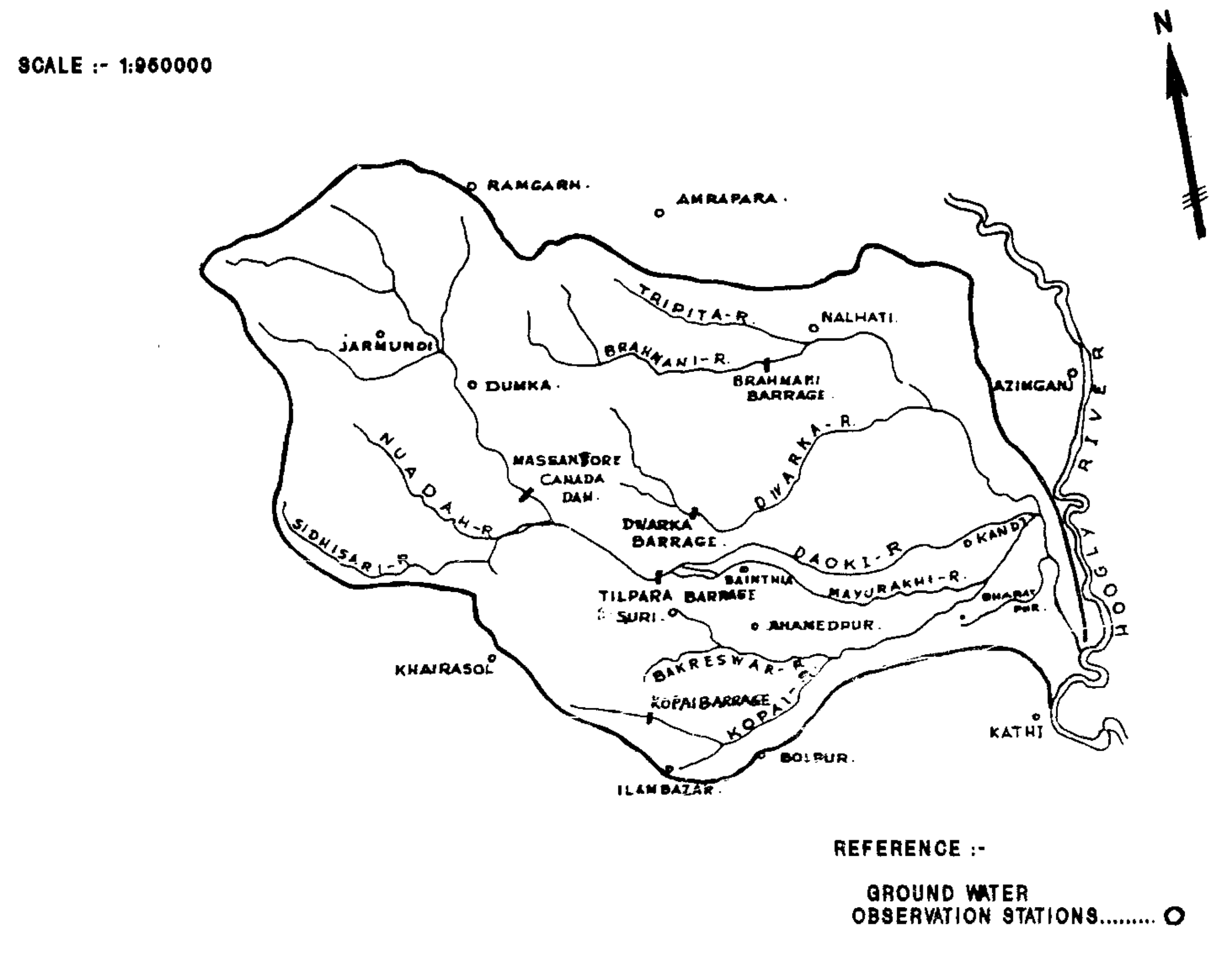

FIG 10.0 GROUND WATER LEVEL OBSERVATION WELLS
IN MAYURAKSHI SUB-BASIN

the basin. The observation is made four times in a year to monitor the ground water table in the basin area.

2.2 Massanjore Reservoir

Massanjore Reservoir formed by the construction of Canada Dam at Massanjore in Bihar is one of the major reservoir in India for which sedimentation surveys were planned by the Central Board of Irrigation and Power under the Fundament and Basic Research program financed by the Ministry of Irrigation and Power, Government of India.

Periodical sedimentation surveys provide the data on the extent of sediment deposition, trends of deposition and characteristics of sediment and water in the reservoir. The sedimentation surveys of Mayurakshi Reservoir conducted over a period of 19 years have indicated high acceleration rate of sedimentation of the reservoir.

2.2.1 Catchment area

The 1,860 sq. km (718 sq miles) catchment of the river above Mayurakshi Dam is leaf-shaped with no appreciable vegetal. The salient features of the reservoir are given in **Table 6** and the sub-basin area distribution are shown in **Table 7.**

2.2.2 Location

The Massanjore reservoir was created by constructing a stone masonry dam on the River Mayurakshi at Massanjore, situated in Bihar about 24.14 km (15 miles) from West Bengal boarder (Fig.11). The reservoir and the catchment area are situated in the district of Santhal Parganas in Bihar. The dam was completed in 1954 when the reservoir started filling. The project is meant for the irrigation and power, and it provides water for irrigation about 242810 ha (600,000 acres) of land, and has an irrigated hydro electric power capacity of 4000 KW.

Table 6: Salient features of the study area

1.	Catchment area	1859.61 sq. km (718 sq miles)
2.	Capacity of the reservoir (398 ft)	60796. 76 ha m (4,93,080 acre ft)
3.	(a) Dead storage capacity below R.L. 106.37 m (349 ft)	6788.37 ha.m 955, 190 acre ft.)
4.	Spillway crest elevation .	116.74 m (383 ft) (R.L.)
5.	Average annual rainfall over the catchment	132.1 cm (52 inches)
6.	Power generated at the dam	4000 kW
7.	Water spread of the reservoir at F.S.L. 121.31 m (398 ft) at D.S.L. 106.37 m (349 ft)	67.34 sq. km (26 sq. km) (12.95 sq. km) (5 sq. km)
8.	Backwater extent at F.S.L. 121.31 m (398 ft.) at D.S.L. 106.38 m (349 ft)	19 river miles upstream 8 river miles upstream.
9.	Spillway capacity at F.S.L. 121.31 m (398 ft)	3792.2 cumecs (1,34, 000 cumecs)
10.	Discharging capacity of 3 sluices at low level	217.3 cumecs 7680 cumecs
11.	Discharge capacity of 3 sluices at high level	173.9 cumecs (6144 cumecs)
12.	Penstock discharge	18.6 cumecs (660 cumecs)
13.	Sediment contributing catchment	= 0.1 - 7 (a) = 718 - 26 = 1792.3 sq km (629 sq miles)
14.	Capacity watershed ratio	339102.4 = 4,93,080/692 acre ft.cum/sq km (712.4 acre. ft/sq miles)
15.	Average annual inflow from 1955 to 1970 (15 years)	= 99,94,177/15 = 82152.1 ha m (6,66,278 acre-ft)
16.	Capacity	= inflow ratio = 4,93,080/6,66,278 = 0.74
17.	Anticipate trap efficiency (From Brune's curves)	= percent sediment trapped in the reservoir = 98%

Table 7: Area-wise distribution of sub-catchments

Sl.No.	Sub-catchment	Catchment area		Percentage of total catchment
		sq km	sq miles	
1	Matihara	360.01	139	19.4
2.	Dhobai	341.88	132	18.4
3.	Bhurbhuri	199.43	77	10.7
4.	Tepra	380.73	147	20.5
5.	Mayurakshi Left Bank	181.30	70	9.7
6.	Mayurakshi Right Bank	253.82	98	13.7
7.	Dauna	142.62	55	7.6
		1859.62	718	100.00

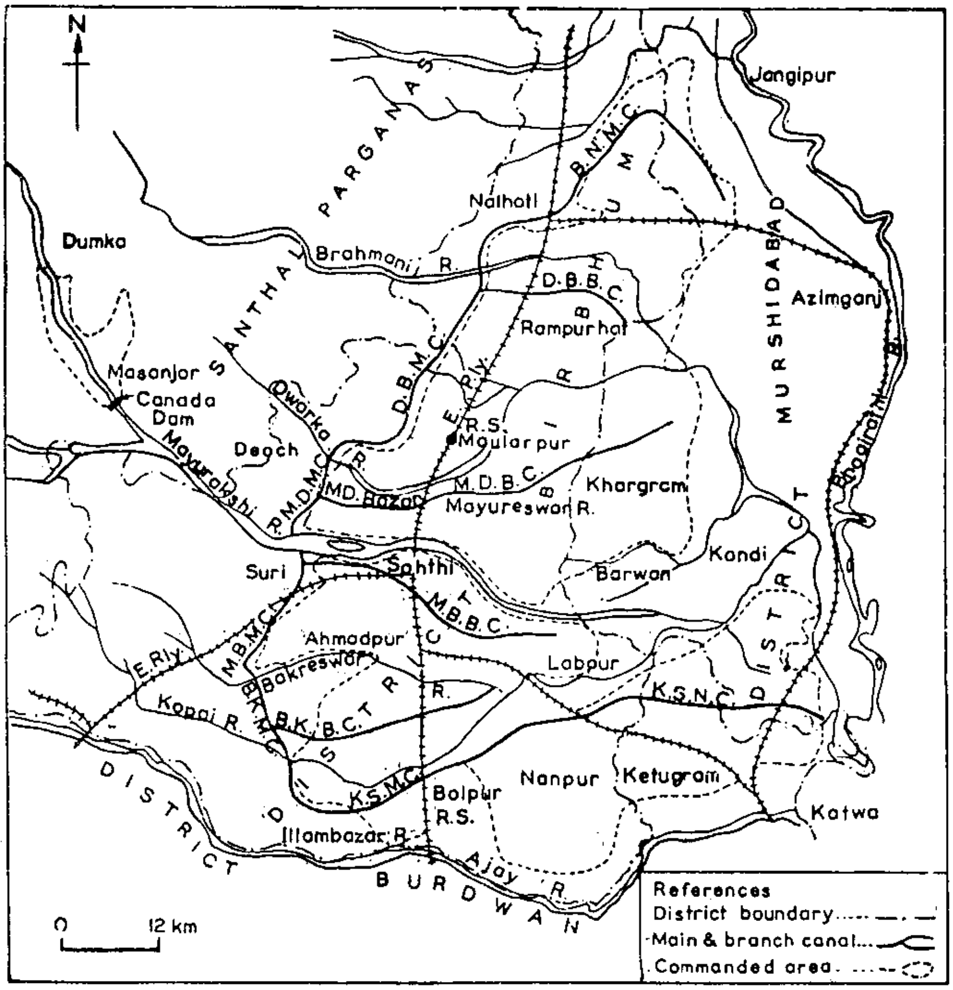

FIG 11a.0 MAYURAKSHI RESERVOIR PROJECT

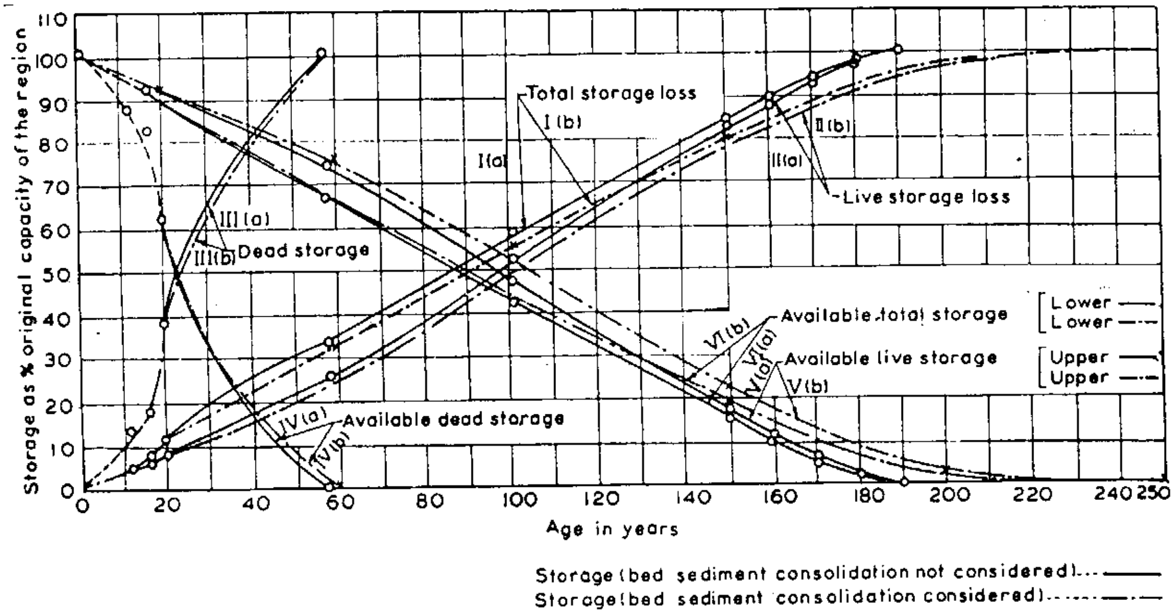

FIG 11b.0 MAYURAKSHI RESERVOIR

3.0 ABOUT THE MASSANJORE RESERVOIR PROJECT

3.1 The Project

3.1.1 Historical background

The origin of this project may be said to date back to the year 1928. Periodical failure of crops was therefore a common experience for the people of this area. There was, however, almost a complete crop failure in 1927 due to failure of rains and an acute famine condition came upon the people of this district in that year. A small irrigation scheme known as "Bakreswar Irrigation Scheme" was taken up by the Government of Bengal, as famine relief measure. It was, however, found that the irrigation facilities were to be extend to other areas also and the storage of the discharge of river Mayurakshi in a reservoir for its utilization in the fields at the time of need was keenly felt.

3.1.2 Necessity of the Project

The area, particularly in the portion of Birbhum district, was peculiarly subject to the danger of periodical crop failure due to deficit or untimely rain. Rice, the only principal crop was cultivated and grown during the monsoon, when the total rainfall was very much adequate. The monsoon rainfall did not however follow a rigid pattern. It is a fact that for paddy cultivation not only the total supply should be sufficient but also it should suit the periodical requirements of the plants. It had been the experience that in many years, even if everything went on well upto the stage of flowering of the crops, absence of a shower at that crucial period had resulted in distinction of a very large part of the crops. This is more particularly the case in respect of paddy cultivation than that of any other crops. Both volume and application are important. It means that the rainfall contribution should be adequate both in quantity and distribution.

3.1.3 Proposal

Most of the annual discharge of river Mayurakshi passes down the river in swift and sudden floods during the monsoon. Except in floods, the river does not carry any appreciable volume of water. A storage reservoir was, therefore, considered to be the only means to hold the water and supply it to the fields.

After considerable amount of investigation, a scheme providing a storage reservoir was taken up in the river Mayurakshi at Massanjore in Santhal Parganas, Dumka, Bihar where the river flow through a narrow valley. Survey, Investigation, Foundation exploration, Soil Survey etc. were carried out by different agencies and a complete scheme prepared and submitted to Govt. of Bengal. This scheme provided a storage reservoir at Massanjore, weir across river mayurakshi at Khatanga 5 miles above Suri and two main canals - one on the north bank and another on the south bank with distributory system to irrigate area in the districts of Birbhum, Murshidabad and a small portion of Bardhman.

Due to the intervention of the Second World War, the scheme was kept in abeyance. In 1945 the work of recasting the project was taken up as a post war development scheme. The net irrigable area has been assumed as against about 75% of the gross commanded area as against about 58 % assumed in the original project. The site of the Barrage across river Mayurakshi was selected at Tilpara, near Suri after gradual investigation of the scheme.

3.1.4 Purpose

The Mayurakshi Reservoir Project was considered as a solution for the optimum utilization of water resources by storing up the excess water which otherwise flowed down during the monsoon, causing havoc in the lower reaches. This ensured not only irrigation for growing crops but also cheap hydro electric power to ensure better standard of living for the people.

3.1.5 Objectives

The project consists of a masonry gravity dam built across the river Mayurakshi at Massanjore and a barrage at Tilpara near Suri across the same river with two main canals taking off from both the banks. There are there pick up barrages across the rivers Brahmani, Dwarka and Kopai and a weir across the river Bakreswar for utilization of the monsoon discharges of these rivulets.

It is a multipurpose project for providing irrigation facilities to an area of 5,60,000 acres during kharif and 50,000 acres during Rabi period in the districts of Birbhum, Murshidabad and Burdwan and generating a power of 4000 K.W. In addition to above, a total area of about 30,000 acres in the territory of Bihar State is supplied with irrigation water through a canal off taking directly from the dam at Massanjore.

Though the project is devoid of any flood control aspect, flood moderation to some extent is also affected by the operation system of the project.

3.1.6 Irrigation system

The main canals take off from left and right banks of the barrage on the river Mayurakshi at Tilpara. The canals are generally fed by storage dam at Massanjore. Water is also supplemented by uncontrolled catchment of the river Mayurakshi above Tilpara Barrage.

The main canal on the left bank is crossed by two rivulets namely the Dwarka and the Brahmani with pick up barrages on each. There are two branch canals on the left bank.

Similarly, on the right bank the main canal has been crossed, by two rivulets namely the Bankrewa and the Kopai with a pickup weir and a barrage respectively. There are two branch canals on this side also.

The distributory system as a whole is compounded of distributaries, minors, sub-minors, water courses and a good number of outlets throughout the command area of the project.

The irrigable area of the project within the state of West Bengal has been divided into blocks as details below :

Block A	.....	Pagha Brahmani Basin	74,000 acres
Block B	.....	Brahmani Dwarka Basin	77,000 acres
Block C	.....	Dwarka Mayurakshi Basin	1,33,750 "
Block D	.....	Mayurakshi Bakreswar Basin...	76,750 "
Block E	.....	Bakreswar Kopai Basin	45,000 "
Block F	.....	Kopai Ajoy Basin	1,53,500 "
		Total	5,60,000 acres

3.1.7 Land & soil characteristics of the command area

Land in the western part of the command area is undulating and slopping in nature, while in the eastern part of the same is flat. Gravelly and moorum soil of shallow depth are common in the western part while in the eastern part of the command area loamy soil is predominant.

Agriculturally speaking, the command area is principally a paddy growing tract. About 93 percent of the area is at present, under paddy in the kharif season. The soil in the village and on the banks of rivers and streams varies from loam to clay-loam, where luxuriant crops are raised with irrigation. The soil in the low lying areas is mostly clay and the principal crop transplanted is paddy. It is rarely possible to raise any rabi crop in such lands. Due to lack of moisture, a considerable part of the area becomes unfit for growing any winter crop. The system of canal irrigation has changed the character of cropping in more areas, both high and low.

3.1.8 Utilization of potential

The project aims at irrigating a net command area of

5,60,000 acres and 50,000 acres of land for kharif and Rabi crops respectively in the districts of Birbhum, Murshidabad and Burdwan. In addition to the above, a total area of about 30,000 acres in the territory of Bihar state is supplied with irrigation water through a canal taken of directly from the dam at Massanjore. The main works of the the period were completed in the year 1956. Since then, necessary extension & improvement works and modernization of the canal system have been taken up for better achievement. It is seen from the enclosed statement of the area irrigated that out of the ultimate target of 5,60,000 acres for irrigation in kharif season, an area of 5,48,763 acres has come to maximum achievement in 1981-82. This is about 95% of the ultimate target. When the target was fixed, the availability of culturable land was more than what it is now at present. Many lands have been utilized for the improvement of roads, construction of the building & other structures. As such, it is apprehended that the reduction of agricultural land in the Mayurakshi command area may stand as a bar in achieving the target potential for kharif. But it is seen that though 50,000 acres was the target for Rabi has been exceeded considerably. Rabi target is fixed from year to year depending upon availability of water in the storage reservoir of the dam after kharif irrigation.

There was no contemplation regarding Boro irrigation in the original project report but the same is actually being done intermittently in each year depending upon the availability of storage water as the cultivators are prone to raise Boro crops instead of the Rabi.

3.2 Project development analysis

The Mayurakshi Reservoir Project incorporates the water resource of four other parallel rivers which are intersected by the main canals through smaller barrages. So in this project the Mayurakshi river has the main role and the other four rivers and their basin have supplementary roles. Although there are no storage reservoirs on these channels viz Brahmani, Dwarka, Bakreswar and Kopai, the run of the river flow can be drawn into the main canal for utilization. Moreover, a proposal for construction of a storage dam on one of these rivers is at an advanced stage to supplement water requirement for proposed thermal power complexes near Bakreswar. In this connection, it may be added that there is a proposal for construction of a storage dam on the Sidheswari between the Massanjore dam and Tilpara barrage to augment the water resources of the system.

The target potential of the project was 2,26,624 ha for kharif and 20,234 ha for rabi. Against this, the actual area irrigated during 1989-90 kharif was 2,20,554 ha, during 1988-89 Rabi was 23,571 ha. During the same year (1988-89) irrigation was provided to 15624 ha of Boro (summer rice) cultivation.

Admittedly there was no provision in the project for Boro cultivation, but the present day development is HY varieties of paddy, boro cultivation has acquired prominence, although it requires more water and is not generally encouraged. Both Rabi and Boro cultivation are dependent on the residual storage in the reservoir in October and, when kharif irrigation requirements have been fulfilled and there is no further possibility of significant inflow into the reservoir before the next monsoon. Hence wide variation in the area under Rabi and Summer rice cultivation can not be avoided.

The objective of the project was irrigation and hydro-power only. Hydropower is generated in a small way (installed capacity 4 megawatt). The incidental benefit of flood control is obtained through operation. Water supply for domestic uses was never significant. Suri town gets its water supply from the Tilpara reservoir and demand for domestic requirement is on the rise. The local inhabitants withdraw water from canal for their domestic uses.

3.2.1 Sedimentation

In case of Mayurakshi provision had been made for a dead storage equivalent of a sediment volume of 380 m^3/year/sq km of effective catchment area (80 acr ft./ year 100 sq miles of effective catchment area) over a 100-year life period. However, this supposition was not proved correct. Firstly the assumption that the live storage will remain sacrosant during the life of the reservoir when only the dead storage was supposed to be filled up proved wrong. Both the dead storage and the live storage started filling up simultaneously right from the beginning although in case of the latter the rate was slower. Secondly, the rate of sedimentation was far higher than the design rate. The following statement would furnish an idea about the progressive sedimentation of the reservoir **(Table 8).**

3.2.2 Seepage Losses

A 1975 report of Government of West Bengal incorporated a statement furnishing the seepage and evaporation loss from the Mayurakshi canal system. It is reproduced below :

Month	Canal transmission losses in PC
July to November	10
December	15
January	20
February	20
March	25
April	25
May	30
June	10

Table 8: Soil erosion distribution in the study area

Sl. no.	Sub Catchment	% of total catchment	Area in sq. miles	Area under erosion :as % sub-catchment area: Ravine	Gully	Sheet to gully	Sheet	Total	Area under erosion in sq miles already various stage of erosion
1.	Machihara	19.4	139	0.096	6.640	12.700	1.010	20.446	28.5
2.	Dhobai	18.4	132	0.870	4.350	7.300	10.550	23.070	30.2
3.	Bhurbhuri	10.7	77	0.242	2.040	5.360	0.440	8.082	6.2
4.	Tepra	20.5	147	0.284	3.820	5.260	0.286	9.45	13.9
5.	Mayurakshi L.B.	9.7	70	0.468	2.570	3.440	0.784	7.262	5.2
6.	Mayurakshi	13.7	98	0.148	2.270	2.940	1.920	7.278	7.0
7.	Dauna	7.6	55	0.146	0.814	0.930	0.844	2.734	1.5
									92.5 sq. miles

3.2.3 Water logging/ salinity

So far there has not been any report regarding water logging a salinity.

3.2.4 Reservoir operation

Presently Mayurakshi project is operated as single reservoir project. However, after construction of one further reservoirs like Sidheswari-Noom bell the question of integrated operation of system of reservoirs will have to be separately considered keeping in view the provisions in 1978 bipartite agreement between Bihar and west Bengal. This aspect is not taken into account in the present context.

3.2.5 Ground water

The existing ground water draft (both potential and net present utilization) is indicated in Table . It may be seen that there is further scope for exploitation of ground water. The various type of existing ground water structures are also enumerated in Table.

The seasonal fluctuation data on ground water table in the command area are available for a period of 11 years from 1982 the 1992. Both spatial and temporal variation to some degree is observed.

(a) Performance

For improved performance some of the tube wells (mini deep and shallow) have been placed under the management of local Panchayet Authority on an experimental measure. This model has been functioning with encouraging prospects. The State Government has been seriously thinking for application of this model to other areas of ground water structures like deep tube well etc. The position of electric power in the State including the command area has improved since latter part of seventh plan period.

(b) Quality

The quality of ground water is fit for irrigation drinking and industrial purpose.

At present water utilization is solely on irrigation. Power is generated incidentally and drinking water is supplied in a small way. However, there is a proposal to supply 67 cusecs of water to the Bakreswar Thermal Power Station (BTS) partly (9 months) from the Tilpara barrage pond and partly (3 months) from the proposed Bakreswar reservoir. To meet the shortfall from the system due to this proposed supply to BTPS a proposal is under investigation to explore the possibility of ground water extraction in the command.

3.2.6 Flood Problem

Within Birbhum district, flood problem is not so relevant except for exceptional years when sustained intense rainfall in the catchment compels large releases from the dam. The problem gets compounded when severe rainfall occurs in the whole basin but the low lying areas mostly in Murshidabad district on west of the Bhagirathi suffers from serious drainage congestion wherever there is some release from the Mayurakshi coupled with the high ruling level of Bhagirathi. Such events usually occur once in five years. There is no flood storage in the reservoir and since Massanjore dam controls only about 15 % of the catchment area, it becomes hardly feasible to expect and substantial flood moderation from the project. However, in the flood prone areas, there are marginal embankments and as long as they can withstand the high levels, flood damages remain minimum. Presently there is no specific flood forecasting system, except the anticipated inflows into the reservoir. However when the dam releases water beyond 10,000 cusecs the concerned officials in Murshidabad district (particularly Kandi area lower down) are kept informed about impending floods.

3.2.7 Drought Management

The Birbhum district gazetteer (1975) reads, 'The old record, however, shows that formerly this districts had to suffer frequently from droughts and crop failure. However, after commissioning of the project there has been hardly any year when crop failure has occurred in the command area. Even in years when the rainfall in the command area had been substainally low, judicious distribution of stored water to meet critical crop water requirements has paid ample dividends.

3.2.8 Environmental Issue

No environmental problem has been reported. Rather there has been some improvements in the ponds and reservoir where migratory birds roost. Tourists are often attracted to the reservoir project areas throughout the year. Presently the States Government has been undertaking works pertaining to tourism promotion with success.

3.2.9 Problems and shortcomings

In the initial stage it was considered adequate if water was brought to the field. However, with the years, technological innovations have sharpended the aspects of water management and hence some shortcoming need be fulfilled to meet the present day requirement of water management. These are indicated below :

(a) Comprehensive water distribution network down to the field channel are needed.

(b) Seepage loss particularly during the dry months is substantial. So lining of canals particularly in the highly permeable zones is specially needed.

(c) Maintenance of canals and structures have suffered mostly due to lack of funds.

(d) Improvement of existing communication system to regulate and control the distribution system is absolutely essential.

3.3 Report of Different Committee

In 1975 Department of erstwhile Agriculture and Community Development (Agrl.), Government of West Bengal had appointed a Review Committee to undertake a survey of the command area of Kangasabati, Mayurakshi and D V canal system with a view to identify the physical constraints that stood in the way of effective and optimum utilization of irrigation water.

The recommendations were (1) watershed management (2) lining of canals (3) construction or water courses and field channels (4) better communication in the distribution system (5) conjunctive use (6) consolidation of land (7) improved crop planning (8) ensuring adequate inputs (9) partial mechanization of farming practices (10) setting up of village committees of outlets for extension work (11) modification of legislation as considered necessary.

Some of these recommendation like lining in selected reaches, village level extension works in an organized way (KPA) and some work in road communication have been fulfilled to some extent.

A central team visited the project in 1975 in connection with maximizing the benefits from Mayurakshi project and the team suggested that a system study be made for this project to achieve maximum benefits from the total water resources i.e. considering rainfall, surface water and ground water.

3.4 Seventh Plan Perspective

There is proposal to take up the work 'Modernization of the Mayurakshi Reservoir Project' during Eighth Plan Period. Some provision has been in the plan document for special repairs to existing irrigation system of Mayurakshi Project. A total provision of Rs. 53 million has been kept for this purpose.

4.0 STATUS OF SEDIMENTATION PROBLEM IN MAYURAKSHI RESERVOIR

4.1 The Sedimentation Survey

One of the important problems in the maintenance of Storage Reservoir is the loss of its capacity due to silt borne by the incoming stream. Decrease of storage capacity prevents the reservoir from supplying the services for which it was designed thus disturbing the economic life of the community which it serves. Sedimentation survey of reservoir comprises.

(1) The land survey of the reservoir region not under water.

(2) The hydrographic survey of the reservoir bed under water.

(3) (a) Collection of suspended sediment samples and bed samples to determine the concentration and characteristics of suspended sediment and bed material and to determine the density of the sediment deposits in the reservoir.

(b) Observation of characteristics of reservoir water such as temperature of various depths, salinity, pH value etc.,

(c) Studies on the existence of density currents.

In India dams were designed providing dead storage on the assumption of 92511 to 111013 cu m per year of silting of reservoir for 259 sq. km of catchment area.

Dr. Khosla's studies on sedimentation of number of reservoirs in the country and the world revealed that the upper limit of silting is 4.5 ha m/year per 100 sq. km (90 acre ft. per year/100 sq. miles) of catchment area and that the rate of sedimentation decrease with age as the lake bed sediment deposits get stabilized.

But trends of silting observed in India during the last 20 years do not support this view. In fact silting 2 to 4 times greater than the upper limit mentioned above has been reported in case of Panchet, Maithon and Tungabhadra Reservoirs. Detailed sediment surveys are therefore under taken to collect the factual data on silting of reservoirs.

4.1.1 Factors affecting reservoir sedimentation

No two reservoirs behave in a like manner in the context of sedimentation. Very high, normal and very low rates of sedimentation were observed in reservoirs. Some of the natural factors affecting sediment yield of watersheds and reservoirs sedimentation are as follows:

(i) Watershed area : The larger the watershed area the less the sediment inflows into the reservoir. The larger the catchment, the greater the scope for the river to shed considerable part of its sediment load on river bed and river margins all along its course well ahead of its entry into the reservoir.

(ii) Topography of Watershed : The greater the undulating and sloping nature of considerable portion of the catchment, the greater the soil erosion and sediment transport.

(iii) Density of Vegetative Cover : The greater the aerial extent and density of vegetative cover in the watershed, the less the sediment yield. Cultivated watersheds have high rates of sediment yield. Watershed with adequate vegetative cover have low rates of sediment yield.

(iv) Sediment Transport Capacity of River and its Tributaries : the steeper the bed slopes of river and its tributaries, the greater the flow-velocities, sediment transport capacity and sediment deposition in reservoirs.

(v) Intensity of Rainfall : The greater the intensity of rainfall in the denuded/open catchment in particular, the greater the soil erosion and sediment yield.

(vi) Nature of Soil in the Watershed : The greater the susceptibility of the watershed soils to erosion, the higher the sediment yield.

(vii) Trap Effective of Reservoir : The grater the trap efficiency of the reservoir the higher the rate to sediment deposition in the reservoir.

4.1.2 The silting effects

(1) Diminution in storage capacity adversely affecting the public utilities for which the project was designed.

(2) Loss of storage by increased evaporation losses on larger surface areas for equal storage relative to those available prior to commencement of accumulation of sediment.

(3) Loss of storage by increased transpiration losses due to vegetal growth on deltas formed at the head of the reservoir.

(4) Inundation of public property in the valley consequent of aggradation of the river and delta formation.

(5) Damage or failure of spillways consequent to discharge in

excess of design flood over spillways resulting from loss of flood absorption capacity.

If the dead storage provision is inadequate, and the observed rate of silting is much higher than anticipated, the life of the reservoir will be radically reduced. To help realistic estimation of the life of the reservoirs of the reservoir to the possible extent, systematic sedimentation surveys and collection of sediment data are essential.

The knowledge of the trends in silting of reservoirs will also help in the formulation of design assumptions for provision of dead storage in reservoirs.

4.2 Assessment of Mayurakshi River and Reservoir

The catchment area of Mayurakshi is 30 percent of that of Lower Bhavani, 29.5 percent of Maithon 16.8 percent of Panchet Hill, 8.9 percent of Matatila, 6.5 percent of Tungabhadra and 3.3 percent of Bhakra reservoirs. 43 percent of its river length lies within the reservoir waterspread area. With bed grades of the river and its tributaries ranging and from 1/100 to 1/250 respectively there is no scope for appreciable sediment shedding ahead of reservoir waterspread. Hardly 6 percent the watershed has forest coverage. Nearly 20 percent of the watershed comprises sloping cultivated lands. 50 percent of the total is susceptible for erosion, its soils being of a highly erodible character. The steep bed grades of river and its tributaries are indicative of high flow-velocities and high sediment-transport capacity of the channels. The intensity of rainfall in the catchment is reportedly high. As inferred from the Burne's curves, trap efficiency varies between 97 to 87 percent during the economic or effective life of the reservoir. With an average trap efficiency of 92 percent during the effective life and the reservoir retaining major portion of the floods, with relatively inappreciable releases during the flood season, almost all the sediment entering the reservoir gets deposited therein.

Thus Mayurakshi reservoir is very unfavorably situated from its sedimentation point of view and high rate of its sedimentation is a consequence which has to be accepted and remedied to the possible extent by striving to control as many adverse factor as possible. The salient reservoir data are shown in **Table 9** and capacity-sediment data are given in **Table 10**.

Measures to bring down the rate of reservoir sedimentation by arresting increase in the quantum of sediment yield from the watershed and its reduction to the extent possible.

Since not much not much can be done to lower the trap efficiency of the reservoir, the only course open to decrease the rate of reservoir sedimentation is to adopt effective soil

Table 9: Salient reservoir data

Spillway crest level	=EL 398.00 (in ft)/121.3 m
Dead storage level	=EL 349.00 (in.ft)/106.4 m
Capacity-inflow ratio	= 0.71
Trap efficiency	= 97 % (from Brune's curves)
Max. inflow (1971-72)	= 19,22,496 acre-ft or 23.70×10^8 m^3
Min. inflow (1955-76)	= 3,69,515 acre-ft or 4.6×10^8 m^3
Catchment area	= 718 sq. miles = 1860 sq. km
Effective catchment area	= 692 sq miles = 1792 sq km
Dead storage capacity (1954)	= 55,200 acre-ft = 0.681×10^8 m^3
Live storage capacity (1954)	= 4,93,100 acre-ft
Total storage capacity (1954)	= 4,93,100 acre-ft
Max. reservoir water-level (1954-73)	= 398.00 (in ft)/121.3 m
Min. reservoir level (1954-73)	= 334.50 (in ft)/102.0 m
Spillway functioned in 1956-57 & 1959-60.	

Table 10: Capacity-sediment data

Survey period	1964-65	1969-70	1972-73
Age of reservoir	11 years(1954-70)	16 years(1954-70)	19 years (1954-73)
Total storage	4,71,400 acre-ft or 5.817 x 10^8 m^3	4,54,800 acre-ft or 5.612 x 10^8 m^3	4,37,800 acre-ft or 5.403 x 10^8 m^3
Dead storage	48,000 acre-ft or 0.593 x 10^8 m^3	45,400 acre-ft or 0.560 x 10^8 m^3	34,100 acre-ft or 0.421 x 10^8 m^3
Live storage	4,23,400 acre-ft or 5.22 x 10^8 m^3	4,09,400 acre-ft or 5.052 x 10^8 m^3	4,03,700 acre-ft or 4.982 x 10^8 m^3
Total storage loss	21,700 acre-ft or 0.267 x 10^8 m^3	38,300 acre-ft or 0.472 x 10^8 m^3	55,300 acre-ft or 0.682 x 10^8 m^3
Dead storage loss	7,200 acre-ft or 0.088 x 10^8 m^3	9,800 acre-ft or 0.121 x 10^8 m^3	21,100 acre-ft or 0.260 x 10^8 m^3
Live storage loss	14,500 acre-ft or 0.179 x 10^8 m^3	28,500 acre-ft or 0.351 m^3	34,200 acre-ft or 0.422 m^3
Sedimentation index in acre-ft/year/100 sq. miles in m^3 /year/km^2	285/1358	346/1648	421/2005

conservation measures in the watershed in order down the quantum of sediment yield therefrom.

4.2.1 Discharge and Suspended Sediment Observation - Pre-dam and Post-dam Periods

Suspended sediment observations have been conducted at the dam site during the years 1946-53. The data shows that the catchment is draining a silt load of 5.6 ha m/ 100 sq. km (112 acre ft. annually per 100 sq. miles) of the catchment, assuming a density of sediment at 1.17 gm/cu m (73 lbs/cft) **(Table 11 and 12)**. The data observed during the post-dam periods show a silt load of about 3.75 ha m/100 sq. km (75 acre ft. annually per 100 sq. miles) of catchment **(Table 13 and 14)**.

The pre-dam conditions show an average yield of 900.44 cu m (0.70 million acre ft.) annually while the average for the post-dam construction are about 826.43 cu m (0.67 million acre ft.). Table 14 shows the maximum and minimum levels attained by the reservoir during the period of operation (1955-70).

4.2.2 First Sedimentary Survey(1964- 65)

The sedimentation survey of Mayurakshi Reservoir was taken up in December, 1964 and completed by April, 1965. The exposed areas areas were covered by land survey and areas under water covered by hydrographic survey **(Table 15)**.

Survey Procedure

There are altogether 95 cross-section or Ranges marked permanently by concrete pillars. These cross section pillars were located by theodolite survey starting from a conspicuous point of the dam. When the survey was taken up, the length of water spread was quite large in a number of cross-section. Consequently, to obtain adequate accuracy in measuring distances some intermediate targets were necessary, since the accuracy of the range finder were necessary, since the accuracy of the range finder decrease as the distance i crease. These intermediate target were placed at 1/3 point of the water spread along a cross-section line and were properly anchored so that they could not be drifted by wind. the floating target consisted of a hollow air-tight pure aluminum tube, at the bottom of which there was a suspension device through which passed a 15.2 cm (1/2 in.) diameter rope carrying an anchor 13.61 kg (30 lbs.) at one end and a weight-can consisting of 3 to 4 nos. mild steel plates of total weight 4.54-5.44 kg (10-12 lbs) at the other end. First of all a boat was brought in the desired position and the 13.61 kg (30 lb.) anchor was lowered with the 15.2 cm. (1/2 in.) diameter rope till it reached the bottom. The other end of the rope was then passed through the slot at the bottom of the aluminum tube and the weight-can was next tied at this end of the rope. After this the

TABLE 12: Post-dam suspended sediment data on Mayurakshi and its tributaries

Sl. No.	Sub-catchment	Area in sq. miles	Sediment in flow per sq. miles in cumecs	Load sediment in acre ft.
1	2	3	4	5
1.	Matahira	139	1.0546	146.59
2.	Dhobai	132	1.0494	138.52
3.	Bhurbhuri	77	0.6525	50.24
4.	Tepra	147	0.5942	87.35
5.	Mayurakshi L.B.	70	0.6369	44.58
6.	Mayurakshi R.B.	98	0.3707	36.33
7.	Dauna	55	0.2256	12.41

TABLE 13: Predam inflow data of Mayurakshi river at Massanjore

Year	Annual monsoon discharge volume at Massanjor in acre ft (June to October)
1946	732000
1947	606000
1948	568000
1949	975000
1950	915000
1951	475000
1952	726000
1953	837000

TABLE 14: Post-dam inflow/outflow data and rainfall data

Post-dam	Annual rainfall in inches	Total inflow into the reservoir (June May) in acre	Total outflow from the reservoir (June-May) in acre ft	Maximum Reservoir elevation		Minimum Reservoir elevation	
				Date	Elevation	Date	Elevation
1	2	3	4	5	6	7	8
1954-55	-	-	-	-	-	-	-
1955-56	-	369515	208975	2.9.55	382.00	5.7.55	334.50
1956-57	-	1172462	1062802	26.9.56	398.50	1.6.56	372.04
1957-58	29.97	413776	630476	17.9.57	392.60	31.5.58	354.50
1958-59	39.74	630541	778341	20.8.58	389.85	23.7.58	249.28
1959-60	88.51	1353644	1196144	2.10.59	398.63	27.7.59	377.05
1960-61	45.68	506141	657410	18.9.60	306.00	31.5.61	377.80
1961-62	59.83	685523	703523	7.10.61	301.60	2.8.61	361.82
1962-63	52.46	561172	693932	31.8.62	382.20	24.7.62	343.75
1963-64	57.24	602234	546974	13.11.63	379.07	1.9.73	146.90
1964-65	50.68	555069	565269	13.9.64	385.25	9.7.64	162.50
1965-66	39.84	577586	607558	12.9.65	380.20	28.7.65	350.25
1966-67	48.86	416520	450760	26.7.66	344.00	18.9.66	381.00
1967-68	38.65	449985	414863	2.10.67	385.00	30.7.67	344.70
1968-69	66.81	1007197	911017	25.5.68	395.62	1.6.68	360.10
1969-70	39.97	8575512	760002	6.10.69	397.40	8.8.69	368.40

Table 15: Capacity and sediment data(1964-65)

Region	Elevation	Depth from F.R.L (d) in ft	Segment-wise depths as % of total depth	Cumulative depth from F.R.S. as % of total depth	Comulative storage capacity as per original pre-dam survey in (1954-65)	Cumulative capacity by capacity as per 1964-65 survey in acre ft	Loss of storage capacity silting acre ft in 11 years	Segment-wise sediment deposit in acre ft: in acre ft	Segment-wise sediment deposit in acre ft: as % of total deposit	Sediment upto as % of total deposit
1	2	3	4	5	6	7	8	9	10	11
	398	-	-	-	493080	471360	21720	-	-	-
	390	8	7.05	7.05	373050	355950	16100	5620	25.86	25.86
Live	380	18	8.85	7.05	252470	240020	12450	3650	16.80	42.66
storage	370	28	8.85	24.75	163160	152710	10450	2000	9.25	51.91
region	360	38	8.85	33.60	99810	91030	8780	1670	7.64	54.55
	350	48	8.85	42.45	57840	50600	7240	1540	7.09	66.64
	349	49	0.01	42.46	55190	48016	7174	66	0.30	66.94
	340	58	8.84	51.30	31300	25460	5840	1400	6.44	73.08
	330	68	8.85	60.15	16240	11100	5140	700	3.22	76.30
Dead	320	78	8.35	69.00	8500	4270	4230	910		
storage	310	88	8.85	77.85	4300	1150	3150	1080	4.97	85.50
region	300	98	8.85	86.70	1700	70	1630	1520	7.00	92.50
	285	113	13.30	100.00	-	-	-	1630	7.50	100.00

weight-can was lowered gradually till the tube came to a vertical position. The tube could not change its position as it was anchored. Normally 1/4 th of the tube length was exposed in air. But, if desired, the exposed length might be increased by suitable changing the weights of the weight-can. The tube was painted with aluminum paints for visibility.

These intermediate targets when placed along a cross-section divided the length of water spread into 3 portions. The sounding work started from one bank to the first intermediate target and from the first intermediate target to the second intermediate target and lastly from the second intermediate target to the other bank of the reservoir.

Out of 95 cross-section, 35 cross-sections on water spread were taken by M.S. 26 Kelvin Hughes Echo-sounder fitted with an outboard oscillator. The echosounder was fitted in a speed boat. This boat had a shallow draft and could go upto the shore. The position of boat was located by a Barr and Stroud Range Finder. From the water-level at the time of the survey to full supply level (i.e 398.00) cross-section was taken by leveling on the same day. Disc type targets with 1.2 m (4 ft.) diameter disc. fitted on a 427 m (14 ft.) high and 5.1 cm (2 in.) diameter hollow steel tube were used in the survey. The targets could be seen with unaided eye clearly from a distance of even 1.6 km (1 mile). Two targets were placed on either bank along the cross-section line when soundings were taken.

12 cross-sections were taken by lead line sounding as depth of water was small in these sections. The position of the boat was however located by the Range Finder. Remaining 48 cross-section were taken by leveling and chaining because at the time of survey they were on the dry portion of the reservoir.

Storage Capacity and the Results

From the ground survey data, a 10.2 cm to 1.6 km (4" = 1 miles) map his been prepared. All the 95 cross sections have been plotted in 152.4 m to 2.54 cm (500 ft. to an inch) horizontal scale and 3 m to 2.54 cm (10 ft. to an inch) vertical scale. The position of 3 m (10 ft. interval contour points is found out from these plotted cross-sections. These points are then transferred to the 10.2 cm = 1.61 km. (4" = 1 miles) map and contours are drawn.

The areas bounded by different contours were planimetered carefully and entered in **Table 16** The pre-dam areas at different contours were also shown in this table. Capacity of the reservoir was calculated by cone formula.

$$V = H*(A_1 + A_2 + \sqrt{A_1 A_2})/3$$

Table 16: Reservoir storage loss by silting during the period 1954-65

Region	Original capacity in acre ft.	Capacity in acre ft as per 1964-65 survey	Loss in capacity in acre ft in 11 years	% loss of storage capacity
Dead storage E.L. 349 and below	55,190	48,016	7,174	13.0
Live Storage E.L. 398- 349	4,37,890	4,23,344	14,546	3.3
Total Storage 398-285	4,93,080	4,71,360	21,720	4.4

Where,

V = volume in ha m (acre ft.)
H = contour interval in m (ft.)

A_1, A_2 areas of two successive contours in acres.

It is observed that capacity is being lost throughout the range of reservoir elevations. The computation shows that the reservoir is receiving an annual silt load of 14.25 ha m/100 sq. km (285 acre ft. per 100 sq. miles) of catchment. Table 16 shows the loss of capacity in different zones of the Reservoir.

Reservoir Bed Sampling

Sampling of deposited sediment under water is necessary for ascertaining the correct density of the sediments. Soil samples under water were collected with phleger type corer. This instrument was procured from M/s General Engineering & Scientific Co., Waltair. It is very convenient to work with this instrument as no hoisting arrangement is necessary to drop this instrument from the boat. The instrument is dropped from a boat whose position is located from a fixed point. Due to a concentrated heavy load over the cutter it enetrates into the soil and soil samples enter into another plastic tube fitted inside and cutter. Exposed reservoir deposits were however collected with ordinary core cutter.

Deposited Sediment, its Density and Granulometric Composition

Reservoir bed samples were collected from the deepest points at different cross-sections upto the uppermost point of the reservoir. There were altogether 263 Nos. of samples collected, out of which 56 Nos. were collected from the dead storage zone and remaining 207 samples were collected from the live storage region. The average density of the samples collected from the dead storage region worked out to be 800.9 kg/cu m (50 lb./cft) and that in the live storage zone worked out to be (1169.3 kg/cu m 73 lb./cft).

Studies on Density Current

Density current is of much interest of Hydraulic Engineers because of the possibilities the such currents may be discharged through the dam. Consequent on which the rate of silting of reservoirs may slow down to that extent to trace density current in Mayurakshi Reservoir prototype observations were taken for four months from July 1965 to October 1965. Seven stations were selected and they were located on C.S 2,5,8, A_3, A_{10}, D_1 D_{11}. As level of water was not high only these seven stations could be selected. Water samples were collected from these stations at 5 different depths. (i.e surface, 0.2 D, 0.4D, 0.6D, and 0.8D.

However, where the difference of depth between bed and 0.8 D was more than 11 ft., samples from 0.9 D were also taken, Reservoir bed deposits were also collected from these stations. The observation were taken from Motor launch "Mayurakshi". Water samples were collected by Nansen Reversible bottle sampler. The temperature of these water samples was measured on the deck and thermometers having a minimum reading of 0.5°C immediately after samples were taken out from Nansen Reversing bottle sample. This procedure had to be adopted for want of a suitable electronic temperature recorder. Two sets of observations were taken when there was inflow and outflow from the reservoir. 278 Nos. of water samples and a second set of 57 Nos. of bed samples were collected and these samples were determinations. Out of 57 samples collected 42 Nos. were from the dead storage zone and the remaining 15 Nos. were from live storage zone. The average density of samples collected from dead storage zone and live storage zone works out to be 880 and 1233.4 kg/cu m (55 and 77 lb./cft) respectively. The results of mechanical analysis of these 57 samples which were all collected with 8.9.3 (5-6 miles) of the reservoir from the dam showed that there was practically no deposition of gravel. The percentage of sand was also quite low. But the deposition of silt and clay was high. There was practically no variation in pH. value. salinity and specific gravity over the depth. However, there was a small variation of water temperature with depth. The variation was of the order of 0.5°C - 3.0 °C. The position of different outlets at different elevations are also shown. The quantity of water flowing into reservoir and water passing out through these outlets are also shown. Now the value of suspended load for this set of observations at different depths at these stations are plotted and points of equal suspended load are joined. These equal suspended load lines density is due to variation of suspended load contents.

These are no specific indications of the existence of density currents.

4.2.3 Second Sedimentation Survey(1969-70)

After a period of 5 years, second sedimentation survey was undertaken to ascertain the extent of silting of the reservoir during the period 1965-70. The survey, commenced in December 1969 and was completed in March 1970.

<u>Storage Capacity as per 1969-70 Survey</u>

Capacity of the reservoir as per 1969-70 survey stood at 56078.1 ha m (4,54,810 acre ft.) as against 58,118.69 ha m (4,71,360 acre ft.) and 60,796.76 ha m (4,93,080 acre ft.) capacity as per 1964-65 survey and predam original survey (1954) respectively. Accordingly the loss of storage by silting in a period of 16 years (1954-70) was 4718.69 ha m (38,270 acre ft.)

and that in 5 years (1965-70) was 4718.69 ha m (38,270 acre ft.) and that in 5 year (1965-70) was 2040 ha m (16,550 acre ft.) respectively. This indicated that sediment equivalent to 3.35 percent the total original predam capacity was trapped in the reservoir during the period 1965-70 and sediment equivalent to 7.75 percent of the predam capacity was deposited in the reservoir during the 16 year period 1954-70. The average rate of sedimentation for the years (1954-70) works out to be 17.3 ha m/100 sq. km (346 acre ft. annually per 100 sq. miles) while it was 14.25 ha m/100 sq. km (285 acre ft. per 100 sq. miles) as miles) as shown by the first sedimentation survey.

Reservoir capacity and sediment data as per 1969-70 survey are shown in Table 17 & Table 18, show the loss óf storage capacity in the different allocated zones. It is further seen the about 75 percent of the silt is deposited in the live storage zone while the dead storage has received only 25 percent. During the intervening years, viz. 1965-70, the annual rate of sediment into the reservoir has been in the order of about 23.75 ha m/100 sq. km (475 acre ft. per 100 sq. miles) of catchment. The rate during the last 5 years has been higher than what it was before and needs further examination **(Table 19)**. **Table 20** shows the loss of capacity in the different allocated zones during the intervening 5 years. **Tables 21 to 22** show the comparative results of different surveys and the loss of storages in horizontal and vertical reading and longitudional profiles of the Mayurakshi river is shown in **Fig. 12**. Also, the silt deposits locations were identified and are shown in **Fig. 13**.

<u>Sediment Deposit, its Density and Granulometric Composition</u>

During the second survey also, reservoir bed samples were collected from the deposit points at different cross-sections upto the uppermost points cross-section. Altogether 296 samples were collected.

The analysis of bed sediment from the 65 samples collected showed that there is no deposition of gravel in the reservoir. Further samples of bed sediment were collected during 1972-73 to determine the density and other characteristics. It may be recalled that 1964-65 survey showed bed sediment density of the order 800.9 - 1121.26 kg/cu m (50-70 lb./cft).

Analysis of water samples showed the following result :

pH value : 7 to 8

Salinity : 10 to 500 p.p.m

Sediment : 10 to 500 in general in p.p.m

Concentration : Some of the samples showed concentration

Table 17: Capacity and sedimentation data(1969-70)

Region	Elevation	Depth from F.R.L (d) in ft	Segment-wise depths as % of total depth	Cumulative depth from F.R.S. as % of total depth	Comulative storage capacity as per original pre-dam survey in (1954-65)	Cumulative capacity by capacity as per 1969-70 survey in acre ft	Loss of storage capacity silting acre ft in 16 years	Segment-wise sediment deposit in acre ft: in acre ft	Segment-wise sediment deposit in acre ft: as % of total deposit	Sediment upto as % of total deposit
1	2	3	4	5	6	7	8	9	10	11
	398	-	-	-	493080	454810	38270	-	-	-
	390	8	7.05	7.05	372050	342450	29600	8670	22.6	22.6
Live storage region	380	18	8.85	15.90	252470	229770	22700	6000	15.6	40.6
	370	28	8.85	24.75	163160	146060	17100	2040	5.3	55.3
	360	38	8.85	33.60	99810	87090	12720	4380	11.4	66.7
	350	48	8.85	42.45	57840	47750	10090	2630	6.8	73.5
	349	49	0.01	42.46	55190	43360	9830	260	0.7	74.2
	340	58	8.84	51.30	31300	23890	7410	2420	6.3	80.5
	330	68	8.85	60.15	16240	10920	5320	2090	5.5	86.0
Dead storage region	320	78	8.85	69.00	8500	4660	3840	1480	4.0	90.0
	310	88	8.85	77.85	4300	1530	2770	1070	2.7	92.7
	300	98	8.85	86.70	1700	290	1410	1360	3.6	96.3
	285	113	13.30	100.00	-	-	-	1410	3.7	100.0

Table 18: Reservoir storage loss by silting during the period 1954-70

Region	Original capacity in acre ft	Capacity in acre ft as per 1969-70	Loss in capacity in acre ft	Present loss of storage capacity
Dead storage R.L. 349 and below	55,190	45,360	9,830	17.81
Live storage R.L. 398-349	4,37,890	4,09,450	28,440	6.48
Total storage 398 and below	4,93,080	4,54,810	38,270	7.75

Table 19: Loss of storage and sediment deposition in the Reservoir during the period of 5 years from 1965-70

Contour	Capacity as per 1964-65 survey in acre ft	Capacity as per 1969-70 survey in acre ft	Loss of storage in acre ft	Sediment deposition in acre ft	Upto depth 'd' from F.R.L. as percent of total sediment
398	4,71,360	3,54,810	16,550	0	-
390	3,55,950	3,42,500	13,450	3,100	18.8
380	2,40,020	2,29,770	10,250	6,300	38.1
370	1,52,710	1,46,060	6,650	9,900	59.8
360	91,030	87,090	3,940	12,610	76.1
350	50,600	47,750	2,850	13,710	83.0
340	25,460	23,890	1,570	14,980	90.4
330	11,100	10,920	180	16,370	99.0
320	4,270	4.270*	-	16,550	100.0

Table 20: Reservoir storage loss by silting during the period 1965-70

Original storage capacaity (1954) : 60796.76 ha m (4,93,080 acre ft)
Original Live storage capacity (1954) : 53991.83 ha m (4,37,890 acre ft)
Original dead storage capacity (1954) : 6804.93 ha m (55,190 acre ft)

Region	Capacity as per 1964-65 survey in acre ft	Capacity as per 1969-70 survey in acre ft	Loss of storage in acre ft	Percent loss of capacity
Dead storage E.L. 349 and below	48,016	45,360	2,656	4.81
Live storage E.L. 398-349	4,23,344	4,09,450	13,894	3.18
Total storage E.L. 398-285	4,71,360	4,54,810	16,550	3.35

Table 21: Comparative study of the rates of silting with age

Region	Percent silting during the period 1954-65 (11 years)		Percent silting during the period 1965-70 (5 years)		Percentage silting during the period 1954-70	
	Total for the period	Average annual	Total for the period	Average annual	Total for the period	Average annual
Dead storage region E.L. 349 and below	1.3	1.18	4.81	0.96	17.81	1.11
Live storage region E.L. 398-349	3.3	0.30	3.18	0.64	6.48	0.41
Total reservoir R.L. 398 to 285	4.4	0.40	3.35	0.67	7.75	0.49

Table 22: Study of the longitudinal reach-wise distribution of Sediment deposited in 5 years (1965-70)

Contour	Capacity in acre ft. as per 1964-65 survey	Capacity in acre ft as per 1969-70 survey	Loss of storage capacity in 5 years (1965-70)	Sediment upto'd' in acre ft	Sediment deposition from F.R.L. as percent of total deposit (1965-70)
398	1,01,737	91,665	10,072	-	-
390	85,953	76,297	9,656	416	4.1
380	67,686	58,987	8,699	1,373	13.6
370	50,893	43,714	7,179	2,893	28.7
360	35,800	30,667	5,133	4,939	49.0
350	24,267	19,947	4,320	5,752	57.1
340	14,974	11,894	3,000	6,992	69.3
330	7,614	6,614	1,000	7,072	70.1
320	3,394	3,347	47	10,025	99.5
310	1,137	1,137*	-	10,072	100.0

* No sediment deposition below E.L. 310

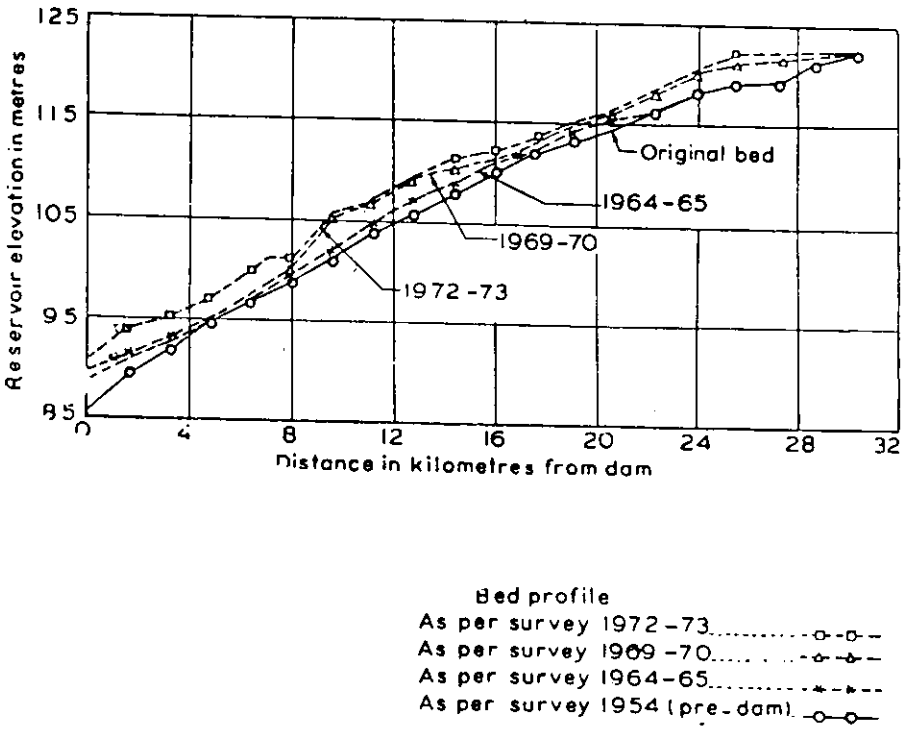

FIG 12.0 LONGITUDINAL SECTION OF MAYURAKSHI RIVER BED (1954 - 73)

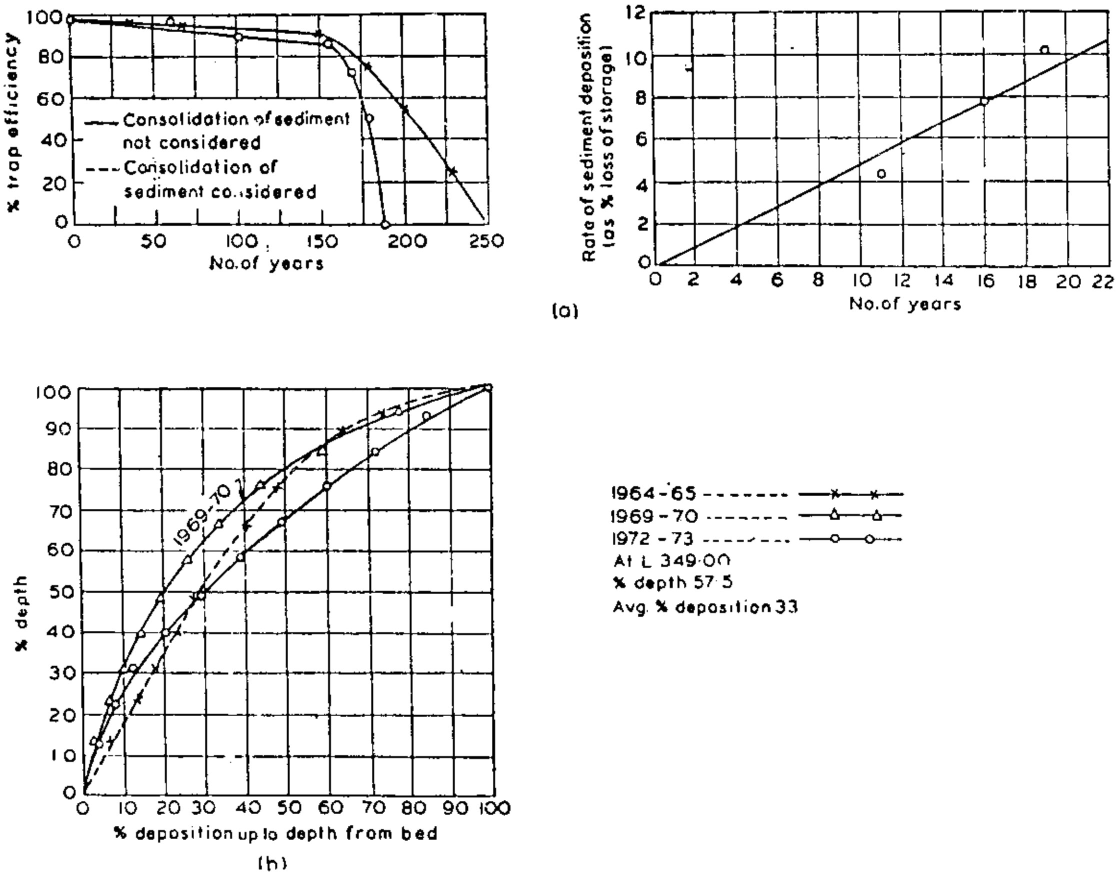

FIG 13.0 SEDIMENTATION SURVEY OF MAYURAKSHI RESERVOIR -LOCATION OF SILT DEPOSIT-

varying from 1300-1700 p.p.m.

Temperature : Variation in temperature with depth (from the free surface to 0.8 D) was of the order of 0.5 to 30.0 and the temperature decreased with depth.

4.3 Measures to bringdown Sedimentation in reservoirs

Since not much can be done to lower the trap efficiency of the reservoir, the only course open to decrease the rate of reservoir sedimentation is to adopt effective soil conservation measures in the watershed in order to bring down the quantum of sediment therefrom.

4.3.1 Soil Conservation Measures under Implementation by the Bihar Government

Mayurakshi Reservoir has its entire catchment in Bihar. Bihar Government has been implementing a commendable soil conservation program in the watershed area the long term results of which are expected to be highly beneficial.

From the aerial survey maps, the soil conservation department of the Government of Bihar prepared the erosion interpretation maps of the catchment. From these maps, the stage of erosion in each of the seven sub-catchment in inferred. 50 percent of the total catchment area is susceptible for heavy erosion out of which more than half is under various stages of erosion.

Soil Conservation Measures

In a planned way the Bihar government has been implementation the following soil conservation measures : (i) Afforestation, (ii) Regeneration of denuded forests, (iii) Contour bounding, (iv) Silt detention dams.

4.3.2 A Critical Appraisal of the Soil Conservation Measures

(i) Afforestation : If the rate of deforestation exceeds that of afforestation, the entire concept of preservation and development of vegetation cover in the watershed in vitiated.

(ii) Pasture Development : Benefits of pasture development program and nullified to a considerable extent by indiscriminate grazing of pastures.

(iii) contour Bunding : Contour bunding, if not scientifically planned and implemented, does not yield satisfactory results.

(iv) Silt detention Dams : These are very effective and give adequate beneficial results in relatively short time.

4.3.3 Planning of Soil Conservation Program for Mayurakshi Catchment

In planning of soil-conservation measures for Mayurakshi catchment, the following criteria may have to be kept in view.

(i) Integrated Approach to the Entire Vulnerable Catchment : As stated earlier 50 percent of the catchment is highly susceptible for erosion. While efforts should be oriented towards intensive conservation measures in the worst affected subcatchments, the less affected subcatchments should not be neglected. An integrated soil conservation program for the entire catchment and the vulnerable part of it in particular has to be framed and implemented. Otherwise, by the time the soil conservation measures start yielding benefits, an equal or more area from the rest of the catchment will become ready for similar priority measures.

(ii) Legislation for Improved Watershed Management : Deforestation in the catchment should altogether be banned. Controlled grazing of pastures should be restored to. Prevention and control of forest fires should receive due attention. Legislative measures in this regard will greatly help the soil conservation program.

(iii) Priorities in Soil Conservation Measures : Short-term soil conservation measures are as important as long-term measures. The priorities may be fixed in the following order:
(1) Silt detention/check dams,
(2) High-level bunds
(3) Contour-bunding
(4) Pasture development, and
(5) Regeneration of denuded forests

In an integrated soil conservation program, all types of measures (1 to 6) have to be concurrently adopted, some relatively more intensively than the rest.

The sediment contribution from cultivated areas and even bunded paddy fields should not be under estimated. The importance of field-bunds has to be explained to the cultivators and construction and maintenance of field-bunds shall have to be made obligatory.

5.0 REMOTE SENSING APPLICATION FOR SEDIMENT MONITORING - A CASE STUDY

Concentration of suspended sediment is an important parameter for monitoring sedimentation in the reservoir. In recent years, remote sensing techniques have been used by several authors(Moore,1980; Muralikrishan,1983; Dubey and Bhatia,1985; Simoda et al,1986; Sahai et al,1987; Jonna et al,1985; Rao et al,1990; Schiebe et al,1992; Choubey et al,1992) to obtain the information on the location and extent of sediment distribution pattern in the water spread area of the reservoir. Seasonal fluctuation on the water spread area have been monitored and corresponding fluctuations in the volume of water and changes in the sediment distribution have been measured. The rate of reservoir sedimentation can be found out by dividing the total sediment volume with the time of deposition of sediments. Turbidity mapping of the reservoir has also been performed. Only synoptic view of the distribution of various sediments levels is possible. Quantitative assessment could have been possible had there been the ground truth data with regard to sediment concentration in the reservoir at different location and at different depths on the data when the satellite passed over the reservoir.

In this study visual interpretation techniques has been used for carrying out the study and analysis. Following remote sensing imageries(FCC) have been utilized to evaluate and extract the meaningful information to sedimentation in Massanjore reservoir of Mayurakshi river basin.

S.No.	SATELLITE	SENSOR	PATH/ROW	DATE	SCALE
1.0	LANDSAT MSS	LISS II	20/51	5.10.89	1:250,000
2.0	LANDSAT MSS	LISS II	20/51	7.4.89	1:250,000

5.1 Interpretation and analysis

Interpretation of remote sensing imageries and analysis has been performed for measuring the waterspread area and mapping various turbidity levels. The interpretation has been done using interpretation keys and image characteristics such as tone, texture, pattern, shape, size and asoociation. The basic data extracted from the satellite data were the waterspread areas at different elevations levels. At greater wavelengths, water apparently acts as a black body absorber and reflected solar energy is very low.

Presence of sediments in water changes the backscattering characteristics of the water. Suspended particles tend to increase the total scatter and backscatter, reduce the average path length and consequently change the spectral distribution of light. Thus, a turbid water is more reflective than clear water. The measured signal at any wavelength depends on the particle size and concentration.

5.2 Results and discussions

Fig. 14 and 15 shows the suspended sediments distribution pattern for different dates. Irrespective of the season sedimentation concentration is generally high along the fringe and at the tail end. The area near the dam, which is deeper remains relatively free from the suspended sediments. The central part of the reservoir , right from the dam to the tail end generally has medium level of sediment concentration.

In premonsoon period i.e. March (Fig.14) only four concentration levels namely moderate to high, moderate, slight to moderate and slight are present. The silting rates of the sediments in the water i.e. settling velocity is dependent on the viscosity of the reservoir water. During summer month , as the temperature rises, the viscosity reduces and consequently more amount of suspended sediments settles in the month of March. The post monsoon data i.e. December (Fig.15) scenes shows very high concentration along the fringe and at the tail end. At the extreme tail end the sedimentation level is less than at the just above the tail end. [illegible] tail end some portion of the river course is included. At the tail end sedimentation is high because of the arrival of the new sediments brought by the flood water through the main channel. In all five concentration levels were identified viz. very high, high, moderate, slight to moderate and slight.

On the basis of this study ,it is concluded that the sediment concentration is very high at the tail end of reservoir, moderate to high at fringes and low at the dam site. Inspite of some advantages of remotely sensed data there are some limitations also. Remote Sensing is pretty much limited to sensing of turbidity and sediment level at surface etc. Remote Sensing can only measure reflected or emitted energy from the surface or near surface. Also turbidity is not a uniform parameter, either spatially or temporally. It will change with changes in inflowing discharge and with internal currents, thermal layering and the life cycles in the water. Remote Sensing provides an excellent method for tracking their spatial and temporal changes.

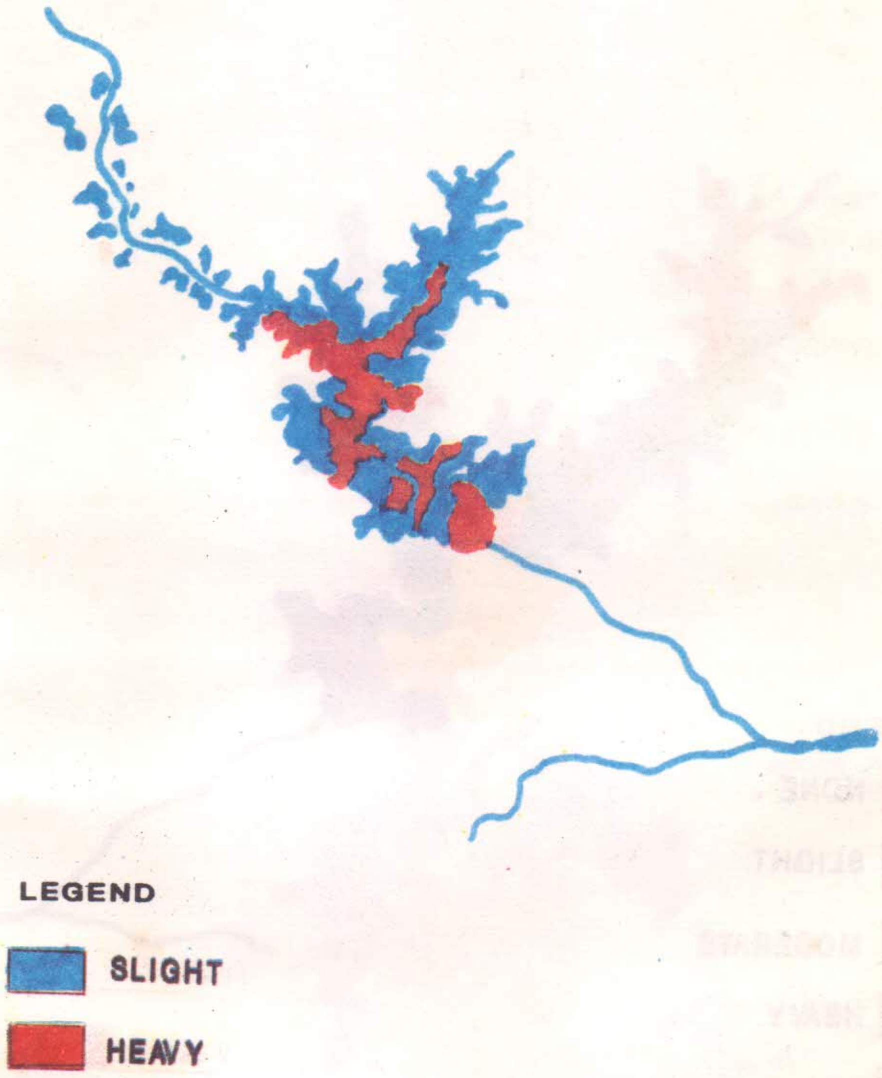

FIG 14.0 SEDIMENT DEPOSITION PATTERN IN MASSANJORE RESERVOIR OF MAYURAKSHI RIVER BASIN (PRE-MONSOON)

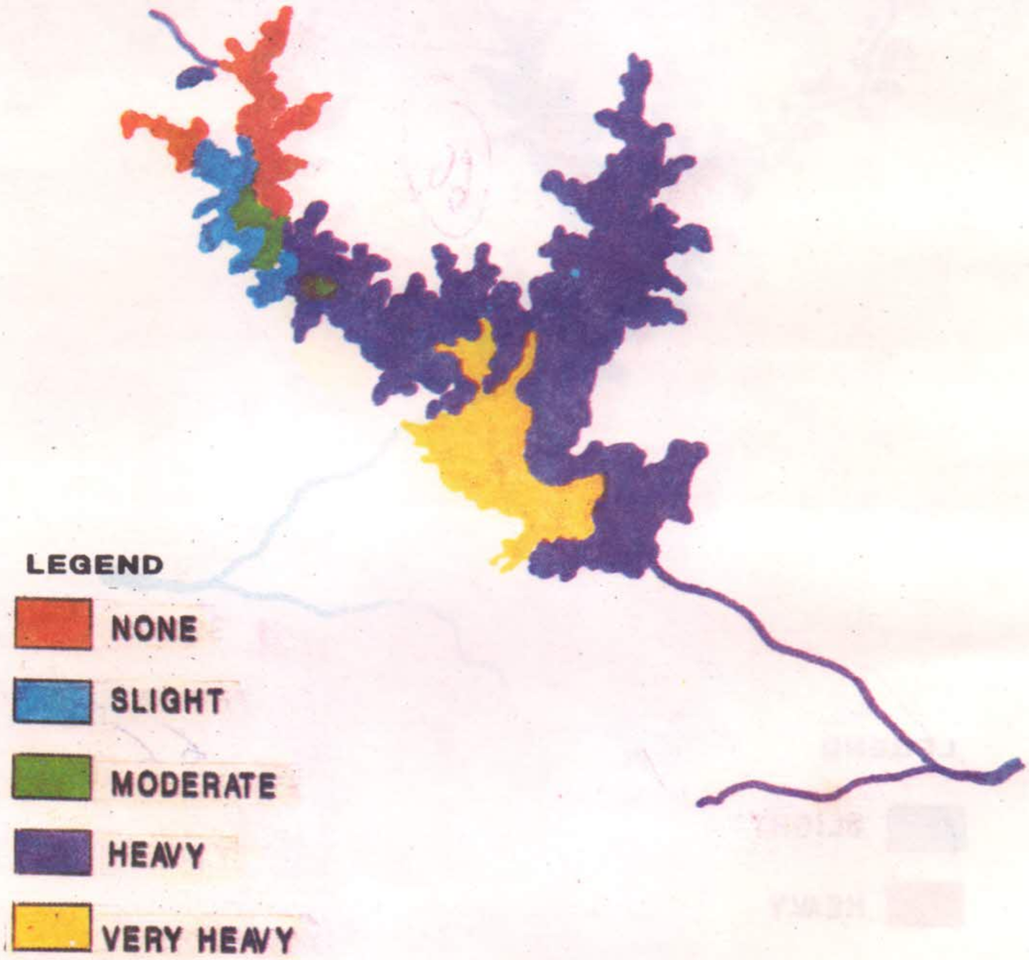

FIG 15.0 SEDIMENT DEPOSITION PATTERN IN MASSANJORE RESERVOIR OF MAYURAKSHI RIVER BASIN (POST-MONSOON)

6.0 CONCLUSION

High rate of sedimentation of Mayurakshi reservoir may be attributed to its high trap efficiency, high sediment yield from the watershed, high sediment transport capacity of the river and its tributaries and unscientific watershed management and land use.

The effect of gain in storage by consolidation of bed sediment with age in enhancing the economic or effective life of the reservoir is not appreciable.

Mayurakshi reservoir lost 11.2 percent of its storage capacity in 19 years. With the presumption that the annual sediment yield will remain at the rate obtaining at 19 years age as a result of check on any increase thereof by effective soil conservation measures in the catchment and reduction in sediment-transport capacity of the channels owing to aggradation, the normal life of the reservoir may be of the order of 60 years. By the end of normal life period the dead storage region will have been completely filled up by sediment deposition with a corresponding live storage loss of 25 percent.

In 100 years time the reservoir will have lost 50 percent of its live storage capacity.

The economic or effective life of the reservoir may be of the order of 160 years. By the end of economic or effective life period, the reservoir will have outlived its utility having lost 85 percent of its total capacity.

The physical or total life of the reservoir may be of the order of 200 years. By the end of physical or total life period, the reservoir will have been practically filled up by the deposited sediment. The reservoir bed will then be a fertile ground for hydro-biological growths.

The overall picture is not very encouraging of the rate of sediment yield from watershed is not checked and arrested, the life of the reservoir may be far less than what is estimated.

Therefore, all-out efforts have to be made to step up the soil conservation program in the watershed not only to arrested the rate of sediment yield but also to bring it down as much as possible. Prolonged life of the reservoir adds to the national wealth.

7.0 REMARKS

Multitemporal and multiband satellite data are extremely useful in determining sedimentation rate in a reservoir and mapping different concentration levels of sediment load. Advantages of using remote sensing data is that it is highly cost effective, very easy to use and takes very little time in analysis as compared to conventional methods. Spatial, spectral and temporal attributes of remote sensing provide invaluable synoptic and timely information regarding the waterspread and sediment distribution pattern in the water body. Qualitative analysis of the satellite data help in the selection of sampling points for quantitative estimation of the sediment in the reservoir. After a relationship between the reflectance and the sediment concentration is established , high resolution satellites can be more useful for the quantitative assessment of suspended load.

In the present study an attempt is made to monitor and develop maps of sediment concentrations in the Massanjore reservoir, Mayurakshi river system, West Bengal using visual interpretation technique. But the digital analysis of remote sensing data seems to give very useful informations of sediment deposition in the reservoir. A study may be carried out utilizing digital data and ground truth data to assess the real time sediment deposition in the reservoir. The study would be of great importance for maintanance and development programmes in the reservoir.

REFERENCES

1. Central Water Commission, New Delhi, "Compendium on Silting of Reservoirs in India". January 1991.
2. Choubey V.K. and V.Subramaniam, 1992, "Estimation of suspended solids using IRS-1A data : a case study from central India", IJRS, Vol. 13, No. 8, 1992.
3. Dubey O.P. and H.C.Bhatia, 1983, "Remote sensing for erosion studies in Tehri reservoir", Proc. of National seminar on remote sensing of water resources, Ahemdabad, Dec. 27, 1985.
4. Indian Standard Institution, New Delhi, "Guidelines for Determination of Effects of Sedimentation in Planning are Performance of Projects". IS:12182-1987.
5. Jonna S., K.V.S.Badrinath and J.Saibaba, 1989, "Digital Image Processing of remote sensing data for water quality studies", Journal of Indian Society of remote sensing, Vol. 17,No. 2 ,1989.
6. Moore, G.K., 1980, "Satellite Remote Sensing of Water Turbidity; Hydrological Sciences Bulletin, Vol. 25, no.4, December, 1980.
7. Muralikrishna, I.V., 1983, "Landsat application to suspended sediments evaluation", Chapter 15 of remote sensing applications in Marine Science and Technology, ed. by A.P.Cracknell, D.Reidel Publishing Company, Boston.
8. Pramanik, H.R. and R.N. De, " Sedimentation Rate of Reservoirs Prototype Observation". River Behavious and Control, Journey of the River Research Institute, West Bengal, Vol. 11, 1967.
9. Sahai, B.N. and R.L. Karale, 1987, "Application of remote sensing techniques for watershed characteriszation in a part of the Ukai catchment", Scientific report, , All India soil and land use survey and S.A.C. (ISRO).
10. Schiebe F.R., J.A.Harrison, J.C.Ritche, 1992, "Remote sensing of suspended sediments: the lake Chicot", Arkanas Project Vol. No. 13, No. 8, 1992.
11. Shimoda H., M.Etaya, T.Sakata, L.Goda and K.Stelezer, 1986, "Water quality monitoring of lake Balaton using Landsat MSS data", Proc. of seventh International symposium on remote sensing for resource development and environment management, ISPRS commision VII, 25-29 Aug., 1986.

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