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PRELIMINARY HYDROLOGICAL INVESTIGATIONS OF DEEPAR BEEL AND STRATEGIES FOR ITS MONITORING AND MANAGEMENT

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PREFACE

Lakes are usually an integral part of a drainage basin and area characteristics of topographical features of humid climate. They tend to form in basin where the water input exceeds loss through evaporation and infiltration. Each lake being a transitory feature of the earth furnace, has a birth, life and death. The life span of a lake vary from a short spell of few floods to millions of years.

The major problems observed in most of the lakes, referred as Beels in North Eastern Region of India, are deteoriation in lake water quality, increasing sedimentation, reduction in lake water capacity and water input. Piecemeal works on evaporation, sedimentation, water balance and quality of lake water has been done. In order to understand in totality the hydrology of the lakes to conserve water in forms of quantity, quality and regimen, lake/beel processes involving hydrology, hydraulics of lakes, water balance of lake, hydrodynamics and thermodynamics of lakes, sedimentation and biological activities in lakes is essential.

The National Institute of Hydrology is a premier institute in the field of hydrology and water resources in the country and undertakes the research related with specific problems. Keeping in view the importance of the natural fresh water lake, known as Deepar Beel near by the city of Guwahati and the problems being faced by this Beel, the North Eastern Regional Center of National Institute of Hydrology has undertaken preliminary hydrological survey of the Deepar Beel. The institute would undertake detailed projects to thoroughly investigate the hydrology and hydraulics of this Beel and come out with a solution manual for the proper monitoring and management of the Beel.

The infrastructure needed would be nuclear techniques, remote sensing techniques, advanced instrumentations using data acquisition system and sophisticated portable equipment for water quality testing. The conventional techniques would also be used to study the sedimentation and other parameters. The present report deals with the theoretical aspects of the techniques to be used, methodologies and instruments which will be used for study of various natural processes in the Deepar Beel.

This report has been prepared by Vijay Kumar Dwivedi, Scientist 'C'. It is hoped that the activities proposed to be carried out and mentioned in this report will enable the institute to achieve the objective envisaged in this report.

S.M. Seth
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ABSTRACT

Deepar Beel on which the present study is focused is a natural fresh water lake locally known as "Beel". Situated on the south-west fringe of the Guwahati city, the beel covers an area of about 40 sq. Kms. The beel serves as a major natural storm water reservoir for the entire Guwahati city. The geology of the surrounding, the hydrology of the inflowing and outflowing streams viz. the Bharalu, Kalmani, Basistha and Khanjan and the nature of land use in the adjoining area greatly influenced the beel development and transformation in the present day status. The quality of soil and water of Deepar beel and its connecting water bodies and the concentration of trace elements in the bottom sediments of the beel is reported herein. Initial attempts on evaluating and monitoring the quantity and quality of the beel water is also mentioned here in. Detailed project plan to investigate the hydrology of the Deepar Beel are presented in this report. The numerical models to be developed for proper monitoring and management of the beel is discussed and otlined in this report.

1. INTRODUCTION

From hydrological point of view, lakes are considered as storage elements of a local or regional hydrologic system. They alter the quantity and quality regime of the water flowing trough the system. Now it has been realized in India that the quality of the lake water has deteriorated too much there by putting much stress on social system. Though there are some differences in the geometrical, hydraulic and biological characteristics of lakes (natural) and reservoirs, still lakes and reservoirs are in most cases being used for similar purposes. The cause of deterioration of lakes in India are manifold. The infra-structural facilities such as water supply, sewage and soil waste disposal, traffic, transportation, tourist facilities etc. are falling short of requirement. Due to this, the rain water fed channels are now serving as conduits to carry sewage and soil wastes into the lakes. Henceforth, springs feeding the lakes are drying up. On the other hand need of water is increasing day by day. Therefore, there is a strong need for the study of all aspects related with lakes for better management of lakes, recharge zones and to restore the health of lakes.

1.1 SIGNIFICANCE OF THE PROBLEM

Lake is considered as a portion of a drainage system where water is retained for considerably larger periods than in normal river channels. Quantitatively, lakes contain only a fraction of the total water at the earth's surface, they have received proportionately greater attention because of their importance to mankind. In most of the places, lakes are being used as a source of drinking water, as a receptacle for sewage and agricultural run off, for recreation, industrial purposes, even disposal of industrial waste. Because of the generally small size of these lakes, they get severely altered by the above activities. Natural or artificial changes in the storage either on quantity or quality of water not only alter the stream flow regime but also the water balance in the region. The major problems faced in the Indian lakes are deterioration in lake water quality, increasing rate of sedimentation, increase in biological activities, growth of hyacinth and plankton, eutrophication, growth of water grass called phumdi resulting in reduction in lake water capacity. Growth of plankton is directly associated with all the processes taking place in a lake such as water balance, sedimentation, hydrodynamics, thermodynamics of the lake. For addressing any problem of the lake and its restoration measures water balance, thermodynamics and hydrodynamics of the lake must first be studied. Determination of positive and negative impacts is important to improve the planning and management of lake based water resources of a region.

2. STUDY AREA

The study area of Dedepar Beel falls in the City of Guwahati, state capital of Assam, the Gateway of the north eastern states of India. It is considered the economic capital of the North Eastern Region of India. Guwahati Metropolitan District covers an area of about 243.20 sq. Kms. (95 sq. miles). The geographical area is located about 26°-10' north of equator and 92°-49' east of Greenwich. The River of Brhamputra flows by the north of the study area. History reveals that Guwahati stands on the most stable bank of the river which has been least disturbed by the erosion of the river Brhamputra. The location of the study area is shown in figure 1. The Greater Guwahati Area of about 243.2 sq. Kms. referred to in this report as the Guwahati Metropolitan District is mostly on the south bank of the river Brhamputra having north Guwahati and some contiguous areas measuring only about 23 sq. Kms. (9 sq. miles) situated on the northern bank. The study area includes one municipality, two town Committees and fifteen different areas administered and occupied by public bodies like Railway, Defense Department, etc. and eighty two rural areas.

2.1. BOUNDARIES OF STUDY AREA

The boundaries of the study area have been fixed by Town and Country Planning Department, Government of Assam. This is based on the following considerations:

- Guwahati town is the first major town of Assam having direct rail, road and air connections with the rest of the country. The navigation is also possible from the Guwahati port through East Pakistan. Though the Indo- Pakistan war in 1965 has entirely sealed the river trade due to the closure of this river route, development of road net-work has compensated to a certain extent this transportation problem. With the establishment of good relation with Bangladesh the water route is being opened again very shortly.

- Mostly all the major business houses who are represented in Assam have their regional office located in Guwahati. The Headquarters of the N.F. Railway is located within the study area which provides a good impetus for its development. It has also the tea auction center, the second of its kind, next to Calcutta.

- The location of the Oil Refinery and subsequent location of other heavy and medium size petro-chemical industries as on offshoot of the refinery has added some industrial development potential to this area.

- It is also expected to expand because of the establishment of Indian Institute of Technology within the study area.

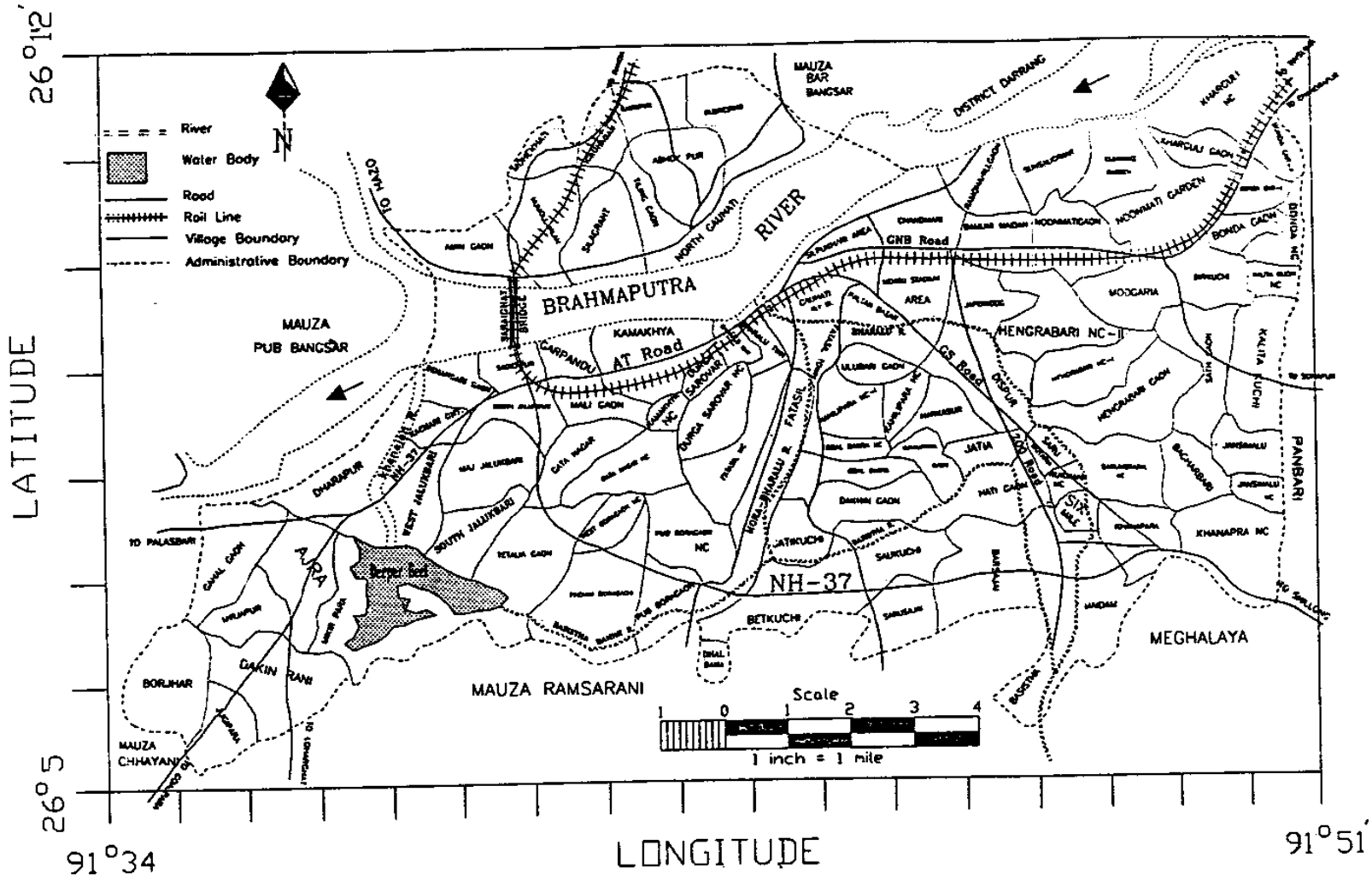

Fig. 1 : Location map of the study area

- All the above considerations have prompted the Government of Assam to declare a total area of about 243.2 sq. Kms. (95 sq. miles) as a Greater Guwahati Area, falling within the influence zone of the study area. The Guwahati area as stated earlier has been invaded and occupied by several outsiders and as a result, it has developed more or less, as a business town. Guwahati is known through out India as a place of religious importance due to the numerous temples constructed during the regions of Cosh and Ahom Kings. Famous Kamakshya temple on the Nilachal Hill, Nabagraha temple, Umananda on the island in Brahmaputra etc. attract a lot of pilgrims through-out the year.

- The Guwahati Municipality came into existence in the year 1865 and the gradual improvement in sanitary condition was started by the Municipal Authority. In 1897, Guwahati experienced one of the heaviest earthquake in its history. This resulted in almost complete destruction of the town. After this catastrophe the town was rebuilt. In 1891, the population of Guwahati was 8394 which gradually increased to 11,661; 12,591; 16580; 21797; 29598; 43614; and 1,00,707 in the subsequent decimal censuses. The Municipal limit was also increased from 7.38 sq. Kms. (3 sq. miles) in 1951 to 14 sq. Kms. (5.5 sq. miles) in 1961. Guwahati secured a place on the Railway Map of India in 1890 when this town was connected with the rest of India by the operation of Assam Bengal Railway. This gave a good impetus to its development. Ultimately after the independence when the Railway system was regrouped on a zonal basis, the zonal headquarters of the Northeast Frontier Railway was placed in the Guwahati area. The subsequent construction of the Railway-cum-Road bridge at Pandu in place of ferrying this mighty river Brhamputra has made the communication system easier and Guwahati has got considerable commercial importance since then. With the establishment of the Guwahati University in 1948 and various other technical institutions like the Assam Engineering Collage, Agricultural University and Indian Institute of Technology in 1994 Guwahati is becoming an Educational center of Assam. Besides, establishment of an Oil Refinery and various ancillary industries during the past few years have given tremendous impetus to the general development of the locality.

2.2 GEOGRAPHICAL FEATURES AND TOPOGRAPHY OF THE AREA

The southern bank of the river Brhamputra rises up from an average ground elevation of 51.3 m. (168 ft.) and except in certain central and western portion, the area goes up to hill ranges namely Khaeghuli and Nabagraha Hill ranges rising to a maximum of 216 m. (712 ft.) in the eastern portion and Nilachal hills rising to a maximum of 303 m. (9660 ft.) in the central portion. Then it falls down to a valley having a average ground level of 49 m. (160 ft.) and a minimum elevation of 41.16 m. (135 ft.) after which it gradually rises again to Khasi and Jaintia hills to a maximum elevation of 575 m. (1866 ft.) which constitutes the southern boundary of the district. In the east, the area slopes down from a hill range having a general elevation of 182 m. (600 ft.) to a value having an elevation of 49 m. (160 ft). Inside the area there are (i) Fatasil range (average elevation of 358 m.), (ii) Sarania Hills (average elevation of 250 m). In between the hills again there are pockets of low-lying areas with an elevation of 49 m. (160 ft.) on an average. On the west there is a valley land including a vast low-lying area named Deepar Bill

which occupies more than 54 sq. Kms. (21 sq. miles) of area. The study area though situated within the seismic zone has a very stable foundation. Even the earthquake of 1950 which registered a magnitude $8^{1/2}$ in the Richter scale did not produce any major fault in the area. There is hardly any area within the Greater Guwahati Metropolitan District where there is any alluvium deposit. Recent findings in Ambari area of Assam by the Archaeological Department show that civilization did exist in the vicinity as early as the 2nd and 3rd century AD There is more or less continuous layer of igneous rock all through out the area. The depression of this rock layer has constituted the valley areas and its outcrop, the hillocks.

2.3 GEOLOGY OF THE AREA

The town of Guwahati is situated on the fringes of hard rock formations. The average elevation of Guwahati township is 62 m. from the mean seal level with an annual rainfall of about 159 cms. Geomorphologically the area can be classified as (i) flat land and (ii) hill areas. The flat land occupies a larger area as compared to the scattered occurrences of hills. The hills often attain a height of about 250-300 m. above mean sea level.

There are distinctly two geological formations. The alluvial plains of Brhamputra are interrupted by insbergs formed by the pre-Cambrian gneiss's and schists. The alluvial plains also include the marshy tracts which comprise the south-western portion of Guwahati. The valley fill areas consists of clay, silt and sandy-clay, sands and gravel. A lot of variations in texture both horizontally and vertically are common features. The basements topography is likely to be very much irregular in nature as indicated by the numerous archaean inliers projecting above the general land surface as hillocks scattered around the township.

It is observed from the available data that the aquifers occurring at depths down to 18.6 m or so are being trapped in alluvial-fill areas through shallow tube wells scattered at several places. Yield from the tube wells are not significant. Possibilities of extracting groundwater in considerable quantity is remote in the hard rock areas. Water in hard work formations occur in joints, cracks and crevices and in the weathered zone. The recharged water often comes out as springs at elevated heights.

River Brhamputra appears to be the principal source for tapping water in large scale for town as well as industrial supplies. A general map of geology is shown in figure 2.

2.4 CLIMATE OF THE AREA

The climate of Guwahati is more or less moderate with temperature variation between the average minimum of 15°C in winter and average maximum in summer limited to around 30°C. The principal characteristic are a cold and foggy weather, a moderately hot spring and temperately hot but very humid summer. The monsoon is rather long extending from May to September. Though most of the rainfall occurs during the monsoon, occasional heavy downpour is often experienced during winter. Mean temperature and rainfall within the Greater Guwahati area is presented in table 1.

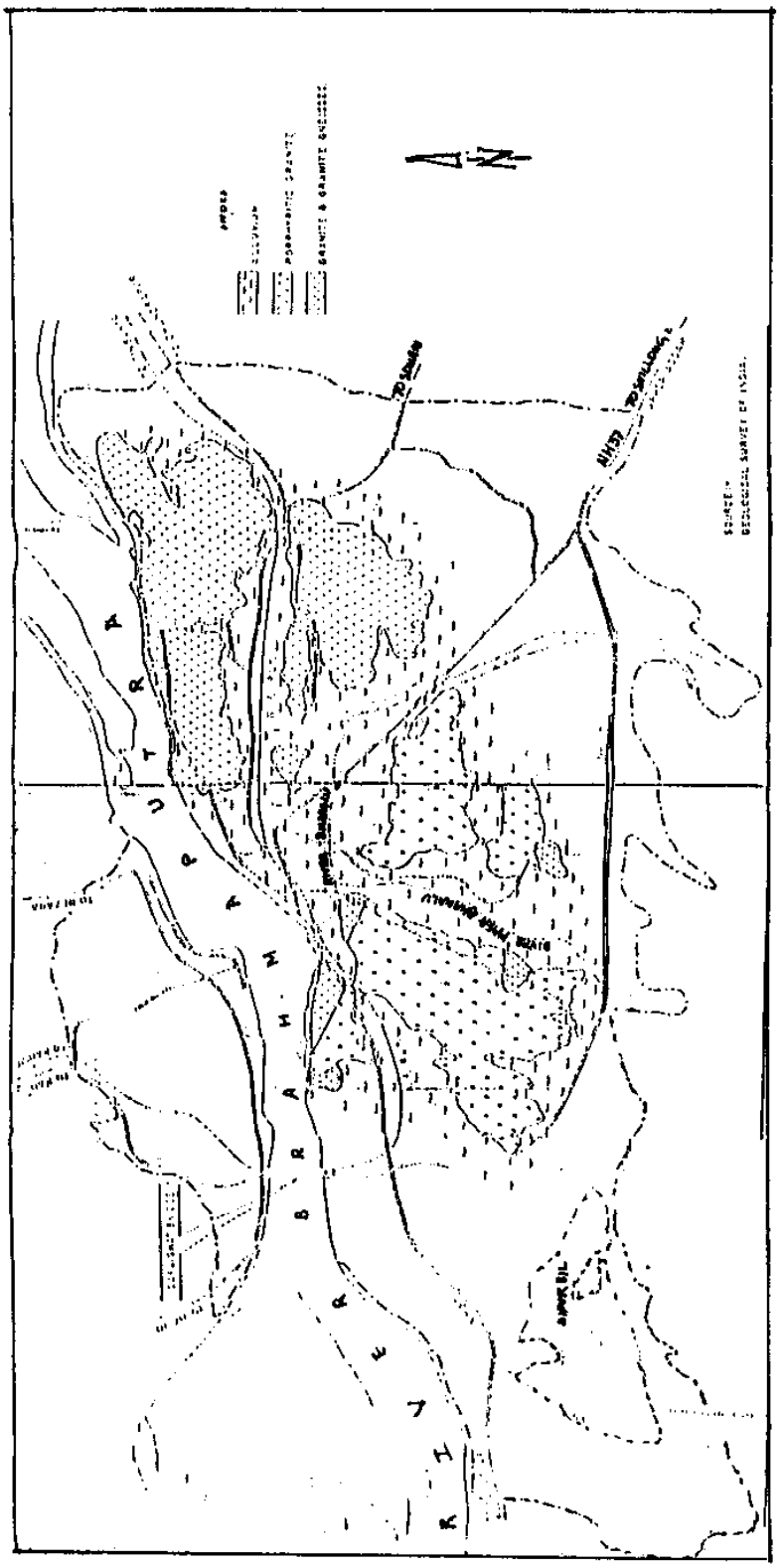

Fig. 2 : Geology map of the area

Table 1 : Mean temperature, humidity and rainfall for Deepar Beel Basin (1931 -1960)

Month	Temperature (oC)			Humidity (%)	Rainfall	Number of Rainy days
	Maximum	Minimum	Mean	08-30		
JAN	24.0	11.0	12.50	88	11.4	1.2
FEN	26.3	12.8	19.55	78	18.3	1.8
MAR	30.2	16.5	23.35	71	53.4	4.2
APR	31.6	20.3	25.95	72	125.9	8.3
MAY	31.0	22.7	26.35	81	273.6	15.1
JUNE	31.5	24.7	28.1	85	301.5	15.1
JULY	32.1	25.8	28.95	85	301.5	14.2
AUG	32.2	25.8	29	84	190.1	9.5
SEPT	32.1	25.2	28.65	84	190.1	9.5
OCT	30.5	22	26.25	84	90.1	4.8
NOV.	27.7	16.9	22.3	87	11.5	1.3
DEC	24.9	125	18.70	89	5.1	Less than 1

2.4.1 FREQUENCY OF RAINFALL

The distribution of rainfall according to duration in the months of occurrence is given in the table below :

Table 2 : Distribution of Rainfall in Deepar Beel Basin

Duration	Month of Occurrences						Total Frequencies
	May	June	July	Augus t	Sept.	Oct.	
2-Day	5	10	7	9	2	1	34
3-Day	8	15	5	4	2	--	34
4-Day	1	8	8	2	4	--	23
5-Day	1	5	1	--	--	--	7
6-Day	--	2	--	--	1	--	3
7-Day	--	1	1	--	--	--	2
Total	15	41	22	15	9	1	103

It is evident from the table-2 that the rainfall occurrences are most frequent in this area in the month of June (41 out of 103), the next higher frequency being in July (22 out of 103). The rainstorms are equally distributed during May and August. In the month of September and

October, the frequency slumps. There are equal number of 2-day and 3-day storms where as storms of 4-day duration are 23 out of 103. Storm duration beyond four days are rare which is 3 and 2 for 5-day, 6-day and 7-day storms respectively.

2.5 DRAINAGE BASINS

The Guwahati Metropolitan District has on the south a hill range known as Khasi and Jaintia Hills, on the east isolated hilly areas, on the north river Brhamputra and on the west low lying areas of Deepar Bank. Though the administrative boundary Thangbhanger hills of the Guwahati Metropolitan district does not include all these hill tracts, yet all these hills have a great effect on the drainage of the area. Any precipitation on these hill slopes towards the metropolitan area creates run-off of considerable volume entering into the metropolitan district. Accordingly for the storm drainage, a considerable area has to be added over the metropolitan boundary considering the topography of the whole area including its neighborhood. The total catchment area thus coming under the drainage proposal for Greater Guwahati City covers approximately 183.50 square kilometers of area.

2.5.1 EXISTING DRAINAGE BASINS

Considering the topographical features, the whole area is divided into 6 (six) numbers of drainage basins which are ultimately drained into the River Brhamputra either directly or through various drainage channels and reservoirs. These are shown in figure and are listed below:

1. Silsako Basin,
2. Bharalu Basin,
3. Foreshore Basin,
4. Deepar Basin,
5. Kalmoni Basin, and
6. North Guwahati Basin.

There is a small area about 15.54 sq. km. (6 square miles) which is included within the administrative boundary of the Guwahati Metropolitan District but falls outside the above drainage basin. This is mostly the Thangbhanga Beel region comprising the villages- Barjhar, Kahikuchi, Jogipara, Mirjapur, Garalgaon etc., and is drained into the river Brhamputra through the Kalbhog River.

2.5.2 DEEPAR BASIN

In the north of the Deepar basin is the Foreshore Basin, in the east is the Bharalu Basin, in the south is the Kalmoni Basin, and in the west is the Kalmoni River. The Khasi and Jaintia Hills also form the south boundary of this basin. This basin is again sub-divided into 2 sub-basins namely Bijubari sub-basin and the Deepar sub-basin. The major river which enters this basin from the Khasi and Jaintia Hills is the Barapani River or the Basistha River and has got two low lying areas within the basin namely Bijubari Beel and the Deepar Beel. The total area in this basin is 133.5 sq. Km. (33,034 acres or 51.6 sq. miles). The Bijubari sub-basin occupies 70.4 sq. Km. (17,424 acres or 27.2 sq. miles) and the Deepar sub-basin occupies 63.0 sq. Km. (15,610 acres or 24.4 sq. miles). The two low lying areas - Bijubari Beel and the Deepar Beel occupy approximately 2.02 sq. Km. (500 acres) and 5.65 sq. km. (1,400 acres) respectively. The outlet from this basin, the river Khanajan, also falls to the river Brhamputra which is controlled by a sluice at its end.

2.6. DEEPAR BEEL

Situated at a distance of 10 km. South west to Guwahati, Deepar Beel is a permanent freshwater lake with altitude of about 53 m. Its geographical location is within the latitude 26° 05' - 26° 09' N and longitude 91° 36' - 91° 45' E. The area of the Beel is about 5.65 sq. Km. Depth of the lake at the maximum flooding is about 4 m. and drops down to about 1 m. in dry season. The main sources of water for the Beel are river Basistha, Kalmani & monsoon runoff from the catchment area. The lake drains into Brhamputra river. Half of the lake dries in winter and the shore is converted into rice fields. The forests to the south of the lake are being felled resulting in the soil erosion and siltation. The runoff water carries agricultural fertilizes and pesticide etc. in to the Beel.

3.0 STATUS OF DEEPAR BEEL

Water of Deepar Beel is highly polluted due to sewage contribution of Guwahati city. In the shallow portion which is more active portion of the Beel, the water quality is much worst. Deepar portion of the Beel is by the foot of the Rani Hills on the eastern side of the Beel. The water in deeper part is less contaminated and henceforth provides sheltering place for aquatic birds such as Ducks, local type of cranes and other migratory birds. Due to changing water quality the variety of migrating birds are also changing over years. The maximum water spread in the Deepar Beel area as in 1988 is shown in figure 3. The depth of water has also reduced over years due to heavy silts coming into the Beel every year. This reason seems quiet obvious due to accelerated deforestation and cutting of the hills of the Rani hills on the eastern side of the Beel due to which heavy load of silts are directly coming into the Beel. The incoming streams into the Beel are also carrying heavy load of silts over the years. The variety and quantity of fish has also reduced considerably due to deteriorating water quality of the Beel. This phenomenon is alarming because fishery and cultivation of local paddy provides livelihood to the local populace. There is cultivation of local type of paddy in the Beel. Due to deteriorating water quality of the Beel the yield of the paddy is going down year by year. The water quality is also affecting the health of the people active in use of the Beel. Water quality parameters in the Deepar Beel and at different locations in its connecting water bodies as shown in figure 4 is detailed in table 3.

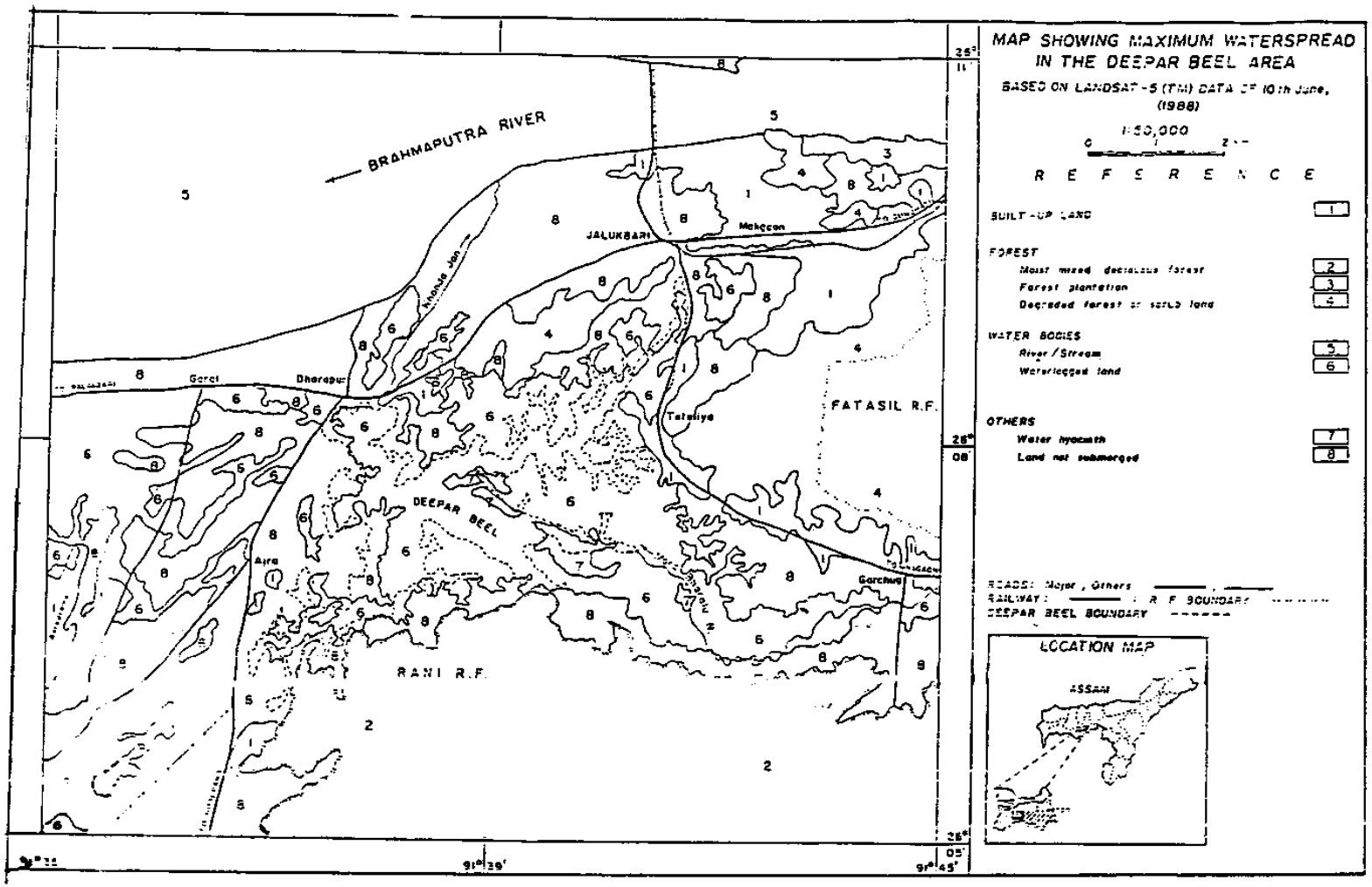

Fig. 3 : Map showing the maximum waterspread in the Deepar Beel area

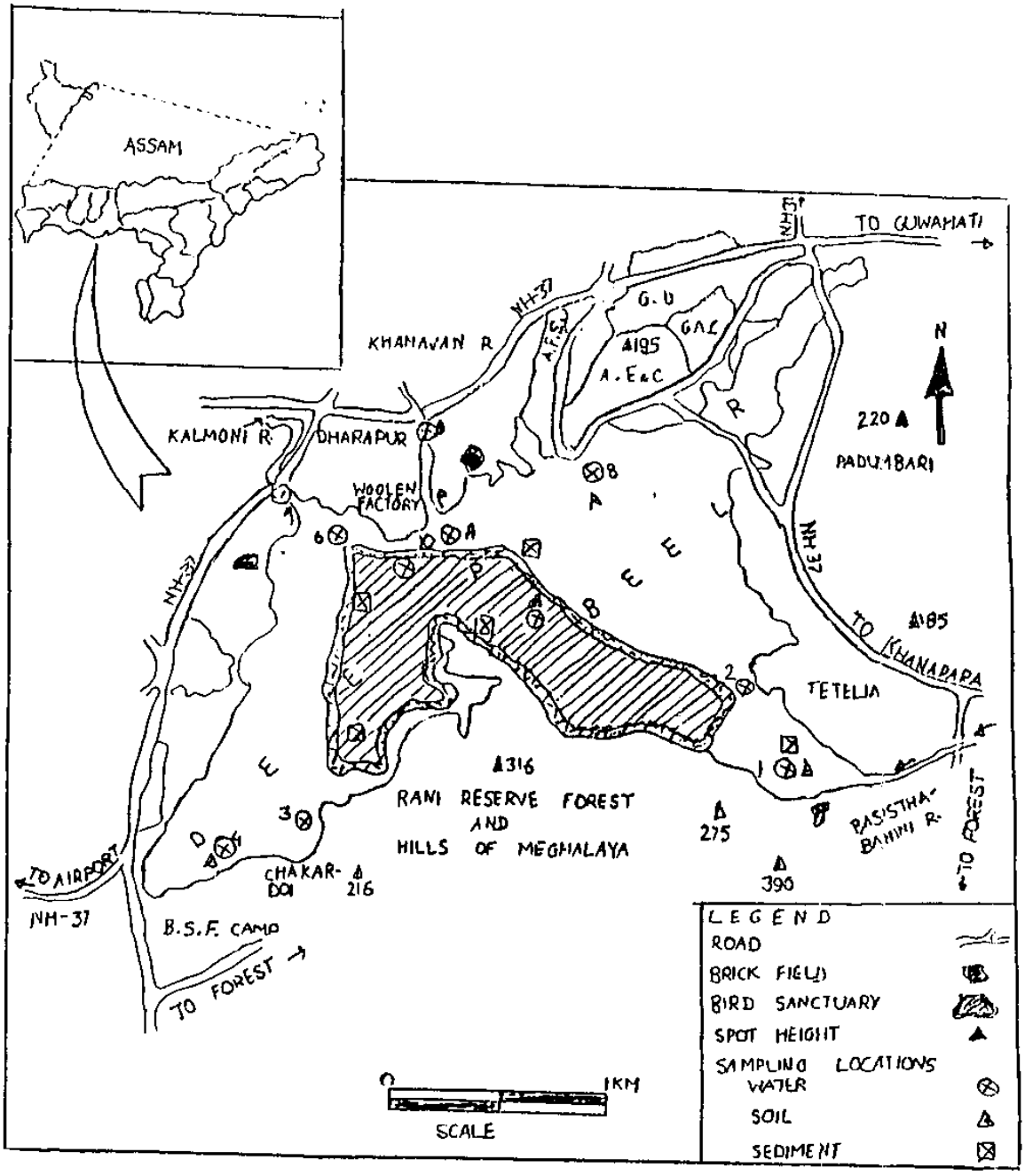

Fig. 4 : Locations for determining water quality parameters in Deepar Beel and its adjoining areas

Table 3 : Water quality parameters of the Deepar Beel and its connected water bodies

Locations	Parameters						
	pH	Conductivity (mmho CM^{-1})	Alkalinity (mg/l)	Turbidity (NTU)	Total Solids (mg/l)	DO (mg/l)	BOD (mg/l)
1. Inlet	7.5	549	56	79	312	1.7	13
2. Tetelia	6.8	460	41	68	143	10.4	1.5
3. Chakardoi	6.8	465	44	12	65	8.2	1.2
4. B.S.F Camp	7.2	5.5	53	75	264	2.6	3.3
5. Kalmoni River	7.0	480	39	5	00	8.8	0.6
6. Dharapur	5.4	510	58	44	75	6	3.4
7. Woolen Factory	7.3	515	57.5	78	276	1.9	10.3
8. A.E. C. College	6.3	470	45	12	80	7.3	3.3
9. Khanamukh	7.0	495	41	10	40	6.7	2.0
10. Outlet	7.0	476	43	65	214	2.7	9.7
11. Middle of	6.9	470	40	64	159	2.8	8.1

Railway department has constructed a permanent concrete bridge in this Beel on river Basistha Bahini just near the entry to the Beel for providing rail connections from Panchratna to Guwahati. For making this bridge whole width of the Beel near its inlet has been bounded by earthen banks and only a water way of about 30 m width has been provided. It may be anticipated that there would be considerable obstruction to the entry of water into the Beel due to which river Basistha Bahini carrying the whole drainage water of Guwahati city would not be able to discharge completely resulting in back water flow through this river and subsequently flash flooding of the city just after instant rainfall.

Though Deepar Beel has been declared as a reserved area by the Forest as well as Department of Town and Country Planning of Govt. of Assam, India still there are growing encroachment in the Beel catchment. There are reclamation of lands on the northern side of the Beel for construction activities which are disturbing the ecology of the Beel. Brick making activities goes in the Beel during dry season. This may not be so much harmful to the health of the Beel because it takes place during dry period and leaves behind ditches which gets filled up during the rainy season. Physio-chemical trace element characteristics of soils of Deepar Beel at selected sites as shown in figure 4 are given in table 4, trace element concentration in bottom sediments of the Deepar Beel are given in table 5 and physical properties of the Beel soil at various depths are given in table 6. The characteristics of water of Bharalu river, the major source of water input for Deepar Beel is given in table 7.

Table 4 : Physio-chemical and trace element characteristics of soils of Deepar Beel and its water bodies at selected sites in the basin

Parameters	Locations				
	Inlet	Outlet	B.S.F. Camp	Woolen Factory	Bottom of the Beel
pH	4.1	5.7	5.3	5.2	4.5
Conductivity (mmho CM^{-1})	0.3	0.24	0.67	0.29	0.17
Alkalinity (ppm)	15.3	26.1	91.1	52.3	30
Sulfate (NTU)	109	162	340	162	100
Phosphorous (ppm)	0.106	0.08	0.096	0.09	0.096
Chloride (ppm)	17	2.9	3.9	5.0	3.0
Organic Content (%)	4.7	0.95	1.03	1.72	4.19
Carbon (%)	2.7	0.55	0.6	0.99	2.43
Boron (ppm)	5.82	3.2	4.4	3.2	3.6
Lead(pb) (ppm)	54	33	36	34	37
Zinc(Zn) (ppm)	122	208	138	140	192
Iron(Fe) (ppm)	40128	36415	26423	24681	31610
Chromium(Cr) (ppm)	129	135	110	104	139

Table 5 : Trace element concentration in bottom sediments of the Deepar Beel

Elements	Site 1	Site 2	Site3	Site 4	Site 5
Pb (ppm)	100	100	100	100	100
Sn (ppm)	10	10	10	10	10
W(ppm)	100	100	100	100	10
Ge (ppm)	10	10	10	10	10
In (ppm)	10	10	10	10	10
Co(ppm)	50	50	50	50	50
Ni (ppm)	50	50	50	50	50
Bi(ppm)	20	20	20	20	20
Ti (ppm)	500	1000	700	1000	500
Mo(ppm)	10	10	10	10	10
V(ppm)	30	100	10	10	10
Cu(ppm)	70	50	50	50	50
Ag(ppm)	1	1	1	1	1
Nb(ppm)	30	30	30	30	30
Ta(ppm)	500	500	500	500	500
Zr(ppm)	10	10	10	10	10
La(ppm)	50	50	50	50	50
Y(ppm)	30	30	30	30	30
Yb(ppm)	5	5	5	5	5
Mn(ppm)	50	30	10	10	10
Sc(ppm)	10	10	10	10	10
Be(ppm)	5	5	5	5	5
Ba(ppm)	50	30	10	10	10
Sr(ppm)	50	100	100	100	100
Zn(ppm)	125	100	100	125	125
Cd(ppm)	20	20	20	20	20
Cu O %	1.19	0.49	0.35	0.35	0.56
Mg O %	1.75	0.70	0.40	0.65	1.10
S (ppm)	1757	6355	2750	1845	6500
Fe_2O_3 %	8.50	5.80	4.20	4.60	8.90
Cl %	0.44	0.96	0.44	0.26	0.44
P_2O_5	0.175%	500 ppm	500 ppm	100 ppm	0.2%

Table 6 : Physical properties of the Deepar Beel soil at various depths

Depths (m)	Specific Gravity	Liquid Limit	Plastic Limit	Plasticity Index
0 - 1.5	2.59	44.00	18.79	25.21
1.5 - 2.1	2.625	----	----	----
2.1 - 3.0	2.59	38.44	19.03	21.41
3.0 - 3.9	2.58	----	----	---
3.9 - 4.2	2.615	52.23	25.49	26.74

During most of the time the Beel is fully covered with thick green floating algae called as phumdi which is collected by the local people for providing fodder to the cattle. These phumdi are also utilized by the fisherman to catch the fishes. Anaerobic decomposition of the phumdi during non-monsoon season is also one of the main reasons for bad water quality and foul smell. During monsoon season these phumdi gets washed away due to flash flood passing through Deepar Beel. These phumdi also obstruct the flow near the sluice gate at river Kanijhan for passing the flow to river Brhamputra. There is cultivation of local type of paddy in the Beel. Due to deteriorating water quality of the Beel the yield of the paddy has also gone down. The water quality is also affecting the health of people active in use of the Beel.

Table 7 : Physical and Chemical Analysis of Water in Bharalu River

Parameters	Sampling Points					
	A	B	C	D	E	F
Color	Slightly Brownish	Slightly Yellowish	Not very clear	Slightly Yellowish	Gray	Slightly Yellowish
Turbidity	Slightly Turbid	Turbid	Not very clear	Turbid	Turbid	Turbid
Smell	No Smell	No Smell	No Smell	No Smell	No Smell	No Smell
Sediment	Present (iron)	Present (clay)	Present (siliceous matter)	Present	Present	Present (clay)
pH	6.9	7.3	6.9	7.1	7.0	6.8
Total Solid	197.0	213.0	138.0	258.0	267.0	281.0
Total Soluble Solid	118.0	109.0	61.0	127.0	157.0	184.0
Total Hardness	40.0	19.0	19.0	32.0	58.0	51.0
Cl	6.0	5.5	5.0	12.0	5.5	13.0
So	Trace	0.82	Trace	1.97	8.24	6.76
Dissolved Oxygen	4.24	7.47	5.75	7.37	7.17	8.98
B.O.D.	26.66	17.90	21.0	9.11	14.03	12.92
Oil & Grease	Trace	4.0	4.8	7.2	6.0	5.2
Phenolic Compoun d	Trace	Negligible	Negligible	Negligible	Negligible	Negligible
Chlorine Demand	3.1	3.0	2.9	3.1	2.6	2.9
Acidity as CaCo3	5.25	Nil	Nil	Nil	Nil	5.25

A : Water sample at U/S of concrete bridge, west of Coca-Cola factory, Narangi.
B : Water sample at U/S of concrete bridge on Bharalu, A.T. Road crossing, Khanapara.
C : Water sample at U/S of concrete bridge near Basistha on the National Highway Diversion.
D : Water sample at D/S of wooden bridge, near concrete bridge of N.H. Diversions.
E : Water sample at U/S of concrete bridge on A.T. Road (Outlet of Deepar Beel).
F : Water sample at D/S of Bharalu sluice gate.

3.1 WASTE CHARACTERISTICS IN DEEPAR BEEL BASIN

Like all other areas the Guwahati Metropolitan District derives the waste water in two basic forms; the domestic wastes and the industrial wastes. The present location and zoning of the industries suggest that industrial waste will be the major contributor of the wastes. The major industries existing at present which produce industrial wastes of appreciable quantity are the Oil Refinery, Industrial Gas, India Carbon etc. located within the Noonmati Sector, the Bi-Cycle factory (producing nitric acid effluent from the pickling and electroplating plant) in the Kalapahar area and some small industries like the Frutos (a good processing industry), some medium and small size automobile garages (contributing oil and grease of appreciable quantity), and some heavy and medium size industries like M/s Steelsworth, a few flour mills, a biscuit manufacturing company located in the Dispur area of Guwahati City. Within Guwahati some minor industries are also located but they do not pose any serious problem.

All these industrial effluents are being collected into the public sewerage system. But before the industries are permitted to connect their effluent into the public sewer lines the effluents should be properly analyzed and checked so that they do not contain any materials above certain specified limit of concentration which may damage the sewer lines and other appurtenances of the system as well as it should conform to the standards laid down in Industrial Waste Ordinance. The industrial waste problem can be best handled if all individual industries are dealt according to its own merit. Some control of the effluent quality and quantity is necessary for the following reasons:

1. To protect the system of conduits from damage which might be caused by acidic corrosion, or alkaline action, explosions of volatile substances or deposits of solids and problems of grease.

2. To prevent disturbance of treatment processes which might be caused by shock loads or substances toxic to biological treatment units.

3. To prevent the deterioration of the receiving water reuse through the addition of undesirable substances, as brines, boron, or heavy metals, etc.

3.2 LAND USE PATTERN OF DEEPAR BEEL

Land use pattern of Deepar Beel area as in 1967-68 is shown in figure 5 where as the land use pattern in 189-90 are shown in figure 6 and 7. Comparision of these figures show the rapid growth of activities in Deepar Beel area. Due to increase activities the pollution load on Deepar Beel water and its resources are increasing termendously.

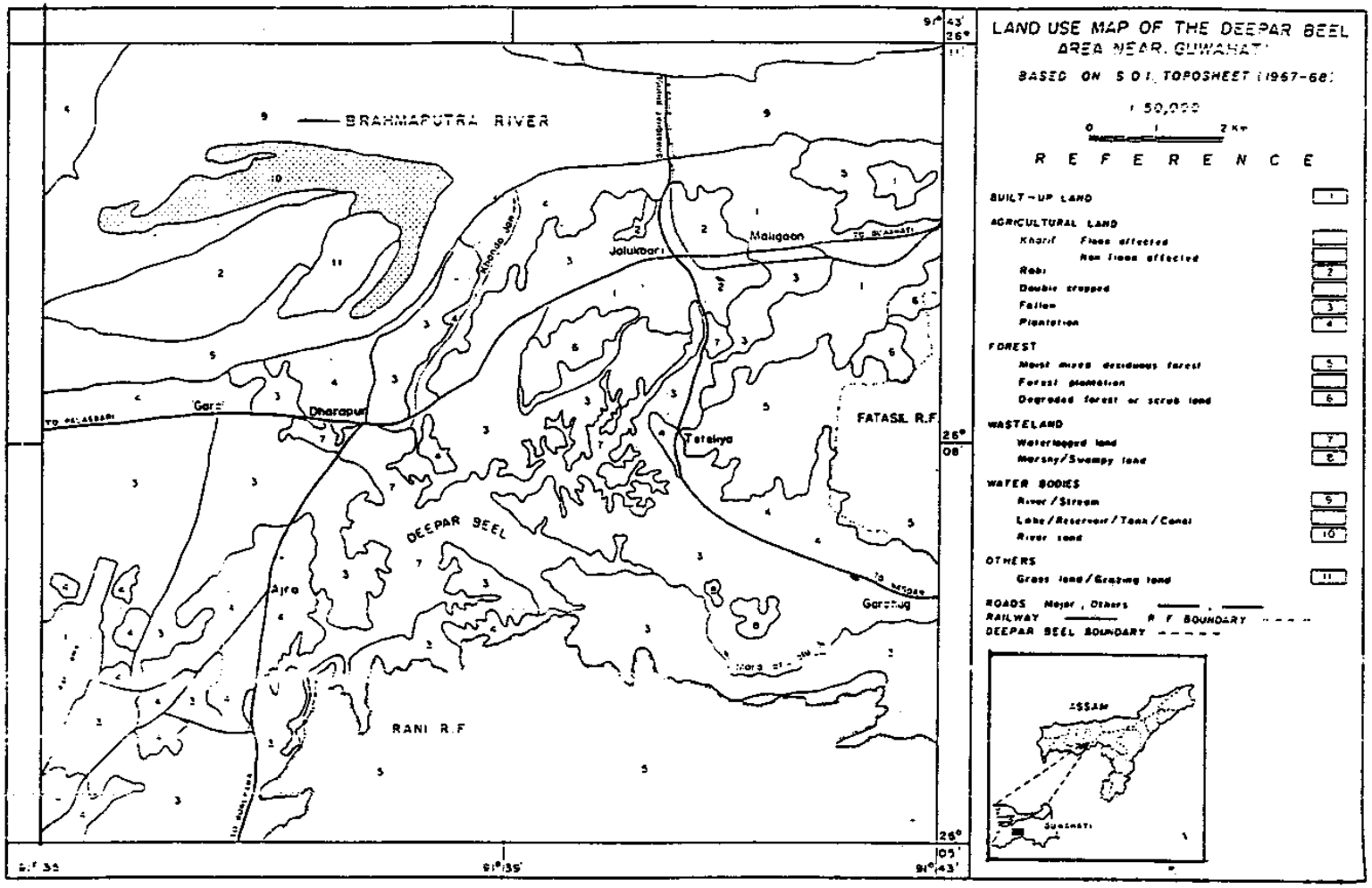

Fig. 5 : Land use map of the Deepar Beel area near Guwahati in 1967-68

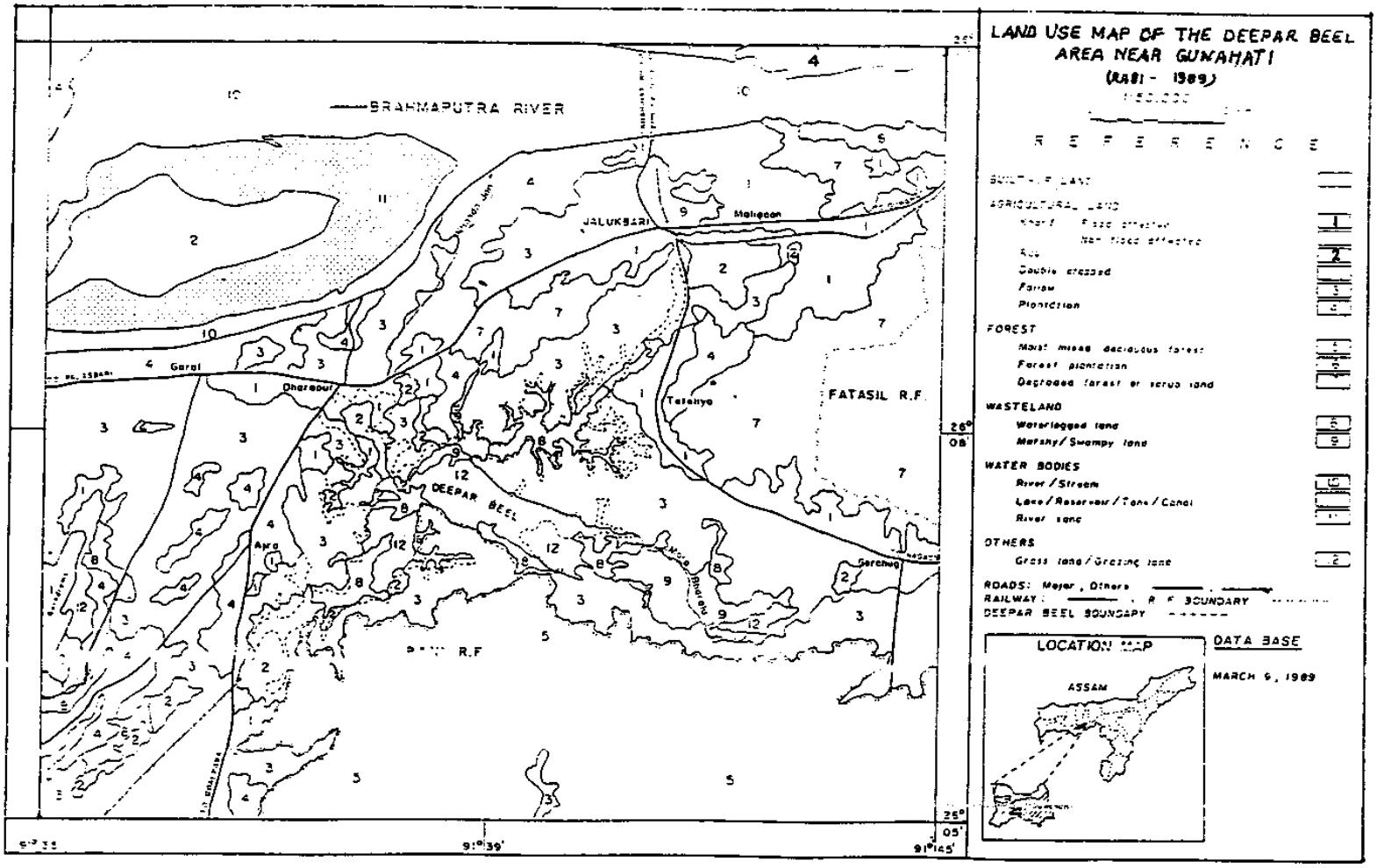

Fig. 6 : Land use map of the Deepar Beel area near Guwahati in Rabi season of the year 1989

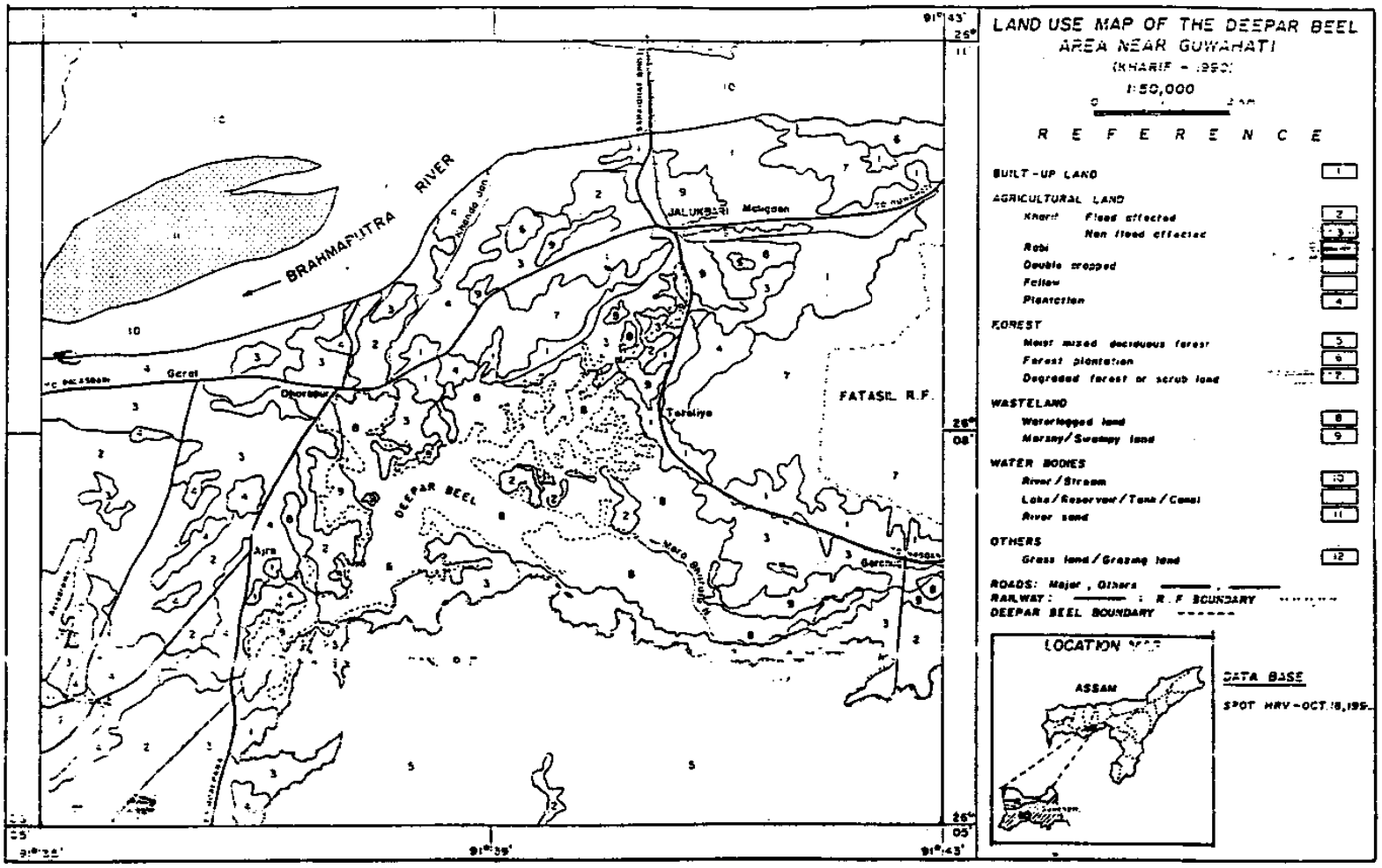

Fig. 7 : Land use map of the Deepar Beel area near Guwahati in Kharif season of the year 1990

4. PRESENT STATUS OF RESEARCH ON DEEPAR BEEL

Even knowing the importance of the Deepar Beel to the city of Greater Guwahati and its adjoining area, little attention has been paid to the detoriating condition of Deepar Beel by State Authorities by declaring the Beel are as the reserve area to prevent further encroachment of the Beel. Neither any restoration work has been taken up nor any research work has been undertaken for predicting the behavior of the Beel under different loading scenario. However, the problems of the Beel have been studied from limnological and ecological importance but no any hydrological aspects has been addressed to. Limnological studies mainly include the study of the various phytoplankton, zooplankton and their relationship with the physio-chemical environment of the Beel, study related to macrophytes and productivity of the lakes, etc. There is no any study reported on evaporation, Beel ground-water interaction, water balance of the Beel, sedimentation in the Beel. A brief mention of the observation of water quality of the Beel and its adjoining catchment area has been made for a year (**et. al, 1990**) in one of the reports but the information is not adequate for the detailed guidelines to monitor the quality of the Beel water. No attempts to evaluate the flux of limiting nutrient, the net nutrient loading etc. has been done so far. No studies are reported on the nutrient budgeting of the Beel. In the absence of these studies a proper appraisals of the eutrophication problem can not be made and no specific control measures for the control of eutrophication is possible. The evaporation rate in the given climatic conditions is expected to be high but no evaporation studies have been carried out so far. It is assumed that the evaporation data giving the pan evaporation observed at the nearest meteorological observatory is made use for all the irrigation design and other purposes. Since the pan evaporation data is not a true representative of the actual evaporation from the Beel, especially in the absence of local pan coefficients, the results obtained can be erroneous thereby affecting the efficiency of water management programs. The relationship between the pan evaporation of the nearby meteorological station data and Beel evaporation needs to be studied. The Beel is reported to show marked fluctuations in its water levels in different seasons and from year to year. However, no attempt to predict these variation have been made so far. Hydrological studies should be taken up and models should be developed to predict the water level fluctuations of the Beel.

5. PRELIMINARY INVESTIGATION OF DEEPAR BEEL

Reconnaissance and preliminary survey of whole Deepar Beel area has been conducted and major features of Deepar Beel such as different portion of the Beel identified by their different names such as Bar Shala, Bara Beel, Kanhia Mukh, Bahini Mukh depending the depth of water and extension of water spread for that depth of water have been identified. In non monsoon season (December to April), the depth of water in shallow portion of the Beel is about 3 feet where as in the deeper portion of the Beel, the depth of water is about 6 feet. These depth of water dry to an approximate lower depth of 2 feet and 5 feet respectively up to the onset of monsoon rainfall. During dry season there are so many islands in the Beel area but during rainy season i.e. from June to October the whole area is completely submerged and the depth of water in the shallow portion go up to about 10 feet and in the deeper portion up to 12-3 feet. The input to the Beel is by Basistha Bahini river at the southwestern portion of the Beel and major exit from the Beel is by river Kanijhan at the north west portion of the Beel. River Kanijhan meets river Brhamputra a short distance north of the Beel. There is significant flow in the stream running across the Beel from entry of the stream to the Beel to the exit of the stream from the Beel. There is another exit also by river Kalmani which merges with river Brhamputra at Palasbari at a distance of about 15 Km from the exit of Deepar Beel. The flow from Kanijhan to Brhamputra is regulated by a sluice gate. During rainy season the level of Brhamputra is higher than that of the Deepar Beel. Any faulty operation of sluice gate on river Kanijahan may prove to be disastrous for the city of Guwahati because drainage of Guwahati is carried to Deepar Beel through river Basistha Bahini and Bharalumukh. One stream of Bharlumukh, called, "Mora Bharalu" meets river Basistha Bahini before entry of Basistha Bahini to Deepar Beel.

5.1 INSTALLATION OF GAUGING SYSTEM IN DEEPAR BEEL

The objective of installation of gauging system in Deepar Beel is to continuously record the water level in the Beel so that the data generated on water level will help in establishing the volume capacity curve of the Beel.

5.1.1. Approach for installation of the Gauging System

For installation of gauging system two site in the Beel were identified during reconnaissance survey. One site was identified in the shallow portion of the Beel and the other in the dipper portion of the Beel which is also the core area of the Beel. In the shallow portion the Beel, water dries during the non rainy season and in the dipper portion the water depth during non rainy season is about 6 to 7 feet. Hence one gauging system was installed in the dipper portion so that water level can be recorded in non rainy season because it was identified that shallow and dipper portion of the Beel are well connected by running streams and level of water can be correlated to each other. During monsoon season the depth of water in the dipper

portion go as high as 15 to 17 feet and in the shallow portion as high as 7 to 8 feet, as came to know during the reconnaissance survey. To take reading in the dipper portion one has to approach by boat where as to take reading in the shallow portion reading can be taken with the help of a binocular from the near by building of the office of the Principal of Assam Engineering College, Guwahati.

5.1.2 Gauging System

A twelve feet wooden log of ten inch diameter was first treated with black tar and driven into the ground in the shallow portion. About six feet of the log was driven into the ground leaving six feet portion to project above the ground. A ten feet long wooden enameled leveling staff, commercially purchased from the market was fixed firmly on the projecting portion of the log with the help of locally fabricated steel clamp. The reduced level established near the Assam Engineering College was transferred to the installed staff. The system was found to be satisfactory. A photograph was taken to be attached with the report.

A twelve feet wooden log of ten inch diameter was first treated with black tar and driven into the bottom of the Beel in the Dipper portion. About six feet of the log was driven into the ground leaving six feet portion to project in the water above the ground. A ten feet long wooden enameled leveling staff, commercially purchased from the market was fixed firmly on the projecting portion of the log with the help of locally fabricated steel clamp. The reduced level established near the Assam Engineering college was transferred to the installed staff. The system was found to be satisfactory.

5.2 STUDIES TO BE TAKEN FOR DEEPAR BEEL

With the growing pressure on the Deepar Beel due to ever increasing population of Guwahati City, the need for proper Beel management and conservation is urgent. Thus, there are two main tasks to be achieved in the area of lake research in India under this pilot project viz. to carry out systematic research in the area of lake hydrology for the Beel and second to tackle the actual problems this Beel is facing. The status of the Deepar Beel has already been discussed in the previous sections. Here the research is required to fulfill the hydrological research needs of this Beel. The evaporation studies, the thermal studies and the water balance studies involving the hydrological inter-relationship studies of the Deepar Beel in particular are the major components of the objectives of hydrological research whereas water quality studies, nutrient budgeting, eutrophication studies should also be taken simultaneously to aid the management of the Deeapr Beel.

Since the water level fluctuates remarkably during different times of the year, there is immediate need to conduct studies on the morphometry and water balance of the Deepar Beel. Since the temperature varies over a range of 15-30° c and wind always blows over the Beel, hydrodynamics, thermodynamics, energy and heat budget of this Beel needs to be investigated

thoroughly. Water quality of the Beel varies considerably over the years and there are indications of bacterial action and eutrophication, a detailed analysis of quality of water in the Beel must be undertaken. Furthermore the Beel capacity is getting reduced gradually, a study on sedimentation processes, rates of sedimentation will be helpful on predicting the life of the Beel and to develop rectification process to restore the Beel.

The following aspects of the Beel need to be studied and model should be developed for the phenomena as seemed to be appropriate.

A) Morphometry of Deepar Beel

Computation of morphometric indices. The determination of the age of Beel water, the turnover time in dipper portion of the Beel, storage period, flow channels and stagnant zones.

B) Water balance of the Beel

Water balance study of the Beel will provide very useful information on availability of water in Beel at any time. In order to properly utilize the Beel water, the knowledge of different components of water balance is essential. Water balance relationships form the basis for rational, deterministic, hydrological forecasting models and are necessary for

⇒ forecasting of Beel water levels for shorelines, property utilization and navigation.
⇒ the design, selection and operation of forecasting models.
⇒ predicting environmental impact i.e. preservation of living resources of a lake or Beel through the maintenance of water quality standards.
⇒ obtaining valuable information base for effective management.
⇒ help in regional studies of climate variability.
⇒ understanding of inter-dependence of Beel and adjoining catchment.

Water balance studies as such are also basic to calculate nutrient budget visa-a-visa to assess the cause of the Beel deterioration and to find the response of the Beel to change in catchment parameters.

To assess the water balance of the Beel the following studies have to be under taken:

⇒ Rainfall runoff modeling of the lake catchment area.
⇒ Routing through the Beel.
⇒ Change in storage i.e. prediction of Beel water fluctuation at different control points in the Beel.
⇒ Surface outflow - the data of lake water which is being drawn for different purposes i.e. irrigation, domestic use, industrial, power generation,
⇒ Evaporation from the Beel water surface and catchment area.
⇒ Beel ground water interactions.

In order to ascertain the water balance of the lake, the following three indices have to be developed :

⇒ The average volume of water in the Beel related to the average annual flux (algebraic sum of input and output) component of the water balance. This ratio characterizes the renewal process of water in the lake.
⇒ Ratio of average annual precipitation on the Beel surface to the average annual flux.
⇒ Ratio of average annual evaporation to the average annual flux.

C) Thermodynamics /thermal regime of the lake

⇒ Study of development of thermal regime by taking temperature depth profile.
⇒ Development and application of one dimensional thermodynamic-hydrodynamic model.

D) Hydrodynamics of the lake

In the beginning it will be assumed that there is complete horizontal mixing in the Beel. Only vertical mixing will be consider to study the hydrodynamics of the lake and develop one dimensional hydrodynamic model for the Beel. Studies will be undertaken

⇒ to determine the magnitude of currents, and current generating mechanism, wind driven currents, waves & oscillation, seiches.
⇒ to determine dispersion in the beel.
⇒ to determine diffusion in the beel.

Radioisotope tracer techniques have come out as a practical tool for studying the local distribution and dilution rate of waste water discharged into a watercourse and the short term and local characteristics of flow patterns in lakes and also to determine the residence time in lakes.

Tritium, the radioisotope of hydrogen will be used :
⇒ to determine the micro-mixing processes and currents in the Beel,
⇒ to examine the water balance of the Beel,
⇒ to determine the composition of water in the Beel according to origin,
⇒ to determine, in principle, the age of Beel water and the changeover period of change,
⇒ to determine the low-velocity flow and diffusion in the Beel water mass.

E) Sedimentation study

⇒ to determine the influx and outflux of sediment into the Beel.
⇒ to determine rate of sedimentation.
⇒ to estimate the life of the Beel.
⇒ to determine the density of suspended sediments by field observation.

F) Water quality study

⇒ Periodic sampling of water of the Deepar Beel for conducting physical, chemical and biological analysis.

G) Energy budget and heat budget

⇒ To compute the net energy being gained by the Beel during different period of the year.
⇒ To determine heat fluxes from sediments to water and from water to sediment.

H) Eutrophication study

Deforestation, conversion of grassland into cropland, intensification of agricultural production, land amelioration etc. are energy input into the catchment of this Beel. The energy input affects micro climate and reduces evapotranspiration thus increasing runoff and siltation viz. nutrient input. Increased eutrophication of the Beel is one of the reason for such nutrient enrichment. Eutrophication is accelerating when the Beel water is not able to purify itself because its dissolved oxygen is consumed in oxygen demanding biochemical processes thereby developing an aerobic conditions. The prolific growth of water hyacinth due to the presence of phosphate and nitrate nutrient and over crowding of algae and weeds, their eventual death and decay is further adding to eutrophication of the Beel. One of the major cause of eutrophication of the Beel is the recent increase in indiscriminate discharge of untreated domestic wastes along the refuse and solid waste resulting in severe impairment of physical, chemical and biological qualities of the Beel water.

The existing data have been collected form the different water resources organization active in the region of the Beel. The available data would be extended and further data would be collected by field study for

⇒ determination of eutrophication using different indices,
⇒ nutrient budgeting in the Beel,
⇒ determination of influx and outflux of nitrogen and phosphorous into the Beel.

5.3 FEASIBILITY FOR THE STUDIES

The National Institute of Hydrology is a premier institute in the field of applied hydrology and water resources in the country and undertakes the research related with specific problems. Keeping in view the importance of natural as well as man made lakes and the problems being faced by Deepar Beel in Guwahati City, National Institute of Hydrology of India at Roorkee would undertake one pilot project to study the problems faced by the Deepar Beel and come out with a solution manual for this lake. Deepar Beel would be analyzed with respect to hydrological and climatological data and model would be developed to predict water balance, water quality of the Beel. After completion of this pilot project, National Institute of Hydrology would be able to take case study of other lakes/beels in different climatological regions of North East India.

5.4 MAPPING OF EXISTING DATA

The existing data related to the Deepar Beel have been collected from different agencies of Govt. of Assam, other relevant sources in India. The mere data available have been complied and analyzed in this report. The inflow and out flow data from the Beel are not available. When there are no measured data available for the drainage basin surrounding the water body or in areas where data are scare, it may be possible to estimate inflow to the Beel through the following commonly used techniques:

(a) The analogue method, (b) The water balance method, and (c) Basin run-off (isochrone) maps.

In the case of non-gauged or insufficiently gauged water bodies, an estimation of the water balance components can in some case be obtained through the use of regional maps and atlases.

For large lakes, inflow may be estimated with the help of runoff isochrone maps. Precipitation isohytes maps can be used directly only for estimating precipitation on small water bodies less than 100 Km^2 in areas. Maps of evaporation from water surface are often based on insufficiently corrected data from evaporation pans or tanks and such maps provide only rough estimation of the true evaporation from lakes. If the evaporation maps are not available, evaporation form the surface of a water body may be approximately determined with the help of maps of net radiation, air temperature and humidity.

5.5 PLANNING AND ORGANIZATION OF MONITORING PROGRAM

For continuously monitoring the Beel, the related data must be collected on a regular basis for which the following activities are proposed:

1. Installation of rain gauges all around the Beel in the catchment area for monitoring precipitation.

2. Installation of automatic water level recorder in the rivers/streams coming in and going out of the Beel to have a continuous record of the discharge. To compute the discharge from the seasonally flowing streams, current meters (Pigmy type) would be used.

3. Isotopes techniques will also be used for measurement of inflow into the lake through visible gullies, nalahs and springs, the changeover time of water in the Beel. Changeover time of a the Beel is a very important hydrological aspects. For concentrating on eutrophication aspects, changeover time in shallow lakes/Beel is of great importance.

4. A Pan-Evaporimeter would be installed at the lake site to estimate the evaporation from the water surface. Evaporation will/may also be measured by evaporation sensor in the data logger.

5. The volume of water being withdrawn from the lake for different purposes would be collected from the concerned authorities.
6. Installation of automatic water level recorder at control points of the lake for knowing the water level fluctuations of the lake.

7. Installation of Automatic Weather Station near the Beel to get the continuous data on precipitation, incoming sunshine radiation, radiation being reflected, net radiation, wind speed and direction, air temperature, soil moisture, relative humidity etc. Automatic weather station has advantages that it stores the short term data on the data logger which can be downloaded at the predetermined time interval and it also gives the graphical representation of the variables.

8. Periodic collection of water samples of the Beel for testing the water quality.

9. Continuously measuring the water temperature at different depths in the Beel.

10. Other periodic data collection and analysis as per the field requirement such as continuously measuring suspended sediment concentrations..

6. PROPOSED DETAILED HYDROLOGICAL INVESTIGATION OF DEEPAR BEEL

6.1 FIELD INVESTIGATIONS

The preliminary investigation of Deepar Beel has been carried out. The detailed field hydrological investigation would consists of :

6.1.1 The Beel Analysis

This would consists of :

I. Identification of the sewage disposal point.
II. Inflow of sewage into the Beel.
III. Water quality analysis of the sewage.
IV. Measurement of inflow of monsoon water
V. Identification of inlet points/area for entry of monsoon water.
VI. Storage of monsoon water in the Beel area.
VII. Outlet points for the Beel water
VIII. Measurement of outflow from the Beel. (Outlet access to the river Brhamputra through the Khanajan outlet).

6.1.2 River Analysis

This would consists of :

I. Cross sectional survey and discharge measurement of Mora Bharalu River near Bharalumukh sluice gate. Suspended and bed load sediment data of this river.

II. Cross sectional survey and discharge measurement of Basistha River before meeting Mora Bharalu river. Suspended and bed load sediment data of this river.

III. Cross sectional survey and discharge measurement of Basistha - Bahini River before entering Deepar Beel. Suspended and bed load sediment data of this river.

IV. Cross sectional survey and discharge measurement of Kalmani River at the site just after emerging from Deepar Beel. Suspended and bed load sediment data of this river.

V. Cross sectional survey and discharge measurement of Khanajan River at the site just after emerging from Deepar Beel. This river is of great importance for hydrology of the Beel because during lean season water of the Beel passes from Beel to river Brhamputra through this river where as during monsoon season there is high flow in river Brhamputra due to which flood water of Brhamputra may enter the Beel area through this river. This case may be very dangerous because Deepar Beel acts as a surge tank for the drainage network of the city of Guwahati. All the drainage network are connected either to river Bharalumukh or Basistha which fall into the Beel, as depicted in the location map. During low flow the water of Bharalumukh is discharged in to river Brhamputra where as during flood season sluice

gate on river Bharalu near Bharalumukh is closed to prevent gushing of flood water of Brhamputra in side the city area. As a result the water of river Bharalu during monsoon season is discharged into Deepar Beel. Suspended and bed load sediment data of this river.

6.2 DEVELOPMENT OF SPECIAL MODELS/PROCESSES FOR DEEPAR BEEL

6.2.1 REVIEW OF EXISTING LAKE MODELS

(A) Lake Biological Process Models

Waste load allocations rely on the concept of reducing inputs of a limiting nutrient to control growth of phytoplankton or by controlling nutrient so that it becomes limiting. Other factors also limit the rate of phytoplankton population growth and resultant population levels. Among the other factors which may be important are meteorological parameters (such as light limitations, temperature etc.), hydrological parameters (such as hydraulic retention time, settling of sediments etc.), grazing by zooplankton. If the limitations on growth imposed by factors other than nutrient concentrations are large, it may not be economically feasible to control eutrophication with reductions in nutrient inputs.

Lake eutrophication models developed till now are classified as

(i) Simplified Models
(ii) Time variable mass balance models
(iii) Non linear eutrophication models

(i) Simplified Lake Nutrient Models

These models involve two distinct steps : (a) establishing a casuals relationship between nutrient loading and lake nutrient concentration and establishing a basis for assigning the lake a trophic state based on lake nutrient concentration which is based on the conservation of mass principle or direct empirical correlation's between pertinent characteristics.

(ii) Time Variable mass balance models

The basic mass balance equations for total phosphorous in a completely mixed lake are employed with provision for flows and load which vary with time. The resultant formulations calculate concentrations of total phosphorous which are a function of time. The calculated time history of phosphorous is then compared to observed phosphorous concentrations to provide calibration for the analysis frame work. The following models are available to calculate the concentration of phosphorous in the lake.

Name of the Model	Developer/Year of Development
(a)Time variable total Phosphorous Model	Steven C. Chapra/Great Lakes Environmental Research Laboratory, Michigan (1974)
(b) Phosphorous Mass Balance Model	David P. Larsen and John Van Sickle, U.S. Agency, Environmental Protection Oregon (1978)

(iii) Non Linear Eutrophication Models

Non linear eutrophication modeling primarily concern with the calculation of food chain extended for simulation to include upper portions of the food web including fish. Analysis of water quality variables such as dissolved oxygen is another part of eutrophication modeling. Non linear equation modeling frame works employ relatively large number of coefficients that describe the chemical, bio-chemical and biological reactions in addition to coefficients which represent physical transport such as advection, dispersion and settling. Following no linear eutrophication models applicable in one, two and three dimensional water bodies and are widely used for determination of eutrophication capacity of lakes.

Name of the Model	Developer/Year of Development
Water Analysis Simulation Program 1979	Robert V. Thomann, Dominic Di Toro, N.Y.(1975-(WASP)
WASP and Advanced Ecosystem Modeling Program (AESOP)	DonaldDominic DiToro, James J. Fitzpatrick, John I Donald, Mancini, J.O'Conner, Robert V. Thomann (1970) AESOP Dominic DiToro, James J. Fitzpatrick, Robert V. Thomann (1975)
CLEAN, CLEANER, CLEANER	Park, O'Neill, Blomfield, Shugart et. al; Eastern MS Deciduous Forest
MINI-CLEANER	Biome International Biological Program, (1973, 1977, 1980, 1981)
LAKECO, ONTARIO	Carl W. Chen, Tetra Tech. Inc. California (1970)
Water Quality for River Reservoir Systems (WQRRS)	Carl W. Chen, G.T. Orlob, W. Norton, D Smith, Water Resources Engineers Inc. (1970, 78, 80 & 1981)
Grand Travers Bay Dynamic Model	R.P. Canale, S. Nachiappan, D.J.Hineman and H.E. Allen (1973)

(B) Lake WATER Quality Models

Nowadays there exist many mathematical distributed models describing hydraulics and pollutant transport processes in large rivers and lakes, e.g. SSAR, FETRA, CE-QUAL-2, DELWAQ, BLOOM-II, MIKE11+MIKE21, AQUATOOL, and others. However, these models are often very complex and treat many substances, fractions, processes which are difficult to verify and validate. Furthermore, these model processes are developed from data and experiences from site specific lakes under mostly temperate conditions.

From another part of the spectrum, there are empirical models which describe the eutrophication level and biological structure of the lakes in relation to nutrient loading (e.g. Vollenweider, 1976; McCuley and Kalff, 1981; NAEP, 1991). During the last two decades a large number of such simple empirical lake models have been developed and used in lake planning and management. As the term "empirical" indicates, there is usually no theoretical justification of this type of lake eutrophication models. These models are mainly regression relations based on existing lake data e.g. morphomety, nutrient loading, sechi-depth, and lake water concentrations. It is well known that extrapolation to conditions which is outside the data base used for model identification is highly questionable. Further, the hydrological and meteorological conditions prevailing in India are quiet different from those of American and/or European lakes for which models have been developed and may have a significant role in the biological and chemical processes and, therefore, the existing models would fail in their predictions.

As a compromise between the complex mathematical distributed models and the simple empirical models, there are conceptual lumped water quality models, also labeled Box-models. Box-models are based on the equation of continuity for one or more components that divide the lake, and the transport processes between the boxes are usually modeled by simple first-order kinetics or empirical relations. Being lumped, the box-models do not give a space-distributed description in excess of the division into boxes or compartments. Stochastic box-models have been treated by Hoybye (1997) in relation to lake restoration and optimal data collection and decision based on model predictions.

One important problem in lake water quality modeling is the influence from internal loading (Ryding, 1985, Marsden, 1989). The term "internal loading" refers to the release (often seasonal) from the lake sediments, where pollutants are deposited during many years of heavy external loading from domestic sewage and/or drainage water from agricultural production. Again the problem has been analyzed mainly in deep, stratified lakes in Northern Europe and North America (OECD, 1982, Sas, 1989), and it is a major question whether these experiences and modeling efforts are applicable for Indian climatic conditions.

6.2.2 MODELS TO BE DEVELOPED FOR DEEPAR BEEL

The work of the model development and implementation for Deepar Beel will be based on studies reported from American and European experiences on modeling and computerized decision support systems for water resources and water quality management for lakes.

Important restrains in the Beel water quality modeling is the basic problem in estimating river inflow of pollutants and organic material from rivers into the lakes. This point has often been neglected, but the external inflow constitutes the boundary conditions for the lake (Beel) water quality models. Also many processes, types and parameters are identified and estimated from mass balances, which again are based on computation of the external loading. It is therefore of utmost importance that the external loading can be measured/computed with a high degree of accuracy for the Deepar Beel. Model must be developed for water balance of the Deepar Beel by considering all the external loading. Since there is pollutant loading in the Beel and at the same time Beel water is also being used for drinking purposes, hydrodynamics and wind induced currents and circulation must also be studied and model should be developed for describing the hydrodynamics of the lake. There exists a clear need for the development and application of dynamic model capable of predicting the response of Beel water and sediment to loading of organic and inorganic material, coupled with on going sediment deposition and resuspension scenario. The model should describe the major dynamics and transformations of N and P within catchment soils, lakes sediment and waters. To start with we will consider the lake as completely mixed horizontally and restrict the study to nutrient balances including resuspension.

Model of Eutrophication of the Deepar Beel Water – With Aggregated Nitrogen and Phosphorous Dynamics would be developed for the Deepar Beel for wide application and scenario assessment. The aim of the model will be to maintain the acid/base chemistry of the lake and consider in addition the impacts of changes in nitrogen and phosphorous deposition (agricultural runoff) due to changes in nitrogen and phosphorous utilization within the lake catchment area. The model will use estimates of nitrification, mineralisation, N fixation and denitrification, phosphorous fixation and changes of these in sediment processes through time. Plant uptake dependent upon inorganic nitrogen and phosphorous concentrations in sediment and water solution will be considered. Calibration of the model will require specification of values for the soil N and P fluxes and for the parameters which describe the uptake function. Field observational and experimental work on N, and P fluxes and dynamics from different systems is essential to facilitate the site specific and regional model calibration. Field work is required to identify ranges of values appropriate to the given Beel species, plants conditions and climatic conditions. This will include more rigorous model sensitivity analysis of existing literature (if any) and data describing N, and P concentrations and catchment characteristics and further field surveys of relevant parameters. Specific catchment related values will be obtained by field survey for the catchment of the Deepar Beel. Selection of uptake parameters must reflect current catchment and Beel vegetation and vegetation changes through time and this would be investigated in the detailed field study of the Deepar Beel. Changes in sediment processes in the Beel through time are also important for model functioning. But change in sediment processes and diffusion of sediment from sediment to water phase will be considered later on.

7. METHODOLOGY FOR THE DETAILED SURVEY

I. Procurement of the equipment and their installation in the Beel catchment.

II. Hydrographic survey of the whole Beel.

III. Depth (bathymetric) and temperature survey of the lake.

IV. Procurement of remote sensed imageries for the Deepar Beel area for pre and post monsoon season.

V. Water sample (Grab and composite) collection and analysis for physical and chemical parameters. A grid will be established for collection of samples for water quality testing. At pre determined points in the Beel water samples would be collected and analyzed on regular basis.

VI. Survey for the turbidity of the beel water. Qualitative assessment of the turbidity will be compared with the remote sensed data.

VII. Cross-sectional, discharge, sediment load measurement for the major inlet and outlet of the Beel. Water quality parameters of these streams will also be measured.

VIII. Vegetation survey of the Beel and their quantification.

IX. Analysis of the Beel as a surge tank for the city of Guwahati because the storm water from city of Guwahati first temporarily gets stored in the Beel and then pass over to the river Brhamputra.

X. Finally Deepar would be completely instrumentalised, computerized with the help of the models developed so that Deepar Beel would act as a tank for Guwahati city. For any activity to take place in Deepar Beel, decision can be taken with the help of the models developed.

8.0 PROJECT WORK PLAN FOR DEEPAR BEEL

8.1 SHORT SUMMARY OF THE PROJECT :

There is complete mixing of water of the Deepar Beel Lake due to continuous inflow of water into the Beel. Hydrodynamics, thermodynamics, wind induced currents and circulation in the Beel would be studied and mathematical models would be developed. Since the Beel water is used for domestic and industrial purposes and at the same time domestic, agricultural, and industrial sewage are finding their way into the Beel, dynamic model capable of predicting the response of lake water and sediment to loading of organic and inorganic material, coupled with on going sediment deposition and re-suspension scenario would be developed. The model would also describe the major dynamics and transformations of Nitrogen (N) and Phosphorous (P) within catchment soils, Beel sediment and water. Change in sediment processes and diffusion of sediment from sediment to water phase due to mixing would be also be tried to be considered.

8.2 DETAILED PROJECT ACTIVITIES

Field work will constitute installation of hydrological and meteorological instruments, bathymetric survey, continuous survey for depth-integrated temperature profile, collection of water samples for physic-chemical analysis, collection and analysis of suspended and bed-load sediment in the lake, measurement for discharge, current velocity and direction.

The project on preliminary hydrological aspects of Deepar Beel would involve various techniques of geological mapping, remote sensing applications, water quality aspects etc. The study planned would be carried out in different phases. The details of these activities are outlined below along with the time frame for different phase.

PHASE I (First two months)

1. Procurement of and remote sensed imageries of the catchment area of Deepar Lake.
2. Installation of equipment/instruments.

PHASE II

1. Remote Sensing Investigation (Next two months)

The following investigations will be carried out using remote sensed imageries

I. Identification of the lake catchment area using available imageries.
II. Geomorphology of the lake.
III. Water spread area of the lake.
IV. Forest and vegetation cover of the catchment area.
V. Turbidity level mapping.

2. Detailed Field Program (Next two months)

I. Collection of data on water level, suspended and bed load in the lake and other water quality parameters including seepage loss measurement.

II. Detailed bathymetric survey of the lake to define configuration of the Beel.

III. Detailed temperature survey of the Beel.

IV. Detailed depth integrated sampling of water for testing water quality.

V. Detailed study for the evaporation loss from the Beel water surface.

VI. The physical parameters such as temperature, pH and electrical conductivity would be determined in the field at the time of sample collection. The total dissolved solids (TDS) will also be determined in the field using portable water testing kit.

3. Laboratory Works (Next three months)

A) The collected water samples will be subjected to the following analysis in the laboratory :

I. The total hardness and calcium hardness will be determined by EDTA titrimetric method, while magnesium hardness by deducting calcium hardness from total hardness. Calcium (as C_a^{+} ions) will be calculated by multiplying calcium hardness by 0.401 while magnesium (as M_g^{++} ions) by multiplying magnesium hardness by 0.243.

II. Sodium and potassium will be determined by flame - emission method using Flame Photometer or by Atomic Absorption Spectrometry.

III. Chloride will be determined by argentometric method in the form of silver chloride.

IV. Acidity/alkalinity will be determined by titrimetric method using phenolphthalein and methyl orange indicators.

V. Phosphate and nitrate will be determined using UV-VIS Spectro-photometer. The sulfate will be determined using turbid metric method. Phosphate is estimated by Stannous Chloride Method in the form of molybdenum blue while sulfate by turbidimetric method in the form of barium sulfate crystals.

VI. Nitrogen in the form of ammonia, nitrate and nitrite is determined by using ion-specific electrodes or spectrometric methods.

VII. The dissolved oxygen (DO) of the collected water samples will be determined in the laboratory using titration method. For the analysis of bio-chemical oxygen demand (BOD) the samples would be incubated using BOD incubator for the standard five day period at 20°

Celsius. The DO will be determined initially and after the incubation. The BOD will be computed from the difference between initial and final DO values.

VIII. Water quality analysis including pollutants.

IX. Trace elements are determined by atomic absorption or atomic emission methods. Solids are determined by gravimetric method.

B) The water of the streams meeting the Beel including tiny streams will also be subjected to the similar analysis.

4) Data compilation and interpretation (Next three months)

All the data collected thorough different field trips, laboratory analyses would be complied, analyzed and presented in the form of a report.

PHASE III (Next twelve months)

I. Time series of annual precipitation, inflow in the Beel and outflow from the Beel, and stages of the beel would be analyzed. The area of the Beel and the corresponding water volume as a function of the level of the Beel would be found out.

II. Water balance of the Beel would be found out by using conventional techniques including remote sensing techniques. The relationship between the mean annual level of the Beel, the mean annual inflow and outflow of the river merging and diverging out of the Beel would be analyzed.

III. Rate of sedimentation would be found out using conventional and remote sensing techniques.

IV. Recharge sources of the lake would be identified using remote sensing techniques.

V. Determination of Beel pollution with respect to the source of pollution and its distribution/mixing with Beel water using chemical/conventional, and remote sensing techniques.

VI. Compilation and analysis of data collected with the help of equipment installed at the Beel site and in the Beel catchment area.

VII. Analysis of the data collected during phase II to derive meaningful interpretation through an integrated approach. To predict a trend of process which started a century ago, even hydrological data for the last 20 years are not sufficient. By applying hydraulic and morphological analysis, it can be possible. Another approach of this problem is through analysis of hydrological data by means of the probability theory and mathematical statistics.

PHASE IV (Next twelve months)

I. Development of temperature model for the Beel.

II. Development of model for water balance for the Beel.

III. Development of model for river induced circulation in the Beel.

IV. Development of model for sedimentation in the Beel.

V. Preparation of final report with possible suggestions for the overall improvement of the Beel conditions.

8.3 PROJECT RESULTS OR OUTPUTS

Progress of the report will be reported every year in the form of an interim report on the work going on. Final report will be in the form of a computer model for the Deepar Beel and a manual detailing the ways to reduce further deterioration of the Beel and steps for monitoring the Beel..

9. ESTIMATE FOR EQUIPMENTS, THEIR INSTALLATION AND DETAILED FIELD SURVEY OF THE DEEPAR BEEL

(A) CAPITAL COST

Sr.No.	Parameter	Equipment/Instrument	Reqd.	No. Rate (Indian Rs.)	Total (Rs.)
For Water Balance Study					
1.	Precipitation	Ordinary Raingauge	Five	2000/-	10,000/-
		S.R.R.G(Automatic)	Five	8000/-	40,000/-
2.	Inflow/Outflow	Automatic Water Level Recorder	Five	15,000/-	75,000/-
		Current Meter	Five	20,000/-	1,00,000/-
		Pigmy Type Current	Five	6,000/-	30,000/-
		Rate Meter/Scaler (For Gamma Ray Tracer)	One	Available at NIH, Roorkee	
		Liquid Scintillation Counter	One	Available at NIH, Roorkee	
3.	Evaporation	Pan Evaporimeter	Two	5,000/-	10,000/-
		By isotopic Method			50,000/-
4.	Sub Surface Inflow/ Outflow	By analyzing the collected sample of water for stable isotopic composition			
5.	Storage Change	Automatic Water Level Recorder	Two	15000/-	30,000/-
For Sediment Studies					
6.	Bathymetric Survey	Echo Sounder	Four	20,000/-	80,000/-
7.	Sedimentation	Digital image processing of high resolution Satellite			
		Coulter Counter	One	40,000/-	40,000/-
		Laser Particle Size Analyser	One	2,00,000/-	2,00,000/-
		Sediment Core Sampler	Two	10,000/-	20,000/-
		Gamma Scattering Probes	Two	40,000/-	80,000/-
		Scintillation Counter	One	1,00,000/-	1,00,000/-
8	Sedimentation Rate	Gamma Ray Spectrometer with HPGE Detector	One	2,00,000/-	2,00,000/-
9.	Bed Load	Bed Load Sampler	Two	15,000/-	30,000/-

For Water Quality Testing

Field Instruments

10.	pH, DO, Conductivity, temperature	Portable Testing Kit	One	30,000/-	30,000/-
11.	Turbidity	Turbidity Meter	Two	15,000/-	30,000/-
12.	Conductivity	Conductivity Meter	Two	10,000/-	20,000/-
13.	Water Sample Collection	Depth Integrated Water Sampler	Two	20,000/-	40,000/-

Laboratory Instruments

14.	Estimation of Alkalis	Flame Photometer	One	Available at NERC, Guwahati
15.	Estimation of Ion	Ion Analyzer	One	Available at NIH, Roorkee
16.	Determination of Organic Content	Total Organic Carbon Analyzer	One	Available at NIH, Roorkee
17.	Determination of Metallic Ion	Atomic Absorption Spectrometer	One	Available at NIH, Roorkee
18.	Determination of Phosphate	Spectrophotometer	One	Available at NIH, Roorkee

General Instruments

19.	BOD Incubator	One	Available at NIH, Roorkee	
20.	Bacteriological Incubator	One	Available at NIH, Roorkee	
21.	Colony Counter	One	Available at NIH, Roorkee	
22.	Universal Oven	One	Available at NIH, Roorkee	
23.	COD Digestor	One	Available at NIH, Roorkee	
24.	Distillation Plant	One	Available at NIH, Roorkee	
25.	Electronic Balance	One	Available at NIH, Roorkee	
26.	Deep Freezer	One	Available at NIH, Roorkee	
27.	Water Sampler	Two	10,000/-	20,000/-

Meteorological Instruments

28.	Ambient Temp.Stevenson Screen consisting of (i) Dry & Wet Bulb Thermometer, (ii) Max. & Mini. Thermometer		Two	15,000/-	30,000/-

Remote Sensing Instruments

29.	Procurement of Remote Sensed Imageries & Digital data				1,00,000/-
30.	Procurement of topographical maps				50,000/-
29.	Image Process.	GIS Systems		Available at	NIH, Roorkee
30.	Digi. of Maps	Digitizre	One	Available at	NIH, Roorkee
31.	Thermal Stratification, turnover period, identification of recharge source and zone to lake water.	Mass Spectrometer	One	2,00,000/-	2,00,000/-
32.	Different Meteorological Parameters	Integrated Data Acquisition System	One	4,00,000/-	4,00,000/-
34.	Miscellaneous				2,00,000/-

Approximate Total : Rs. 22,15,000/-

(B) RUNNING COST

1.	Installation of the equipment				1,00,000/-
2.	Project Staff				
(i)	Project Assistant	Field Survey of the beel (for six months)	Three	10,000/month	1,80,000/-
(ii)	Data Operator	To collect the data regularly (two years)	One	5,000/month	1,20,000/-
(iii)	Security Staff	To guard the safety of equipment (two years)	One	3,000/month	72,000/-

(iv)	Remote Sensing Specialist	To carry out remote sensing investigation (six months)	One	15,000/-	90,000/-
(v)	Limnologist	To carry out limnological investigation (one year)	One	10,000/-	1,20,000/-
(vi)	Biologist	To carry out biological investigation (one year)	One	12,000/-	1,20,000/-
(vii)	Chemist	To carry out chemical investigation (one year)	One	12,000/-	1,20,000/-
3	Running cost of equipments (3/99 to 12/2001)				2,00,000/-
4	Maintenance of equipments				2,00,000/-
5.	Stationeries, books & reports				2,00,000/-

Approximate Cost : Rs. 15,21,000/-

3 Field Program

(i)	Hiring of infrastructural facilities for conducting bathymetric survey and depth integrated temperature profile from time to time	2,00,000/-
(ii)	Visit of project related staff and Scientist to the field from time to time	4,00,000/-

Approximate Cost : Rs. 6,00,000/-

Total Cost : Rs. 43,36,000/- (Forty three lakhs thirty six thousand only)

9.1 Phasing of Budget :

Initial Phase

Procurement of equipments	Rs. 22,15,000/-
Field Works	
Installation of equipments/field stations	Rs. 15,21,000/-
Conducting field survey/tests, laboratory tests etc.	Rs. 6,00,000/-
	Total : Rs. 43,36,000/-

10. CONCLUSION

Deepar Beel which acts as a natural storm water reservoir during monsoon period is greatly influenced by the rapid urbanization and improper land use pattern of the Guwahati City. As it receives a large portion of sewage of the Guwahati City, the water quality of the Beel is affected due to pollution. But the preliminary hydrological investigation reveal that the Beel water is largely free from any significant level of pollution because of the dilution effects of large storm water run-off during the monsoons and the exit of Beel water to river Brhamputra through the Khanajan outlet. On the other hand, the soil quality is found to have deteriorated to a large extent. Various parameters of the soil and water quality indicate that the process of eutrophication has already started in this wetland. Although many trace elements are present in the Beel sediments, no known toxic effects are observed on aquatic life as the Beel water is not contaminated by these trace elements. The detailed investigation would help in classifying the criteria for proper management of the Beel water.

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TITLE OF THE REPORT : PRELIMINARY HYDROLOGICAL INVESTIGATIONS OF DEEPAR BEEL AND STRATEGIES FOR ITS MONITORING AND MANAGEMENT

DIVISION : NORTH EASTERN REGIONAL CENTRE, NIH, GUWAHATI, 1998 – 99

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