NATIONAL WETLAND ATLAS:

TRIPURA

Sponsored by

Ministry of Environment and Forests

Government of India

Space Applications centre
Indian Space Research Organisation
Ahmedabad – 380 015

This publication deals with the updated database and status of wetlands, compiled in Atlas format. Increasing concern about how our wetlands are being influenced has led to formulation of a project entitled “National Wetland Inventory and Assessment (NWIA)” to create an updated database of the wetlands of India. The wetlands are categorised under 19 classes and mapped using satellite remote sensing data from Indian Remote Sensing Satellite: IRS P6- LISS III sensor. The results are organised at 1: 50, 000 scales at district, state and topographic map sheet (Survey of India reference) level using Geographic Information System (GIS). This publication is a part of this national work and deals with the wetland status of a particular State/Union Territory of India, through text, statistical tables, satellite images, maps and ground photographs.

The atlas comprises wetland information arranged into nine sections. How the NWIA project work has been executed highlighted in the first six sections viz: Introduction, NWIA project, Study area, Data used, Methodology, and Accuracy. This is the first time that high resolution digital remote sensing data has been used to map and decipher the status of the wetlands at national scale. The methodology highlights how the four spectral bands of LISS III data (green, red, near infra red and short wave infra red) have been used to derive various indices and decipher information regarding water spread, turbidity and aquatic vegetation. Since, the aim was to generate a GIS compatible database, details of the standards of database are also highlighted in the methodology.

The results and finding are organised in three sections; viz: Maps and Statistics, Major wetland types, and Important Wetlands of the area. The Maps and Statistics are shown for state and district level. It gives details of what type of wetlands exists in the area, how many numbers in each type, their area estimates in hectare. Since, the hydrology of wetlands are influenced by monsoon performance, extent of water spread and their turbidity (qualitative) in wet and dry season (post-monsoon and pre-monsoon period) are also given. Similarly the status of aquatic vegetation (mainly floating and emergent types) in two seasons is also accounted for. Status of small wetlands are also accounted as numbers and depicted in maps as points. Wetland map also show important ancillary information like roads/rail, relevant habitations. False Colour Composite (FCC) of the satellite image used (any one season) is shown along with the derived wetland map to give a feeling of manifestation of wetlands in remote sensing data and synoptic view of the area. The status of some of the important wetlands like Ramsar sites, National Parks are shown with recent field photographs.

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As a part of the project on National Wetland Inventory and Assessment (NWIA)

Space Applications Centre (ISRO), Ahmedabad

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MESSAGE

It gives me great pleasure to introduce this Atlas, the latest in a series, prepared by Space Applications Centre, Ahmedabad in connection with the National Wetland Inventory and Assessment Project.

This Atlas maps and catalogues information on Wetlands across India using the latest in satellite imaging, one of the first of its kind. Wetlands are areas of land critical ecological significance that support a large variety of plant and animal species adapted to fluctuating water levels. Their identification and protection becomes very important.

Utility-wise, wetlands directly and indirectly support millions of people in providing services such as food, fiber and raw materials. They play important roles in storm and flood control, in supply of clean water, along with other educational and recreational benefits. Despite these benefits, wetlands are the first target of human interference and are among the most threatened of all natural resources. Around 50% of the earth's wetlands are estimated to already have disappeared worldwide over the last hundred years through conversion to industrial, agricultural and residential purposes. Even in current scenario, when the ecosystem services provided by wetlands are better understood - degradation and conversion of wetlands continues.

Aware of their importance, the Government of India has formulated several policies and plans for the conservation and preservation of these crucial ecosystems. Realising the need of an updated geospatial data base of these natural resources as the pre-requisite for management and conservation planning, National Wetland Inventory and Assessment (NWIA) project was formulated as a joint vision of Ministry of Environment & Forestry, Govt. India, and Space Applications Centre (ISRO). I am told that the latest remote sensing data from Indian Remote Sensing satellite (IRS P6) have been used to map the wetlands. The present atlas is part of this project and highlights the results of the study state in terms of statistics of various types of wetlands, extent of water, aquatic vegetation and turbidity in pre and post monsoon period. I also note that special efforts are made to provide detailed information of important wetlands like Ramsar sites, National Parks etc.

I am certain that this Atlas will raise the bar in developing such database and will be of great use for researchers, planners, policy makers, and also members of the general public.

(Jairam Ramesh)

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FOREWORD

Wetlands defined as areas of land that are either temporarily or permanently covered by water exhibit enormous diversity according to their genesis, geographical location, water regime and chemistry. Wetlands are one of the most productive ecosystems and play crucial role in hydrological cycle. Utility wise, wetlands directly and indirectly support millions of people in providing services such as storm and flood control, clean water supply, food, fiber and raw materials, scenic beauty, educational and recreational benefits. The Millennium Ecosystem Assessment estimates conservatively that wetlands cover seven percent of the earth's surface and deliver 45% of the world's natural productivity and ecosystem services. However, the very existence of these unique resources is under threat due to developmental activities, and population pressure. This calls for a long term planning for preservation and conservation of these resources. An updated and accurate database that will support research and decision is the first step towards this. Use of advanced techniques like Satellite remote sensing, Geographic Information System (GIS) is now essential for accurate and timely spatial database of large areas. Space Applications Centre (ISRO) took up this challenging task under the project "NWIA" (National Wetland Inventory and Assessment) sponsored by Ministry of Environment & Forests. To account for numerous small yet important wetlands found in the country, mapping at 1:50,000 scales has been taken up. Two date IRS LISS III data acquired during pre and post monsoon season are used for inventory to account for wet and dry season hydrology of wetlands. The map outputs include the status of water spread, aquatic vegetation and turbidity. Ancillary layers like road/rail, habitations are also created. Very small wetlands below the mappable unit are also identified and shown points. The results are complied as Atlases of wetlands for states/Union Territories of India. This Atlas highlights results for a particular state/UT and hopes to improve our understanding of the dynamics and distribution of wetlands and their status in the area.

I congratulate the team for bringing out this informative atlas and sincerely hope that this will serve as a useful source of information to researchers, planners and general public.

January 25, 2010

(Ranganath R. Navalgund)

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This project has benefited from the wisdom of many people**.** It is a pleasure to acknowledge the contributions made by the wetland experts especially to Prof. C.K. Varshney, Former Dean, School of Environmental Sciences, Jawaharlal Nehru University, New Delhi, Prof. A.R. Yousuf, The University of Kashmir, Srinagar, Prof. Pradeeep Shrivastava, Head, Wetland Research Centre, Barakatullah University, Bhopal, Dr. Prikshit Gautam, Director, WWF-India, Dr. S. Narendra Prasad, Salim Ali Centre for Ornithology and Nature, Coimbtore and Dr. R.K. Suri, Additional Director, Ministry of Environment and Forests, Govt. of India, New Delhi, and the database experts from ISRO who participated in the peer Review meeting to finalise the “Wetland Classification System” followed in this project

We acknowledge the positive role played by 16th SC-B (Standing Committee on Bioresources and Environment) of NNRMS (National Natural Resources Management System) meeting in formulating this project. We are extremely thankful to the members of the“Steering Committee” of the project, under the chairmanship of Dr E J James, Director – Water Institute, Karunya University, for their periodical review, critical comments and appreciation of the efforts by the project team. We are thankful to SC-B under the chairmanship of Secretary, MoEF, for periodic review of the progress of the project and guidance towards timely completion of the work. We acknowledge the valuable contributions made by Dr J K Garg, the then scientist of SAC for his active role in formulation of this project, co-authoring the procedure manual document.

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(Sushma Panigrahy)

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CONTENTS

List of Figures

List of Tables

List of Plates

1.0 INTRODUCTION

It is increasingly realized that the planet earth is facing grave environmental problems with fast depleting natural resources and threatening the very existence of most of the ecosystems. Serious concerns are voiced among scientists, planners, sociologists, politicians, and economists to conserve and preserve the natural resources of the world. One of the constraints most frequently faced for decision making is lack of scientific data of our natural resources. Often the data are sparse or unauthentic, rarely in the form of geospatial database (map), thus open to challenges. Hence, the current emphasis of every country is to have an appropriate geospatial database of natural resources based on unambiguous scientific methods. The wetland atlas of Tripura, which is part of the National Wetland Atlas of India, is an attempt in this direction.

1.1 Wetlands

Wetlands are one of the crucial natural resources. Wetlands are areas of land that are either temporarily or permanently covered by water. This means that a wetland is neither truly aquatic nor terrestrial; it is possible that wetlands can be both at the same time depending on seasonal variability. Thus, wetlands exhibit enormous diversity according to their genesis, geographical location, water regime and chemistry, dominant plants and soil or sediment characteristics. Because of their transitional nature, the boundaries of wetlands are often difficult to define. Wetlands do, however, share a few attributes common to all forms. Of these, hydrological structure (the dynamics of water supply, throughput, storage and loss) is most fundamental to the nature of a wetland system. It is the presence of water for a significant period of time which is principally responsible for the development of a wetland. One of the first widely used classifications systems, devised by Cowardin *et al,* 1979, was associated to its hydrological, ecological and geological aspects, such as: marine (coastal wetlands including rock shores and coral reefs, estuarine (including deltas, tidal marshes, and mangrove swamps), lacustarine (lakes), riverine (along rivers and streams), palustarine ('marshy'- marshes, swamps and bogs). Given these characteristics, wetlands support a large variety of plant and animal species adapted to fluctuating water levels, making the wetlands of critical ecological significance. Utility wise, wetlands directly and indirectly support millions of people in providing services such as food, fiber and raw materials, storm and flood control, clean water supply, scenic beauty and educational and recreational benefits. The Millennium Ecosystem Assessment estimates conservatively that wetlands cover seven percent of the earth's surface and deliver 45% of the world's natural productivity and ecosystem services of which the benefits are estimated at $20 trillion a year (Source: www.MAweb.org). The Millennium Assessment (MA) uses the following typology to categorise ecosystem services:

Provisioning services:	The resources or products provided by ecosystems, such as food, raw materials (wood), genetic resources, medicinal resources, ornamental resources (skin, shells, flowers).
Regulating services:	Ecosystems maintain the essential ecological processes and life support systems, like gas and climate regulation, water supply and regulation, waste treatment, pollination, etc.
Cultural and Amenity services:	Ecosystems are a source of inspiration to human culture and education throughout recreation, cultural, artistic, spiritual and historic information, Science and education.
Supporting services:	Ecosystems provide habitat for flora and fauna in order to maintain biological and genetic diversity.

Despite these benefits, wetlands are the first target of human interference and are among the most threatened of all natural resources. Around 50% of the earth's wetland area is estimated to already have disappeared over the last hundred years through conversion to industrial, agricultural and residential developments. Even in current scenario, when the ecosystem services provided by wetlands are better understood - degradation and conversion of wetlands continues. This is largely due to the fact that the 'full value' of ecosystem functions is often ignored in policy-making, plans and corporate evaluations of development projects.

1.2 Mapping and Geospatial technique

To conserve and manage wetland resources, it is important to have inventory of wetlands and their catchments. The ability to store and analyse the data is essential. Digital maps are very powerful tools to achieve this. Maps relate the feature to any given geographical location has a strong visual impact. Maps are thus essential for monitoring and quantifying change over time scale, assist in decision making. The technique used in the preparation of map started with ground survey. The Survey of India (SOI) topographical maps are the earliest true maps of India showing various land use/cover classes including wetlands. Recent years have seen advances in mapping technique to prepare maps with much more information. Of particular importance is the remote sensing and geographic information system (GIS)

technique. Remote sensing is now recognised as an essential tool for viewing, analyzing, characterizing, and making decisions about land, water and atmospheric components.

From a general perspective, remote sensing is the science of acquiring and analyzing information about objects or phenomena from a distance (Jensen, 1986; Lillesand and Keifer, 1987). Today, satellite remote sensing can be defined as the use of satellite borne sensors to observe, measure, and record the electromagnetic radiation (EMR) reflected or emitted by the earth and its environment for subsequent analysis and extraction of information. EMR sensors includes visible light, near-, mid- and far-infrared (thermal), microwave, and long-wave radio energy. The capability of multiple sources of information is unique to remote sensing. Of specific advantage is the spectral, temporal, and spatial resolution. Spectral resolution refers to the width or range of each spectral band being recorded. Since each target affects different wavelengths of incident energy differently, they are absorbed, reflected or transmitted in different proportions. Currently, there are many land resource remote sensing satellites that have sensors operating in the green, red, near infrared and short wave Infra red regions of the electromagnetic spectrum giving a definite spectral signature of various targets due to difference in radiation absorption and reflectance of targets. These sensors are of common use for land cover studies, including wetlands**.** Figure 1 shows typical spectral signature of few targets from green to SWIR region. Converted to image, in a typical false colour composite (FCC) created using NIR, red and green bands assigned as red, green and blue colour, the features become very distinct as shown in Figure 2. In FCC, the vegetation thus appears invariably red (due to high reflectance in NIR from green leaves).

Since the early 1960s, several satellites with suitable sensors have been launched into orbit to observe and monitor the earth and its environment. Most early satellite sensors acquired data for meteorological purposes. The advent of earth resources satellite sensors (those with a primary objective of mapping and monitoring land cover) occurred, when the first Landsat satellite was launched in July 1972. Currently, more than a dozen orbiting satellites of various types provide data crucial to improving our knowledge of the earth's atmosphere, oceans, ice and snow, and land. Of particular interest to India is the indigenous series of satellites called Indian Remote Sensing satellites (IRS-Series). Since the launch of the first satellite IRS 1A in 1987, India has now a number of satellites providing data in multi-spectral bands with different spatial resolution. IRS P6/RESOURCESAT 1 is the current generation satellite that provides multi-spectral images in spatial resolution of 5.8 m (LISS IV), 23.5 m (LISS III) and 56m (AWiFS). Over the past few decades, Indian remote sensing data has been successfully used in various fields of natural resources (Navalgund *et al*, 2002).

Development of technologies like Geographic Information System (GIS) has enhanced the use of RS data to obtain accurate geospatial database. GIS specialises in handling related, spatially referenced data, combining mapped information with other data and acts as analytical tool for research and decision making. During the past few decades, technological advances in the field of satellite remote sensing (RS) sensors, computerized mapping techniques, global positioning system (GPS) and geographic information system (GIS) has enhanced the ability to capture more detailed and timely information about the natural resources at various scales catering to local, regional, national and global level study.

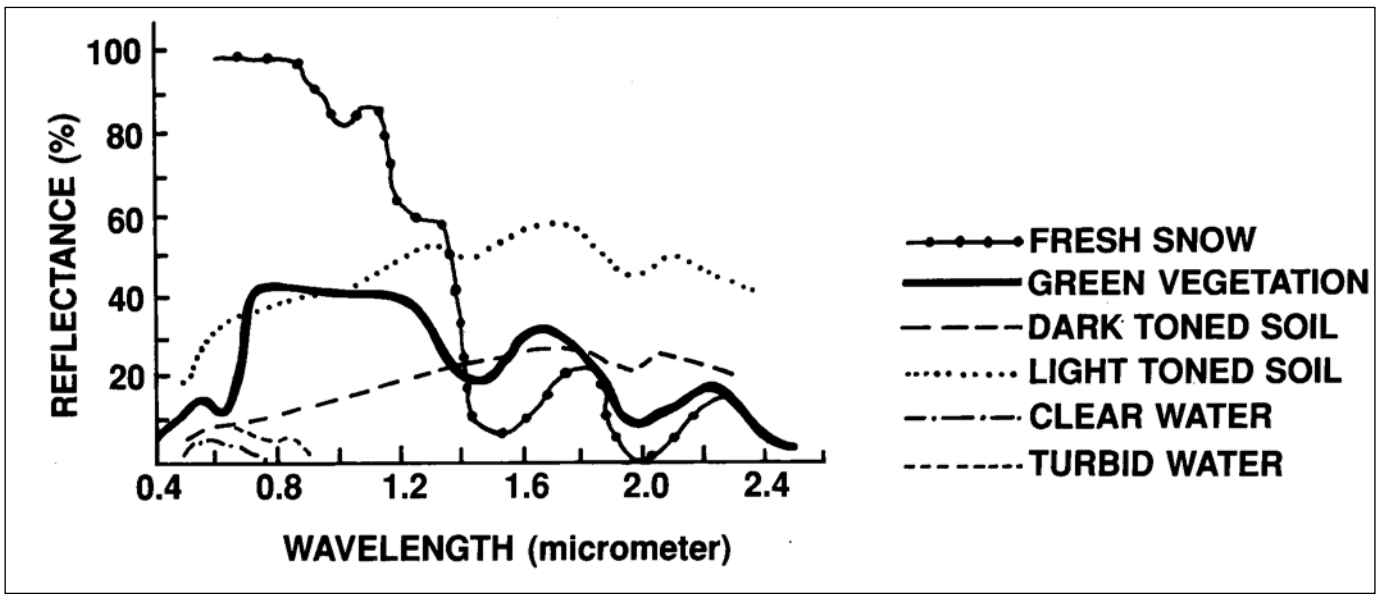
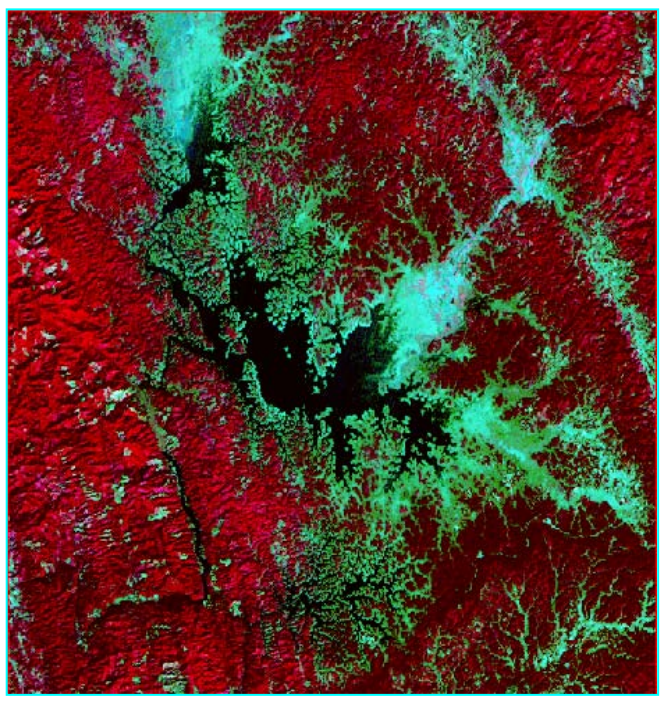


Figure 1: Spectral Signature of various targets

BAND1: GREEN

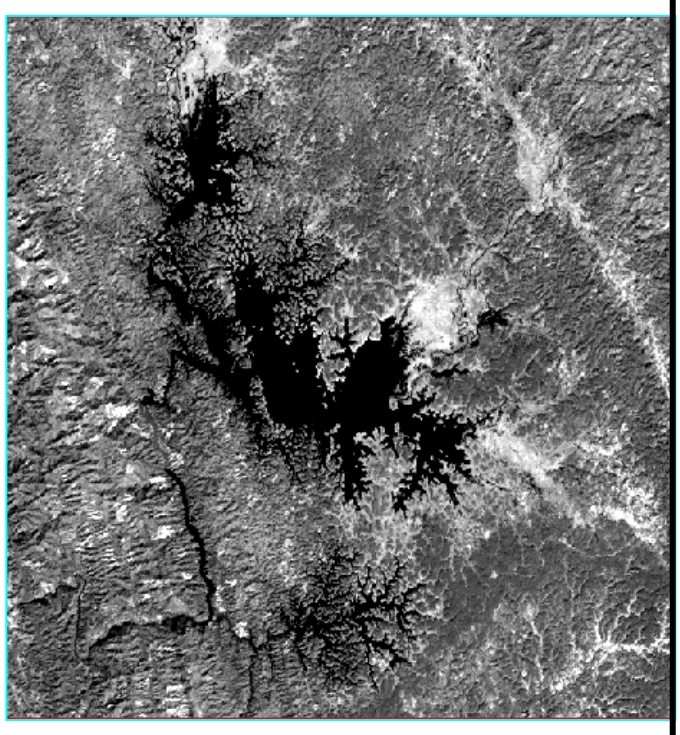
BAND2: RED



GREEN RED NIR

LISS-III FCC

BAND3: NIR



BAND4: SWIR

Figure 2: Various land features as they appear in four spectral bands and in a typical three band FCC

1.3 Wetland Inventory of India

India with its large geographical spread supports large and diverse wetland classes, some of which are unique. Wetlands, variously estimated to be occupying 1-5 per cent of geographical area of the country, support about a fifth of the known biodiversity. Like any other places in the world, there is a looming threat to the aquatic biodiversity of the Indian wetlands as they are often under a regime of unsustainable human pressures. Sustainable management of these assets therefore is highly relevant. Realising this, Govt. of India has initiated many appropriate steps in terms of policies, programmes and plans for the preservation and conservation of these ecosystems. India is a signatory to the Ramsar Convention for management of wetland, for conserving their biodiversity and wise use extending its scope to a wide variety of habitats, including rivers and lakes, coastal lagoons, mangroves, peatlands, coral reefs, and numerous human-made wetland, such as fish and shrimp ponds, farm ponds, irrigated agricultural land, salt pans reservoirs, gravel pits, sewage farms, and canals. The Ministry of Environment and Forests has identified a number of wetlands for conservation and management under the National Wetland Conservation Programme and some financial assistance is being provided to State Governments for various conservation activities through approval of the Management Action Plans. The need to have an updated map database of wetlands that will support such actions has long been realized.

Mapping requires a standard classification system. Though there are many classification systems for wetlands in the world, the Ramsar classification system is the most preferred one. The 1971 Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat is the oldest conservation convention. It owes its name to its place of adoption in Iran. It came into being due to serious decline in populations of waterfowl (mainly ducks) and conservation of habitats of migratory waterfowl. Convention provides framework for the conservation and 'wise use' of wetland biomes. Ramsar convention is the first modern global intergovernmental treaty on conservation and wise use of natural resources (www.ramsar.org). Ramsar convention entered into force in 1975. Under the text of the Convention (Article 1.1) wetlands are defined as:

"areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters".

In addition, the Convention (Article 2.1) provides that wetlands:

"may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands".

The first scientific mapping of wetlands of India was carried out during1992-93 by Space Applications Centre (ISRO), Ahmedabad, at the behest of the Ministry of Environment and Forests (MoEF), Govt. of India using remote sensing data from Indian Remote Sensing satellite (IRS). The mapping was done at 1:250,000 scale using IRS 1A LISS-I/II data of 1992-93 timeframe under the Nation-wide Wetland Mapping Project. Since, no suitable wetland classification existed for comprehensive inventory of wetlands in the country at that time; the project used a classification system based on Ramsar Convention definition of wetlands. The classification considers all parts of a water mass including its ecotonal area as wetland. In addition, fish and shrimp ponds, saltpans, reservoirs, gravel pits were also included as wetlands. This inventory put the wetland extent (inland as well as coastal) at about 8.26 million ha (Garg *et al*, 1998). These estimates (24 categories) do not include rice/paddy fields, rivers, canals and irrigation channels.

Further updating of wetland maps of India was carried out by SAC using IRS P6/Resourcesat AWiFS data of 2004-05 at 1:250000 scale. In recent years, a conservation atlas has been brought out by Salim Ali Centre for Ornithology and Natural History (SACON, 2004), which provide basic information required by stakeholders in both wetland habitat and species conservation. Space Applications Centre has carried out many pilot projects for development of GIS based wetland information system (Patel *et al*, 2003) and Lake Information system (Singh *et al*, 2003).

2.0 NATIONAL WETLAND INVENTORY AND ASSESSMENT (NWIA) PROJECT

Realising the importance of many small wetlands that dot the Indian landscape, it has been unanimously felt that inventory of the wetlands at 1:50,000 scale is essential. The task seemed challenging in view of the vast geographic area of our country enriched with diverse wetland classes. Space Applications Centre with its experience in use of RS and GIS in the field of wetland studies, took up this challenging task. This is further strengthened by the fact that guidelines to create geospatial framework, codification scheme, data base structure etc. for natural resources survey has already been well established by the initiative of ISRO under various national level mapping projects. With this strength, the National Wetland Inventory and Assessment (NWIA) project was formulated by SAC, which was approved and funded by MoEF.

The main objectives of the project are:

- To map the wetlands on 1:50000 scale using two date (pre and post monsoon) IRS LISS III digital data following a standard wetland classification system.
- Integration of ancillary theme layers (road, rail, settlements, drainage, administrative boundaries)
- Creation of a seamless database of the states and country in GIS environment.
- Preparation of State-wise wetland atlases.

The project was initiated during 2007. The first task was to have a classification system that can be used by different types of users while amenable to database. An expert/peer group was formed and the peer review was held at SAC on June 2007 where wetland experts and database experts participated and finalized the classification system. It was agreed to follow the classification system that has been used for the earlier project of 1:250,000 scale, with slight modification. Modified National Wetland Classification system for wetland delineation and mapping comprise 19 wetland classes which are organized under a Level III hierarchical system. The definition of each wetland class and its interpretation method was finalized. The technical/procedure manual was prepared as the standard guideline for the project execution across the country (Garg and Patel, 2007). The present atlas is part of the national level data base and deals with the state of Tripura.

2.1 Wetland Classification System

In the present project, Modified National Wetland Classification system is used for wetland delineation and mapping comprising of 19 wetland classes which are organized under a Level III hierarchical system (Table 1). Level one has two classes: inland and coastal, these are further bifurcated into two categories as: natural and man-made under which the 19 wetland classes are suitably placed. Two-date data pertaining to pre-monsoon and post-monsoon was used to confirm the classes. Wetlands put to agriculture use in any of the two dates are not considered as wetland class. Definitions used for the interpretation of various wetland types are given in Annexure-I.

2.2.1 Spatial Framework and GIS Database

The National Spatial Framework) (NSF) has been used as the spatial framework to create the database (Anon. 2005a). The database design and creation standard suggested by NRDB/NNRMS guidelines is followed. Feature codification scheme for every input element has been worked out keeping in view the nationwide administrative (State-district) as well as natural hierarchy within the feature class for each of the theme. All data elements are given a unique name, which are self explanatory with short forms.

Following wetland layers are generated for each inland wetland:

- Wetland extent: As wetlands encompass open water, aquatic vegetation (submerged, floating and emergent), the wetland boundary should ideally include all these. Satellite image gives a clear signature of the wetland extends from the imprint of water spread over the years.

- Water spread: There are two layers representing post-monsoon and pre-monsoon water spread during the year of data acquisition.

- Aquatic vegetation spread: The presence of vegetation in wetlands provides information about its trophic condition. As is known, aquatic vegetation is of four types, viz. benthic, submerged, floating and emergent. It is possible to delineate last two types of vegetation using optical remote sensing data. A qualitative layer pertaining to presence of vegetation is generated for each season (as manifested on pre-monsoon and post-monsoon imagery).

- Turbidity of open water: A layer pertaining to a qualitative turbidity rating is generated. Three qualitative turbidity ratings (low, medium and high) is followed for pre- and post-monsoon turbidity of lakes, reservoirs, barrages and other large wetlands.

- Small wetlands (smaller than minimum mappable unit: < 2.25 ha) are mapped as point features.

- Base layers like major road network, railway, settlements, and surface drainage are created (either from the current image or taken from other project data base).

Table 1: Wetland Classification System and coding

Wettcode*	Level I	Level II	Level III
1000	Inland Wetlands		
1100		Natural	
1101			Lakes
1102			Ox-Bow Lakes/ Cut-Off Meanders
1103			High altitude Wetlands
1104			Riverine Wetlands
1105			Waterlogged
1106			River/stream
1200		Man-made	
1201			Reservoirs/ Barrages
1202			Tanks/Ponds
1203			Waterlogged
1204			Salt pans
2000	Coastal Wetlands		
2100		Natural	
2101			Lagoons
2102			Creeks
2103			Sand/Beach
2104			Intertidal mud flats
2105			Salt Marsh
2106			Mangroves
2107			Coral Reefs
2200		Man-made	
2201			Salt pans
2202			Aquaculture ponds

* Wetland type code

3.0 STUDY AREA

Tripura one of the seven North-Eastern states of India, is situated between 22°56’ and 24°32’ North Latitudes and between 91°10’and 92°22’ East Longitudes (Figure 3). It is bounded on north by the Sylhet district of Bangladesh; on the south by the districts of Noakhali and Chittangong of Bandladesh; on the east by the district Cachar of Assam and the Mizoram; and on the west by the districts of Commilla and Noahkali(Bangladesh). It has an International boundary of about 850 km and is connected with the rest of India by a 201km access road through the hills to the border of Cachar district of Assam. The length and breadth of Tripura are admeasuring 183.50 km and 112.70 km respectively. According to Survey of India, it has an area of 10,491.69 square kilometers, accounting for 0.32% of the total land area of India and occupies the 22nd position in terms of area among the states and Union territories of India. Agartala, the capital of the state, is situated on the bank of the river Haora. Total population of the state is 3,191,168 as per 2001 census.

Physiography and Soil

Tripura is predominantly a hilly country, with around 60% of its land being hilly. Even the plain land is broken by many low hills of 30 to 60 m in elevation, covered with trees and turf. There are five parallel ranges of hills increasing in height towards east, striking approximately in a north-south direction with an average interval of about 19 km. The increasing elevation from west to east shows a gentle gradient of land-form.

In general soil of Tripura can be divided into two broad types namely: (i) Soil of the uplands and (ii) Soil of the lowlands. Soil of the uplands is the product of disintegration of rocks, mainly sandstones and shales. Soil developed from the disintegration from sandstones are coarse in texture reddish brown to brown in colour, poor in humus and lime content. It is very deep, well drained, acidic and have high infiltration capacity. Soil developed from disintegration of shales are medium to fine grained in texture, dark brown to dark grey brown in colour, acidic and poor in permeability and lime content. Soils of the lowlands are mostly alluvial soil. It covers river valleys and flood plains. This soil is entirely a transported soil, brought down by innumerable rivers and chharas that drain them and deposited as sedimentary alluvium. This soil is deep, medium to fine grained and light grey in colour. The presence of organic matter in the soil is medium. These soils are intensively cultivated with rice, jute, pulses and other cereal crops.

Climate

Tripura enjoys warm humid tropical climate. Rainfall in Tripura is mostly derived from the southwest monsoon. The average annual rainfall in Tripura is around 2500 mm. In general, rainfall increases towards north and east and decreases towards south and west. Yearly variation of temperature is between 5°C and 38°C. The summer temperature ranges between 24°C and 35°C, where winter temperature varies between 5°C and 27°C. Fogs are frequent in winter and hail storms are observed occasionally.

The jungles of Tripura form impassible belts in low and swampy areas, and form the favourite habitat for the various wild lives. Many species of birds such as parrot, pigeon, snipe, quail, jungle fowl etc. found in Tripura. Altogether, 342 species of birds belonging to 51 families have been recorded from this state. Some migratory birds, mostly cranes and varieties of ducks of Himalayan origin visit Tripura every winter at different water sites and riverine tracts.

Spatial frame work

The state is divided into four administrative districts namely, North Tripura, West Tripura, South Tripura and Dhalai with the last one being created only in 1995. The entire Tripura is covered by twenty nine 1:50,000 scale SOI topographical maps that form the spatial frame work for mapping (Figure 4).

A detail of district information followed in the atlas is given in Annexure-II.

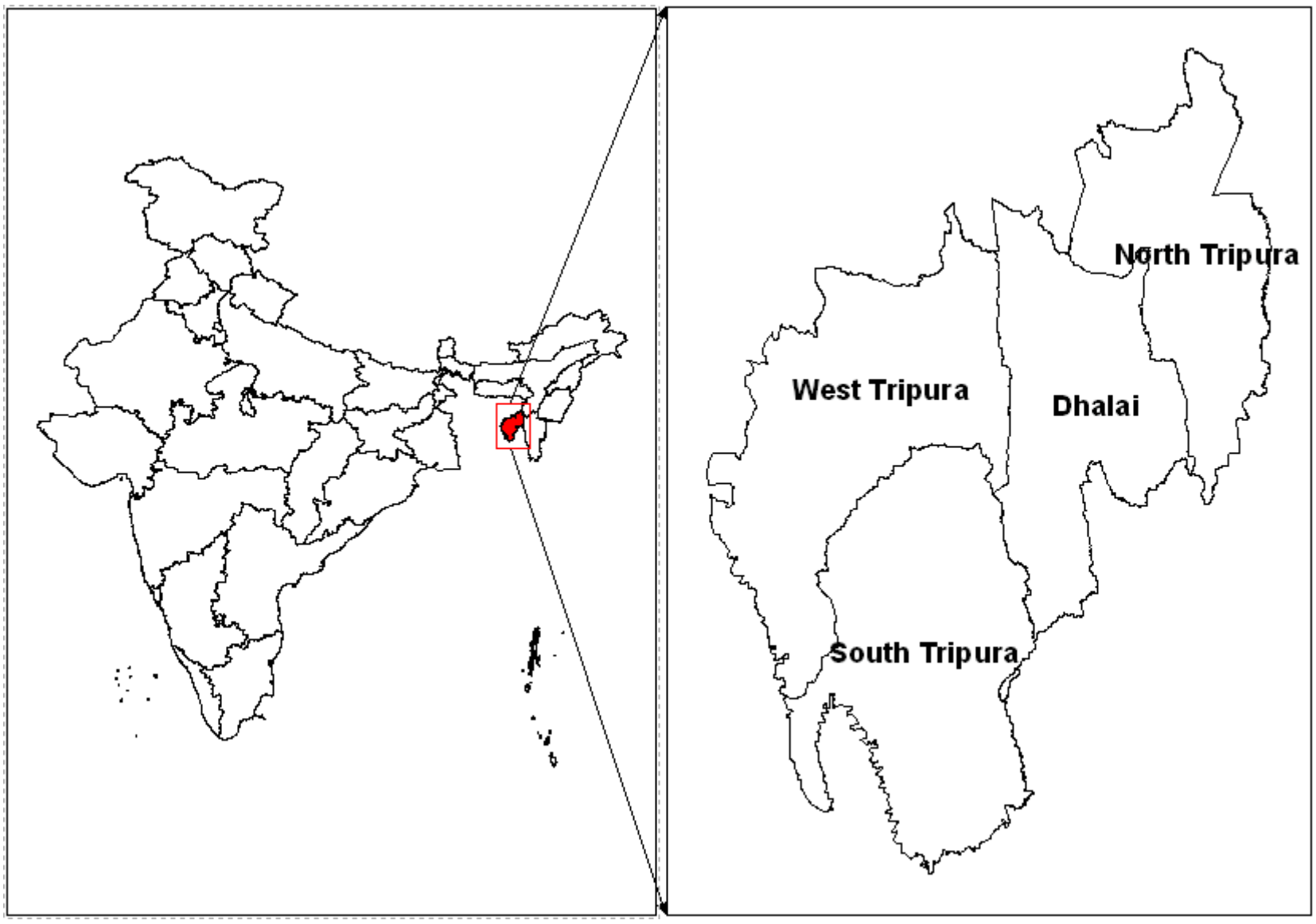


Figure 3: Location map

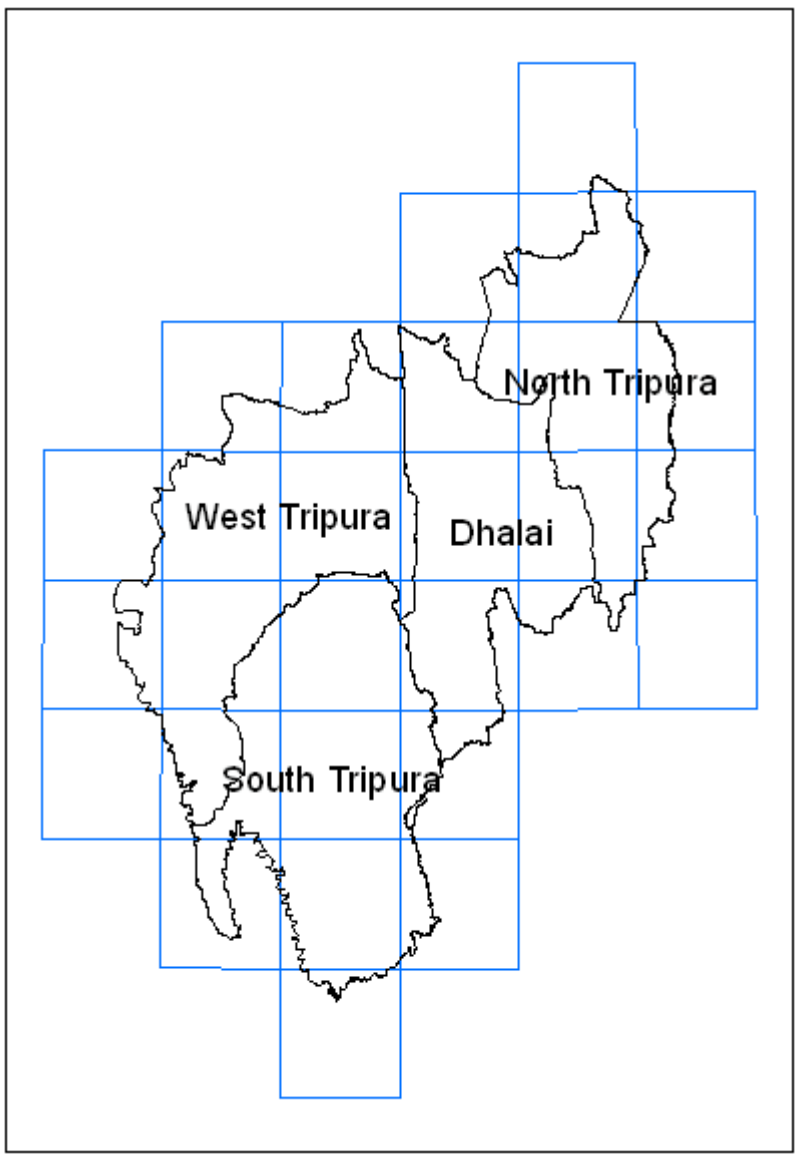


Figure 4: Spatial Framework of Tripura state

4.0 DATA USED

Remote sensing data

IRS P6 LISS III data was used to map the wetlands. IRS P6 LISS III provide data in 4 spectral bands; green, red, Near Infra Red (NIR) and Short wave Infra Red (SWIR), with 23.5 m spatial resolution and 24 day repeat cycle. The spatial resolution is suitable for 1:50,000 scale mapping. The state of Tripura is covered in four IRS LISS III scene (Figure 5). Two date data, used to capture the pre-monsoon and post-monsoon hydrological variability of the wetlands respectively (Table-2). Figure 6 shows the overview of the part of Tripura as seen in the LISS III FCC of post- monsoon and pre-monsoon data respectively.

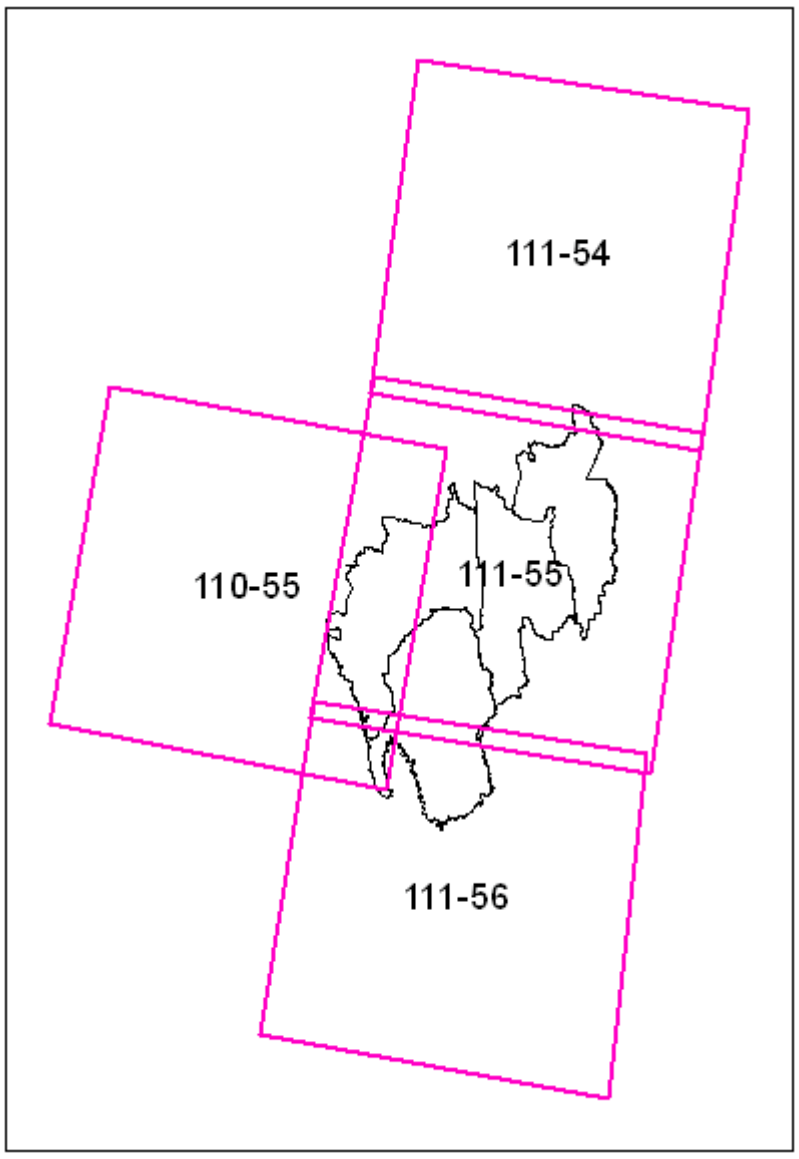


Figure 5: IRS P6 LISS-III coverage (path-row) of Tripura

Table-2: Satellite data used

Sr. No.	Satellite/Sensor	Path	Row	Date
1	P6-LISS-III	110	055	06-02-2006 & 21-03-2007
2	P6-LISS-III	111	054	06-02-2006 & 21-03-2207
3	P6-LISS-III	111	055	06-02-2006 & 21-03-2007
4	P6-LISS-III	111	056	20-12-2006 & 02-03-2007

Ground truth data

Remote sensing techniques require certain amount of field observation called “ground truth” in order to convert the inferences into meaningful information. Such work involves visiting a number of test sites, usually taking the satellite images. The location of the features is recorded using the GPS. The field data has been collected during various other projects in the area has been utilized. Field photographs are also taken to record the status of wetland.

Other data

Survey of India topographical maps (SOI) were used for reference purpose. Lineage data of National Wetland Maps at 1: 50,000 scale of was also used for reference.

5.0 METHODOLOGY

The methodology to create the state level atlas of wetlands is adhered to NWIA technical guidelines and procedure manual (Garg and Patel, 2007). The overview of the steps used is shown in Figure 7. Salient features of methodology adopted are

- Generation of spatial framework in GIS environment for database creation and organisation.
- Geo-referencing of satellite data
- Identification of wetland classes as per the classification system given in NWIA Manual and mapping of the classes using a knowledge based digital classification and onscreen interpretation
- Generation of base layers (rail, road network, settlements, drainage, administrative boundaries) from satellite image and ancillary data.
- Mosaicing/edge matching to create district and state level database.
- Coding of the wetlands following the standard classification system and codification as per NWIA manual.
- Preparation of map compositions and generation of statistics
- Outputs on A3 size prints and charts for atlas.

Work was carried out using ERDAS Imagine, Arc/Info and ArcGIS software.

5.1 Creation of spatial framework

This is the most important task as the state forms a part of the national frame work and is covered in multiple map sheets. To create NWIA database, NNRMS/NRDB standards is followed and four corners of the 1:50,000 (15' x 15') grids is taken as the tics or registration points to create each map taking master grid as the reference. Spatial framework details are given in NWIA manual (Garg and Patel, 2007). The spatial framework for Tripura is shown in Figure 4.

5.2 Geo-referencing of satellite data

In this step the raw satellite images were converted to specific map projection using geometric correction. This is done using archived geometrically corrected LISS III data (ISRO-NRC-land use / land cover project). Standard image processing software was used for geo-referencing. First one date data was registered with the archive image. The second date data was then registered with the first date data.

5.3 Mapping of wetlands

The delineation of wetlands through image analysis forms the foundation for deriving all wetland classes and results. Consequently, a great deal of emphasis has been placed on the quality of the image interpretation. In the present study, the mapping of wetlands was done following digital classification and onscreen visual interpretation. Wetlands were identified based on vegetation, visible hydrology and geography. There are various methods for extraction of water information from remote sensing imagery, which according to the number of bands used, are generally divided into two categories, i.e. Single-band and multi-band methods. Single-band method usually involves choosing a band from multi-spectral image to distinguish water from land by subjective threshold values. It may lead to over- or under-estimation of open water area. Multi-band method takes advantage of reflective differences of each band. In this project, five indices known in literature that enhances various wetland characteristics were used (McFeetres, 1986; Xu Hanqiu, 2006; Lacaux *et al*, 2007; Townshend and Justice, 1986; Tucker and Sellers, 1986) as given below:

i) Normalised Difference Water Index (NDWI) = (Green-NIR) / (Green + NIR)

ii) Modified Normalised Difference Water Index (MNDWI) = (Green-MIR) / (Green + MIR)

iii) Normalised Difference Vegetation Index (NDVI) = (NIR - Red) / (NIR + Red)

iv) Normalised Difference Pond Index (NDPI) = (MIR – Green / MIR + Green)

v) Normalised Difference Turbidity Index (NDTI) = (Red – Green) / (Red + Green)

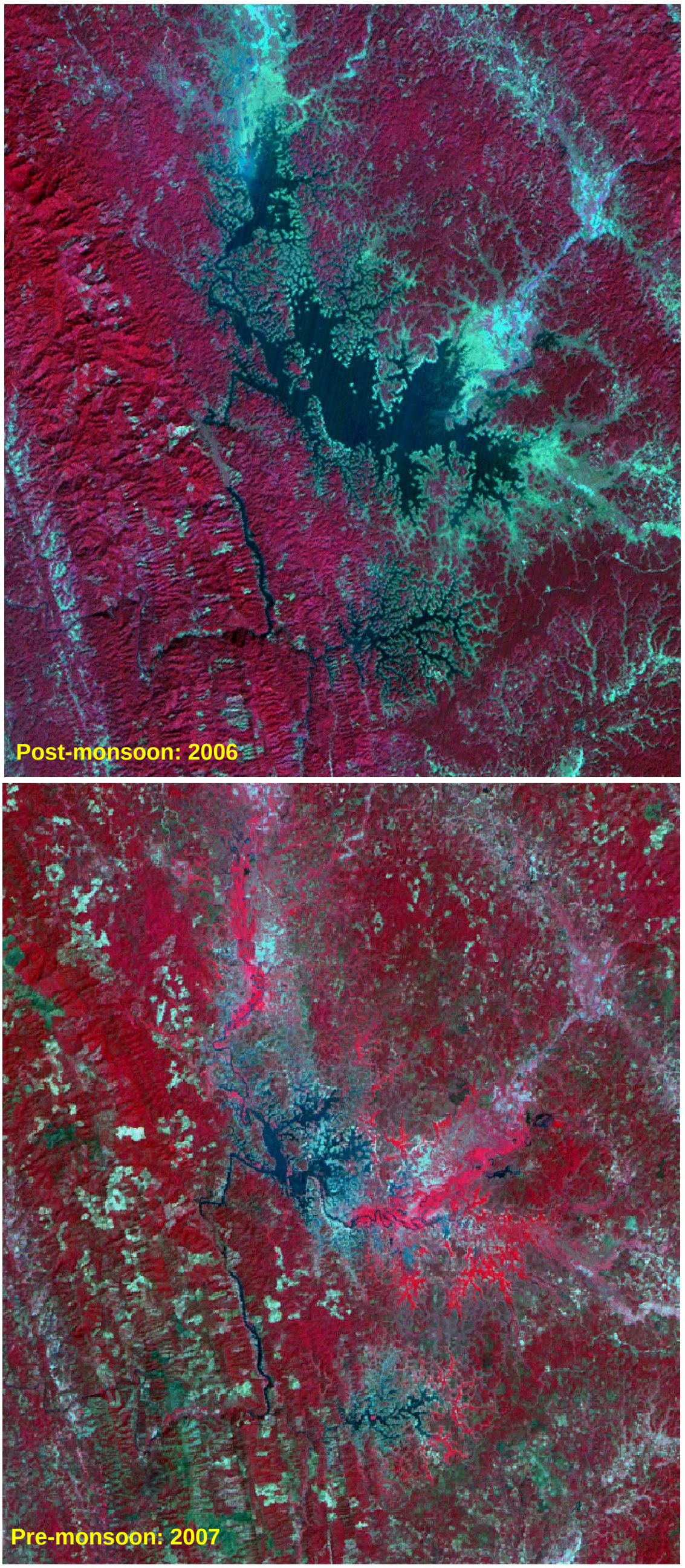


Figure 6: Part of Tripura as seen on IRS LISS-III FCC (Post-monsoon: 2006 and Pre-monsoon: 2007)

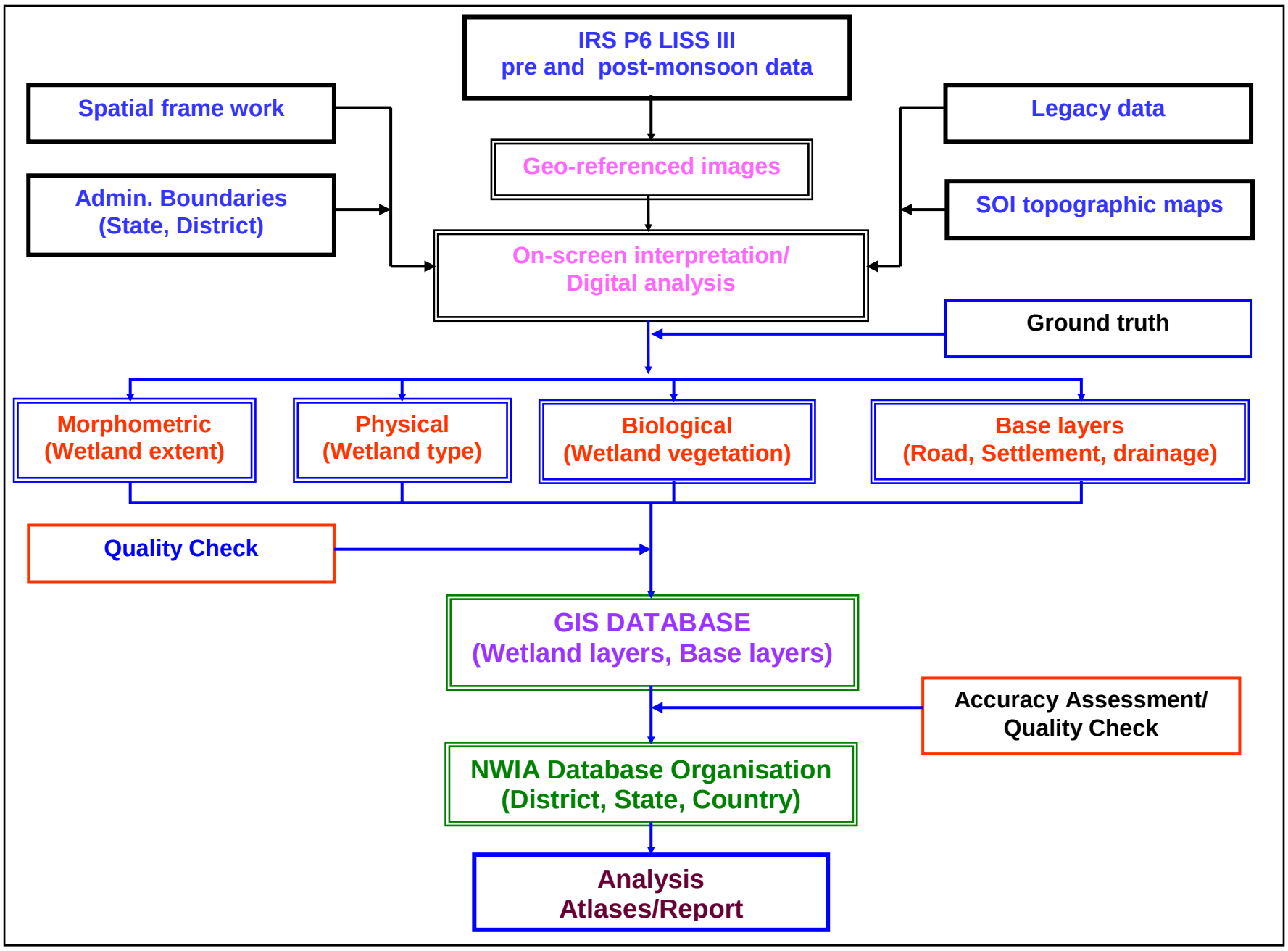


Figure 7: Flow chart of the methodology used

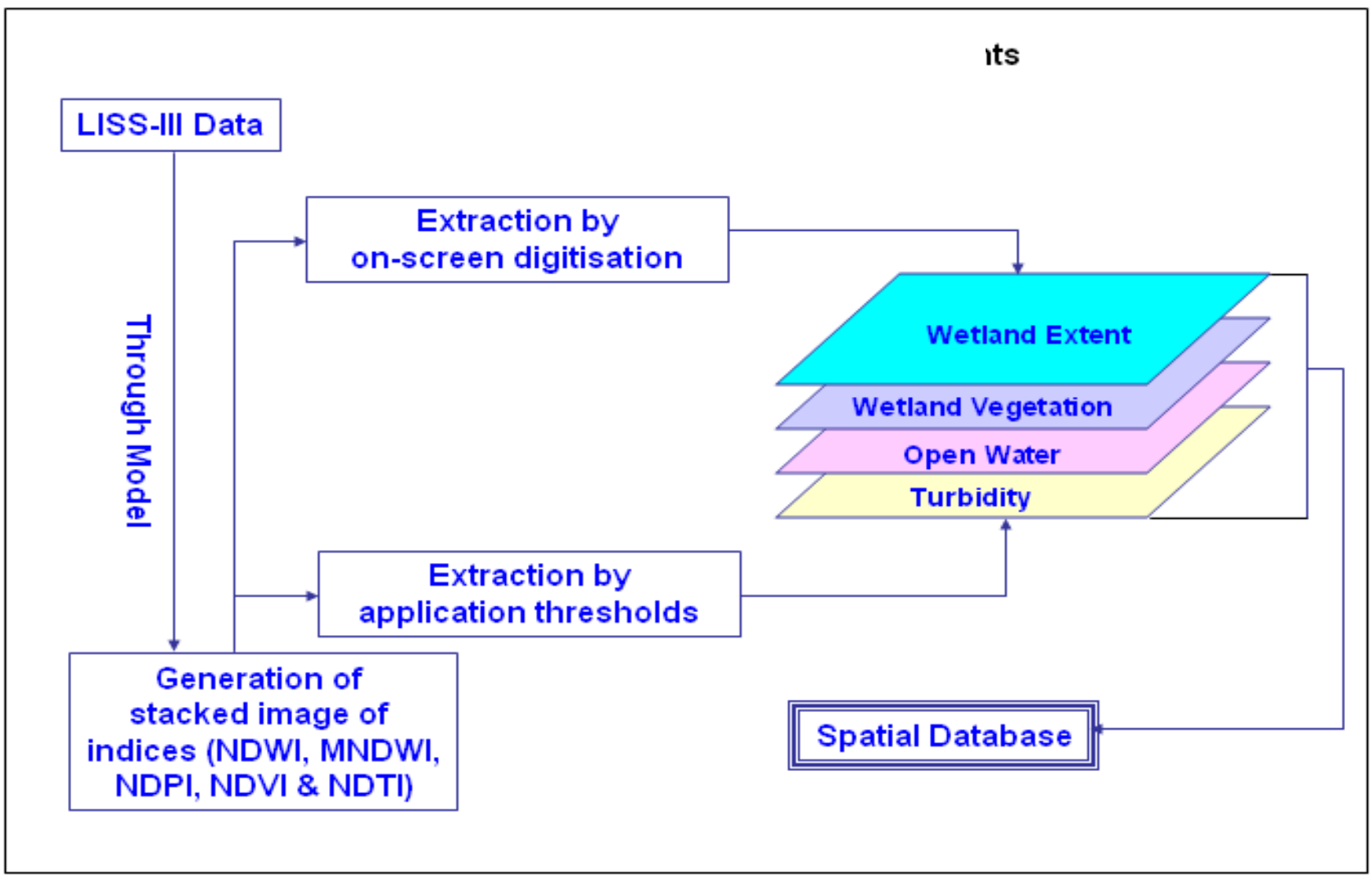


Figure 8: Steps in the extraction of wetland structural components

The indices were generated using standard image processing software, stacked as layers (Figure 8). Various combinations of the indices/spectral bands were used to identify the wetland features as shown in Figure 9. The following indices were used for various layer extractions:

- Extraction of wetland extent :
  MNDWI, NDPI and NDVI image was used to extract the wetland boundary through suitable hierarchical thresholds. Visually, the FCC of NDTI, NDVI and MNDWI on RED, GREEN and BLUE planes allows the discrimination wetland classes like mangroves, mudflats and creeks easy.

- Extraction of open water :
  MNDWI was used within the wetland mask to delineate the water and no-water areas. Visually, the FCC of NDVI, NDPI and MNDWI on RED, GREEN and BLUE planes allows the discrimination of open water easy.

- Extraction of wetland vegetation :
  NDPI and NDVI image was used to generate the vegetation and no-vegetation areas within a wetland using a suitable threshold. Visually, the FCC of NDVI, NDPI and MNDWI on RED, GREEN and BLUE planes allows the discrimination wetland classes like mangroves easy from non-wetland areas.

- Turbidity information extraction :
  MNDWI image was used to generate qualitative turbidity level (high, moderate and low) based on following steps:

  a) Conversion of post- and pre-monsoon water spread polygons into Area of Interest (AoI).
  b) Grouping of all AoIs excluding all non-wetland areas into a single entity.
  c) Generate a signature statistics like minimum, maximum, mean and standard deviations.
  d) Generate a raster turbidity image through a model for AoI only with *conditional* categorisation.
  e) Convert the raster into vector and update the attributes or edit the water spread layer (copied as turbidity layer) in polygon mode so as to retain all the attributes.
  f) Assign turbidity classes as per the table 3.

Table 3: Qualitative turbidity based on Mean and Standard deviation observed in the MNDWI image

Sr. No.	**Conditional criteria**	**Qualitative Turbidity**
1.	<= $\mu - 1\sigma$	High/Bottom reflectance
2.	> -1σ to <= $+1\sigma$	Moderate
3.	> $+1\sigma$	Low

5.4 Conversion of raster (indices) into a vector layer

The information on wetland extent, open water extent, vegetation extent and turbidity information was converted into vector layers using region growing properties or on-screen digitisation.

5.5 *Generation of reference layers*

Base layers like major rail, road network, settlements, drainage are interpreted from the current image or taken from other project database. The administrative boundaries (district, state) are taken from the known reference data.

5.6 *Coding and attribute scheme*

Feature codification scheme for every input element has been worked out keeping in view the nationwide administrative as well as natural hierarchy (State-district-taluka) within the feature class for each of the theme. All data elements are given a unique name/code, which are self explanatory with short forms.

5.7 Map composition and output

Map composition for atlas has been done at district and state level. A standard color scheme has been used for the wetland classes and other layers. The digital files are made at 1:50,000 scale. The hard copy outputs are taken on A3 size.

6.0 ACCURACY ASSESSMENT

A comprehensive accuracy assessment protocol has been followed for determining the quality of information derived from remotely sensed data. Accuracy assessment involves determination of thematic (classification) as well as locational accuracy. In addition, GIS database(s) contents have been also evaluated for accuracy. To ensure the reliability of wetland status data, the project adhered to established quality assurance and quality control measures for data collection, analysis, verification and reporting.

This study used well established, time-tested, fully documented data collection conventions. It employed skilled and trained personnel for image interpretation, processing and digital database creation. All interpreted imagery were reviewed by technical expert team for accuracy and code. The reviewing analyst adhered to all standards, quality requirements and technical specifications and reviewed 100 percent of the work. The various stages of quality check include:

1. Image to Image Geo-referencing/Data generation

2. Reference layer preparation using NWIA post monsoon and pre-monsoon LISS-III data.

3. Wetland mapping using visual/digital interpretation techniques.

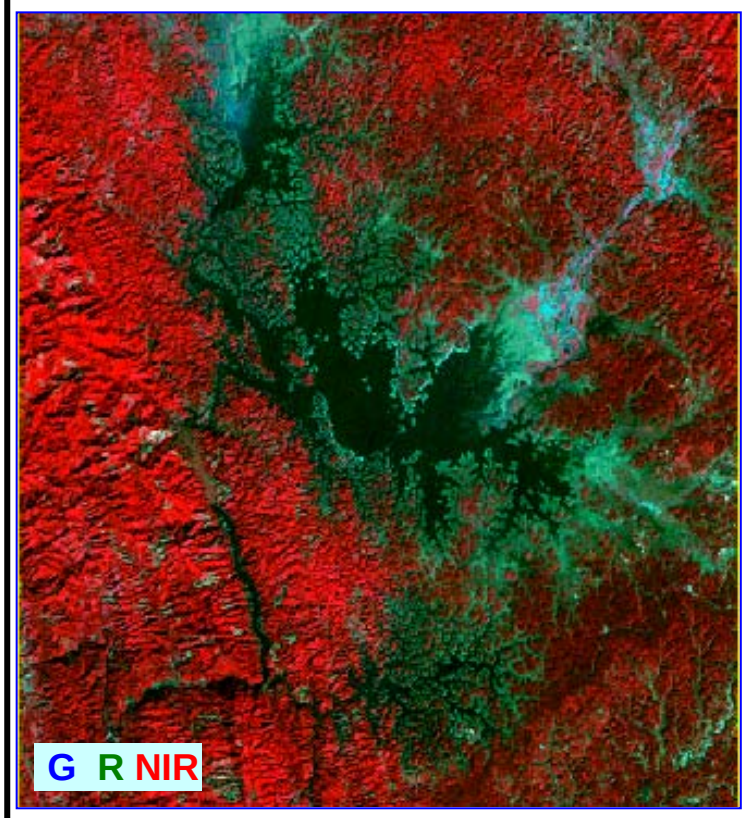
4. Geo-data base creation and organization

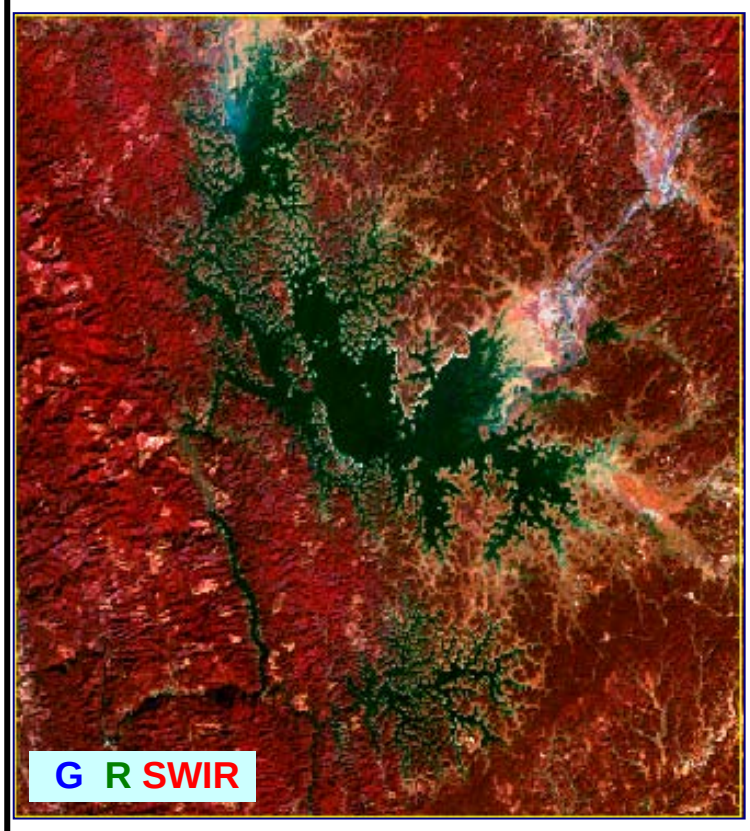
5. Output products.

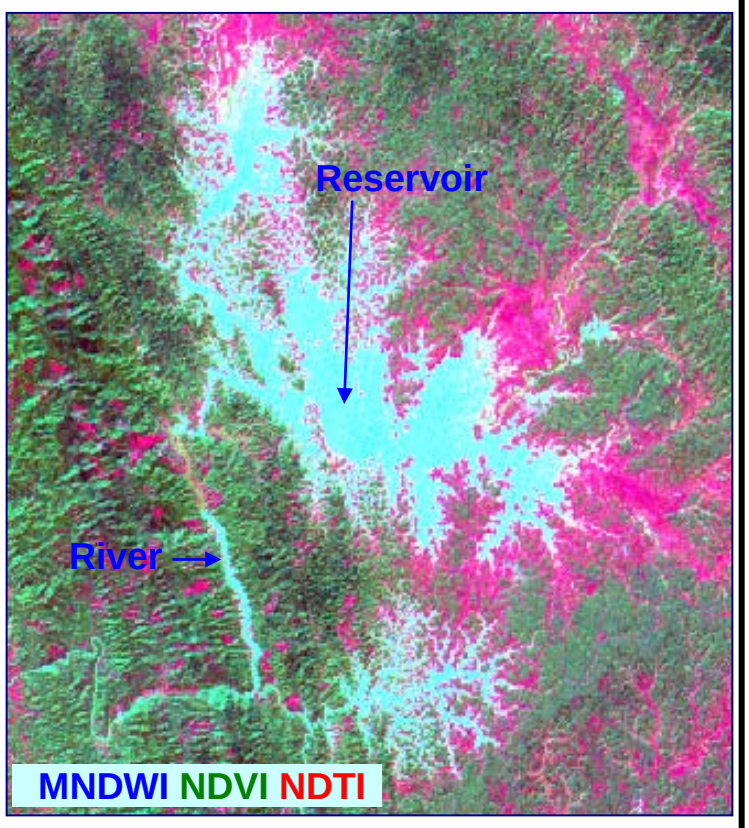
6.1 Data verification and quality assurance of output digital data files

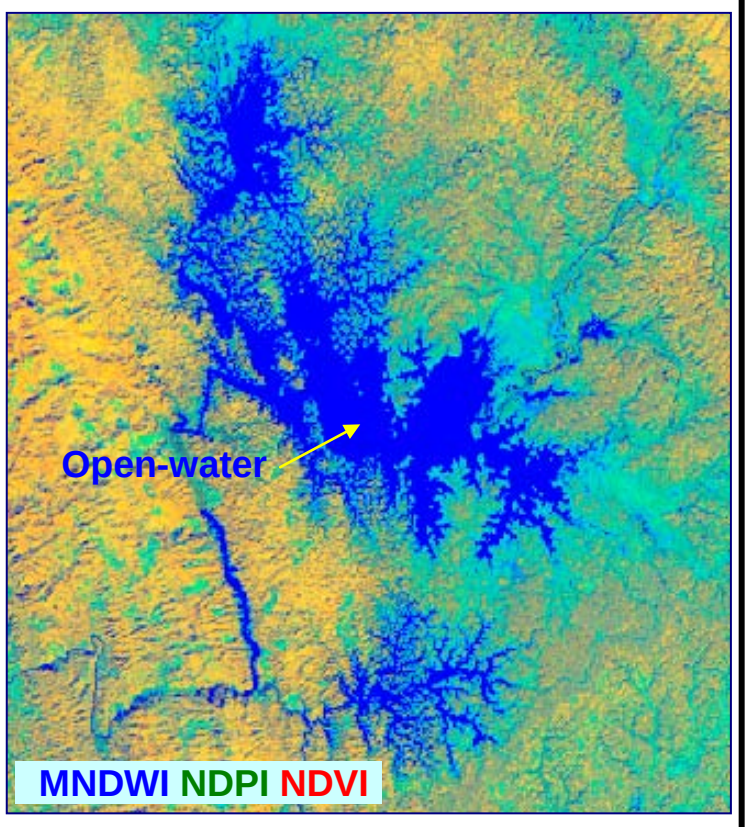
All digital data files were subjected to rigorous quality control inspections. Digital data verification included quality control checks that addressed the geospatial correctness, digital integrity and some cartographic aspects of the data. Implementation of quality checks ensured that the data conformed to the specified criteria, thus achieving the project objectives. There were tremendous advantages in using newer technologies to store and analyze the geographic data. The geospatial analysis capability built into this study provided a complete digital database to better assist analysis of wetland change information. All digital data files were subjected to rigorous quality control inspections. Automated checking modules incorporated in the geographic information system (Arc/GIS) were used to correct digital artifacts including polygon topology. Additional customized data inspections were made to ensure that the changes indicated at the image interpretation stage were properly executed.

Part of Tripura showing wetland (reservoir) - Post-monsoon, 2006









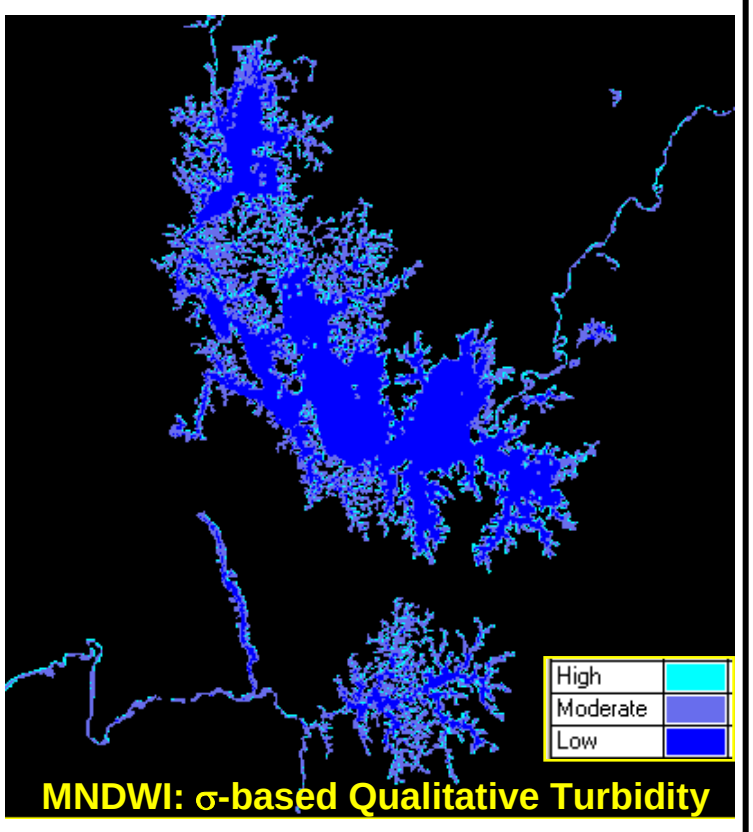


Figure 9: Various combinations of the indices/spectral bands used to discriminate wetland structural components

MAPS AND STATISTICS

7.0 WETLANDS OF TRIPURA: MAPS AND STATISTICS

Area estimates of various wetland categories for Tripura have been carried out using GIS layers of wetland boundary, water-spread, aquatic vegetation and turbidity. In the state, 432 wetlands have been mapped and 2983 small wetlands (< 2.25 ha) identified. Total wetland area estimated is 17542 ha (Table 4). Inland natural wetlands dominated in the state with 63% share. The major natural wetland types are; River/stream (42.30 %) and waterlogged (16.79 %). There are 60 Lake/Pond with about 1.7 % area. Under manmade wetlands, Reservoir/Barrage is the major wetland type with 18.93% share. Graphical distribution of wetland type is shown in figure 10.

In terms of open water area, the natural wetlands showed 6769 ha in post-monsoon and 6085 ha in Pre-monsoon seasons. The reduction in open water area is mainly due to change in Waterlogged. In case of man-made wetlands, the open water is 3078 ha and 938 ha respectively for post- and pre-monsoon. The reduction in open water in Pre-monsoon is significant in Reservoir/Barrage. The details of type-wise aerial extents of wetland is given in the table 5.

Table 4: Area estimates of wetlands in Tripura

Area in ha

Sr. No.	Wettcode	Wetland Category	Number of Wetlands	Total Wetland area	% of wetland area	Open Water	
						Post-monsoon area	Pre-monsoon area
	1100	**Inland Wetlands – Natural**					
1	1101	Lakes/Ponds	60	300	1.71	180	153
2	1102	Ox-bow lakes/ Cut-off meanders	78	387	2.21	229	170
3	1105	Waterlogged	244	2946	16.79	1872	647
4	1106	River/Stream	17	7420	42.30	4488	5115
	1200	**Inland Wetlands -Man-made**					
5	1201	Reservoirs/Barrages	12	3320	18.93	2936	796
6	1202	Tanks/Ponds	21	186	1.06	142	142
		Sub-Total	**432**	**14559**	**83.00**	**9847**	**7023**
		Wetlands (<2.25 ha), mainly Tanks	2983	2983	17.00	-	-
		Total	**3415**	**17542**	**100.00**	**9847**	**7023**
		Area under Aquatic Vegetation				1779	5232
		Area under turbidity levels					
		Low				2672	641
		Moderate				7149	6328
		High				27	53

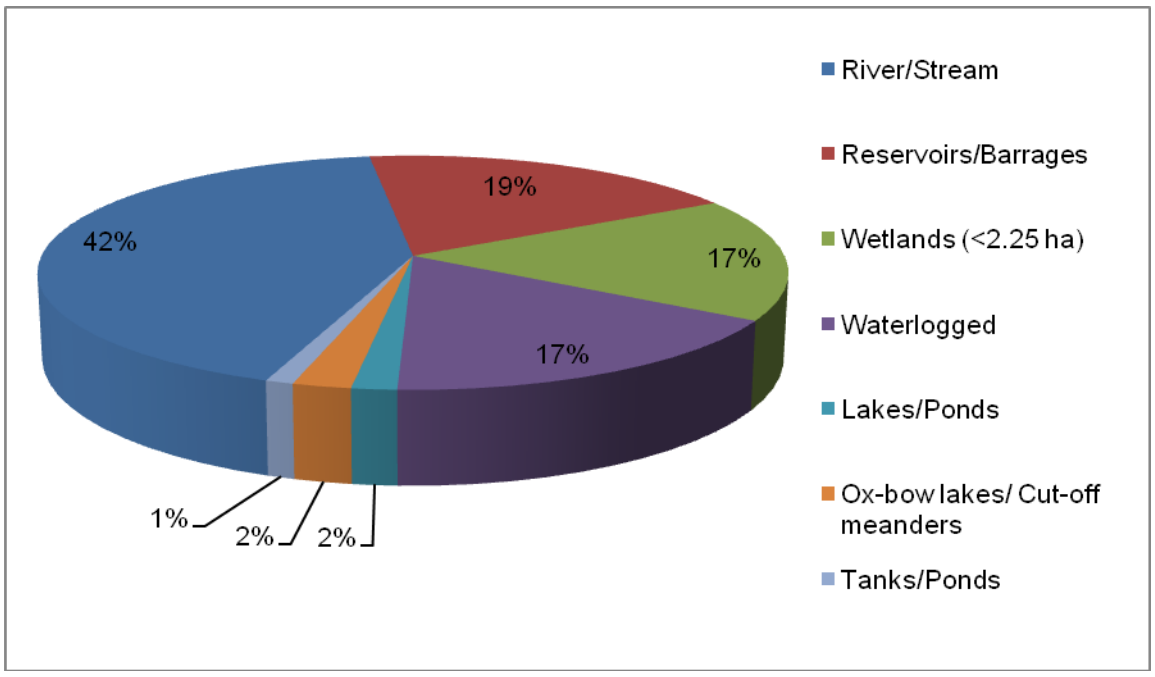


Figure 10: Type-wise wetland distribution in Tripura

Wetland Vegetation

Lake/Pond, Ox-Bow Lakes/Cut-off Meanders, Waterlogged, River/stream, Reservoir/Barrage and Tank/Pond are the only wetland types that have vegetation. Together the all classes comprise 1779 ha in post-monsoon season while it has shown an increase to 5232ha in Pre-monsoon (Table 5).

Table 5: Area estimates of wetland vegetation in Tripura

Area in ha

Sr. No.	Wetland code	Wetland Category	Post-monsoon (2006)	Pre-monsoon (2007)
	1100	**Inland Wetlands - Natural**		
1	1101	Lake/Pond	120	147
2	1102	Ox-Bow Lakes/ Cut-Off Meanders	157	217
3	1105	Waterlogged	1073	2299
4	1106	River/Stream	-	-
		Sub-total	**1350**	**2663**
	1200	**Inland Wetlands -Man-made**		
5	1201	Reservoir/Barrage	383	2524
6	1202	Tank/Pond	45	45
		Sub-total	**428**	**2569**
		Total	**1779**	**5232**

Turbidity Status

Overall six wetland types are assessed for qualitative turbidity namely; Lake/Pond, Ox-Bow Lakes/ Cut-Off Meanders, Waterlogged, River/Stream, Reservoir/Barrage and Tank/Pond. Turbidity of water in all Natural wetlands is in general moderate in both the seasons. The turbidity of water in Reservoir/Barrage types is low to moderate in post-monsoon, while mainly moderate in Pre-monsoon (Table 6). Overall, the open water features of wetlands in Tripura are dominantly moderate in turbidity in both the seasons followed by low and high turbidity. Moderate turbidity constituted largest area in post-monsoon (7149 ha) out of 9847 ha of open water i.e. about 73 per cent. While in Pre-monsoon it dominated the open water with 6328 ha out of 7023 ha of open water, which turns out to be about 90 per cent (Table 6). Low turbidity accounted for about 27 % in post-monsoon and 9 % in Pre-monsoon while the area under high turbidity was insignificant (about 1 %) in both the seasons.

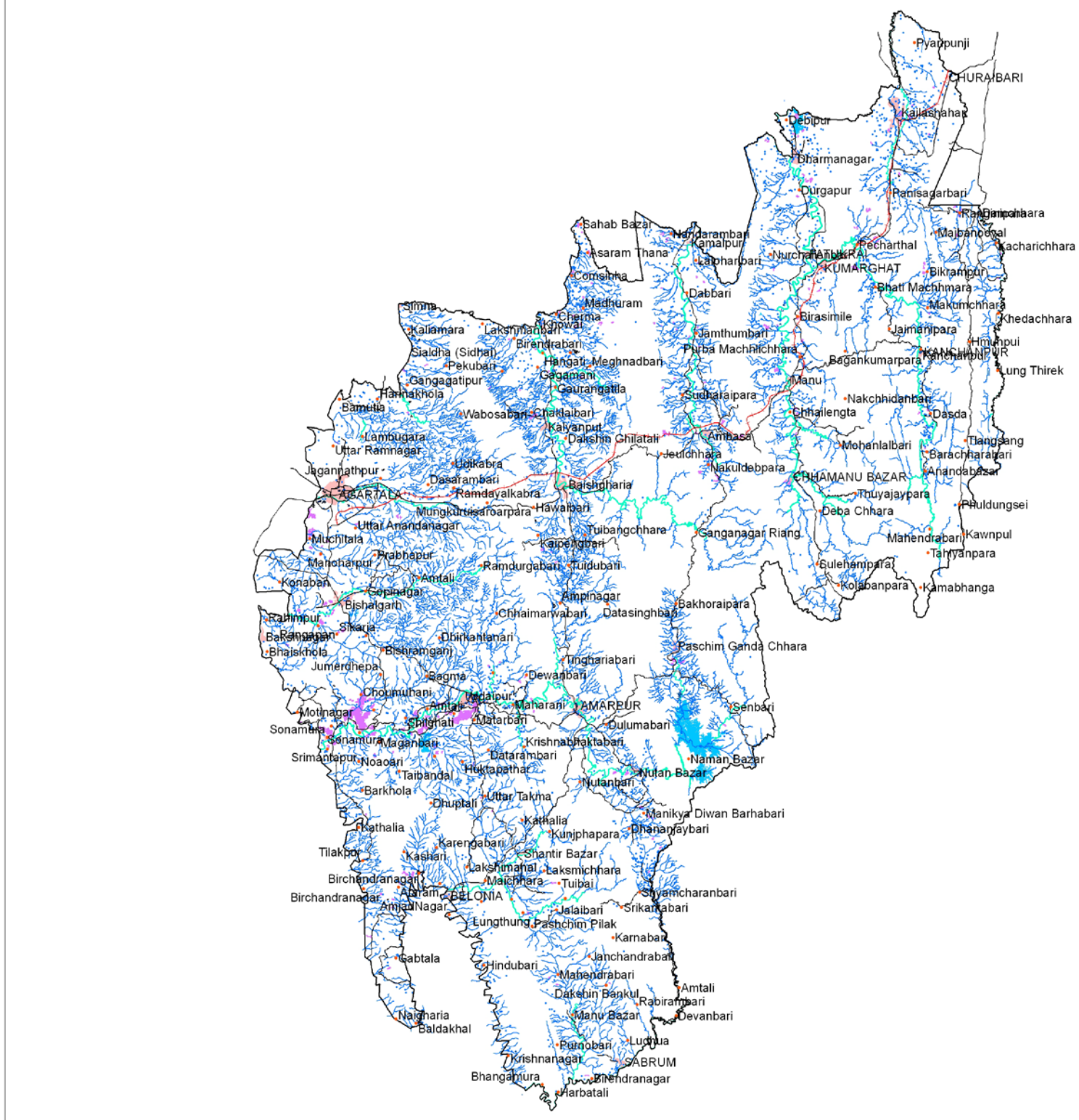
Table 6: Turbidity status of open water associated with wetlands in Tripura

Area in ha

Sr. No.	Wetland code	Wetland Category	Turbidity (Post-monsoon:2006)			Turbidity (Pre-monsoon:2007)		
			Low	Moderate	High	Low	Moderate	High
	1100	**Inland Wetlands - Natural**						
1	1101	Lake/Pond	21	159	-	44	109	-
2	1102	Ox-Bow Lakes/ Cut-Off Meanders	20	209	-	37	133	-
3	1105	Waterlogged	525	1345	2	190	457	-
4	1106	River/Stream	494	3969	25	55	5008	52
		Sub-total	**1060**	**5682**	**27**	**326**	**5707**	**52**
	1200	**Inland Wetlands -Man-made**						
5	1201	Reservoir/Barrage	1524	1412	-	195	601	-
6	1202	Tank/Pond	87	55	-	122	20	-
		Sub-total	**1611**	**1467**	**-**	**317**	**621**	**-**
		Total	**2671**	**7149**	**27**	**643**	**6328**	**52**

State : Tripura

WETLAND MAP

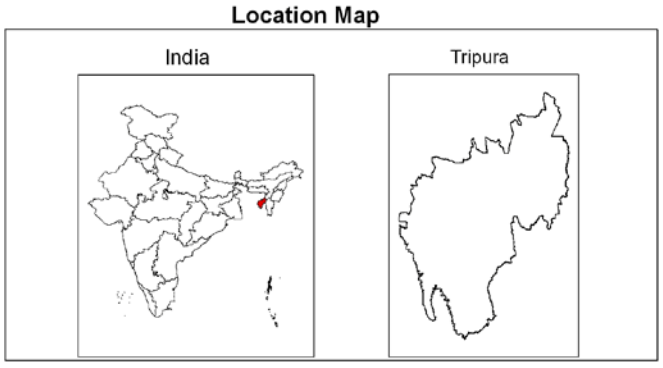


Legend

Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Wetlands (<2.25 ha)
Settlements
Drainage (line)
Canal
Roads
Railways
Town/Settlements
District Boundary
State Boundary
International Boundary

Location Map



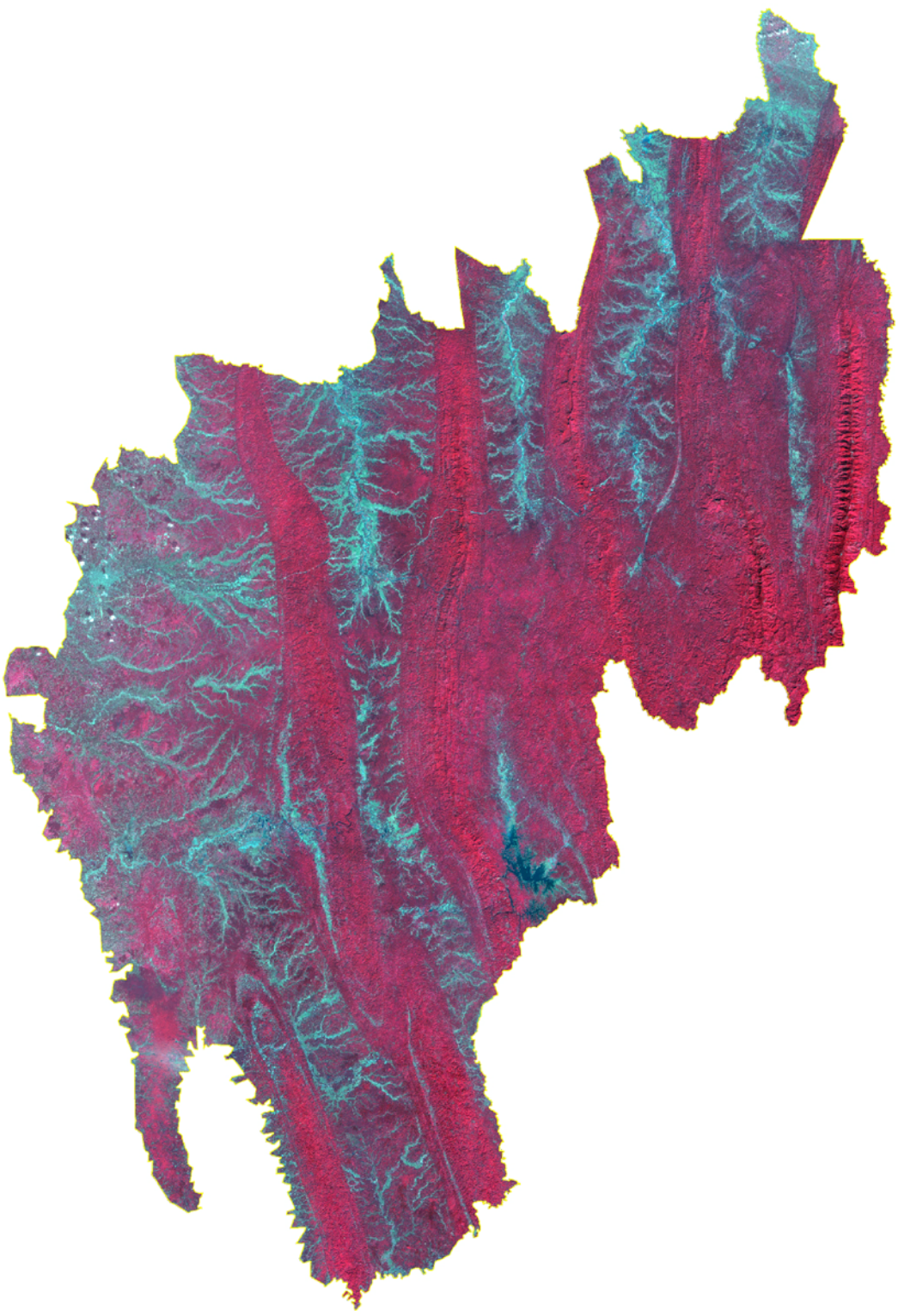
0 5 10 20 30 Kilometers

Data Source:
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By :
Ministry of Environment and Forests
Government of India

State : Tripura



IRS P6 LISS-III Post-monsoon data(2006)

7.1 DISTRICT-WISE WETLAND MAPS AND STATISTICS

The state Tripura has four districts (Manorama Year Book, 2007). Tripura is comprised of four districts namely; West Tripura, South Tripura, Dhalai and North Tripura. The geographical extents of these districts ranging from 2152 km^2 (South Tripura) to 3544 km^2 (West Tripura). The wetlands are more or less equally distributed among the districts (Figure 11) except in North Tripura where they constitute 3404 ha (Table 7). In terms of per cent geographical area of district, the variation is about 1 ranging from a minimum of 1.21 in North Tripura to 2.13 in South Tripura (Table 7).

Table-7: District-wise wetland area

Sr. No.	District	Geographical area (sq. km)	Wetland area (ha)	% of total wetland area	% of district geographical area
1	West Tripura	3544	4749	27.07	1.34
2	South Tripura	2152	4574	26.07	2.13
3	Dhalai	2523	4815	27.45	1.91
4	North Tripura	2821	3404	19.40	1.21
	Total	**11040**	**17542**	**100.00**	

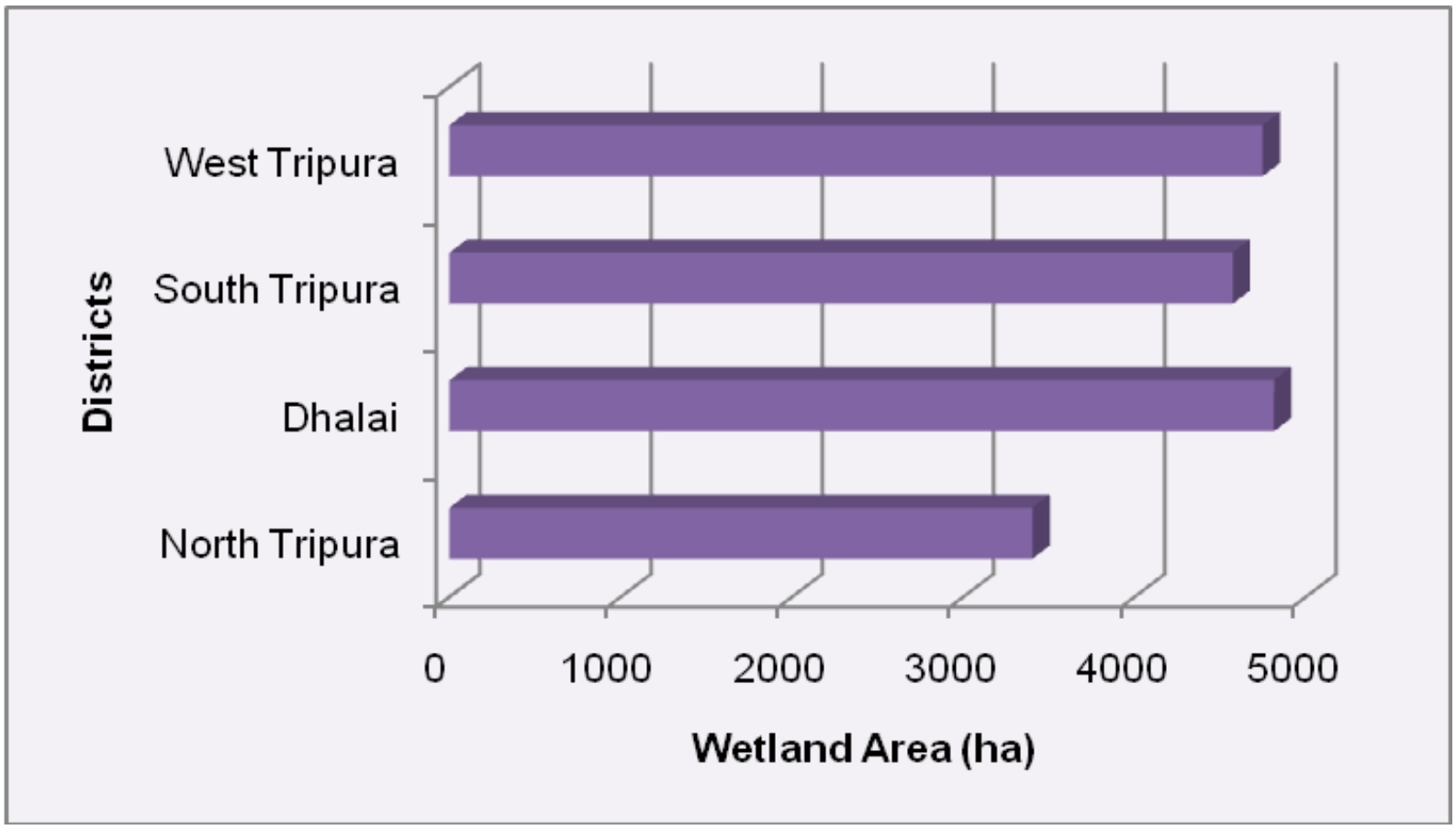


Figure 11: District-wise graphical distribution of wetlands

7.1.1 West Tripura

The district of West Tripura (2997 km²) lies at a longitude of 91° 09' to 91° 47' E and at a latitude of 23°16' to 24°14' N. The district is bordered by North Tripura in the east, by South Tripura in the south and Bangladesh in the north. The geographic area of the district is 3544 Sq. km. The capital of the state of Tripura, Agartala, is also the district headquarter of West Tripura. The area is having many rives. Rising from the Baramura range River Howrah has a number of tributaries including, Dhobatilachhara, Bangeswargang, Dowaigang, Ghoramara, Charupanadi and Debda. River Burigang originates from the Baramura range and flows west into Bangladesh. The colossal alluvial deposit of this river creates a number of river valleys which are extremely fertile. River Gumti formed by the confluence of two rivulets, the Raimas and Sarma, is the principal river of West Tripura. Total 162 wetlands have been mapped and 1075 small wetlands (< 2.25 ha) identified. The inland-Natural wetlands comprise about 75.9 %. The Waterlogged occupies the largest area (1527 ha) next to River/Stream (1764 ha). The other major natural wetland types are Lake/pond and Ox-Bow lakes. Total 43 Lakes/Ponds are mapped occupying 225 ha area (4.8 %). Detailed wetland statistics of the district is given in table 8. The open water spread area is significantly more during post-monsoon (2430 ha) than that of Pre-monsoon (1876 ha). Considerable reduction in water spread is observed in case of Waterlogged during Pre-monsoon (281 a) than that of post-monsoon (1032 ha).

Table 8: Area estimates of wetlands in West Tripura

Area in ha

Sr. No.	Wettcode	Wetland Category	Number of Wetlands	Total Wetland area	% of wetland area	Open Water	
						Post-monsoon area	Pre-monsoon area
	1100	**Inland Wetlands - Natural**					
1	1101	Lakes/Ponds	43	225	4.74	137	115
2	1102	Ox-bow lakes/ Cut-off meanders	14	88	1.85	55	36
3	1105	Waterlogged	90	1527	32.15	1032	281
4	1106	River/Stream	6	1764	37.14	1158	1400
	1200	**Inland Wetlands -Man-made**					
5	1201	Reservoirs/Barrages	5	57	1.20	36	32
6	1202	Tanks/Ponds	4	13	0.27	12	12
		Sub-Total	**162**	**3674**	**77.36**	**2430**	**1876**
		Wetlands (<2.25 ha), mainly Tanks	1075	1075	22.64	-	-
		Total	**1237**	**4749**	**100.00**	**2430**	**1876**

Area under Aquatic Vegetation	637	1435

Area under turbidity levels		
Low	528	199
Moderate	1891	1625
High	11	52

Wetland Vegetation

Aquatic vegetation is observed in all types of wetlands except River/stream. Area under wetland vegetation is more during Pre-monsoon (1434 ha) than that of post-monsoon (637 ha). This is mainly due to increased area in vegetation in natural Waterlogged wetland type (table 9) which has shown dominating presence and increased from 495 ha in post-monsoon to 1244 ha in pre-monsoon.

Table 9: Area estimates of wetland vegetation in West Tripura

Area in ha

Sr. No.	Wetland code	Wetland Category	Post-monsoon (2006)	Pre-monsoon (2007)
	1100	**Inland Wetlands - Natural**		
1	1101	Lake/Pond	89	111
2	1102	Ox-Bow Lakes/ Cut-Off Meanders	32	51
3	1105	Waterlogged	495	1244
4	1106	River/Stream	-	-
		Sub-total	**616**	**1407**
	1200	**Inland Wetlands -Man-made**		
5	1201	Reservoir/Barrage	20	25
6	1202	Tank/Pond	1	2
		Sub-total	**22**	**27**
		Total	**637**	**1434**

Turbidity Status

Qualitative turbidity of open water is in general medium in both the seasons. The dominance of moderate turbidity is mainly because of river/stream (1010 ha) and natural waterlogged areas (675 ha) out of 1889 ha of moderately turbid water (Table 10). Extent under low turbidity decreased from 530 ha in post-monsoon to 198 ha in pre-monsoon. Extent under high turbidity is insignificant in both the seasons (Table 10). Moderate turbidity is dominant and accounts for 78 % and 87 % in post- and Pre-monsoon seasons respectively. In terms of per cent extent, the low turbidity comprised about 22 % of open water in post–monsoon and has got reduced to half (about 11 %).

Table 10: Turbidity status of open water associated with wetlands in West Tripura

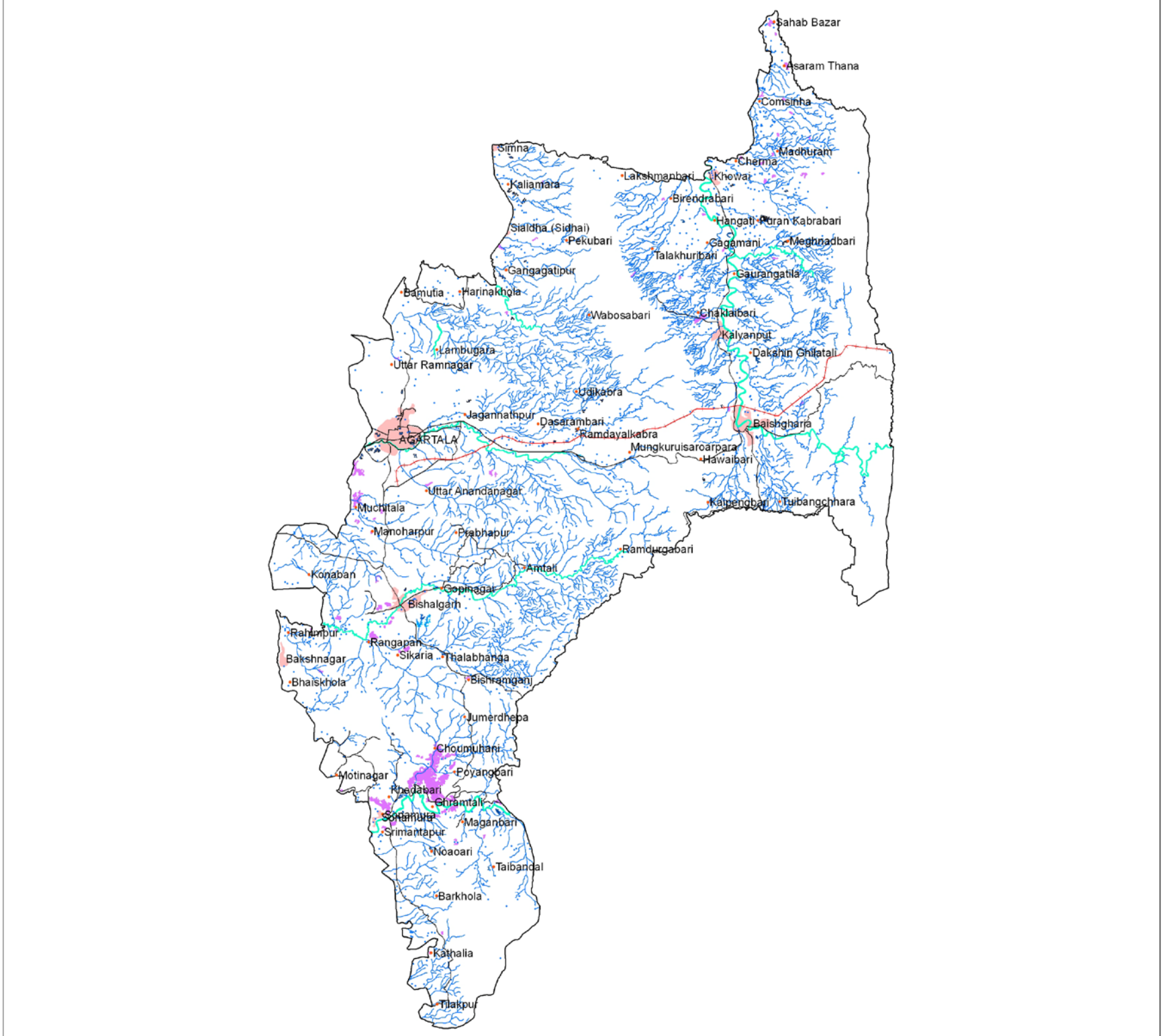
Area in ha

Sr. No.	Wetland code	Wetland Category	Turbidity Post-monsoon:2006			Turbidity Pre-monsoon:2007		
			Low	Moderate	High	Low	Moderate	High
	1100	**Inland Wetlands - Natural**						
1	1101	Lake/Pond	16	121	-	35	79	-
2	1102	Ox-Bow Lakes/ Cut-Off Meanders	3	52	-	11	24	-
3	1105	Waterlogged	353	675	2	120	161	-
4	1106	River/Stream	140	1010	9	-	1350	53
		Sub-total	**512**	**1858**	**11**	**166**	**1614**	**53**
	1200	**Inland Wetlands -Man-made**						
5	1201	Reservoir/Barrage	13	24	-	23	8	-
6	1202	Tank/Pond	5	7	-	9	3	-
		Sub-total	**18**	**31**	**-**	**32**	**11**	**-**
		Total	**530**	**1889**	**11**	**198**	**1625**	**53**

State : Tripura

WETLAND MAP

District : West Tripura

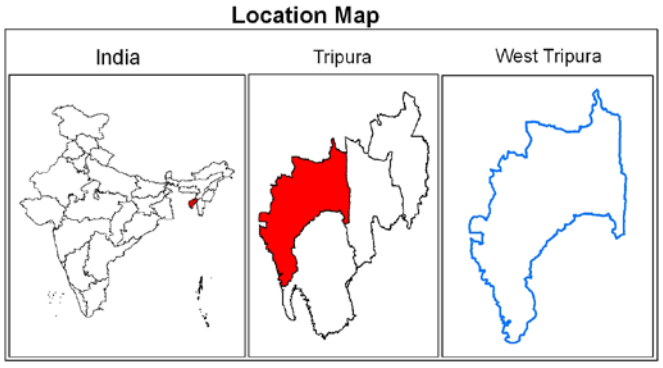


Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- Wetlands (<2.25 ha)
- Settlements
- Drainage (line)
- Canal
- Roads
- Railways
- Town/Settlements
- District Boundary
- State Boundary
- International Boundary

Location Map



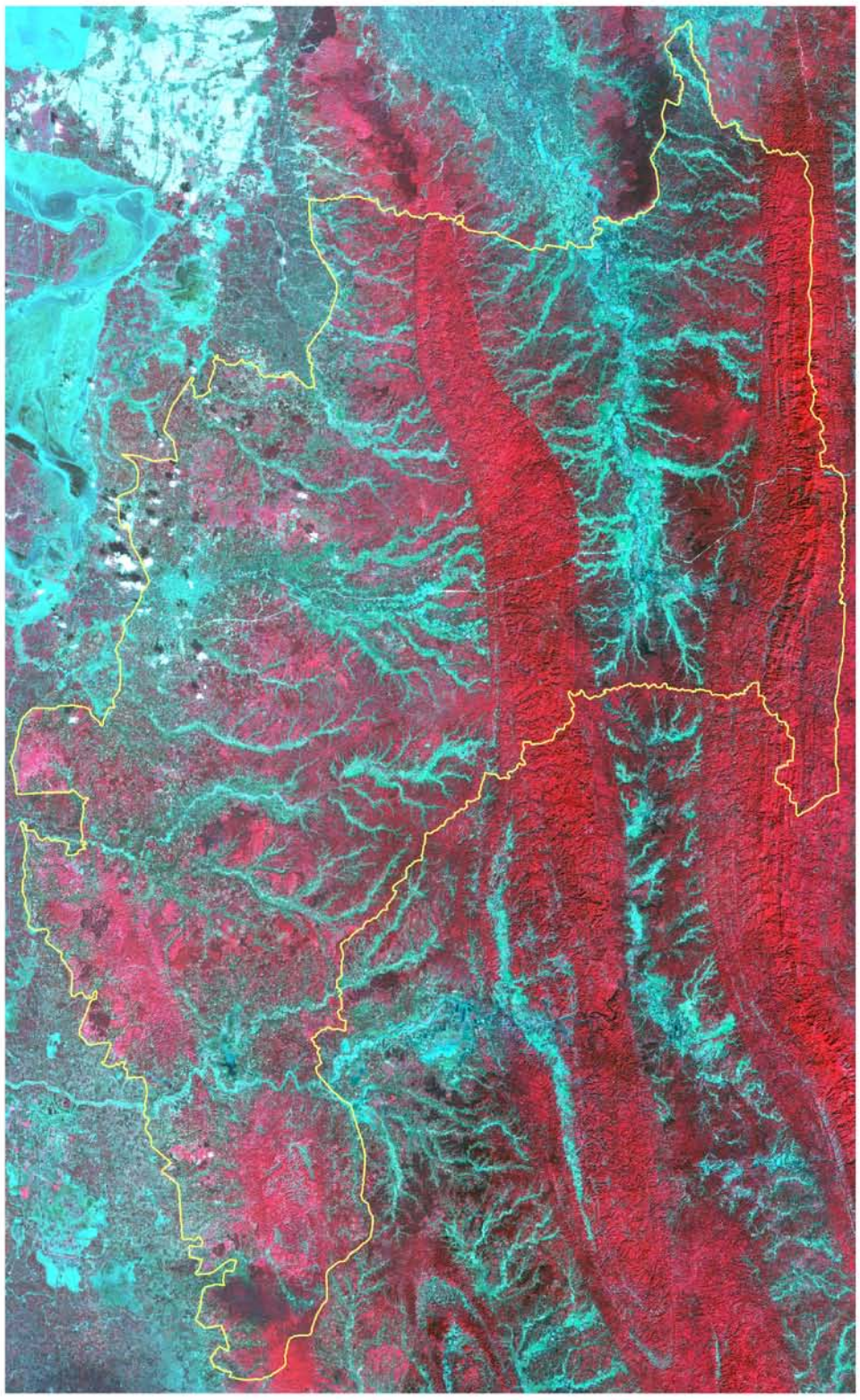
Data Source:
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By :
Ministry of Environment and Forests
Government of India

State : Tripura

District : West Tripura



IRS P6 LISS-III Post-monsoon data (2006)

7.1.2 South Tripura

The district of South Tripura is situated at a longitude of 91°18’ and 91°59’ East and at a latitude of 22°56’ and 23°45’ N. Covering a total geographical area of 2152 Sq. km, South Tripura is bordered by the Dalai district, West Tripura and Bangladesh. Udaipur is the district headquarter of South Tripura. Like most other parts of Tripura, the district of South Tripura is also dotted with a number of rivers and mountain ranges. There are a number of rivers that criss cross the district of South Tripura, the most important among them are Feni, Muhuri and Gumti. Total 116 wetlands have been delineated in addition to the 824 small wetlands (< 2.25 ha) identified. The inland-Natural wetlands comprise about 65 %. The major natural wetlands are River/stream (41.74 %), followed Waterlogged (19.09 %) and Ox-bow Lakes (2.93 %). Reservoir/Barrage is the major man-made wetlands. Total 4 such wetland types mapped with 625 ha area occupying 13.66 % of wetlands. Detailed statistics of wetlands of South Tripura district is given in table 11. The open water spread area is more in post-monsoon (2474 ha) than in Pre-monsoon (1799 ha). The reduction in open water spread area in Pre-monsoon is more significant in case of Reservoir/Barrages and Waterlogged types.

Table 11: Area estimates of wetlands in South Tripura

Area in ha

Sr. No.	Wettcode	Wetland Category	Number of Wetlands	Total Wetland area	% of wetland area	Open Water	
						Post-monsoon area	Pre-monsoon area
	1100	**Inland Wetlands – Natural**					
1	1101	Lakes/Ponds	9	41	0.90	25	20
2	1102	Ox-bow lakes/ Cut-off meanders	29	134	2.93	85	68
3	1105	Waterlogged	55	873	19.09	598	122
4	1106	River/Stream	4	1909	41.74	1159	1370
	1200	**Inland Wetlands -Man-made**					
5	1201	Reservoirs/Barrages	3	625	13.66	482	94
6	1202	Tanks/Ponds	16	168	3.67	125	125
		Sub-Total	**116**	**3750**	**81.99**	**2474**	**1799**
		Wetlands (<2.25 ha), mainly Tanks	824	824	18.01	-	-
		Total	**940**	**4574**	**100.00**	**2474**	**1799**

Area under Aquatic Vegetation	526	1412

Area under turbidity levels		
Low	633	210
Moderate	1830	1589
High	11	-

Wetland Vegetation

Wetland vegetation is observed in all types of wetlands except River/stream. Area under aquatic vegetation is more during Pre-monsoon (1412 ha) compared to post-monsoon (526 ha). This is mainly due to significant increase in vegetation area in case of Waterlogged wetlands and Reservoir/Barrage (Table 12). Man-made wetlands have significantly lower extents (185 ha and 574 ha) of aquatic vegetation in both the seasons compared to natural wetlands (341 ha and 838 ha).

Table 12: Area estimates of wetland vegetation in South Tripura

Area in ha

Sr. No.	Wetland code	Wetland Category	Post-monsoon (2006)	Pre-monsoon (2007)
	1100	**Inland Wetlands - Natural**		
1	1101	Lake/Pond	16	21
2	1102	Ox-Bow Lakes/ Cut-Off Meanders	49	66
3	1105	Waterlogged	276	751
4	1106	River/Stream	-	-
		Sub-total	**341**	**838**
	1200	**Inland Wetlands -Man-made**		
5	1201	Reservoir/Barrage	143	531
6	1202	Tank/Pond	42	43
		Sub-total	**185**	**574**
		Total	**526**	**1412**

Turbidity Status

The turbidity of open water is in general moderate in both the seasons. However, in case of Reservoir/ Barrages, the turbidity of water is mainly moderate (85 ha) during pre-monsoon, while it is moderate (305 ha) to low (178 ha) during post-monsoon. Moderate turbidity dominated the open water features of wetlands in this district accounting for 74 % (post-monsoon) and 88 % (pre-monsoon), which is observed to be mainly due to river/stream category. Low turbidity in post-monsoon (633 ha) was found to have decreased to 210 ha in pre-monsoon. High turbidity areas are insignificant in post-monsoon and absent in pre-monsoon. Turbidity status of various wetlands under low, moderate and high turbidity is given in the table 13.

Table 13: Turbidity status of open water associated with wetlands in South Tripura

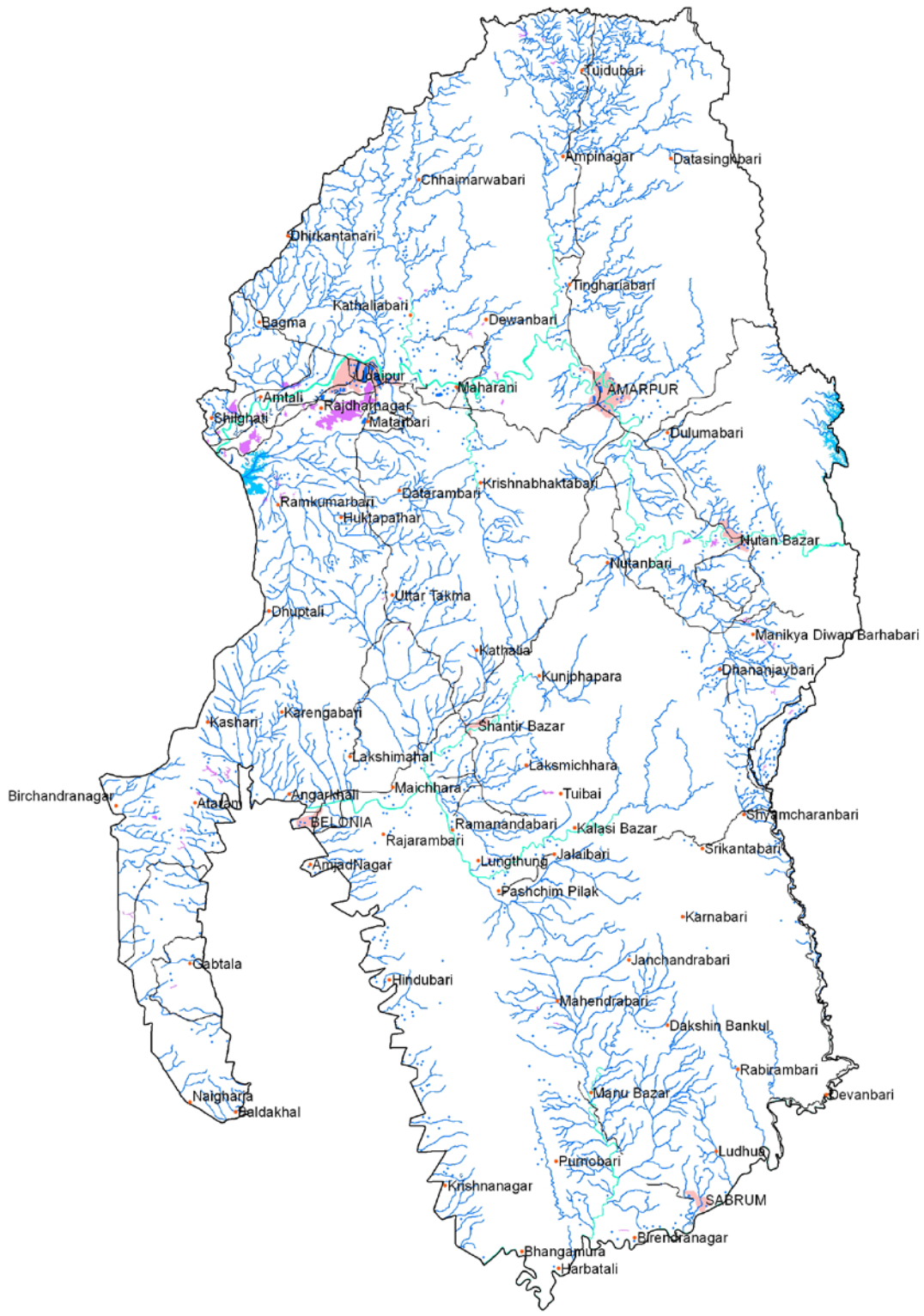
Area in ha

Sr. No.	Wetland code	Wetland Category	Turbidity			Turbidity		
			Post-monsoon:2006			Pre-monsoon:2007		
			Low	Moderate	High	Low	Moderate	High
	1100	**Inland Wetlands - Natural**						
1	1101	Lake/Pond	4	21	-	9	11	-
2	1102	Ox-Bow Lakes/ Cut-Off Meanders	7	79	-	20	49	-
3	1105	Waterlogged	160	437	-	39	83	-
4	1106	River/Stream	204	943	11	26	1344	-
		Sub-total	**376**	**1479**	**11**	**94**	**1487**	**-**
	1200	**Inland Wetlands -Man-made**						
5	1201	Reservoir/Barrage	178	305	-	9	85	-
6	1202	Tank/Pond	80	45	-	107	17	-
		Sub-total	**258**	**350**	**-**	**116**	**102**	**-**
		Total	**633**	**1830**	**11**	**210**	**1589**	**-**

State : Tripura

WETLAND MAP

District : South Tripura

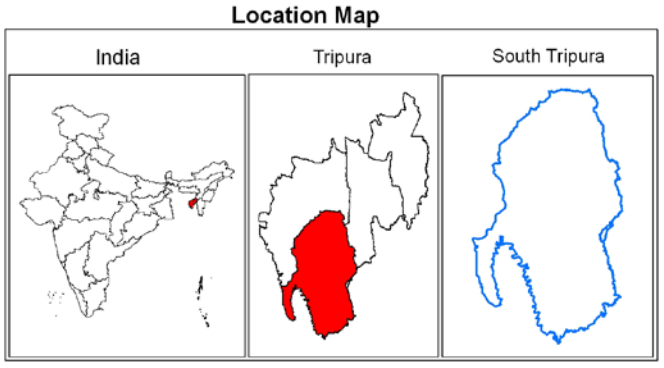


Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- Wetlands (<2.25 ha)
- Settlements
- Drainage (line)
- Canal
- Roads
- Railways
- Town/Settlements
- District Boundary
- State Boundary
- International Boundary

Location Map



0 2.5 5 10 15 Kilometers

Data Source:
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By :
Ministry of Environment and Forests
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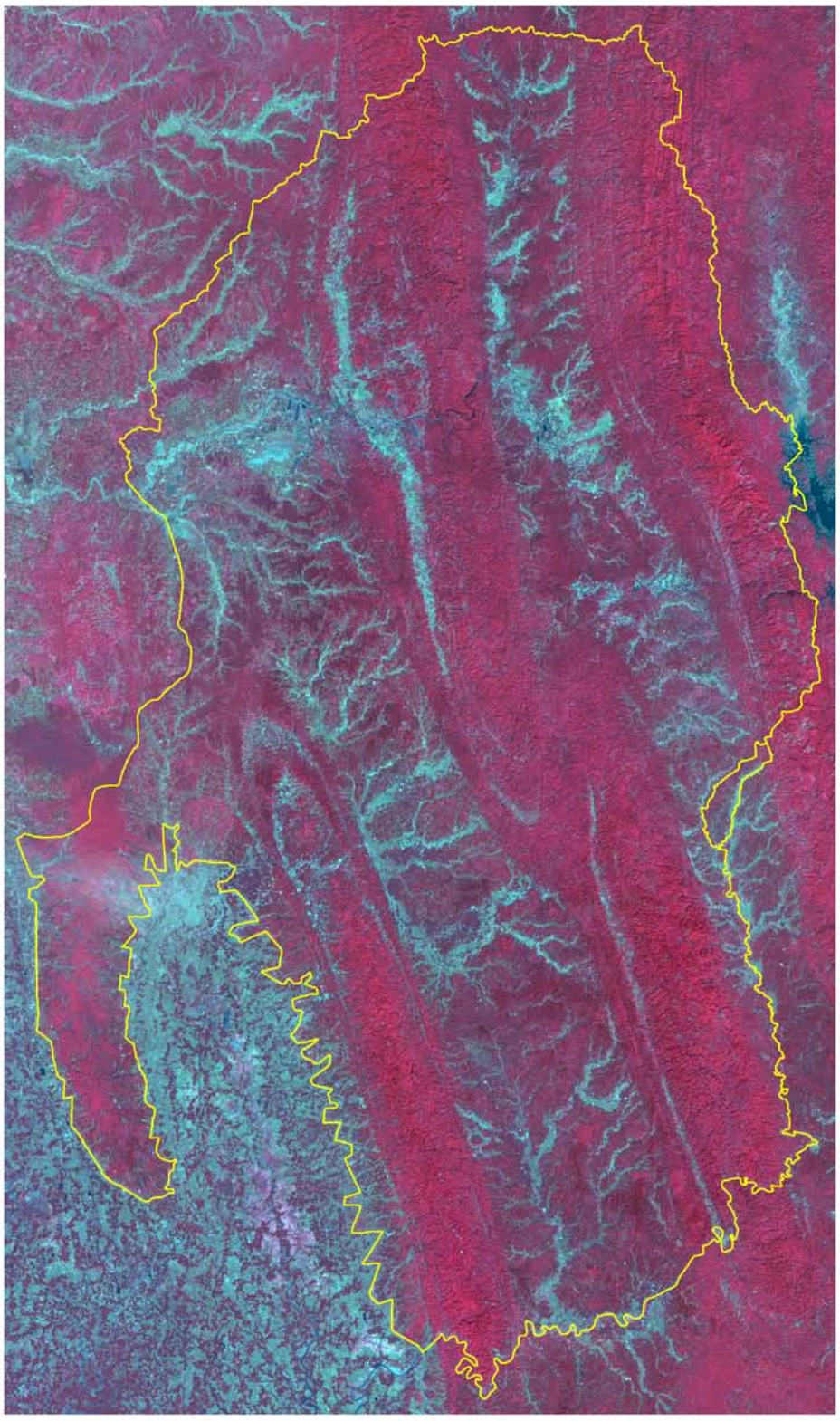
State : Tripura

District : South Tripura



IRS P6 LISS-III Post-monsoon data92006)

7.1.3 Dhalai District

Dhalai District of Tripura occupies a total area of 2523 Sq. km and has population of around 307,417. This is the youngest district of Tripura and Ambassa is its headquarter. The general topography of this district of Tripura is hilly and around 70% area is covered with forests. The major rivers of Dhalai District are Khowai, Manu, and Dhalai. Total 77 wetlands mapped 349 small wetlands (<2.25ha) delineated as point features. The total wetland area is 4815 ha. The inland-Natural wetlands comprise about 43 % and inland-Man-made wetlands comprise about 50 % of wetland area. Reservoir/Barrage occupies the largest area (2383 ha) followed by River/Stream (1751 ha). The other major wetland types are waterlogged (264 ha) followed by Ox-Bow lakes (54 ha). Details of wetland statistics is given in Table-14. The open water spread of River/stream does not show significant seasonal change. However, in case of Reservoir/Barrage, the open water is significantly reduced during Pre-monsoon (587 ha) compared to post-monsoon (2211 ha).

Table 14: Area estimates of wetlands in Dhalai District

Area in ha

Sr. No.	Wettcode	Wetland Category	Number of Wetlands	Total Wetland Area	% of wetland area	Open Water	
						Post-monsoon Area	Pre-monsoon Area
	1100	**Inland Wetlands - Natural**					
1	1101	Lakes/Ponds	2	9	0.19	6	5
2	1102	Ox-bow lakes/ Cut-off meanders	13	54	1.12	34	19
3	1105	Waterlogged	50	264	5.48	114	118
4	1106	River/Stream	6	1751	36.37	991	1130
	1200	**Inland Wetlands -Man-made**					
5	1201	Reservoirs/Barrages	5	2383	49.49	2211	587
6	1202	Tanks/Ponds	1	5	0.10	5	5
		Sub-Total	**77**	**4466**	**92.75**	**3361**	**1864**
		Wetlands (<2.25 ha), mainly Tanks	349	349	7.25	-	-
		Total	**426**	**4815**	**100.00**	**3361**	**1864**

Area under Aquatic Vegetation	344	1983

Area under turbidity levels		
Low	1309	166
Moderate	2047	1697
High	5	1

Wetland Vegetation

Aquatic vegetation is observed in Lake/Pond, Ox-Bow Lakes/ Cut-Off Meanders, Waterlogged, Reservoir/Barrage and Tank/Pond wetland types. Area under aquatic vegetation (floating and emergent) is less (344 ha) during post-monsoon season than that of Pre-monsoon (1983 ha). This is mainly due to increase in vegetation in the Reservoir/ Barrage wetland types (Table 15).

Table 15: Area estimates of wetland vegetation in Dhalai District

Area in ha

Sr. No.	Wetland code	Wetland Category	Post-monsoon (2006)	Pre-monsoon (2007)
	1100	**Inland Wetlands - Natural**		
1	1101	Lake/Pond	3	4
2	1102	Ox-Bow Lakes/ Cut-Off Meanders	20	35
3	1105	Waterlogged	149	147
4	1106	River/Stream	-	-
		Sub-total	**171**	**186**
	1200	**Inland Wetlands -Man-made**		
5	1201	Reservoir/Barrage	172	1797
6	1202	Tank/Pond	-	-
		Sub-total	**173**	**1797**
		Total	**344**	**1983**

Turbidity Status

The qualitative turbidity of open water in wetlands is in general moderate during pre-monsoon. Moderate turbidity is significant (61 %) in post-monsoon, which has become dominant in pre-monsoon (91 %). Low turbid open water features account for 39 % in post-monsoon got reduced to 9 in pre-monsoon. High turbidity is insignificant in post-monsoon and is absent in pre-monsoon. The turbidity of open water in case of Reservoirs/ Barrages is low (1261 ha) to moderate (951 ha) and is mainly responsible overall moderate turbidity of open water features in this district. Turbidity status of various wetlands under low, moderate and high turbidity is given in the table 16.

Table 16: Turbidity status of open water associated with wetlands in Dhalai district

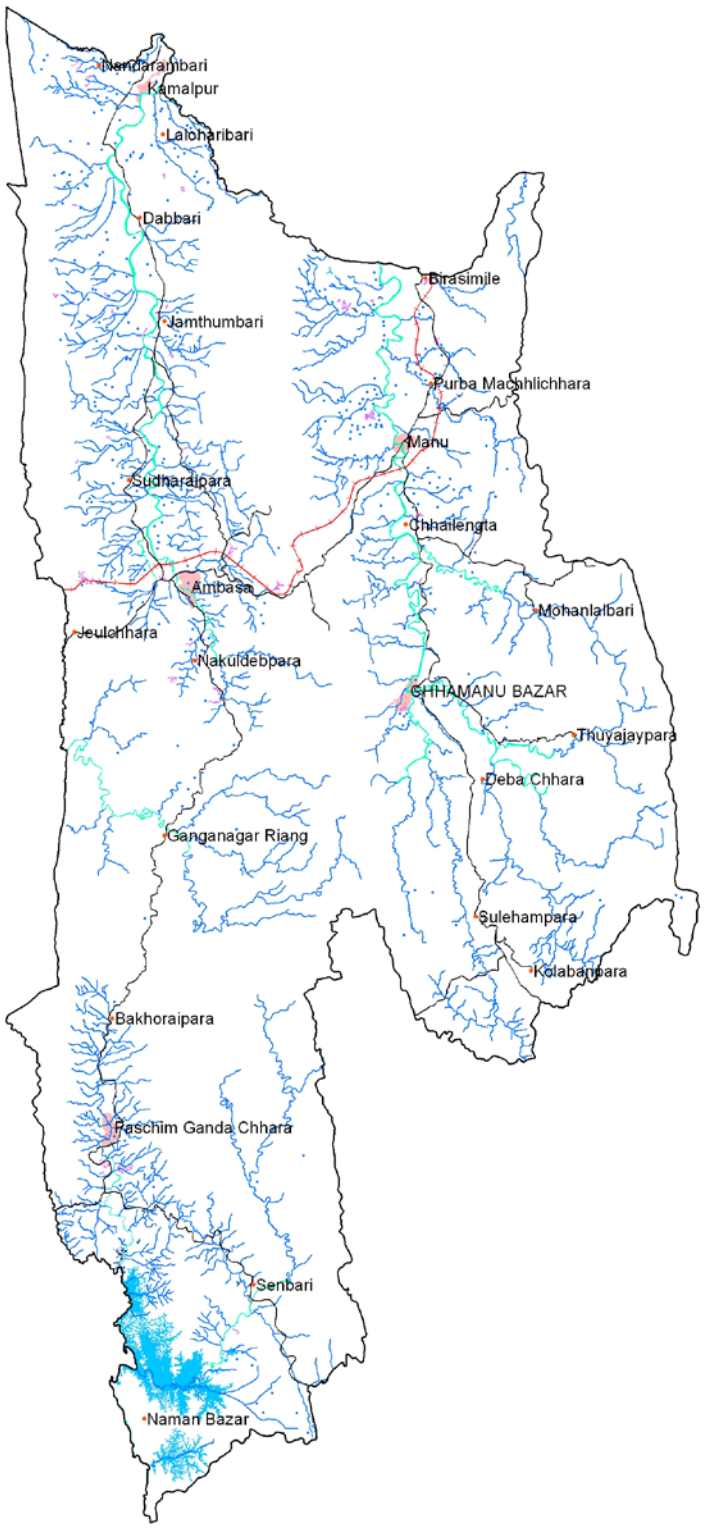
Area in ha

Sr. No.	Wetland code	Wetland Category	Turbidity Post-monsoon:2006			Turbidity Pre-monsoon:2007		
			Low	Moderate	High	Low	Moderate	High
	1100	**Inland Wetlands - Natural**						
1	1101	Lake/Pond	-	6	-	-	5	-
2	1102	Ox-Bow Lakes/ Cut-Off Meanders	1	33	-	2	17	-
3	1105	Waterlogged	4	111	-	11	106	-
4	1106	River/Stream	42	944	5	29	1101	1
		Sub-total	**47**	**1095**	**5**	**41**	**1230**	**1**
	1200	**Inland Wetlands -Man-made**						
5	1201	Reservoir/Barrage	1261	951	-	119	468	-
6	1202	Tank/Pond	2	2	-	5	-	-
		Sub-total	**1263**	**952**	**-**	**124**	**468**	**-**
		Total	**1309**	**2047**	**5**	**166**	**1697**	**1**

State : Tripura

WETLAND MAP

District : Dhalai

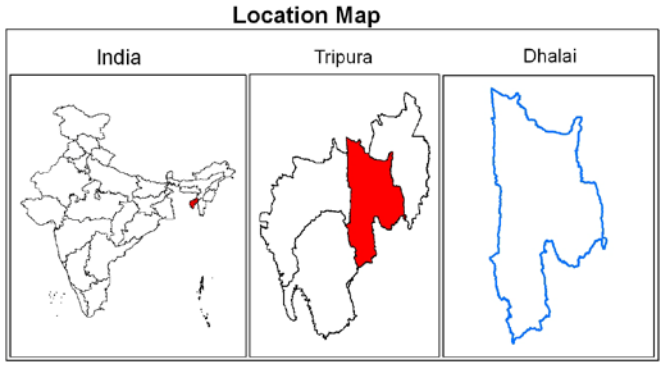


Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- Wetlands (<2.25 ha)
- Settlements
- Drainage (line)
- Canal
- Roads
- Railways
- Town/Settlements
- District Boundary
- State Boundary
- International Boundary

Location Map



Data Source:
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

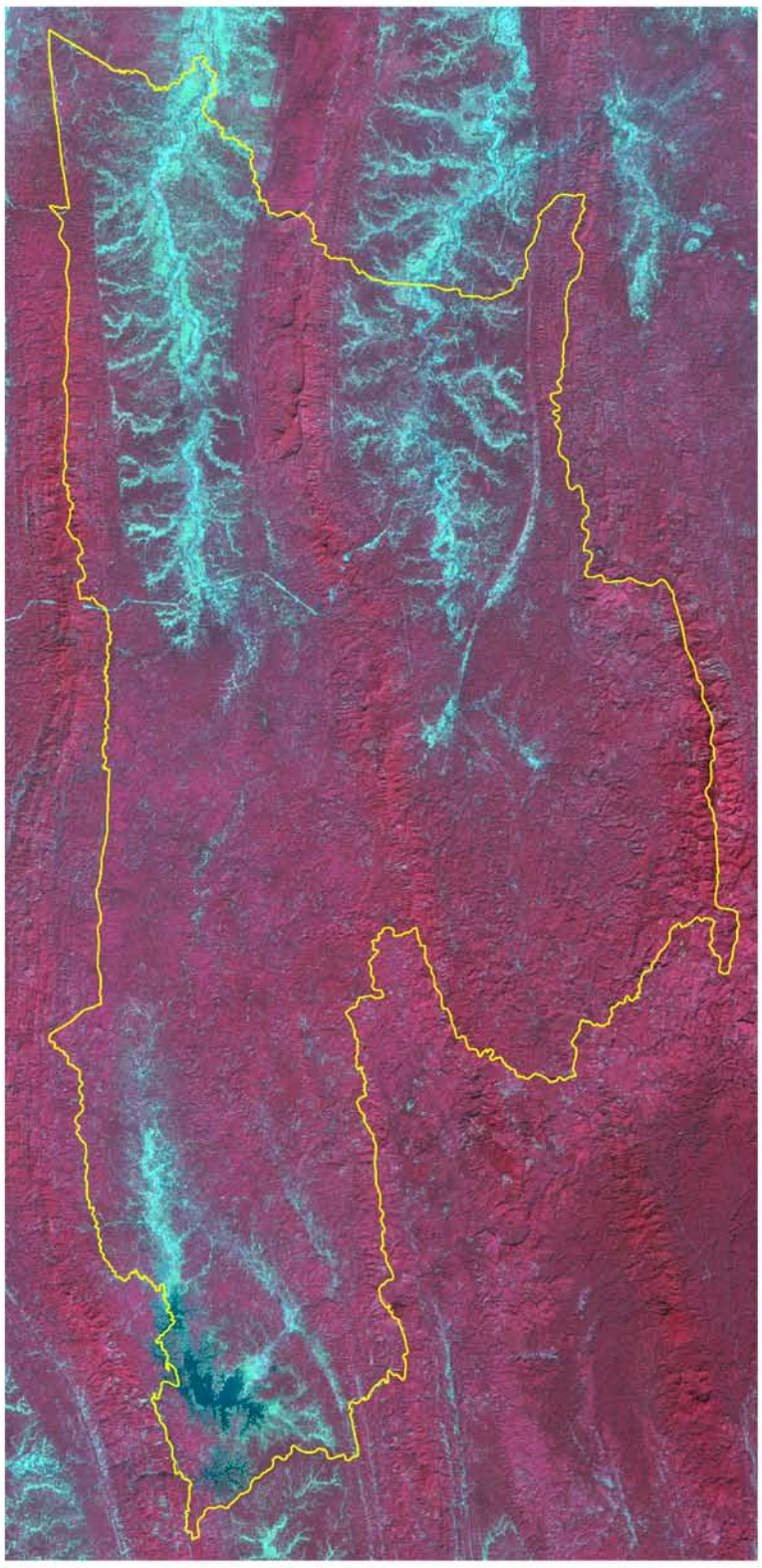
Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By :
Ministry of Environment and Forests
Government of India

State : Tripura

WETLAND MAP

District : Dhalai



IRS P6 LISS-III Post-monsoon data(2006)

7.1.4 North Tripura

The North District of Tripura covers a total area of 2821 Sq. km with Kailasahar as the district headquarters. This district is sub divided into three divisions, Kailashahar, Dharmanagar and Kanchanpur. The total geographic area of North Tripura is 2821 km². In the North Tripura district, 92 wetlands have been delineated in addition to 735 small wetlands (<2.25 ha) identified. The inland-Natural wetlands comprise about 70.9 % of total wetland area. River/stream is the dominant wetland type (58.6 %), followed by Waterlogged (8.3 %). The other major natural wetland type is Ox-Bow lakes (111 ha). Reservoir/Barrage is the major Man made wetland type. Total 3 are mapped under this category with 255 ha area that turns out to be 7.5 %. Detailed wetland statistics is given in table-17. The open water spread in wetlands does not show significant seasonal variation, except for Reservoir/Barrages. The water spread in Reservoirs/Barrages reduced significantly (83 ha) during Pre-monsoon compared to post-monsoon (206 ha).

Table 17: Area estimates of wetlands in North Tripura

Area in ha

Sr. No.	Wettcode	Wetland Category	Number of Wetlands	Total Wetland Area	% of wetland area	Open Water	
						Post-monsoon Area	Pre-monsoon Area
	1100	**Inland Wetlands - Natural**					
1	1101	Lakes/Ponds	6	25	0.73	12	13
2	1102	Ox-bow lakes/ Cut-off meanders	26	111	3.26	55	47
3	1105	Waterlogged	51	282	8.28	128	126
4	1106	River/Stream	6	1996	58.64	1180	1215
	1200	**Inland Wetlands -Man-made**					
5	1201	Reservoirs/Barrages	3	255	7.49	207	83
6	1202	Tanks/Ponds	-	-	-	-	-
		Sub-Total	**92**	**2669**	**78.41**	**1582**	**1484**
		Wetlands (<2.25 ha), mainly Tanks	735	735	21.59	-	-
		Total	**827**	**3404**	**100.00**	**1582**	**1484**

Area under Aquatic Vegetation	272	402

Area under turbidity levels		
Low	202	66
Moderate	1380	1418
High	-	-

Wetland Vegetation

Lake/Pond, Ox-Bow Lakes/ Cut-Off Meanders, Waterlogged and Reservoir/Barrage are the only wetland types that have vegetation. Area under aquatic vegetation mapped is 272 ha in post-monsoon season which increased to 402 ha in Pre-monsoon (Table 18). This is mainly due to change in wetland vegetation area in Reservoir/ Barrages.

Table 18: Area estimates of wetland vegetation in North Tripura

Area in ha

Sr. No.	Wetland code	Wetland Category	Post-monsoon (2006)	Pre-monsoon (2007)
	1100	**Inland Wetlands - Natural**		
1	1101	Lake/Pond	13	12
2	1102	Ox-Bow Lakes/ Cut-Off Meanders	57	65
3	1105	Waterlogged	154	156
4	1106	River/Stream	-	-
		Sub-total	**224**	**232**
	1200	**Inland Wetlands -Man-made**		
5	1201	Reservoir/Barrage	48	170
6	1202	Tank/Pond	-	
		Sub-total	**48**	**170**
		Total	**272**	**402**

Turbidity Status

The turbidity of open water is in mainly moderate in both the seasons. It was observed to 87 % of the open water features in post-monsoon got increased to 96 % in pre-monsoon. Low turbidity was observed to be 13 % in post-monsoon has reduced to mere 4 % in pre-monsoon. High turbidity has not been exhibited by wetlands in this district in both the seasons. However, in case of Reservoir/ Barrages, the turbidity of water is low (43 ha) to moderate (40 ha) during pre-monsoon, while mainly moderate (133 ha) during post-monsoon. Turbidity status of various wetlands under low, moderate and high turbidity is given in the table 19.

Table 19: Turbidity status of open water associated with wetlands in North Tripura

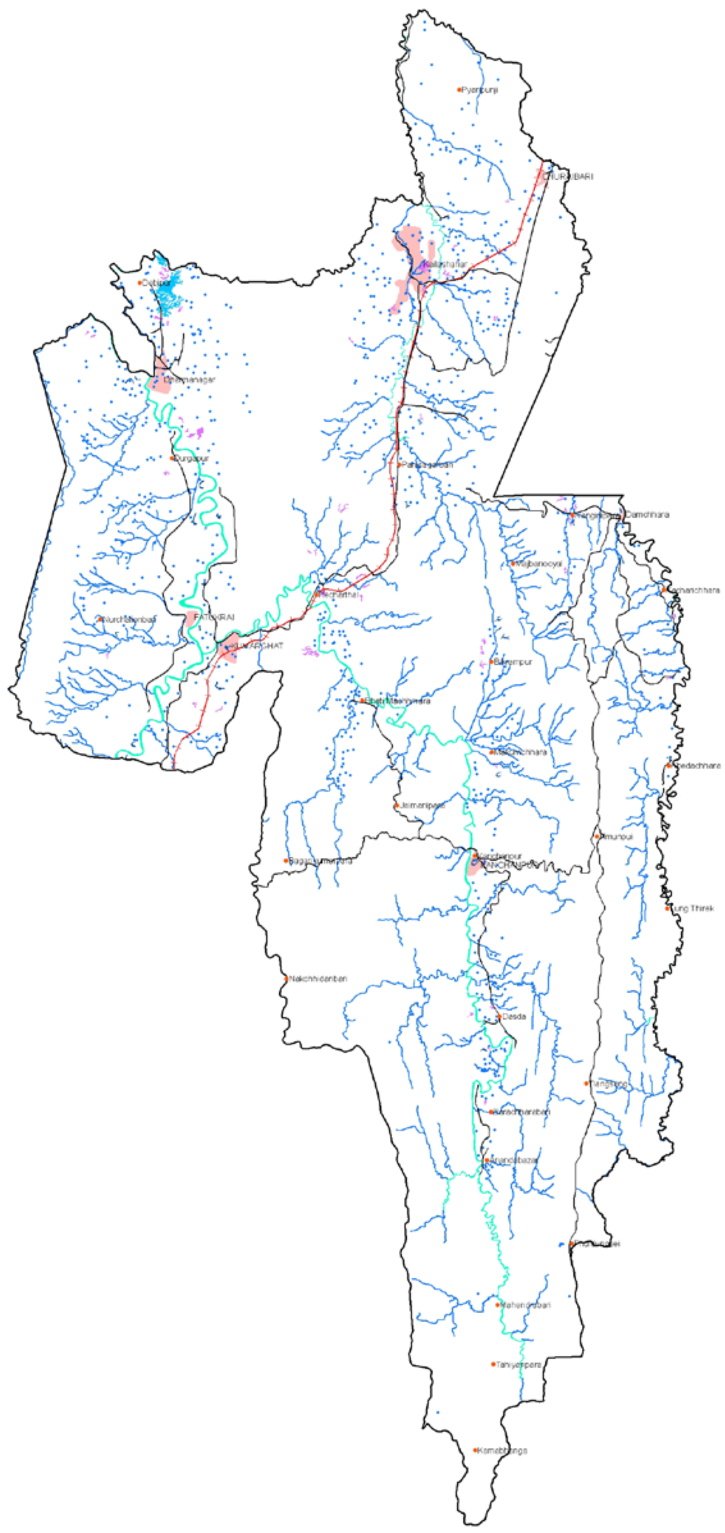
Area in ha

Sr. No.	Wetland code	Wetland Category	Turbidity Post-monsoon:2006			Turbidity Pre-monsoon:2007		
			Low	Moderate	High	Low	Moderate	High
	1100	**Inland Wetlands - Natural**						
1	1101	Lake/Pond	1	11	-	-	13	-
2	1102	Ox-Bow Lakes/ Cut-Off Meanders	9	46	-	3	44	-
3	1105	Waterlogged	7	120	-	20	106	-
4	1106	River/Stream	112	1070	-	-	1215	-
		Sub-total	**129**	**1247**	**-**	**23**	**1378**	**-**
	1200	**Inland Wetlands -Man-made**						
5	1201	Reservoir/Barrage	73	133	-	43	40	-
6	1202	Tank/Pond	-	-	-	-	-	-
		Sub-total	**73**	**133**	**-**	**43**	**40**	**-**
		Total	**202**	**1380**	**-**	**66**	**1418**	**-**

State : Tripura

WETLAND MAP

District : North Tripura

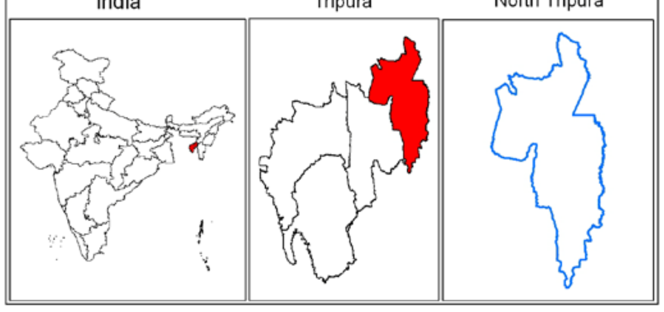


Legend

Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

- Wetlands (<2.25 ha)
- Settlements
- Drainage (line)
- Canal
- Roads
- Railways
- Town/Settlements
- District Boundary
- State Boundary
- International Boundary

Location Map



0 3 6 12 18 Kilometers

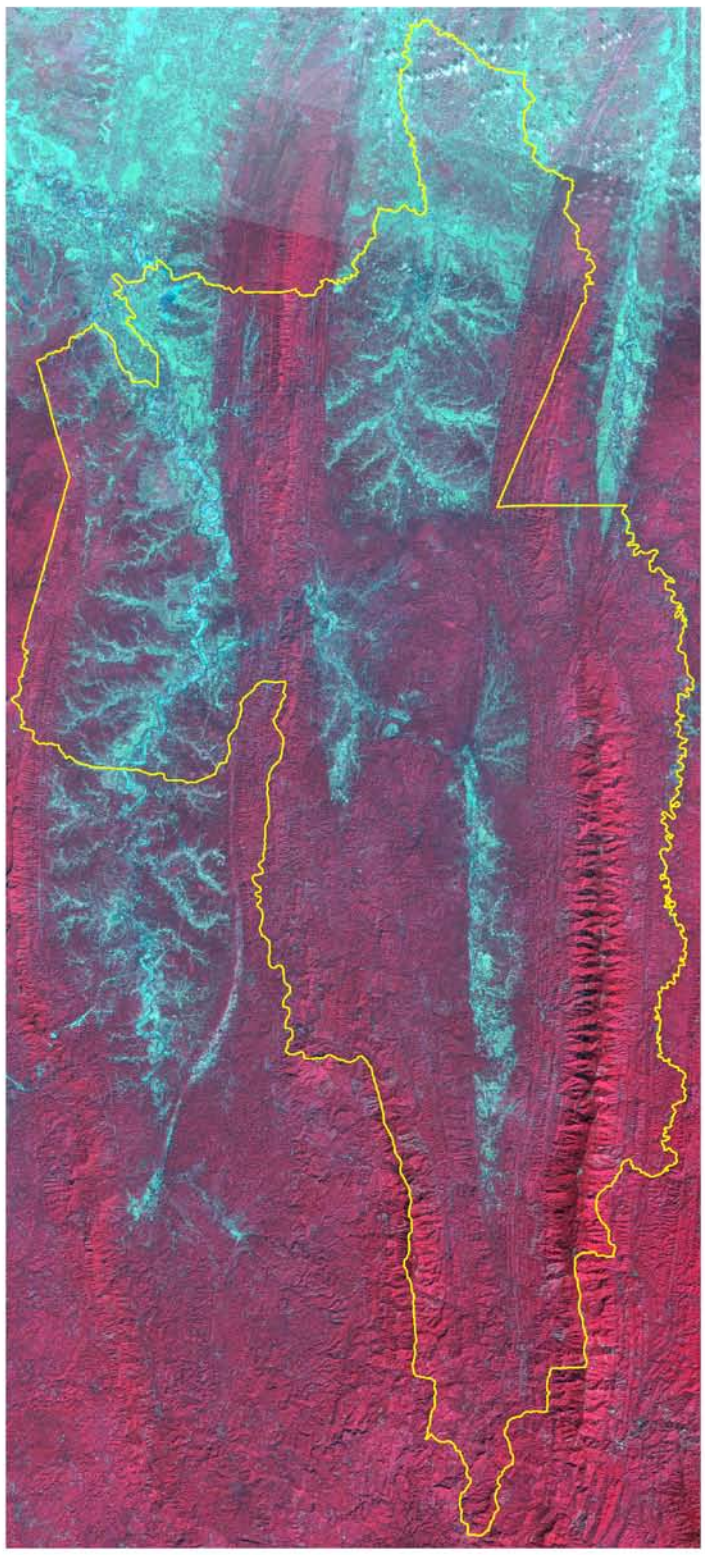
Data Source:
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By :
Ministry of Environment and Forests
Government of India

State : Tripura

District : North Tripura



IRS P6 LISS-III Post-monsoon data(2006)

MAJOR WETLAND TYPES

8.0 MAJOR WETLAND TYPES IN TRIPURA

Major wetland types observed in the state are Lake/Tank, Ox-bow lake, Waterlogged, River/stream, Reservoir/barrage and Lake/Pond. The manifestation of major wetland types on satellite imagery and their enhancement using certain combination of indices are given in Plate-1. Ground truth data was collected for selected wetland sites. Standard procedure was adopted to record the field data. Field photographs were also taken to record the status of the wetland category like status of aquatic vegetation and water. The location of the features was recorded using GPS. Field photographs and ground truth data of different wetland types are shown in Plates 2a, 2b and 2c.

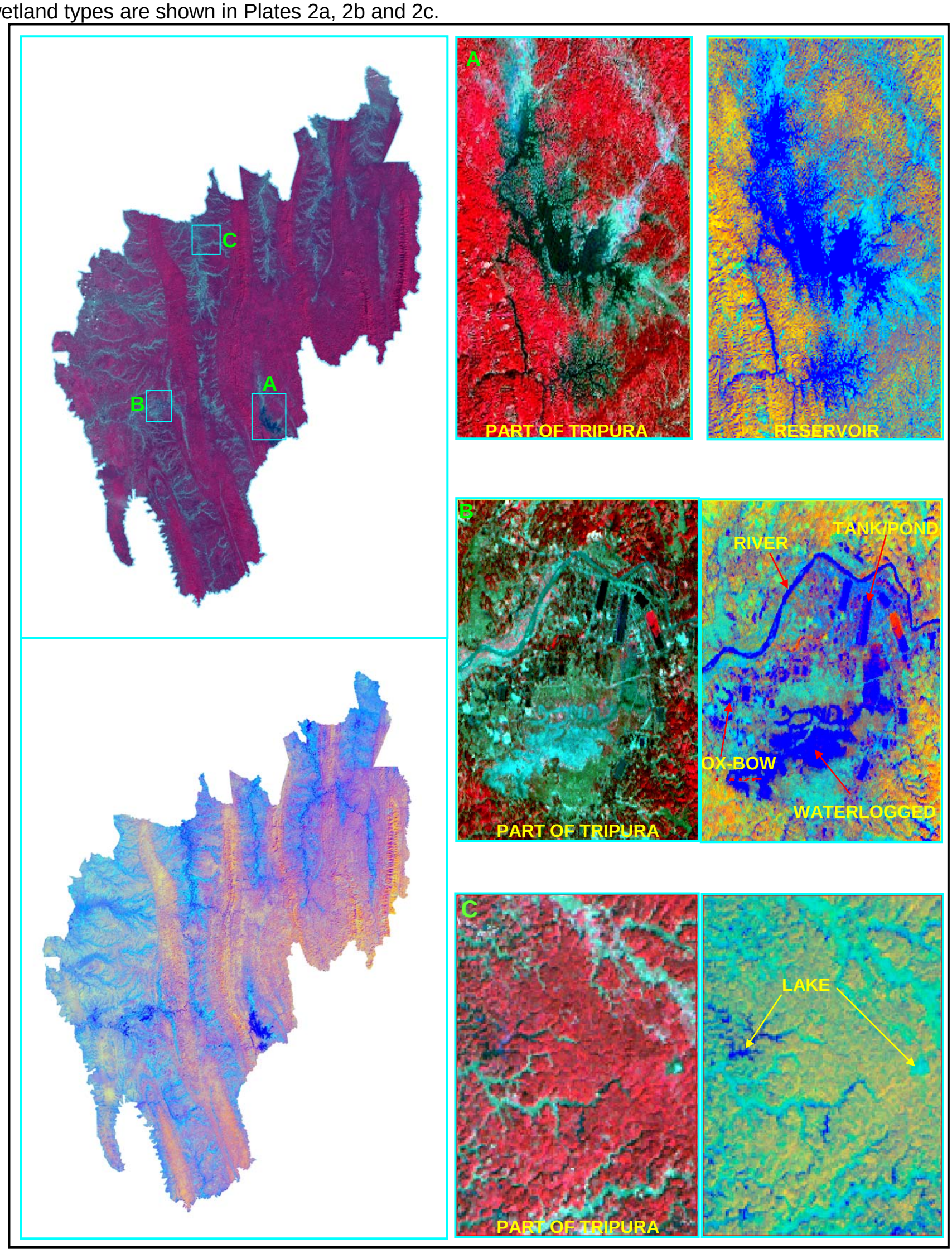


Plate - 1: Major wetland types of Tripura

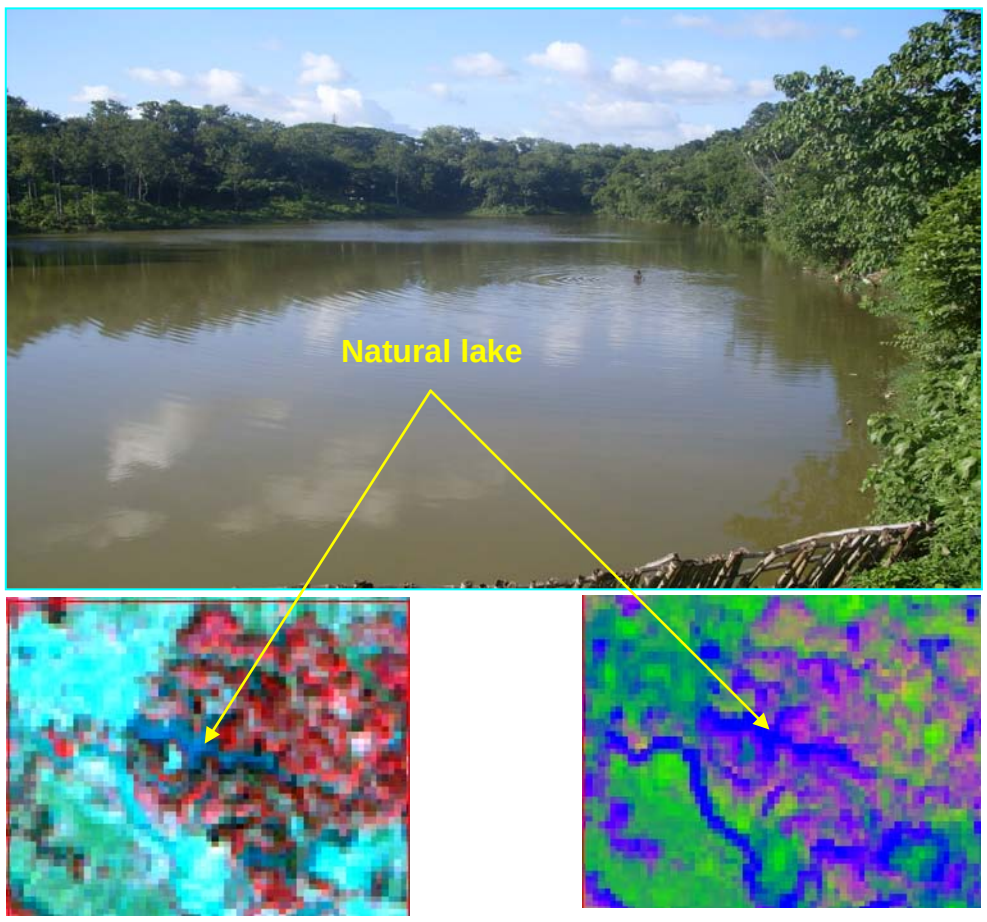
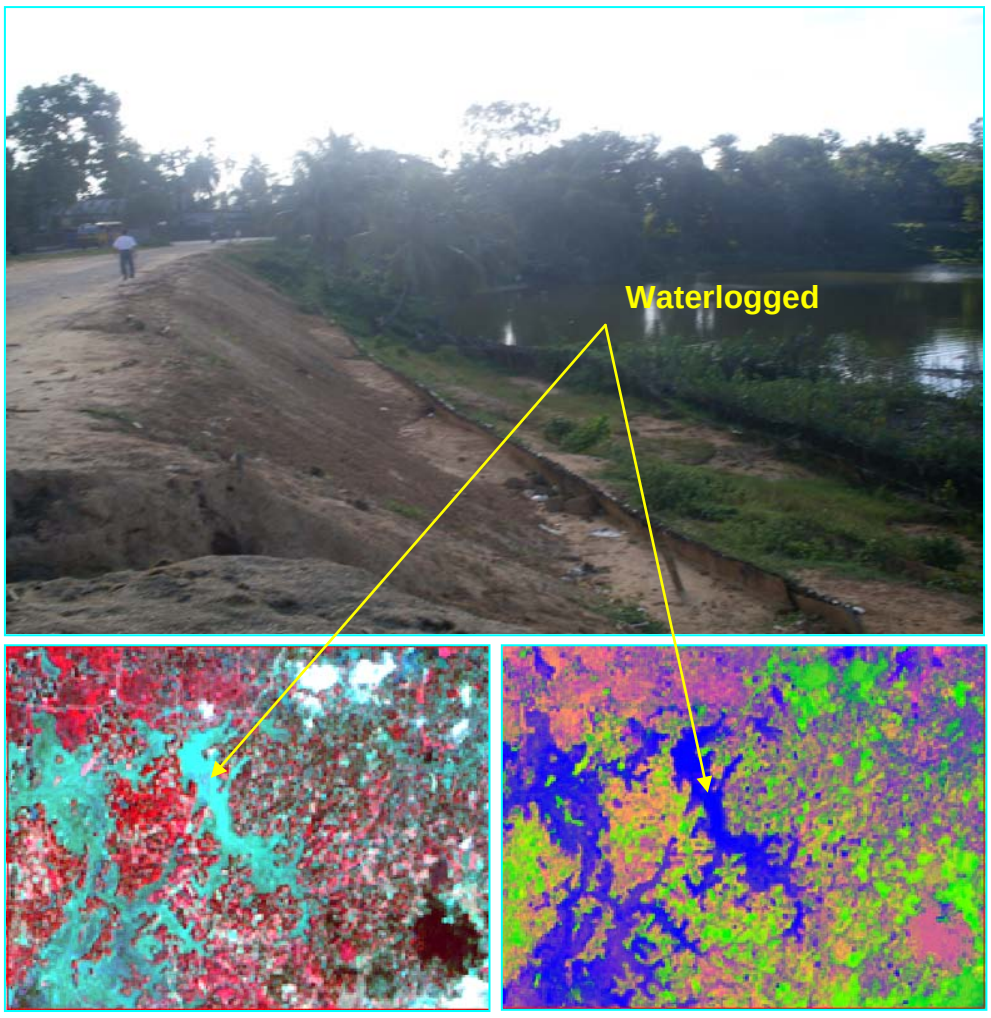
Sr. No.	Site Description	Wetland Category
1	Name of the Wetland: College Tilla lake Type: Lake District: West Tripura Village: College Tilla Location: 91:27:59.00E 23:49:21.00N Size: 6 ha Turbidity: 88.78 NTU pH: 8.53. Combination indices (NDTI MNDWI NDWI) aids in enhancement and delineation of water, which appears blue in colour and other vegetation in purple.	
2	Name of the Wetland: Belabar jola Type: Waterlogged District: West Tripura Village: Belabar Location: 23:48:19.00 N 91:14:18.00E Size: 49 ha Turbidity: 88.78 NTU pH: 6.99 Combination indices (NDTI MNDWI NDWI) aids in enhancement and delineation of waterlogged area, which appears water as blue in colour and other vegetation in purple.	

Plate 2a: Field photographs and their manifestation on LISS-III imagery of various wetland types in Tripura.

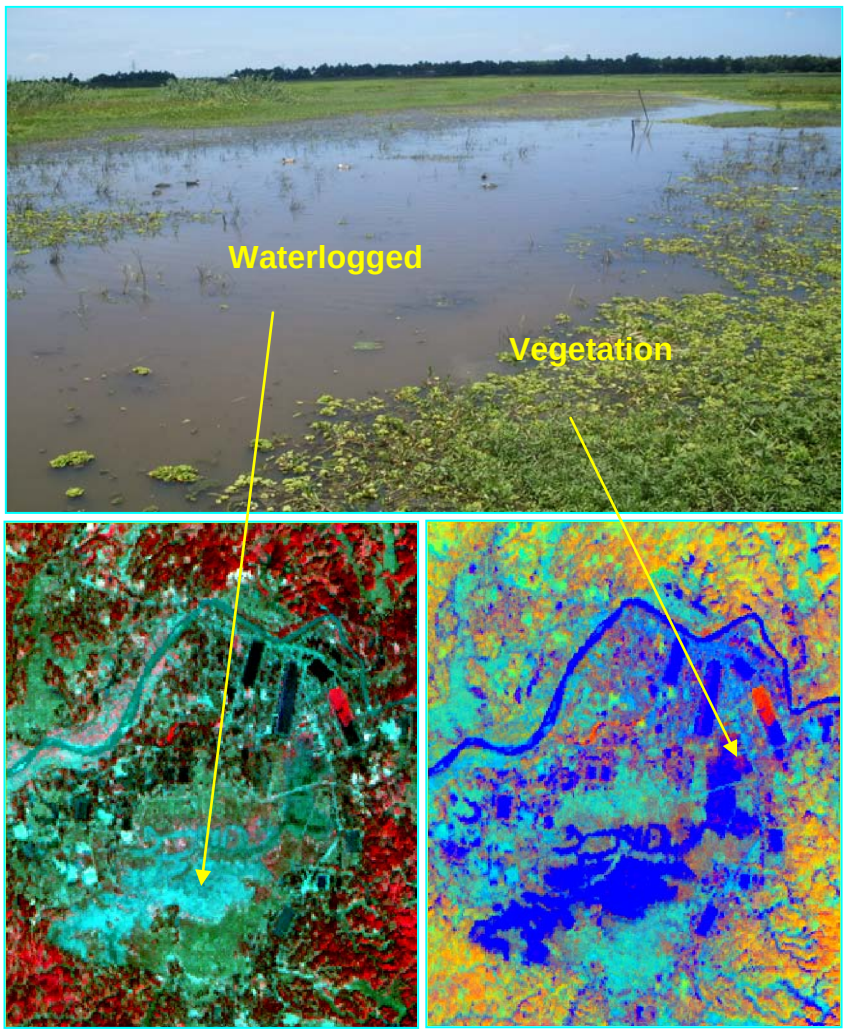
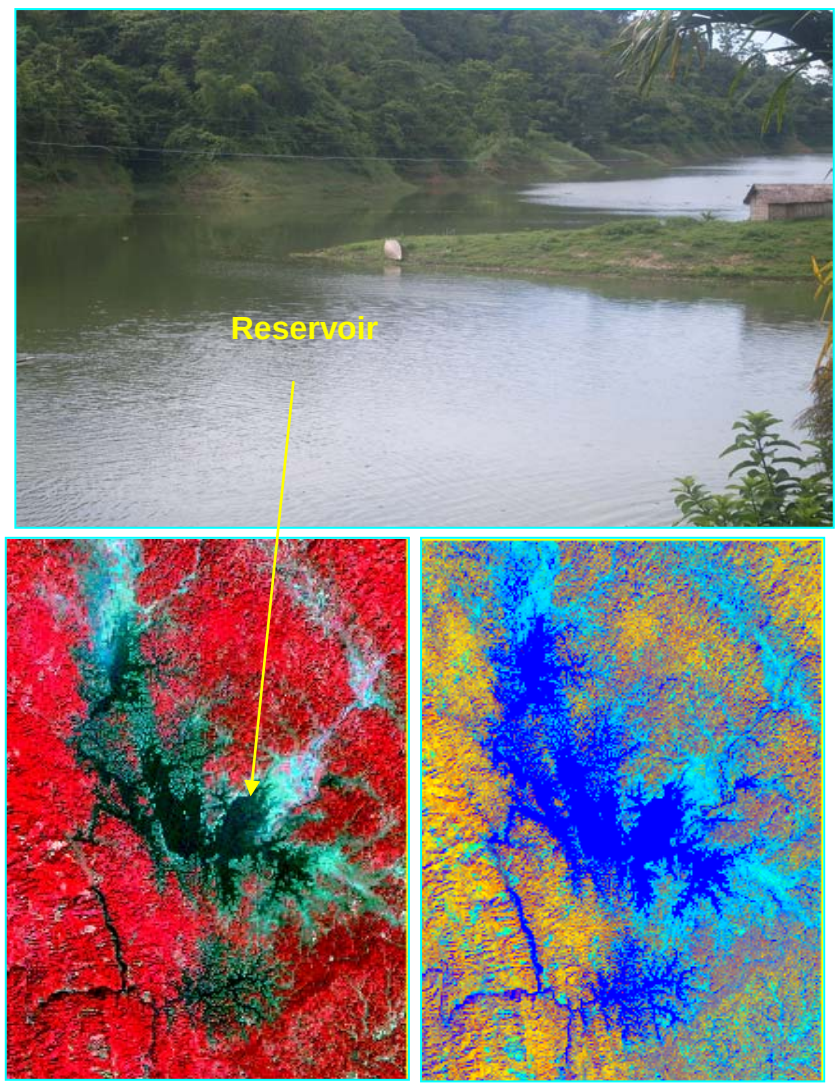
Sr. No.	Site Description	Wetland Category
1	Name of the Wetland: Sukh Sagar Type: Waterlogged District: South Tripura Village: Fulkumari (Udaipur) Location: 23:31:31.00N 91:30:10.00E Size: 380 ha Turbidity: 5.71 NTU pH: 7.32 Combination indices (NDTI MNDWI NDWI) aids in enhancement and delineation of waterlogged area, which appears water as blue in colour and other vegetation in purple.	
2	Name of the Wetland: Dumbur Reservoir Type: Reservoir District: South Tripura Village: Mandirghat (Udaipur) Location: 23:25:28.00N 91:49:49.00E Size: 2328 ha Turbidity: 119.84 NTU pH: 7.52 Combination indices (NDTI MNDWI NDWI) aids in enhancement and delineation of reservoir area, which appears water as blue in colour and other vegetation in purple.	

Plate 2b: Field photographs and their manifestation on LISS-III imagery of various wetland types in Tripura

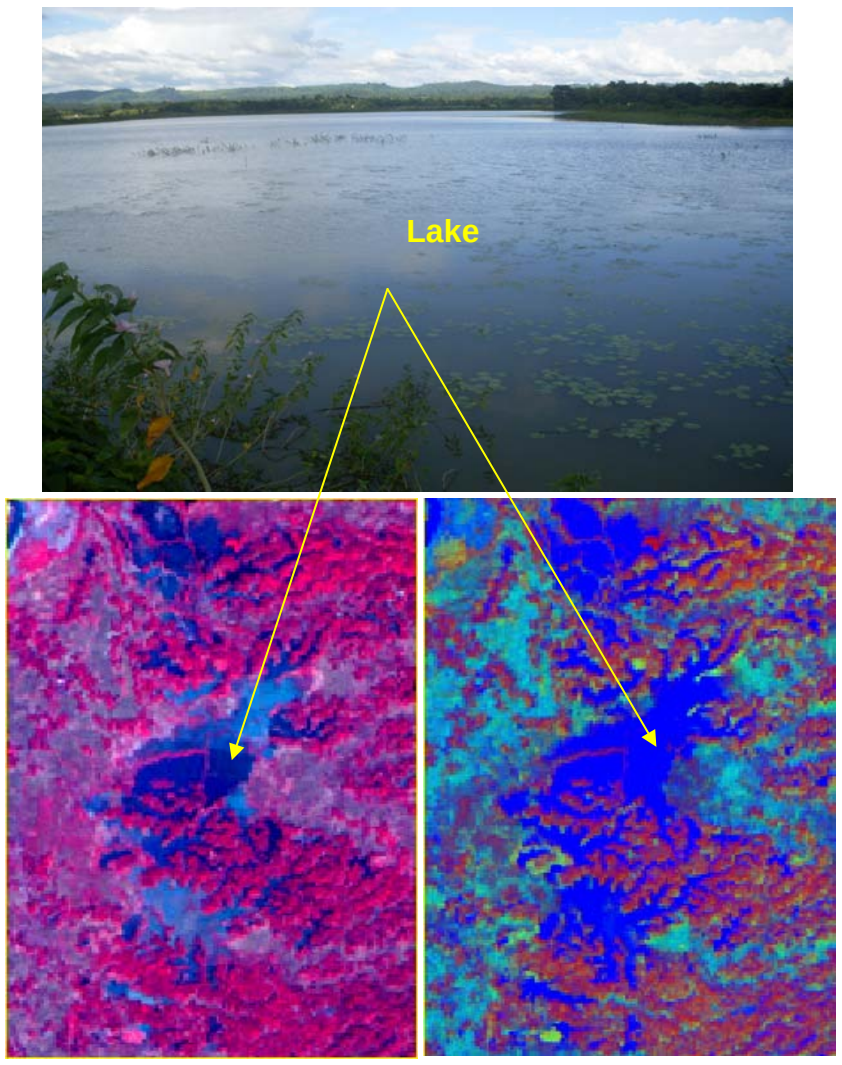
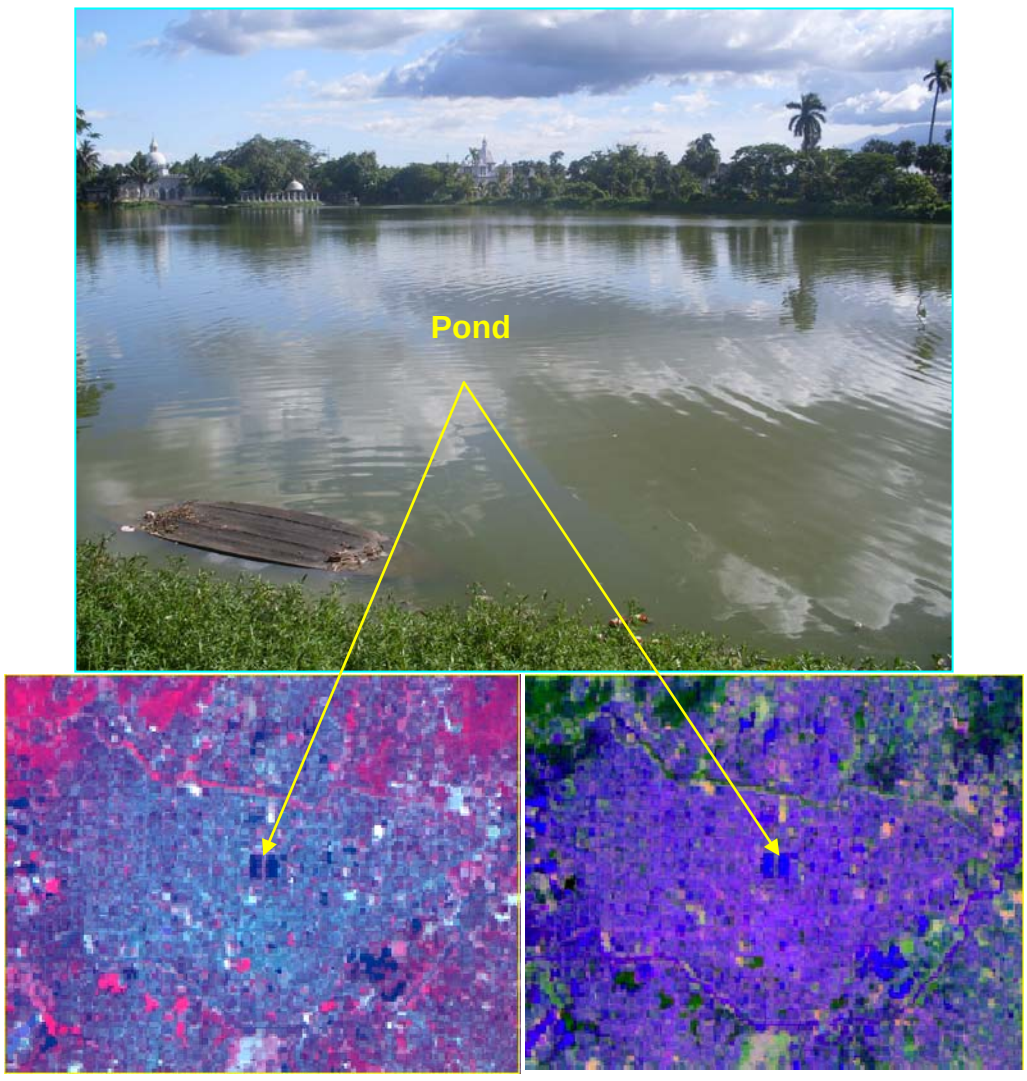
Sr. No.	Site Description	Wetland Category
1	Name of the Wetland: Khawra Bil District: North Tripura Village: Khawra Location: 24:22:11.00N 92:00:12.00E Size: 222 ha Turbidity: 19.20 NTU pH: 7.38 Combination indices (NDTI MNDWI NDWI) aids in enhancement and delineation of lake area, which appears water as blue in colour and other vegetation in purple.	
2	Name of the Wetland: Lakhi Narayan Bari Dighi Type: Tank/Pond District: West Tripura Village: Agartala Location: 23:50:09.00N 91:17:14.00E Size: 2328 ha Turbidity: 40.01 NTU pH: 9.30 Combination indices (NDTI MNDWI NDWI) aids in enhancement and delineation of pond area, which appears water as blue in colour and other vegetation in purple.	

Plate 2c: Field photographs and their manifestation on LISS-III imagery of various wetland types in Tripura

IMPORTANT WETLANDS OF TRIPURA

9.0 IMPORTANT WETLANDS OF TRIPURA

Tripura has seven wetlands important in the context of state. These are Rudra Sagar, Gomti Reservoir (Dumbur Lake), Sipahijala Resercvoir, Trishna, Sattar Mia's Hoar, Batapura Lake and College Tilla Lake. Details of each these with a map are shown in plates 3-11 along with the 5 km buffer map and corresponding LISS-III image of post-monsoon season.

9.1 Rudrasagar Lake

Wetland Type: Reservoir
Name: Rudrasagar
Village-District: Melagarh-West Tripura
Location: 23° 29’ 00” N and 90° 01’ 00” E
Annual rainfall: 2500 mm (June to September with 4-5 peak floods)
Depth: 2 to 9 m
Area: 688 ha
General Turbidity: 7.1 NTU (low)
pH: 6.75

Geologically the area has been formed by silt deposition on seabed and soil in the catchment. The lake is a natural sedimentation reservoir, which receives flow from three perennial streams namely, Oacherra, Durlanaraya cherra and Kemtalicherra. After settling the sediment from the received flow, clear water discharges into the river Gomti through a connective channel namely Kachigang.

Macrophytes: *Azolla pinnata, Eichhornia crassipes*, *Hydrilla verticillata, Ipomea aquatica, Lemna minor, Najas graminea, Pistia stratiotes, Salvinia natans, Trapa natans, Typha angustifolia, Utricularia striatula and vallisneria spiralis*

Fish: Six rare species namely *Botia* sp*., Cyclinia* sp*., Kachuga* sp*., Macrobrachium* sp*., Notopterus chitala, Oxygstus* sp*.* and nine species of endangered species namely *Channa marulius, Cirrhinus reba, Labeo bata, Macrobrachium rosenbergii, M. rude, Mystus aor, M. gulio, Notopterus chitala and Ompak paba.* The lake has perennial connection with one of the major rivers facilitating the natural breeding ground for fish and freshwater turtle and tortoise.

The wetland supports IUCN Red listed endangered Three-striped Roof turtle (*Kachuga dhongka*).

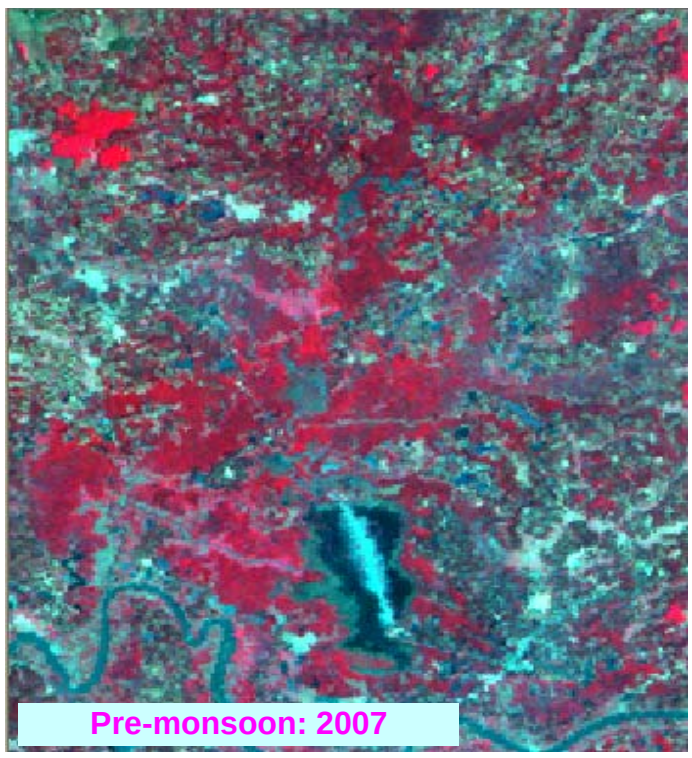
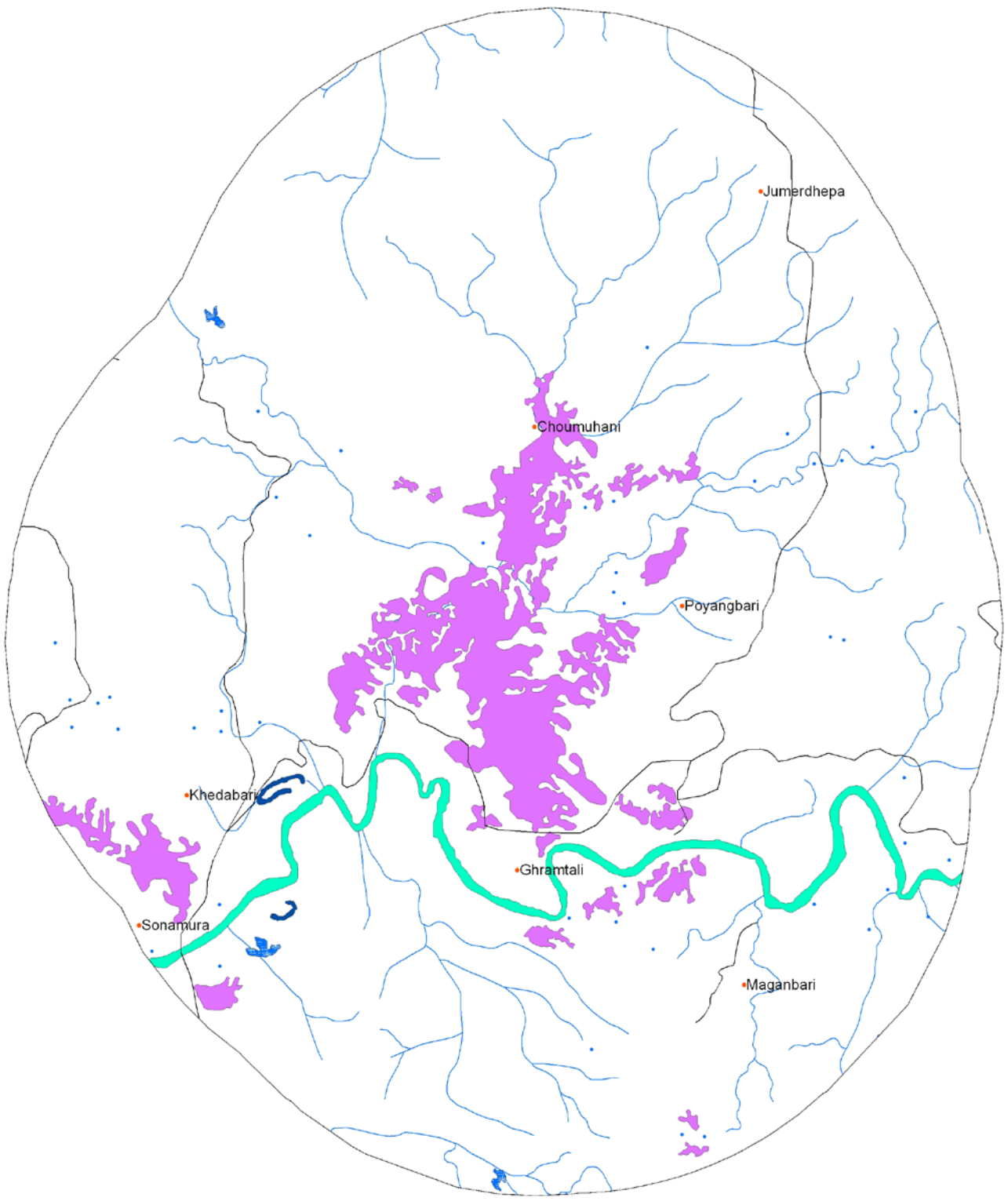


Plate-3: Rudrasagar Lake

State : Tripura

WETLAND MAP

Rudrasagar

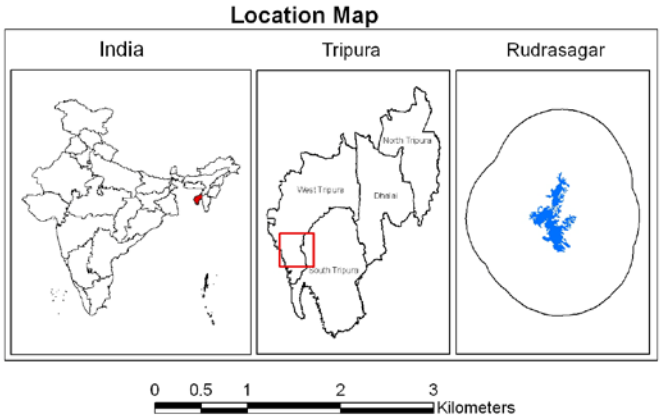


Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- Wetlands (<2.25 ha)
- Settlements
- Roads
- Railways
- Drainage
- District Boundary
- State Boundary
- Town/Settlements

Location Map



0 0.5 1 2 3 Kilometers

Data Source:
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

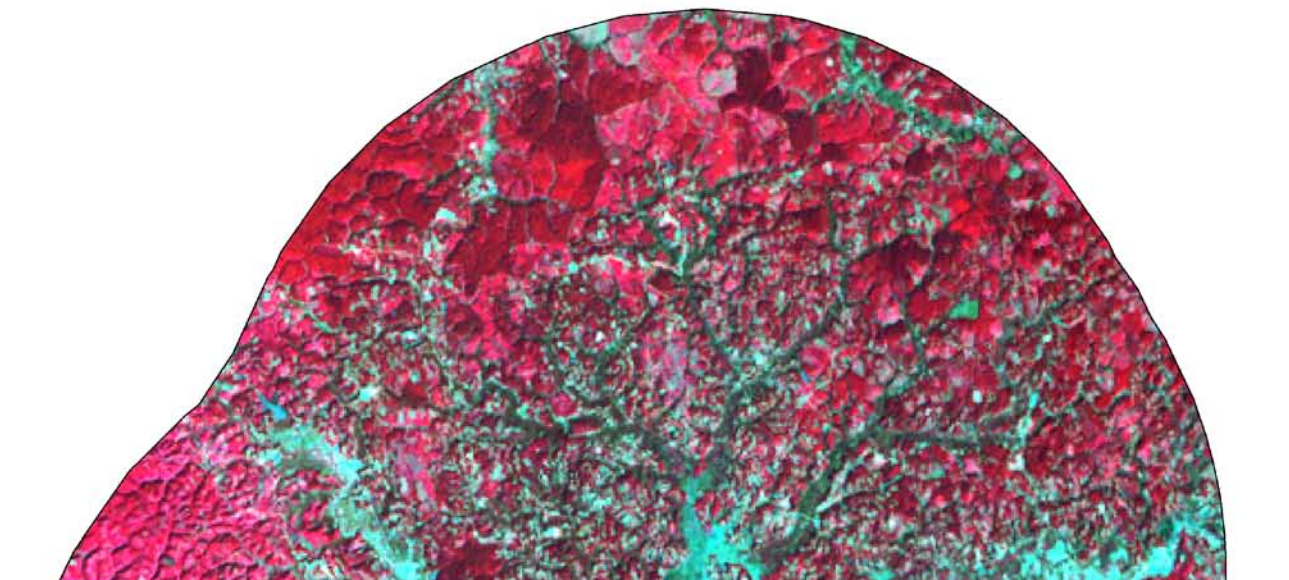
Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By :
Ministry of Environment and Forests
Government of India

Plate 4: Wetland map - 5 km buffer area of Rudrasagar lake

State : Tripura

Rudrasagar



IRS-P6 LISS-III Post-monsoon data(2006)

Plate 5: IRS P6 LISS-III FCC of 5 km buffer area of Rudrasagar Lake

9.2 Gumti Reservoir(Dumbur Lake)

Wetland Type: Reservoir
Name: Dumbur Lake (Gumti Reservoir)
Village-District: Mandirghat-South Tripura
Location: 23° 25’ 45” N and 91° 49’ 20” E
Annual rainfall: 173 cm
Depth: 2 to 9 m
Area: 2328 ha
General Turbidity: 119.8 NTU (high)
pH: 7.52

The reservoir draws water from Barak, Raima and Sarma river basins. Completed in the year 1977, the 103 m long, 30 m high, straight gravity dam is made of brick and stone concrete, holding a storage of 235.62 million m^3 at the FRL. The river at the dam site has a catchment area of 547 km^2 receiving rainfall of 173 cm. Turbidity of water is very high due to soil erosion on account of denudation of forests in catchment area by shifting cultivators (*jhoom*).

Macrophytes: A rich macrophytic community in the reservoir, comprising *Eichhornia crassipes, Nymphaea sp., Lymnanthemum sp., Trapa natans, Vallisneria spiralis, Hydrilla verticillata* and *Potamogeton nodosus*. The phyto- and zooplankton exhibit strong seasonal and spatial cycles with a domination of blue-green algae and copepods.

Fish: More than 47 species have been reported from the reservoir, commercially important among them being *Aorichthys aor, Channa marulius, C. punctatus, Mastacembelus pancalus, M. guentheri, Puntius stigma, P. ticto, P. sarana, Xenentodon cancila, Amblypharyngodon mola, Chanda ranga, Heteropneustes fossilis, Clarias batrachus, Notopterus notopterus, Tor tor and Labeo gonius*. Besides, the Indian and exotic carps, viz., *Catla catla, Labeo rohita, Cirrhinus mrigala, Hypophthalmichthys molitrix, Ctenopharyngodon idella* and *Cyprinus carpio*, have been introduced successfully in the reservoir. Catla-rohu and rohu-catla hybrids are also reported from the reservoir. Indian major carps breed in the upper reaches of the river at Ultacherra, Chitrajhari, Gandacherra, Rangajhari, Sarmacherra, Thakurcherra and Raimacherra. The highest fish production of 246.6 t was reported in 1981–82, with a steep decline thereafter with an average production for the last 15 years being 141.74 t (31.5 kg ha^{-1}).

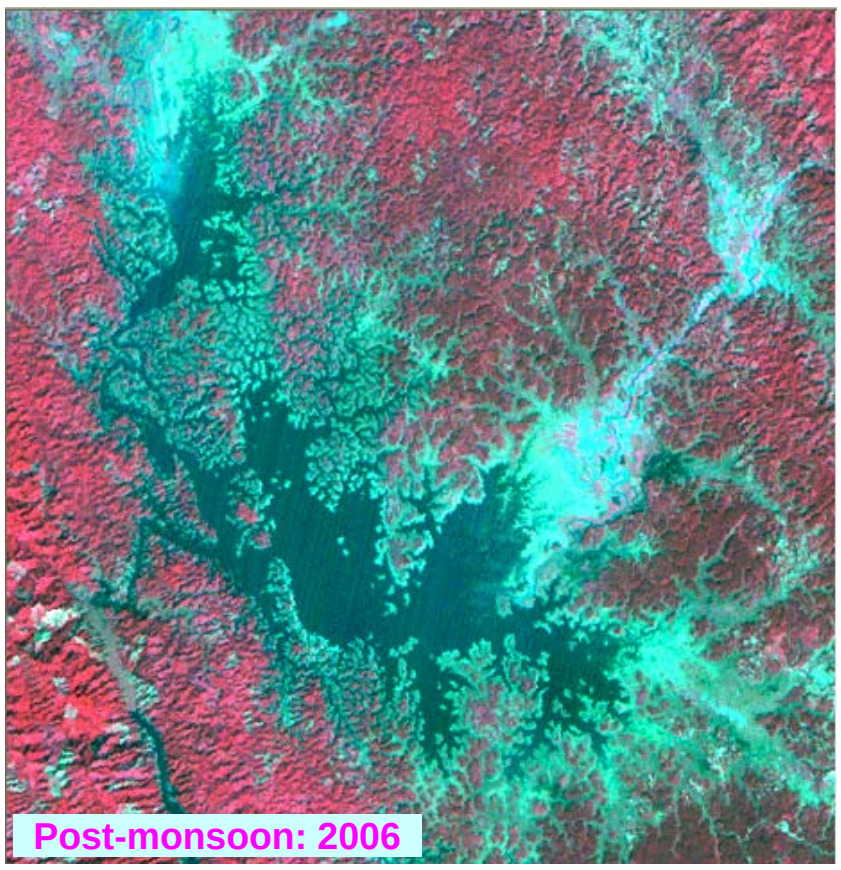
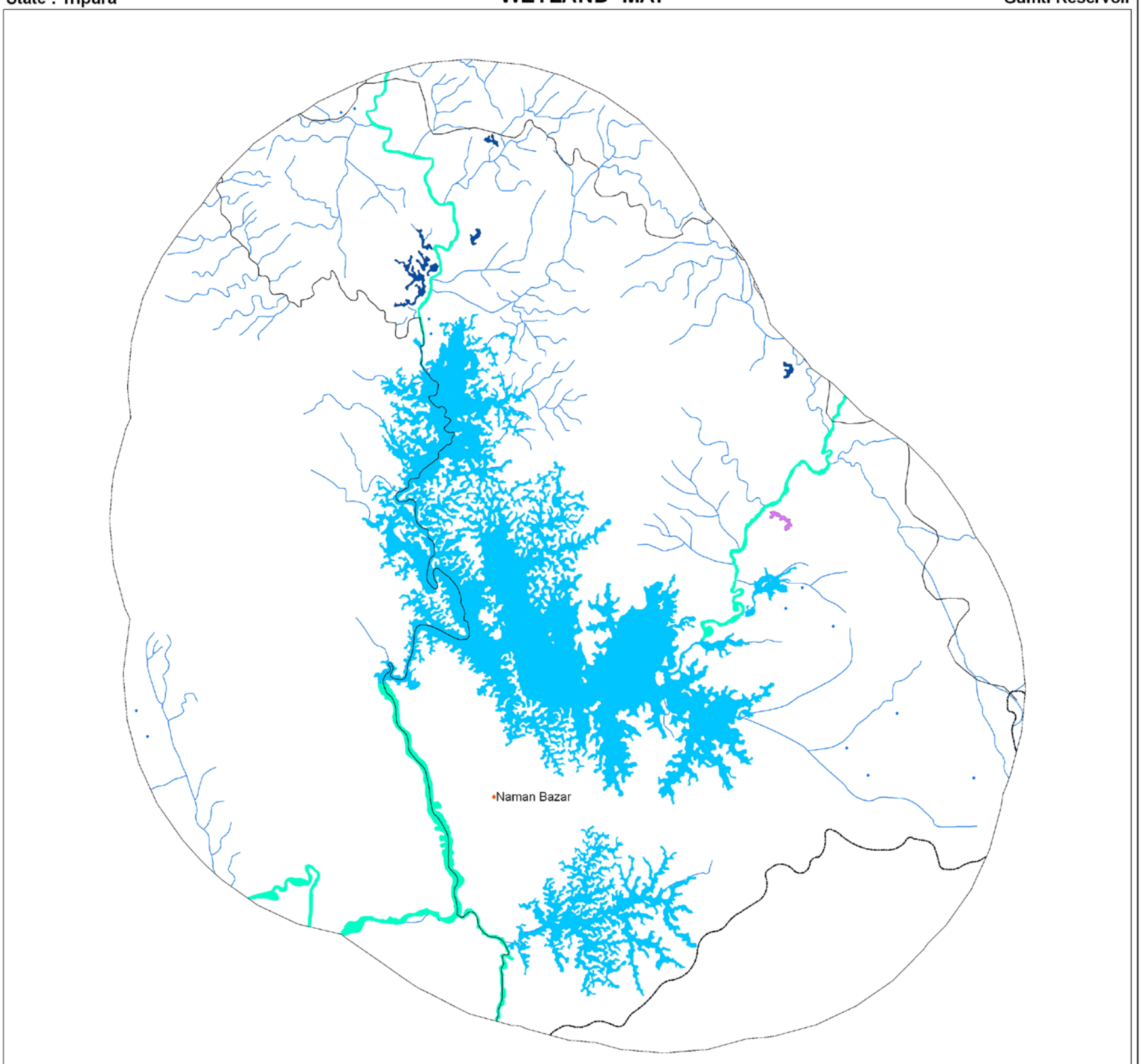


Plate – 6: Gumti Reservoir (Dhumbur Lake)

State : Tripura

WETLAND MAP

Gumti Reservoir

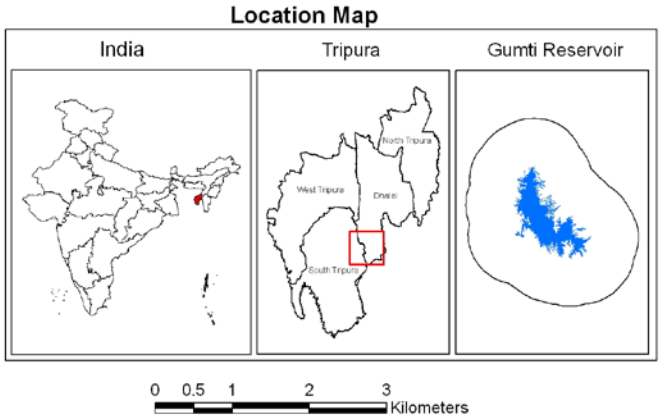


Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- Wetlands (<2.25 ha)
- Settlements
- Roads
- Railways
- Drainage
- District Boundary
- State Boundary
- Town/Settlements

Location Map



Data Source:
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

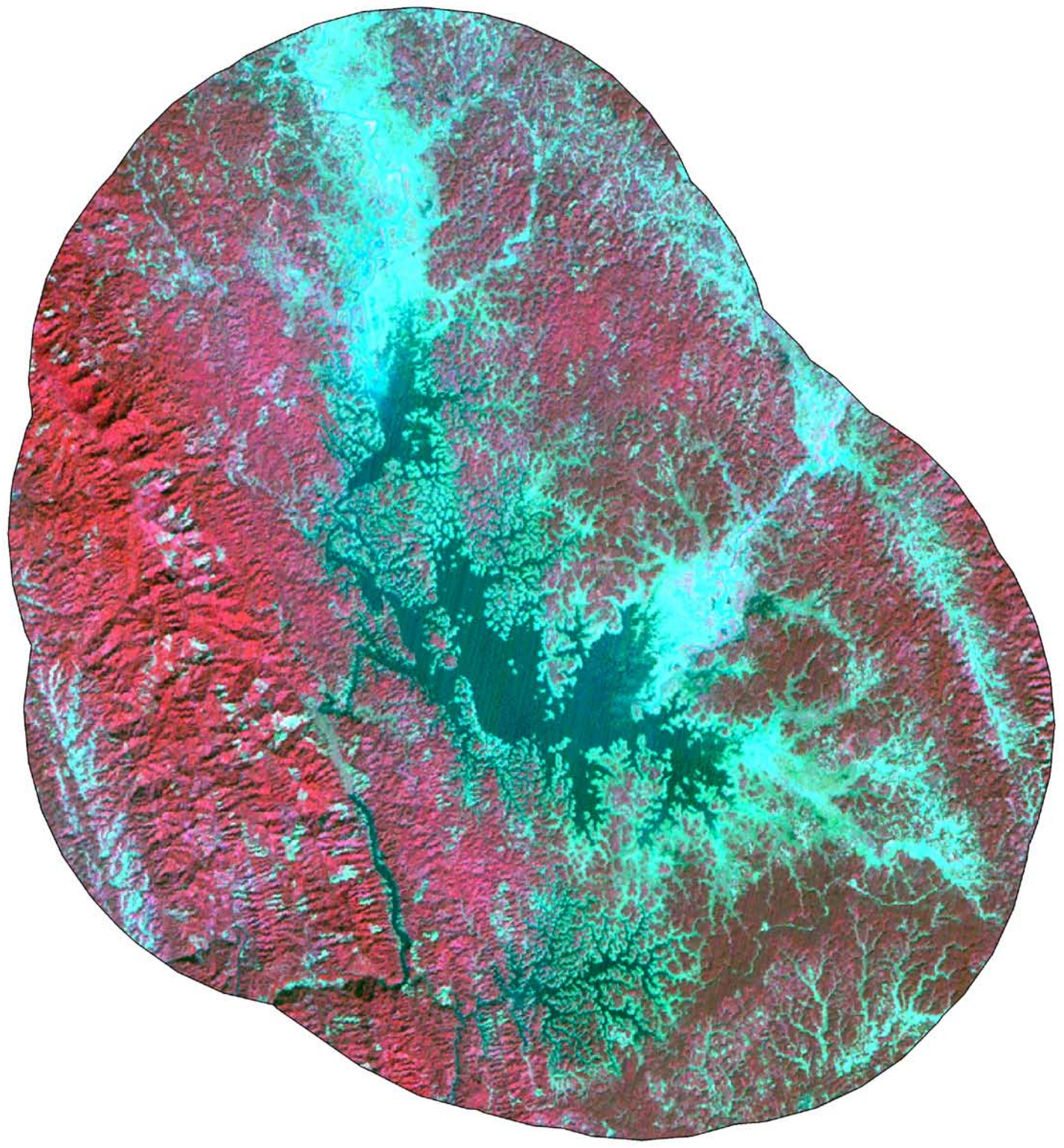
Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By :
Ministry of Environment and Forests
Government of India

Plate 7: Wetland map - 5 km buffer area of Gumti Reservoir

State : Tripura

Gumti Reservoir



IRS-P6 LISS-III Post-monsoon data(2006)

Plate 8: IRS P6 LISS-III FCC of 5 km buffer area of Gumti Reservoir

9.3 Trishna Wildlife Sanctuary

Wetland Type: Reservoir
Name: Trishna Sanctuary
Village-District: South Tripura
Location: 23° 28’ 06” N and 91° 24’ 44” E
Area: 295 ha
General Turbidity: 70.2 NTU (medium)
pH: 7.5

Trishna Wildlife Sanctuary was notified in November 1988. The total area of the sanctuary is 194.704 sq km comprising 27 revenue moujas of Belonia, Udaipur and Sonamura civil subdivisions in South Tripura district. The Trishna sanctuary has diversity in its floral and faunal contents. The sanctuary has a number of perennial water rivulets, wetlands and grasslands. The sanctuary is famous for bison locally known as 'gaba' and home to several species of primates.

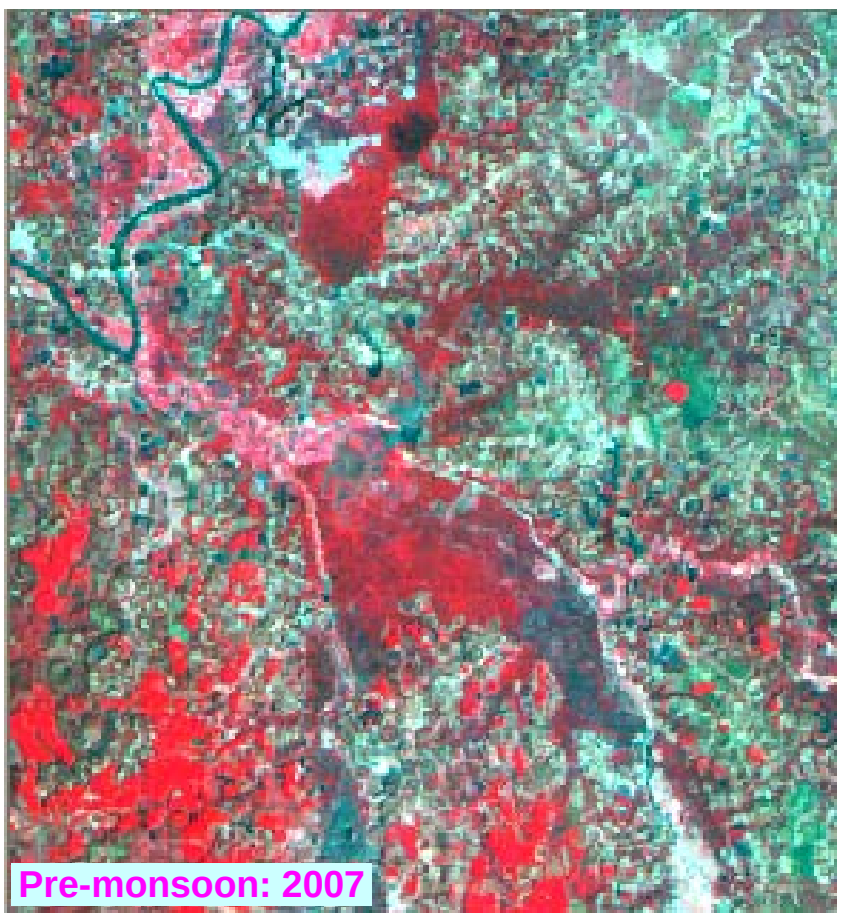
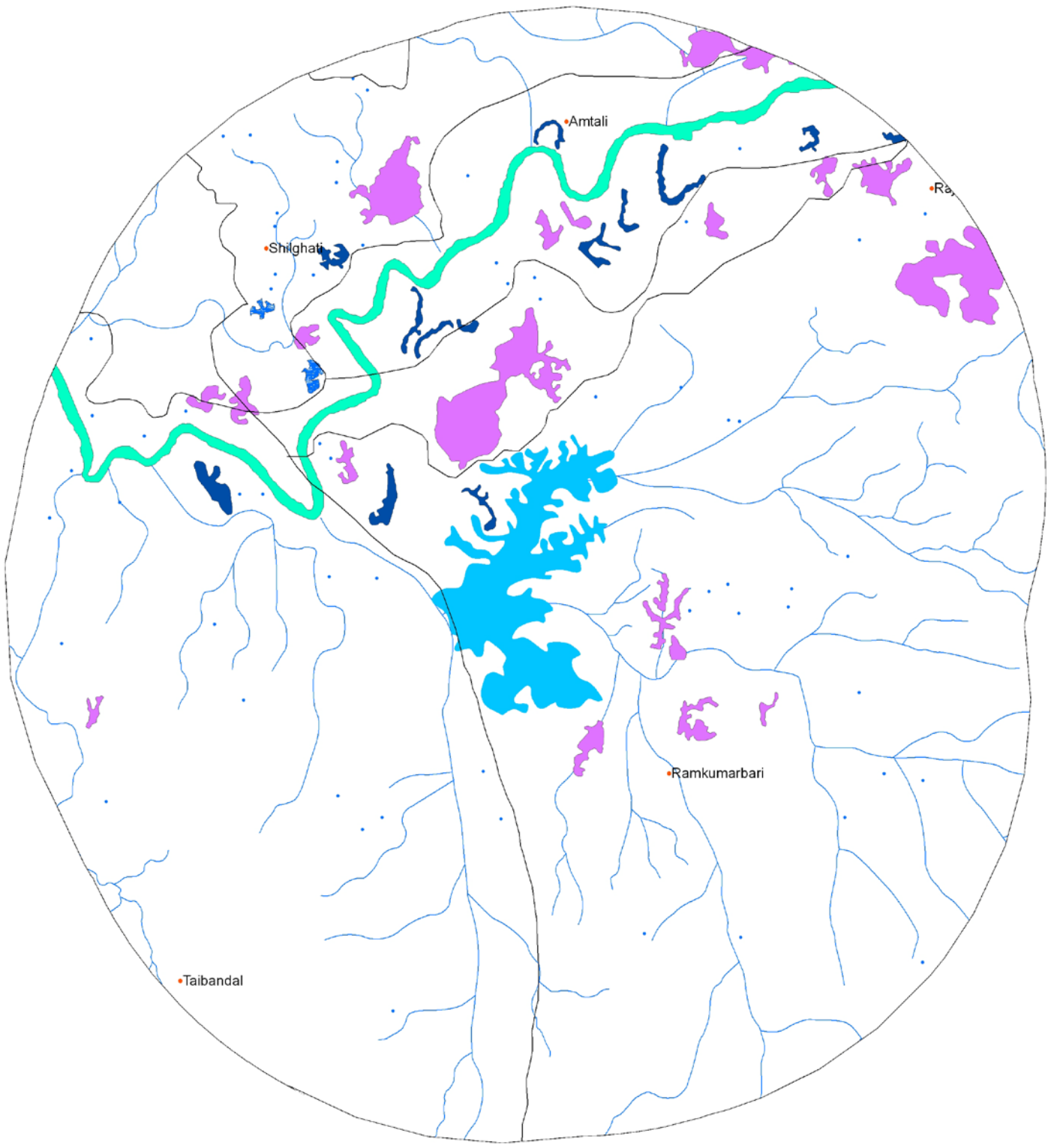


Plate 9: Trishna Wildlife Sanctuary

State : Tripura

WETLAND MAP

Trishna Wildlife Sanctuary



Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
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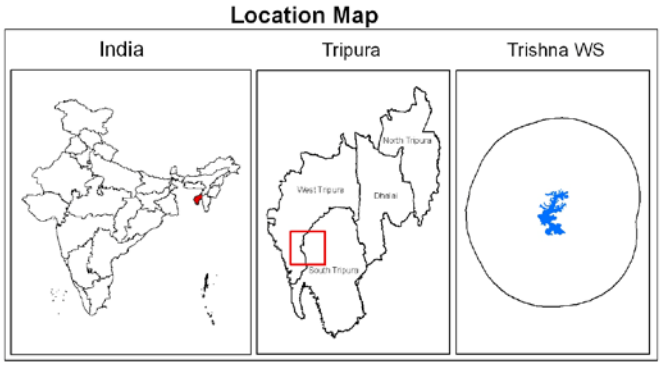
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- Wetlands (<2.25 ha)
- Settlements
- Roads
- Railways
- Drainage
- District Boundary
- State Boundary
- Town/Settlements

Location Map



0 0.5 1 2 3 Kilometers

Data Source:
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

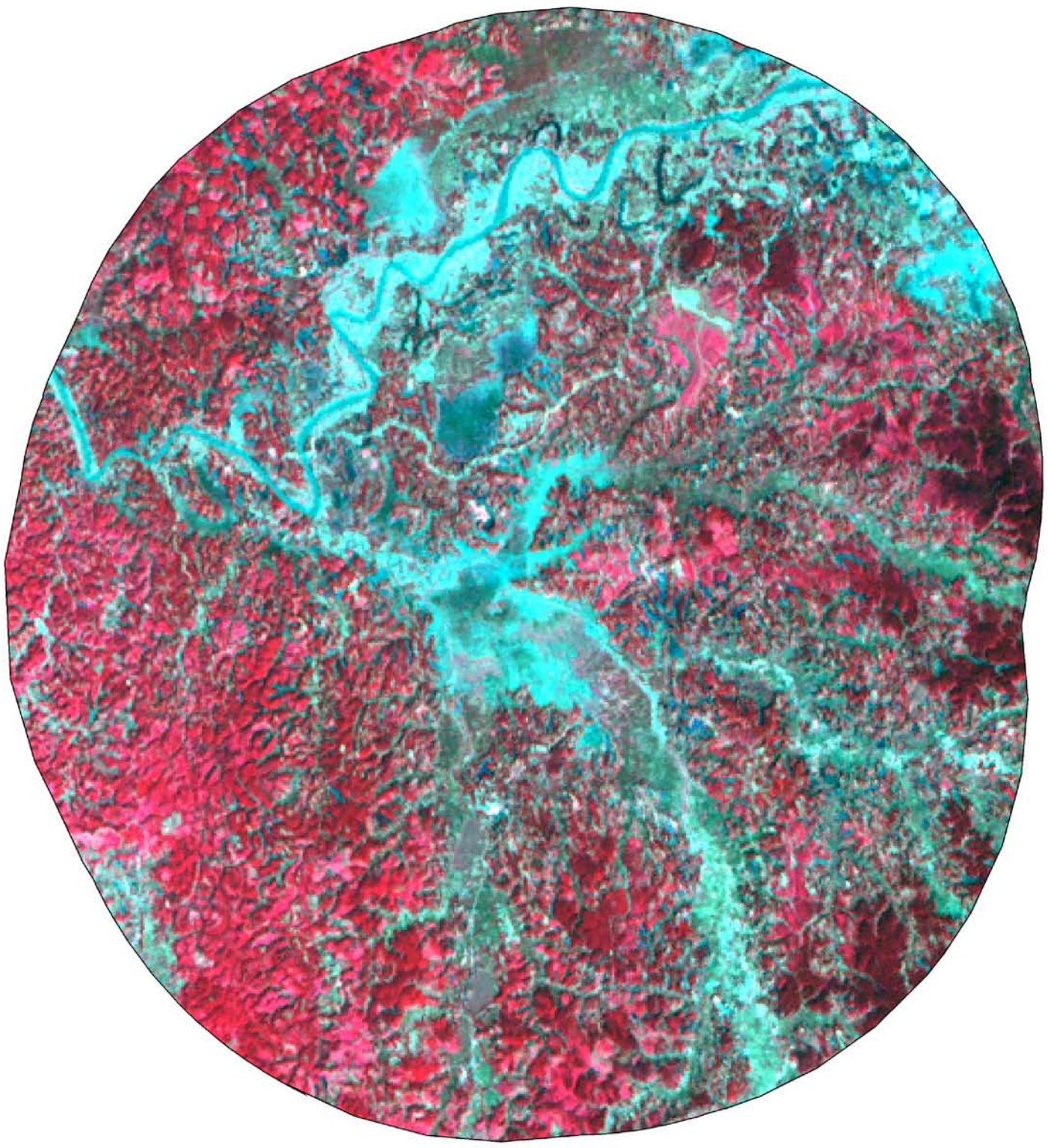
Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By :
Ministry of Environment and Forests
Government of India

Plate 10: Wetland map - 5 km buffer area of Trishna Wildlife Sanctuary

State : Tripura

Trishna Wildlife Sanctuary



IRS-P6 LISS-III Post-monsoon data(2006)

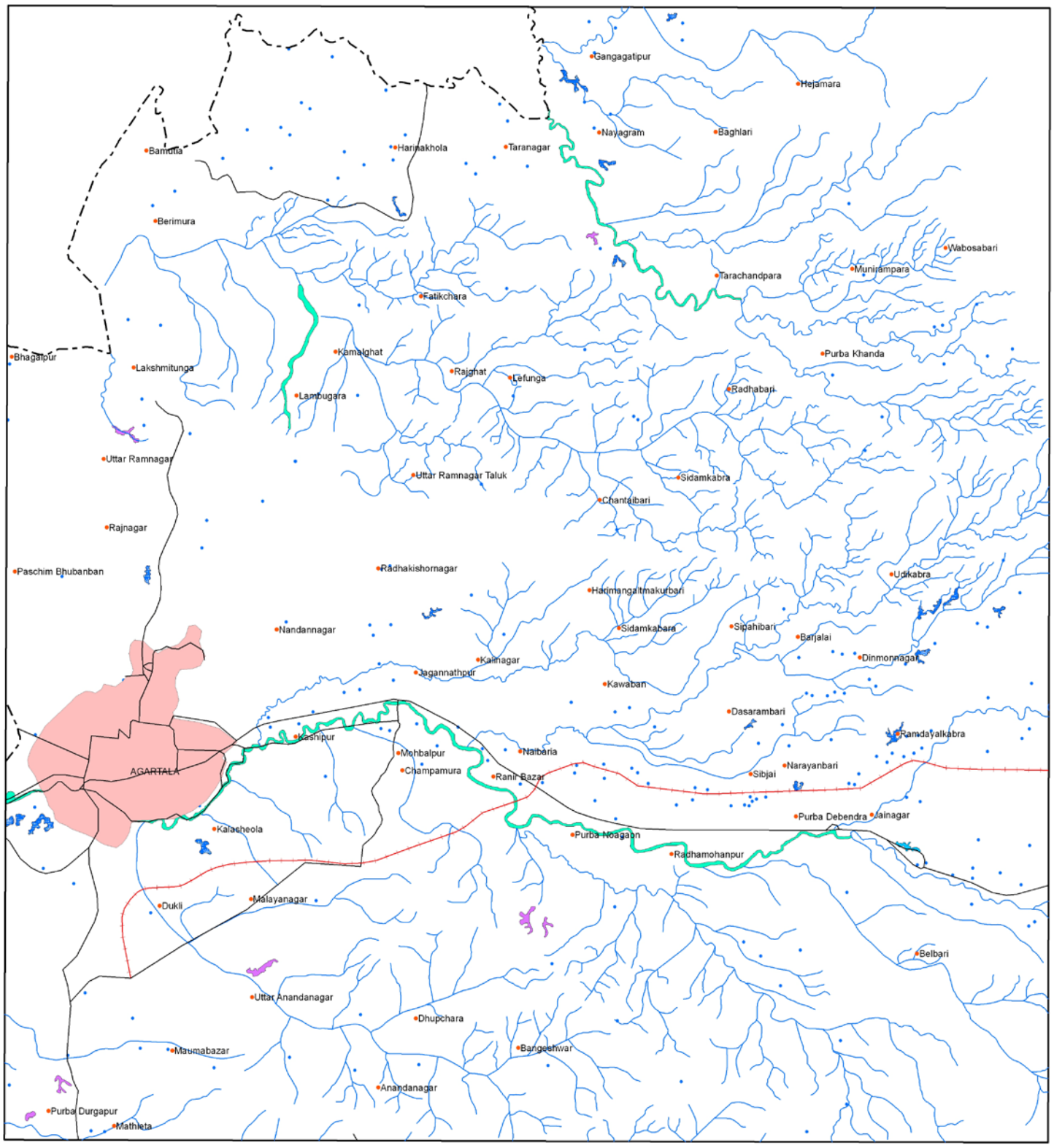
Plate 11: IRS P6 LISS-III FCC of 5 km buffer area of **Trishna Wildlife Sanctuary**

SOI MAP-SHEET WISE WETLAND MAPS
(Selected)

State : Tripura

WETLAND MAP

Map No : 79M/05



Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
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	1102			Ox-bow lakes/ Cut-off meanders
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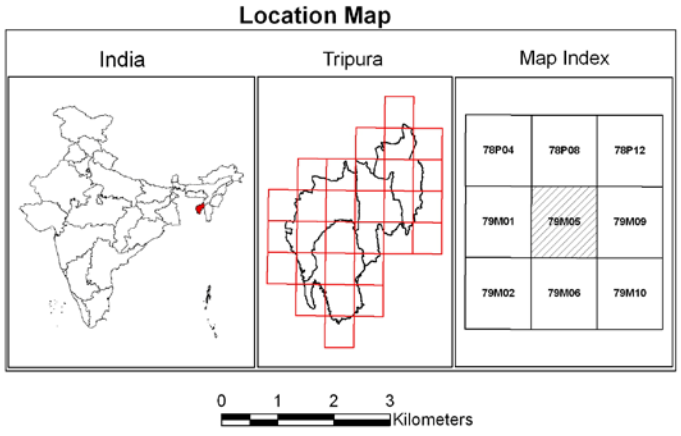
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- Wetlands (<2.25 ha)
- Settlements
- Roads
- Railways
- Drainage
- District Boundary
- State Boundary
- Town/Settlements

Location Map



Data Source:
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

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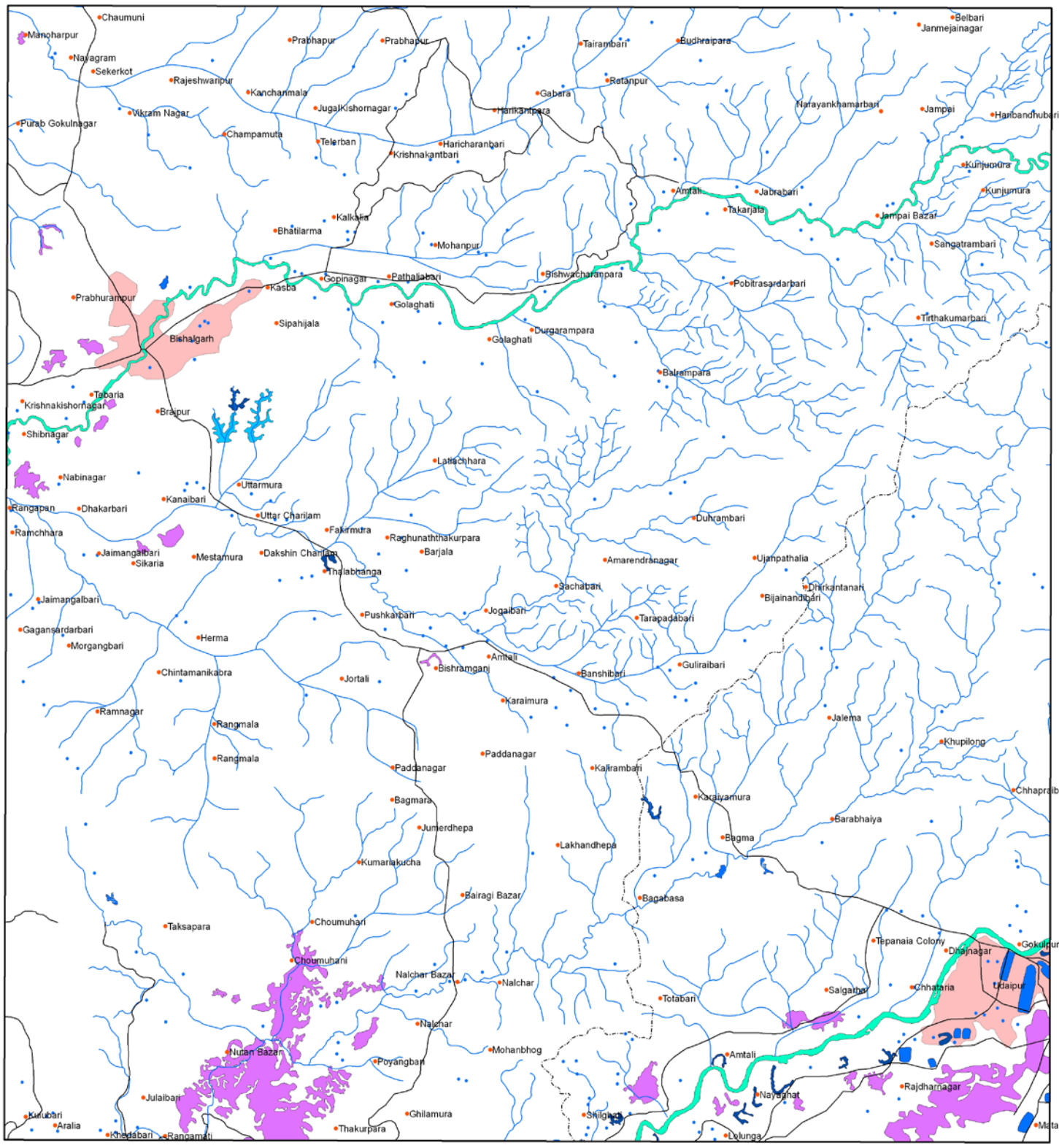
Government of India

State : Tripura

WETLAND MAP

Map No : 79M/06

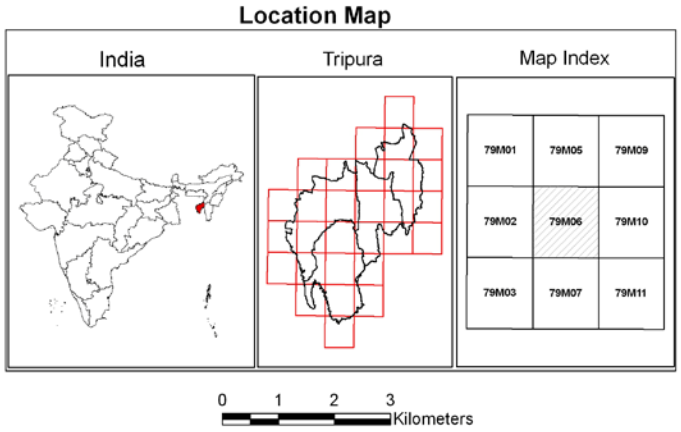


Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- Wetlands (<2.25 ha)
- Settlements
- Roads
- Railways
- Drainage
- District Boundary
- State Boundary
- Town/Settlements

Location Map



Data Source:
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

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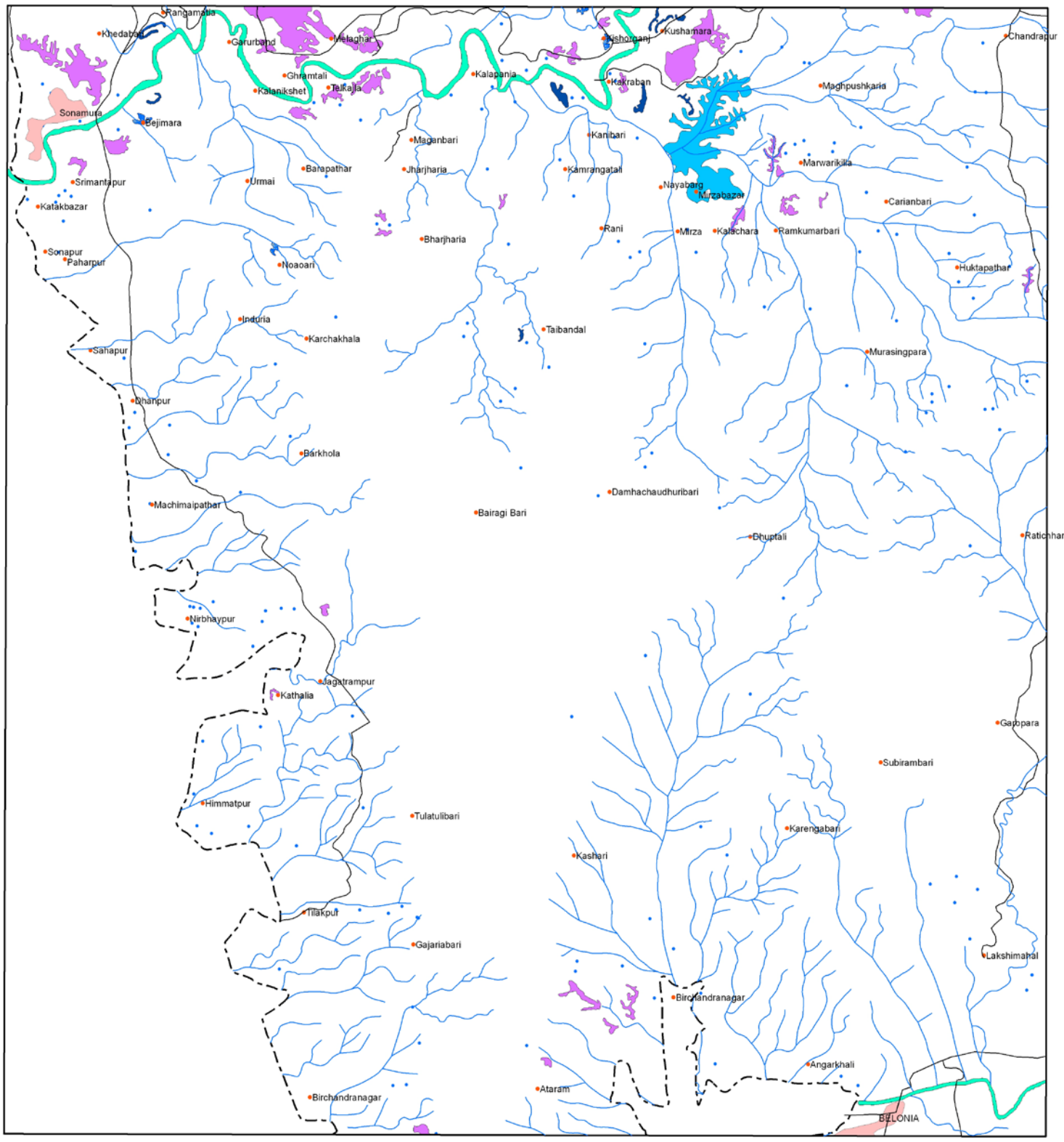
Government of India

State : Tripura

WETLAND MAP

Map No : 79M/07

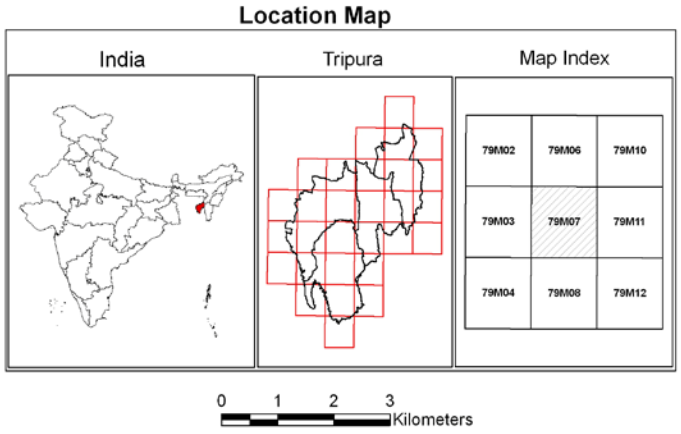


Symbol Typecode	Level I	Level II	Level III
	Inland Wetlands		
		Natural	
1101			Lakes/Ponds
1102			Ox-bow lakes/ Cut-off meanders
1103			High altitude wetlands
1104			Reverine wetlands
1105			Waterlogged
1106			River/Stream
		Man-made	
1201			Reservoirs/Barrages
1202			Tanks/Ponds
1203			Waterlogged
1204			Salt pans
	Coastal Wetlands		
		Natural	
2101			Lagoons
2102			Creeks
2103			Sand/Beach
2104			Intertidal mud flats
2105			Salt marsh
2106			Mangroves
2107			Coral reefs
		Man-made	
2201			Salt pans
2202			Aquaculture ponds

Legend

- Wetlands (<2.25 ha)
- Settlements
- Roads
- Railways
- Drainage
- District Boundary
- State Boundary
- Town/Settlements

Location Map



Data Source:
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Government of India

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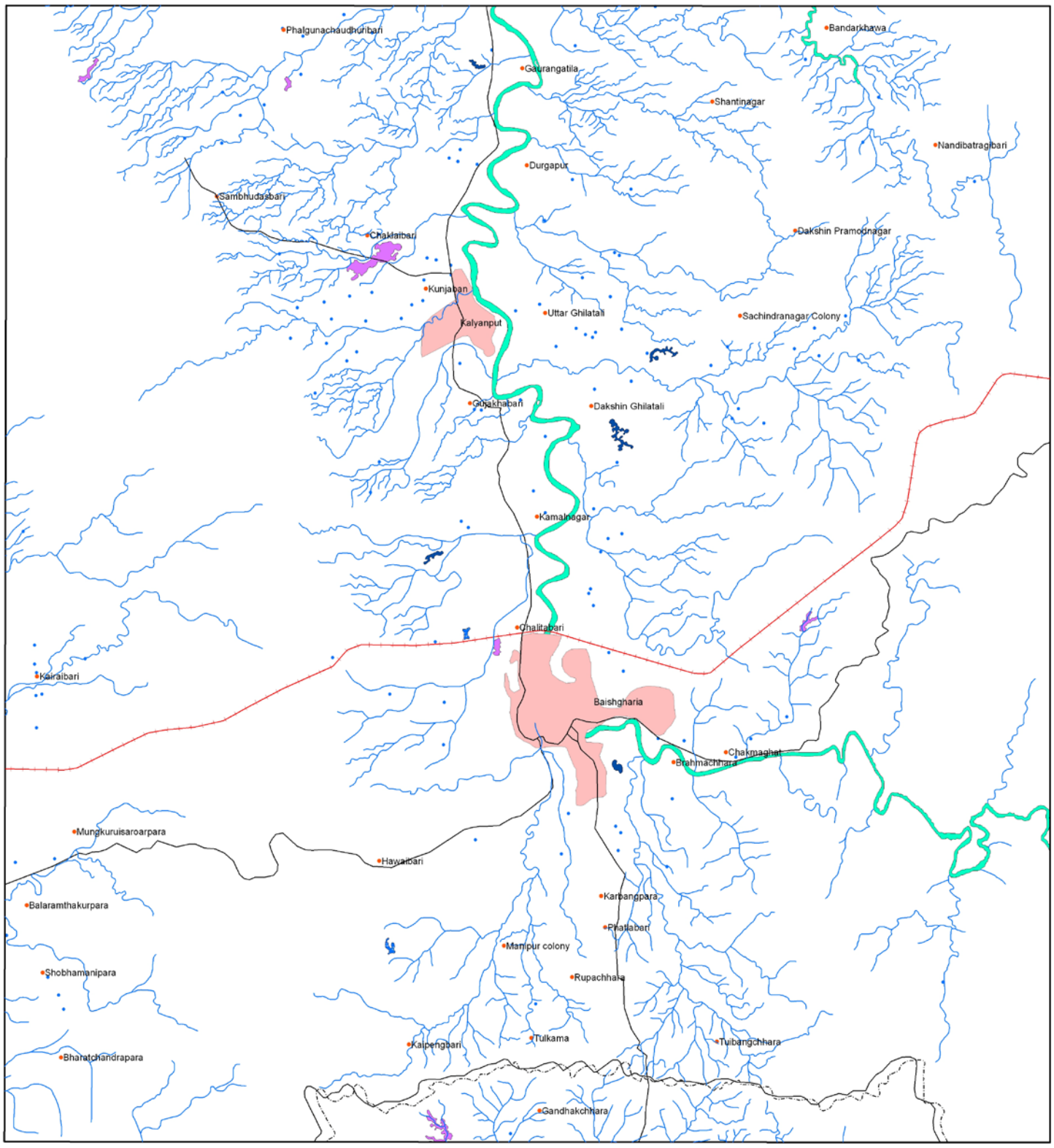
WETLAND MAP

Map No : 79M/09

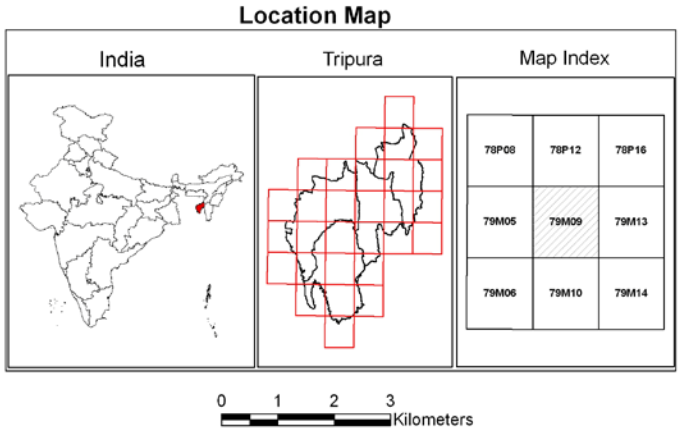


Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- Wetlands (<2.25 ha)
- Settlements
- Roads
- Railways
- Drainage
- District Boundary
- State Boundary
- Town/Settlements

Location Map



Data Source:
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Government of India

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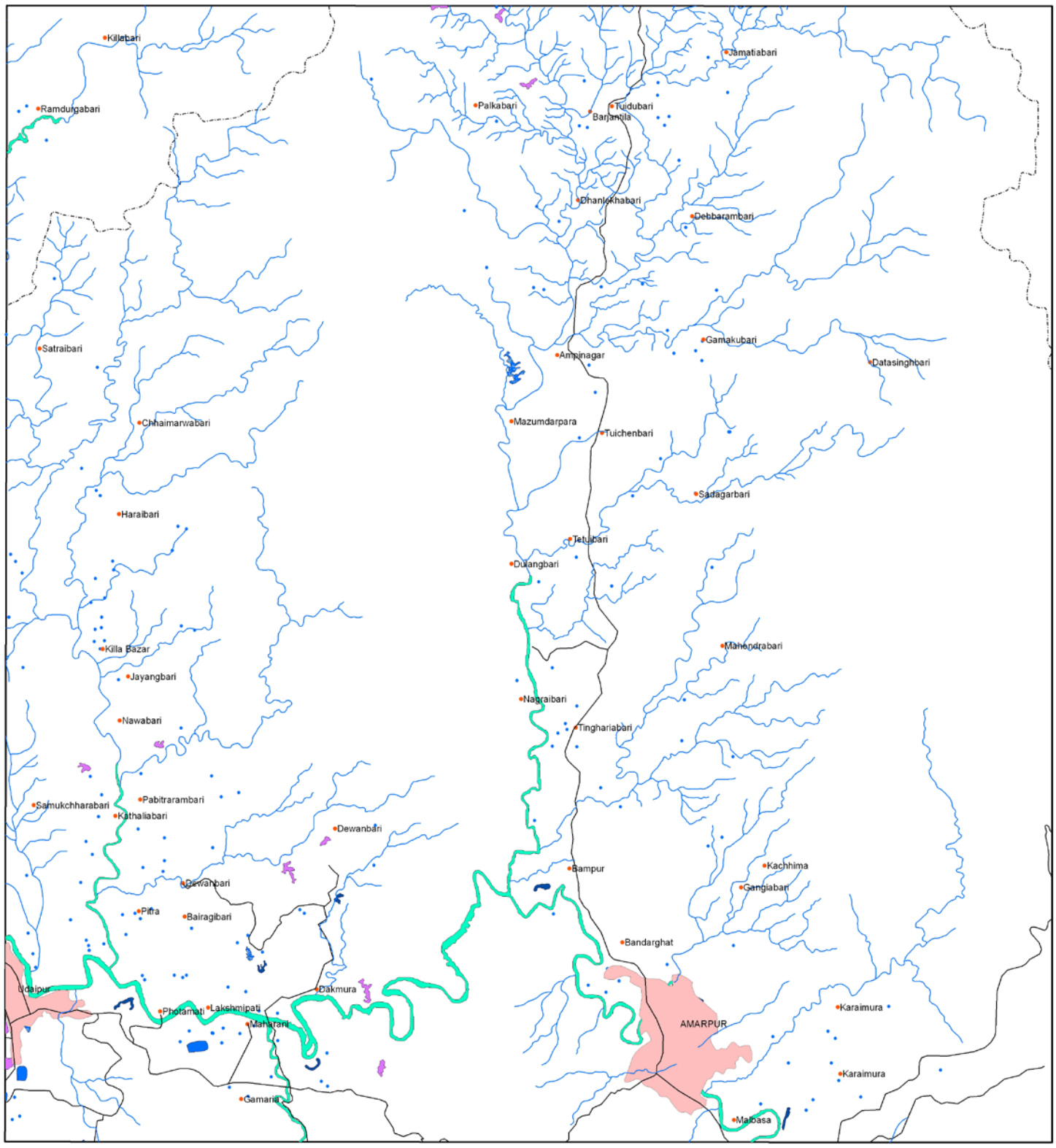
WETLAND MAP

Map No : 79M/10

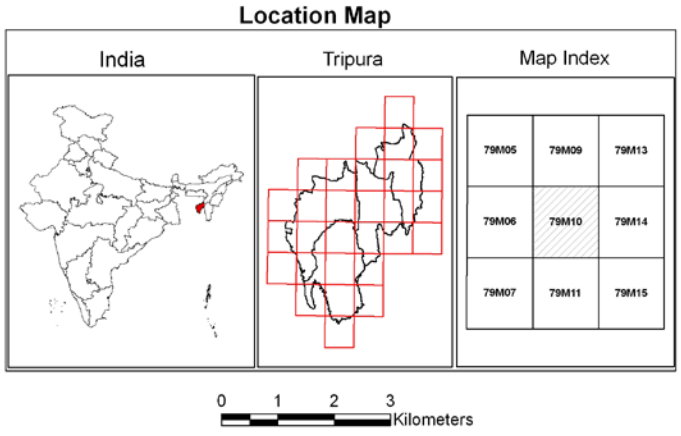


Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- Wetlands (<2.25 ha)
- Settlements
- Roads
- Railways
- Drainage
- District Boundary
- State Boundary
- Town/Settlements

Location Map



Data Source:
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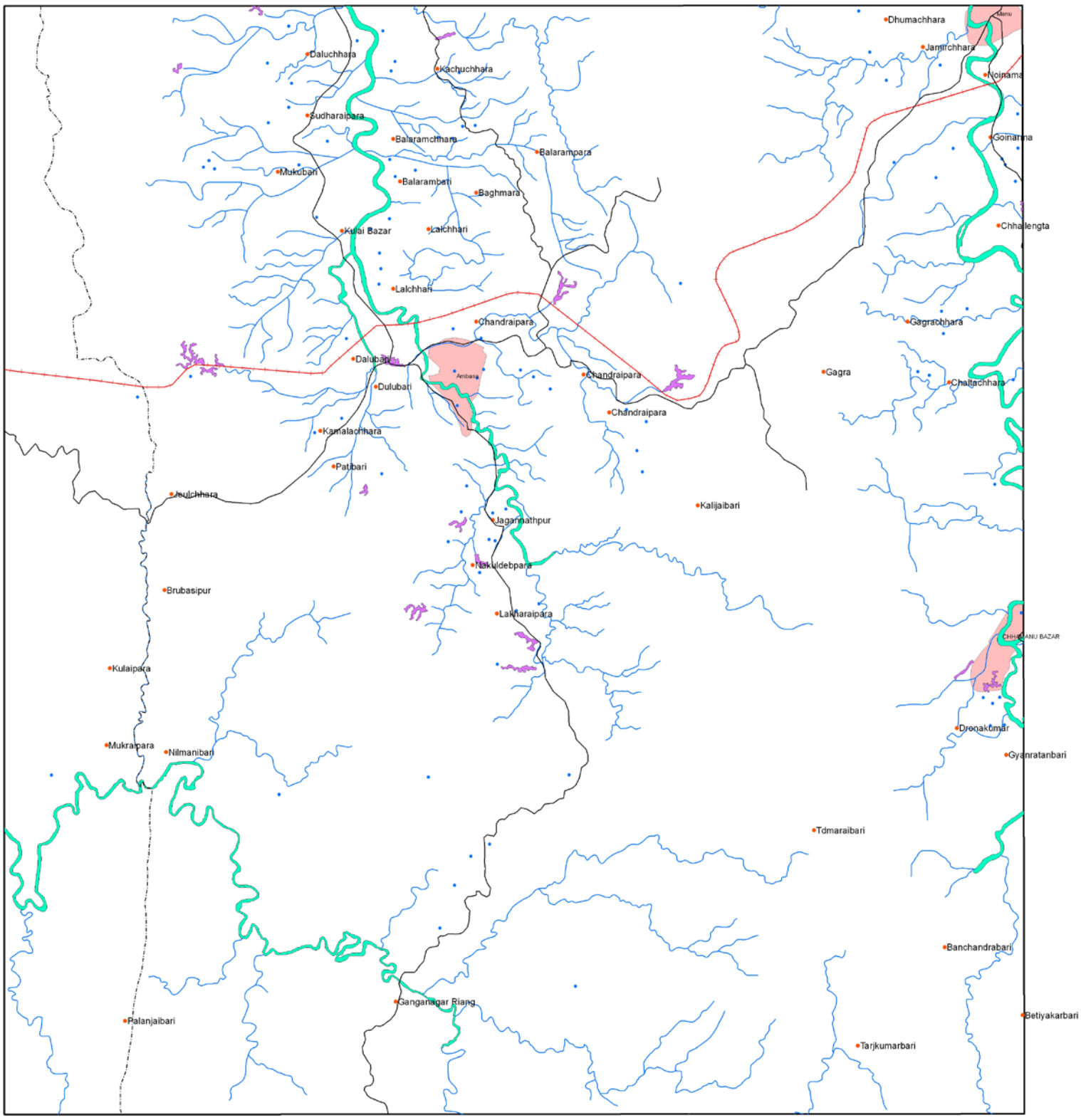
Government of India

State : Tripura

WETLAND MAP

Map No : 79M/13

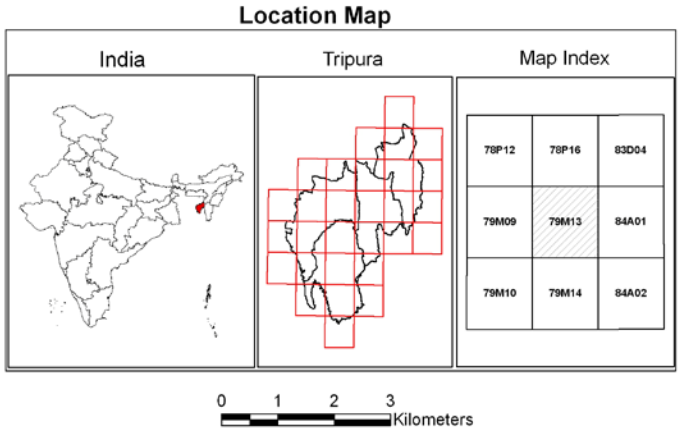


Symbol Typecode	Level I	Level II	Level III
	Inland Wetlands		
		Natural	
1101			Lakes/Ponds
1102			Ox-bow lakes/ Cut-off meanders
1103			High altitude wetlands
1104			Reverine wetlands
1105			Waterlogged
1106			River/Stream
		Man-made	
1201			Reservoirs/Barrages
1202			Tanks/Ponds
1203			Waterlogged
1204			Salt pans
	Coastal Wetlands		
		Natural	
2101			Lagoons
2102			Creeks
2103			Sand/Beach
2104			Intertidal mud flats
2105			Salt marsh
2106			Mangroves
2107			Coral reefs
		Man-made	
2201			Salt pans
2202			Aquaculture ponds

Legend

- Wetlands (<2.25 ha)
- Settlements
- Roads
- Railways
- Drainage
- District Boundary
- State Boundary
- Town/Settlements

Location Map



Data Source:
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

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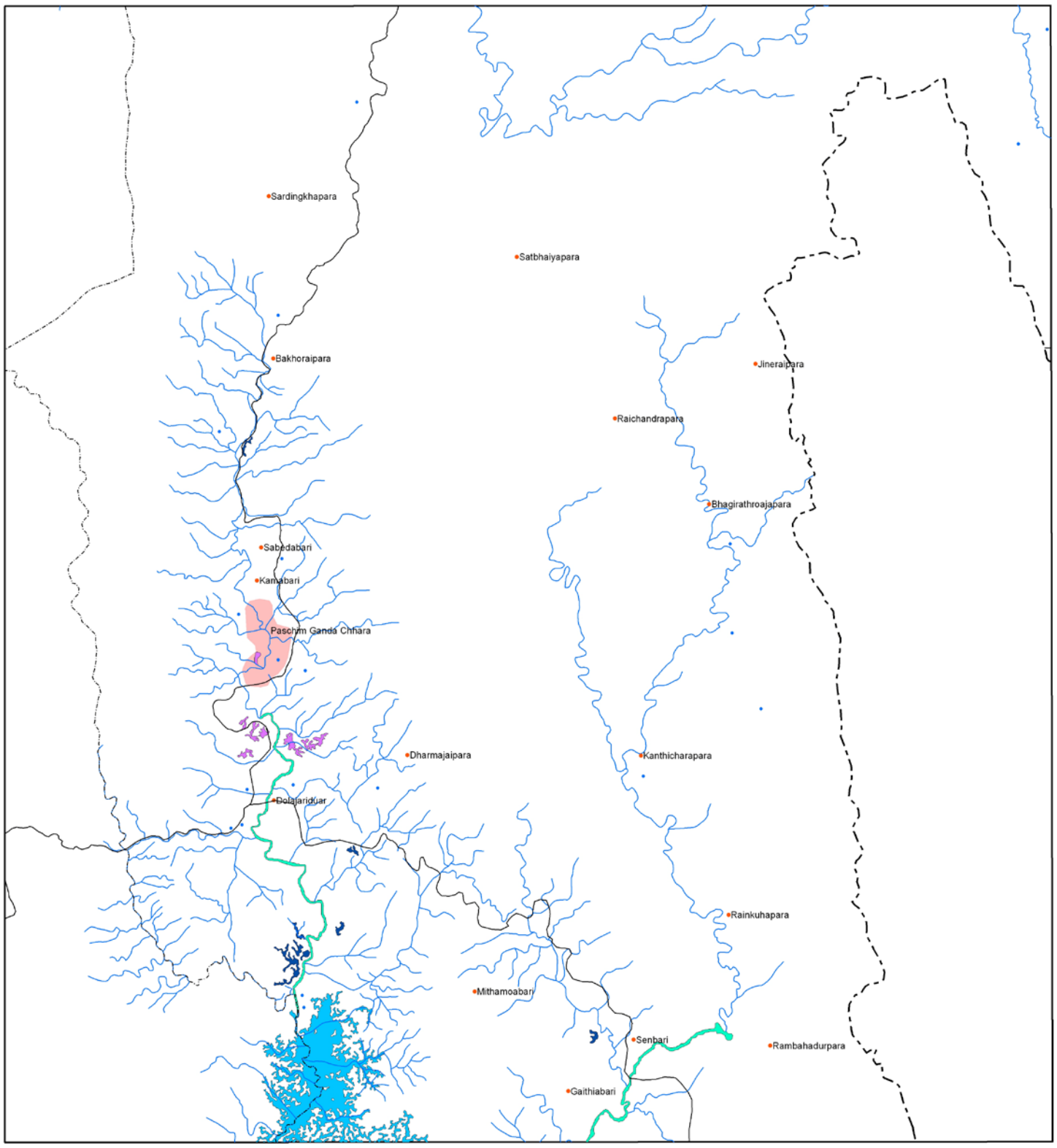
Government of India

State : Tripura

WETLAND MAP

Map No : 79M/14

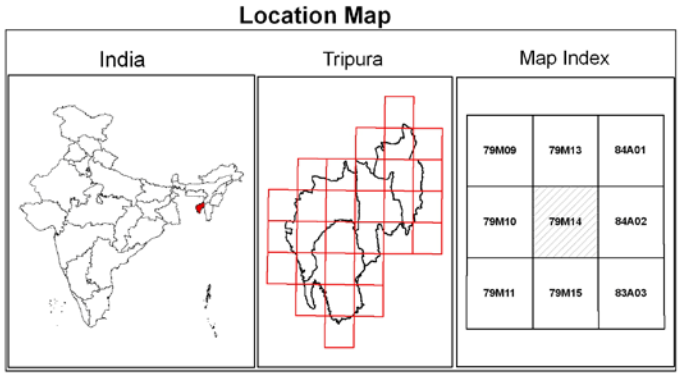


Symbol Typecode	Level I	Level II	Level III
	Inland Wetlands		
		Natural	
1101			Lakes/Ponds
1102			Ox-bow lakes/ Cut-off meanders
1103			High altitude wetlands
1104			Reverine wetlands
1105			Waterlogged
1106			River/Stream
		Man-made	
1201			Reservoirs/Barrages
1202			Tanks/Ponds
1203			Waterlogged
1204			Salt pans
	Coastal Wetlands		
		Natural	
2101			Lagoons
2102			Creeks
2103			Sand/Beach
2104			Intertidal mud flats
2105			Salt marsh
2106			Mangroves
2107			Coral reefs
		Man-made	
2201			Salt pans
2202			Aquaculture ponds

Legend

- Wetlands (<2.25 ha)
- Settlements
- Roads
- Railways
- Drainage
- District Boundary
- State Boundary
- Town/Settlements

Location Map



Data Source:
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

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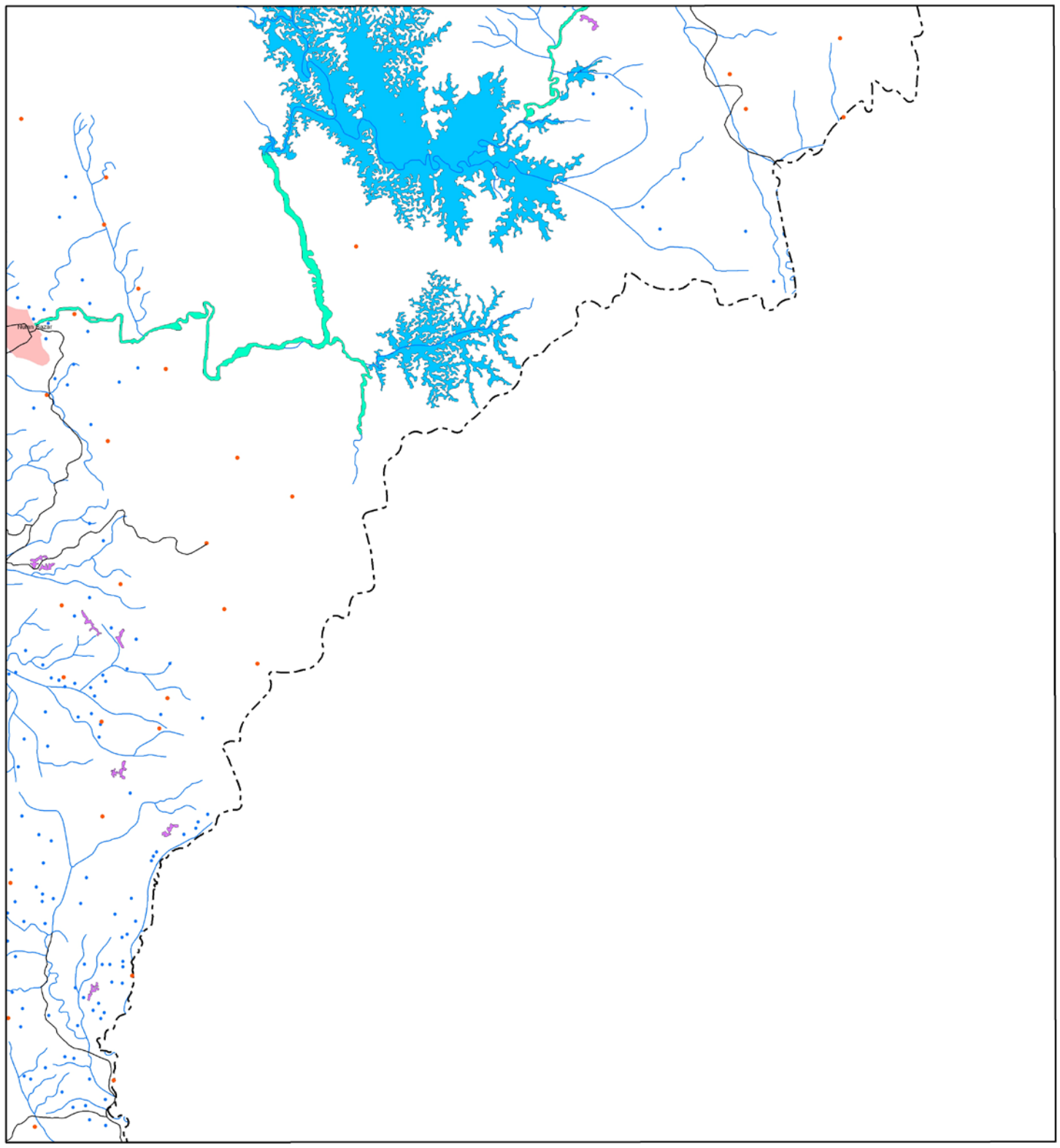
Government of India

State : Tripura

WETLAND MAP

Map No : 79M/15

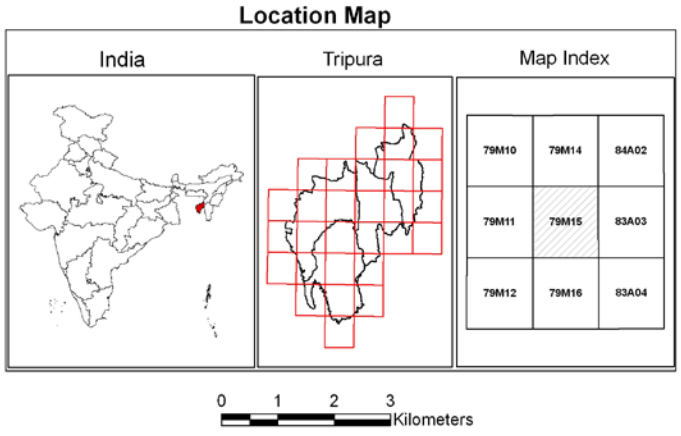


Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- Wetlands (<2.25 ha)
- Settlements
- Roads
- Railways
- Drainage
- District Boundary
- State Boundary
- Town/Settlements

Location Map



Data Source:
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

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Government of India

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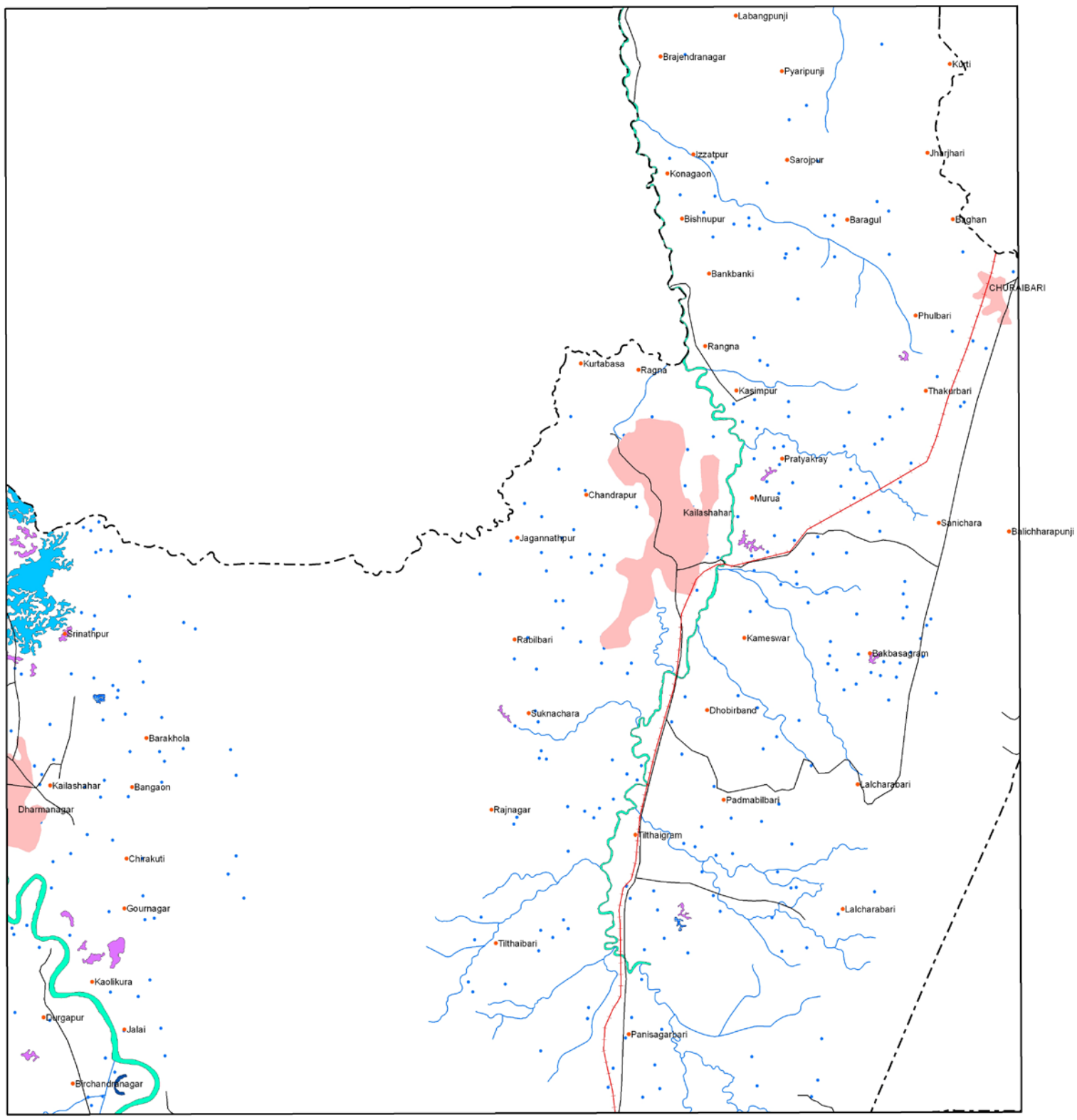
WETLAND MAP

Map No : 83D/03

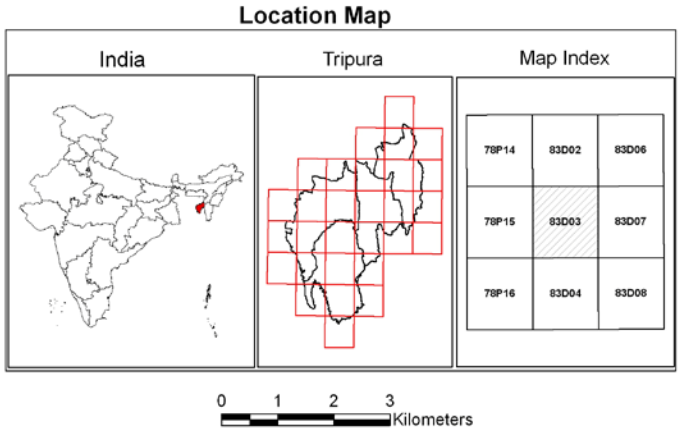


Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- Wetlands (<2.25 ha)
- Settlements
- Roads
- Railways
- Drainage
- District Boundary
- State Boundary
- Town/Settlements

Location Map



Data Source:
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

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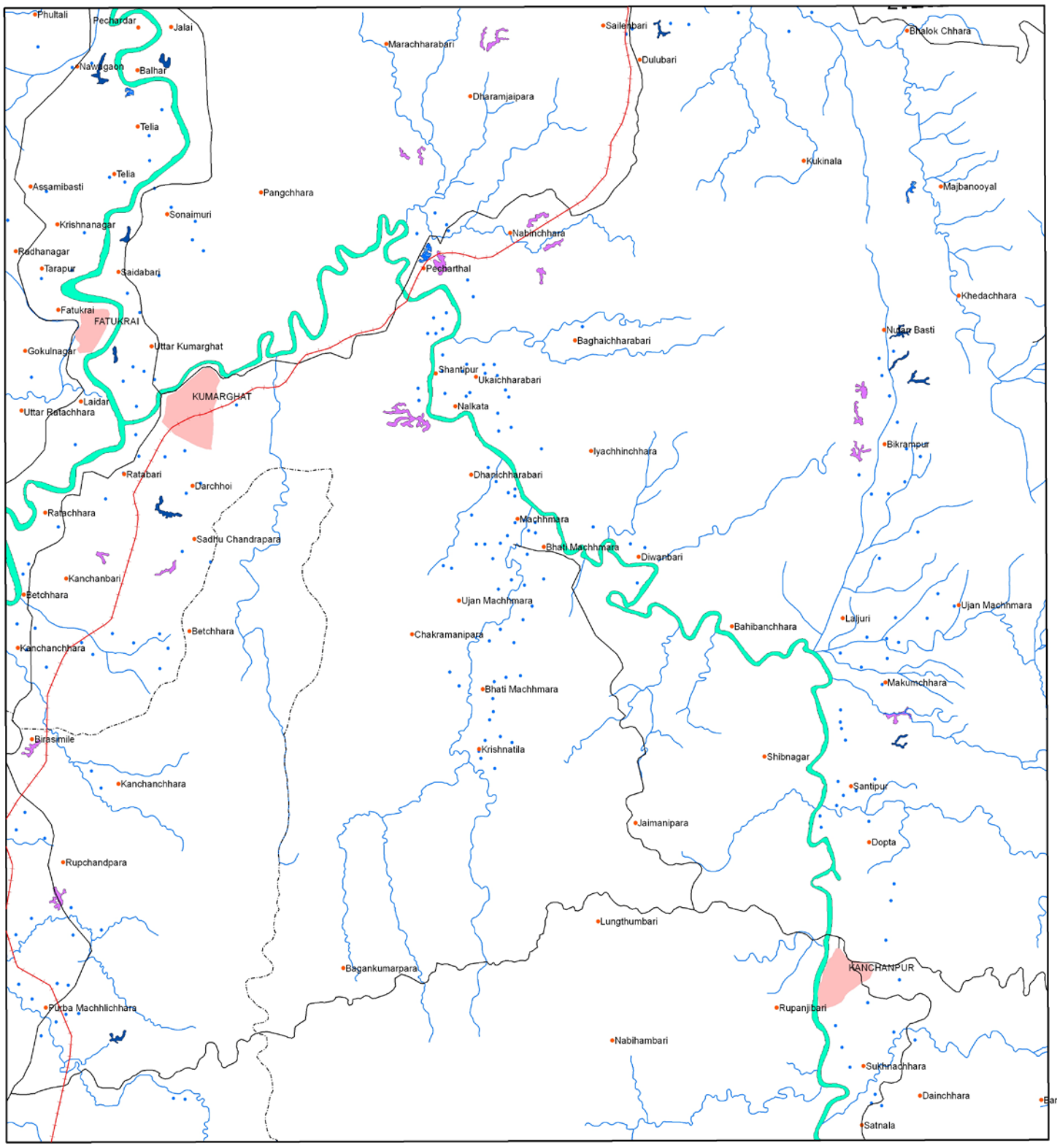
Government of India

State : Tripura

WETLAND MAP

Map No : 83D/04

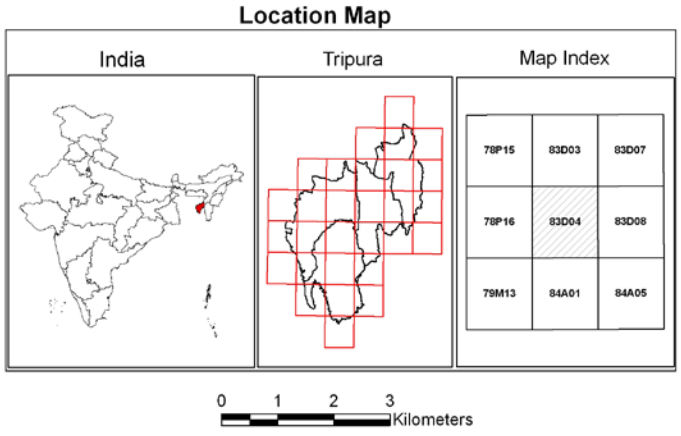


Symbol Typecode	Level I	Level II	Level III
	Inland Wetlands		
		Natural	
1101			Lakes/Ponds
1102			Ox-bow lakes/ Cut-off meanders
1103			High altitude wetlands
1104			Reverine wetlands
1105			Waterlogged
1106			River/Stream
		Man-made	
1201			Reservoirs/Barrages
1202			Tanks/Ponds
1203			Waterlogged
1204			Salt pans
	Coastal Wetlands		
		Natural	
2101			Lagoons
2102			Creeks
2103			Sand/Beach
2104			Intertidal mud flats
2105			Salt marsh
2106			Mangroves
2107			Coral reefs
		Man-made	
2201			Salt pans
2202			Aquaculture ponds

Legend

- Wetlands (<2.25 ha)
- Settlements
- Roads
- Railways
- Drainage
- District Boundary
- State Boundary
- Town/Settlements

Location Map



Data Source:
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By :
Ministry of Environment and Forests
Government of India

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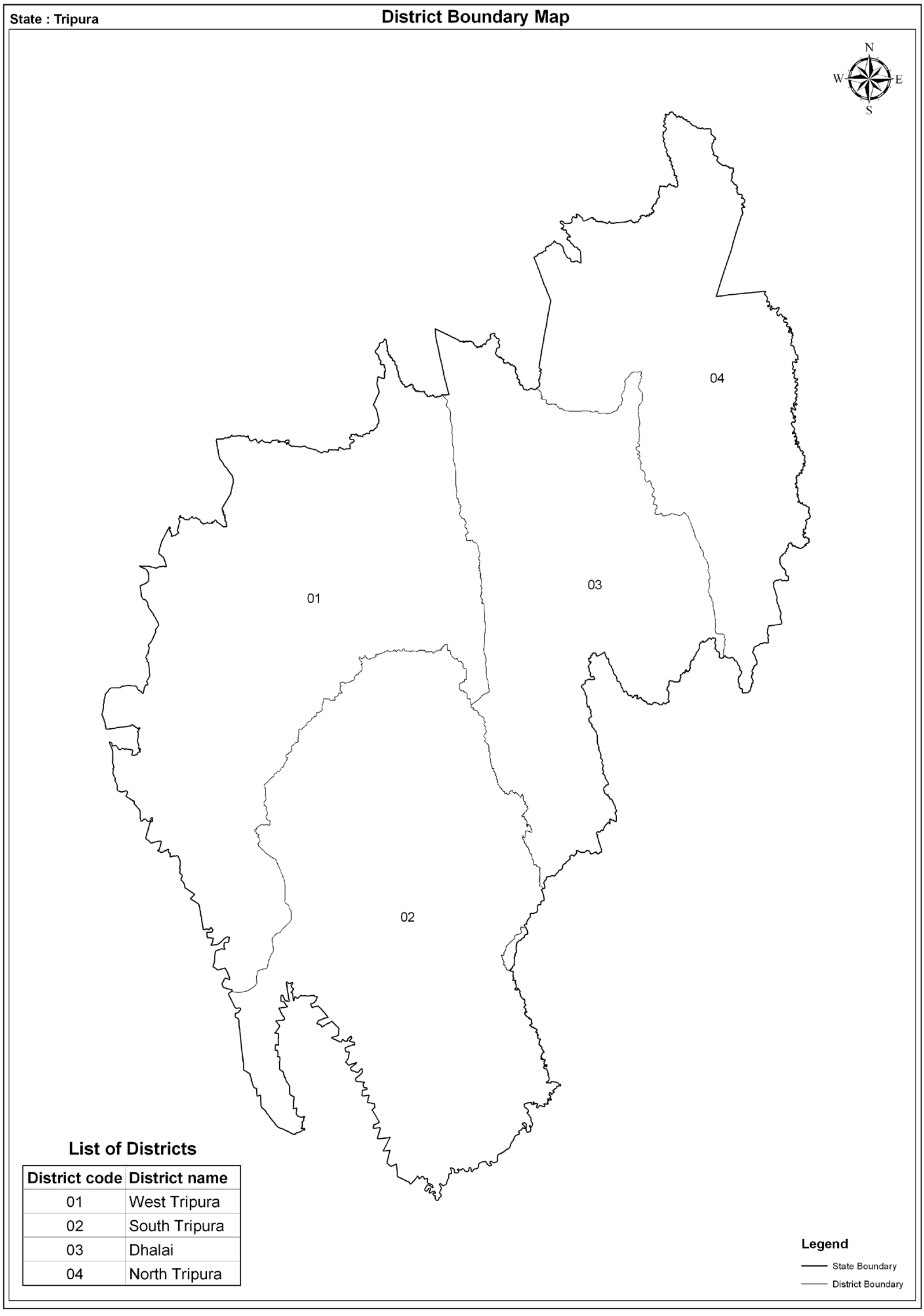
Annexure I
Definitions of wetland categories used in the project

For ease of understanding, definitions of wetland categories and their typical appearance on satellite imagery is given below:

Wetland type code	Definition and description
1000	**Inland Wetlands**
1100	**Natural**
1101	**Lakes**: Larger bodies of standing water occupying distinct basins (Reid *et al*, 1976). These wetlands occur in natural depressions and normally fed by streams/rivers. On satellite images lakes appear in different hues of blue interspersed with pink (aquatic vegetation), islands (white if non-vegetated, red in case of terrestrial vegetation). Vegetation if scattered make texture rough.
1102	**Ox-bow lakes/ Cut off meanders**: A meandering stream may erode the outside shores of its broad bends, and in time the loops may become cut-off, leaving basins. The resulting shallow crescent-shaped lakes are called oxbow lakes (Reid *et al*, 1976). On the satellite image Ox-bow lakes occur near the rivers in plain areas. Some part of the lake normally has aquatic vegetation (red/pink in colour) during pre-monsoon season.
1103	**High Altitude lakes:** These lakes occur in the Himalayan region. Landscapes around high lakes are characterized by hilly topography. Otherwise they resemble lakes in the plain areas. For keeping uniformity in the delineation of these lakes contour line of 3000 m above msl will be taken as reference and all lakes above this contour line will be classified as high altitude lakes.
1104	**Riverine Wetlands**: Along the major rivers, especially in plains water accumulates leading to formation of marshes and swamp. **Swamps** are 'Wetland dominated by trees or shrubs' (U.S. Definition). In Europe, a forested fen (a peat accumulating wetland that has no significant inflows or outflows and supports acidophilic mosses, particularly *Sphagnum*) could be called a swamp. In some areas reed grass - dominated wetlands are also called swamps). (Mitsch and Gosselink, 1986). **Marsh**: A frequently or continually inundated wetland characterised by emergent herbaceous vegetation adapted to saturated soil conditions. In European terminology a marsh has a mineral soil substrate and does not accumulate peat (Mitsch and Gosselink, 1986). Tone is grey blue and texture is smooth. **Comment**: Using satellite data it is difficult to differentiate between swamp and marsh. Hence, both have been clubbed together.
1105	**Waterlogged:** Said of an area in which water stands near, at, or above the land surface, so that the roots of all plants except hydrophytes are drowned and the plants die (Glossary of Geology, 1974). Floods or unlined canal seepage and other irrigation network may cause waterlogging. Spectrally, during the period when surface water exists, waterlogged areas appear more or less similar to lakes/ponds. However, during dry season large or all parts of such areas dry up and give the appearance of mud/salt flats (grey bluish).
1106	**River/stream:** Rivers are linear water features of the landscape. Rivers that are wider than the mapping unit will be mapped as polygons. Its importance arises from the fact that many stretches of the rivers in Indo-Gangetic Plains and peninsular India are declared important national and international wetlands (Ex. The river Ganga between Brajghat and Garh Mukteshwar, is a Ramsar site, Ranganthattu on the Cavery river is a bird sanctuary etc.). Wherever, rivers are wide and features like sand bars etc. are visible, they will be mapped.
1200	**Man-made**
1201	**Reservoir**: A pond or lake built for the storage of water, usually by the construction of a dam across a river (Glossary of Geology, 1974). On RS images, reservoirs have irregular boundary behind a prominent dyke. Wetland boundary in case of reservoir incorporates water, aquatic vegetation and footprint of water as well. In the accompanying images aquatic vegetation in the reservoir is seen in bright pink tone. Tone is dark blue in deep reservoirs while it is ink blue in case of shallow reservoirs or reservoirs with high silt load. These will be annotated as Reservoirs/Dam. **Barrage:** Dykes are constructed in the plain areas over rivers for creating Irrigation/water facilities. Such water storage areas develop into wetlands (Harike Barrage on Satluj – a Ramsar site, Okhla barrage on the Yamuna etc. – a bird sanctuary). Water appears in dark blue tone with a smooth texture. Aquatic vegetation appears in pink colour, which is scattered, or contiguous depending on the density. Reservoirs formed by barrages will be annotated as reservoir/barrage.

1202	**Tanks/Ponds:** A term used in Ceylon and the drier parts of Peninsular India for an artificial pond, pool or lake formed by building a mud wall across the valley of a small stream to retain the monsoon (Glossary of Geology, 1974). **Ponds** Generally, suggest a small, quiet body of standing water, usually shallow enough to permit the growth of rooted plants from one shore to another (Reid *et al*, 1976). Tanks appear in light blue colour showing bottom reflectance. In this category **Industrial ponds/mining pools mainly comprising Abandoned Quarries are also included** Quarry is defined as "An open or surface working or excavation for the extraction of stone, ore, coal, gravel or minerals." In such pits water accumulate (McGraw Hill Encyclopedia of Environmental Sciences, 1974), **Ash pond/Cooling pond** The water body created for discharging effluents in industry, especially in thermal power plants (Encyclopedic Directory of Environment, 1988) and **Cooling pond**: An artificial lake used for the natural cooling of condenser-cooling water serving a conventional power station (Encyclopedic Directory of Environment, 1988). These ponds can be of any shape and size. Texture is rough and tonal appearance light (quarry) to blue shade (cooling pond).
1203	**Waterlogged:** Man-made activities like canals cause water-logging in adjacent areas due to seepage especially when canals are unlined. Such areas can be identified on the images along canal network. Tonal appearance is in various hues of blue. Sometimes, such waterlogged areas dry up and leave white scars on the land. Texture is smooth.
1204	**Salt pans:** Inland salt pans in India occur in Rajasthan (Sambhar lake). These are shallow rectangular man-made depressions in which saline water is accumulated for drying in the sun for making salt.
2000	**Coastal Wetlands**
2100	**Natural**
2101	**Lagoons/Backwaters:** Such coastal bodies of water, partly separated from the sea by barrier beaches or bass of marine origin, are more properly termed lagoons. As a rule, lagoons are elongate and lie parallel to the shoreline. They are usually characteristic of, but not restricted to, shores of emergence. Lagoons are generally shallower and more saline than typical estuaries (Reid *et al*, 1976). **Backwater**: A creek, arm of the sea or series of connected lagoons, usually parallel to the coast, separated from the sea by a narrow strip of land but communicating with it through barred outlets (Glossary of Geology, 1974).
2102	**Creek:** A notable physiographic feature of salt marshes, especially low marshes. These creeks develop as do rivers "with minor irregularities sooner or later causing the water to be deflected into definite channels" (Mitsch and Gosselink, 1986). Creeks will be delineated; however, their area will not be estimated.
2103	**Sand/Beach:** Beach is an non-vegetated part of the shoreline formed of loose material, usually sand that extends from the upper berm (a ridge or ridges on the backshore of the beach, formed by the deposit of material by wave action, that marks the upper limit of ordinary high tides and wave wash to low water mark (Clark, 1977).Beach comprising rocky material is called rocky beach.
2104	**Intertidal mudflats**: Most non-vegetated areas that are alternately exposed and inundated by the falling and rising of the tide. They may be mudflats or sand flats depending on the coarseness of the material of which they are made (Clark, 1977).
2105	**Salt Marsh**: Natural or semi-natural halophytic grassland and dwarf brushwood on the alluvial sediments bordering saline water bodies whose water level fluctuates either tidally or non- tidally (Mitsch and Gosselink, 1986). Salt marshes look in grey blue shade when wet.
2106	**Mangroves**: The mangrove swamp is an association of halophytic trees, shrubs, and other plants growing in brackish to saline tidal waters of tropical and sub-tropical coastlines (Mitsch and Gosselink, 1986). On the satellite images mangroves occur in red colour if in contiguous patch. When mangrove associations are scattered or are degraded then instead of red colour, brick red colour may be seen.
2107	**Coral reefs:** Consolidated living colonies of microscopic organisms found in warm tropical waters. The term coral reef or organic reef is applied to the rock- like reefs built-up of living things, principally corals. They consist of accumulations of calcareous deposits of corals and corraline algae with the intervening space connected with sand, which consists largely of shells of foraminifera. Present reefs are living associations growing on this accumulation of past (Clark, 1977). Reefs appear in light blue shade.
2200	**Man-made**
2201	**Salt pans**: An undrained usually small and shallow rectangular, man-made depression or hollow in which saline water accumulates and evaporates leaving a salt deposit (Glossary of Geology, 1974). Salt pans are square or rectangular in shape. When water is there appearance is blue while salt is formed tone is white.
2202	**Aquaculture ponds**: Aquaculture is defined as "The breeding and rearing of fresh-water or marine fish in captivity. Fish farming or ranching". The water bodies used for the above are called aquaculture ponds (Encyclopedic Directory of Environment, 1988). Aquaculture ponds are geometrical in shape usually square or rectangular. Tone is blue.

Annexure II
Definitions of wetland categories used in the project



Source : Survey of India (Surveyed in 2004 and published in 2005)

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SAC is a host institution for the training programmes related to Satellite Communication, Satellite Meteorology and global change under the Centre for Space Science & Technology Education in Asia and the Pacific (CSSTEAP) affiliated to the United Nations (UN).

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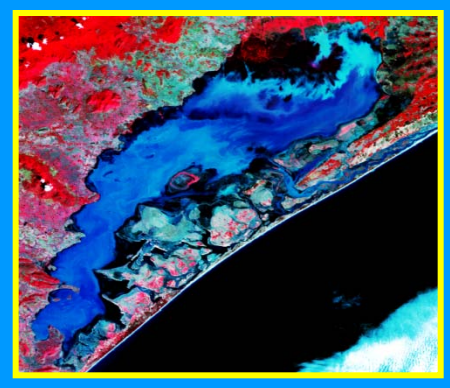

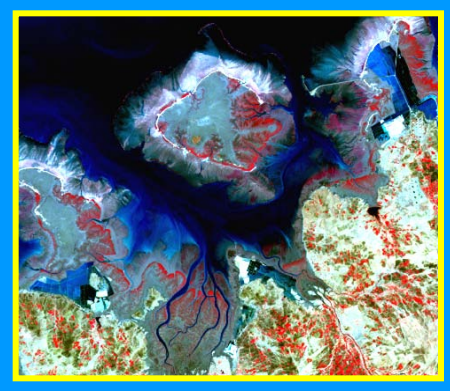

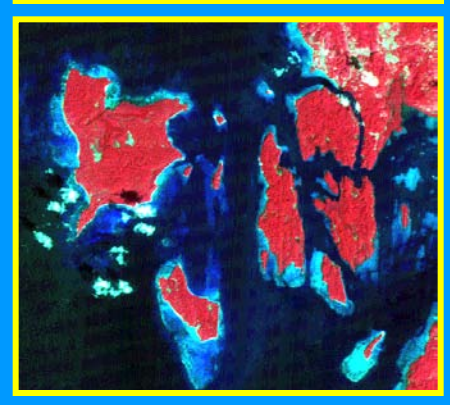

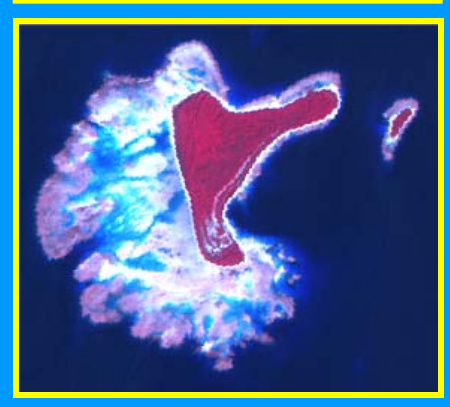

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