NATIONAL WETLAND ATLAS:

DELHI

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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Ministry of Environment and Forests, Government of India

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

Space Applications Centre (ISRO), Ahmedabad
and
M. G. Science Institute, 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, Coimbatore and Dr. R.K. Suri, Additional Director, Ministry of Environment and Forests, Govt. of India, New Delhi, to finalise the “Wetland Classification System” followed in this project by their active participation in the Peer Review meeting. We are thankful to the database experts from ISRO who participated in the peer Review meeting to finalise the hierarchical classification system.

We acknowledge the support received from Dr P S Roy, Dy Director, NRSC and Dr S Sudhakar, Head, LRD, NRSC in terms of valuable suggestions and providing the geo-referenced image of NRC-LU&LC project for use as master image 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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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 difficulties most frequently faced for decision making is lack of scientific data of our natural resources. Often the data are sparse or unconvincing, rarely in the form of geospatial database (map), thus open to challenges. Thus, the current thrust of every country is to have an appropriate geospatial database of natural resources that is based on unambiguous scientific methods. The wetland atlas of Delhi, 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 wetlands is estimated to already have disappeared worldwide 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 relating the feature to any given geographical location has a strong visual impact. Maps, 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) topographic 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 recognized 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, we define satellite remote sensing 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 reflection in NIR from green leaves).

Since the early 1960s, numerous satellite 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 (IRS) satellites. 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.

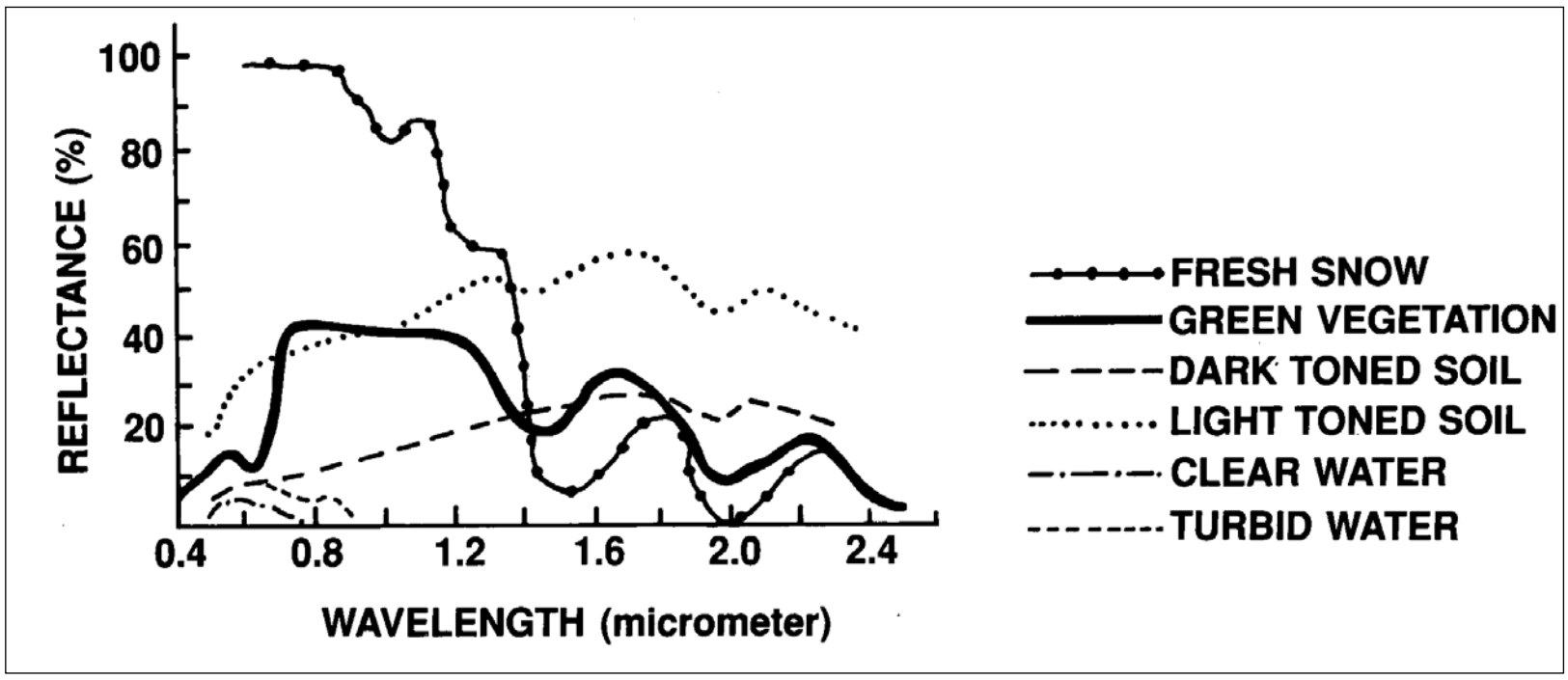


Figure 1: Spectral Signature of various targets

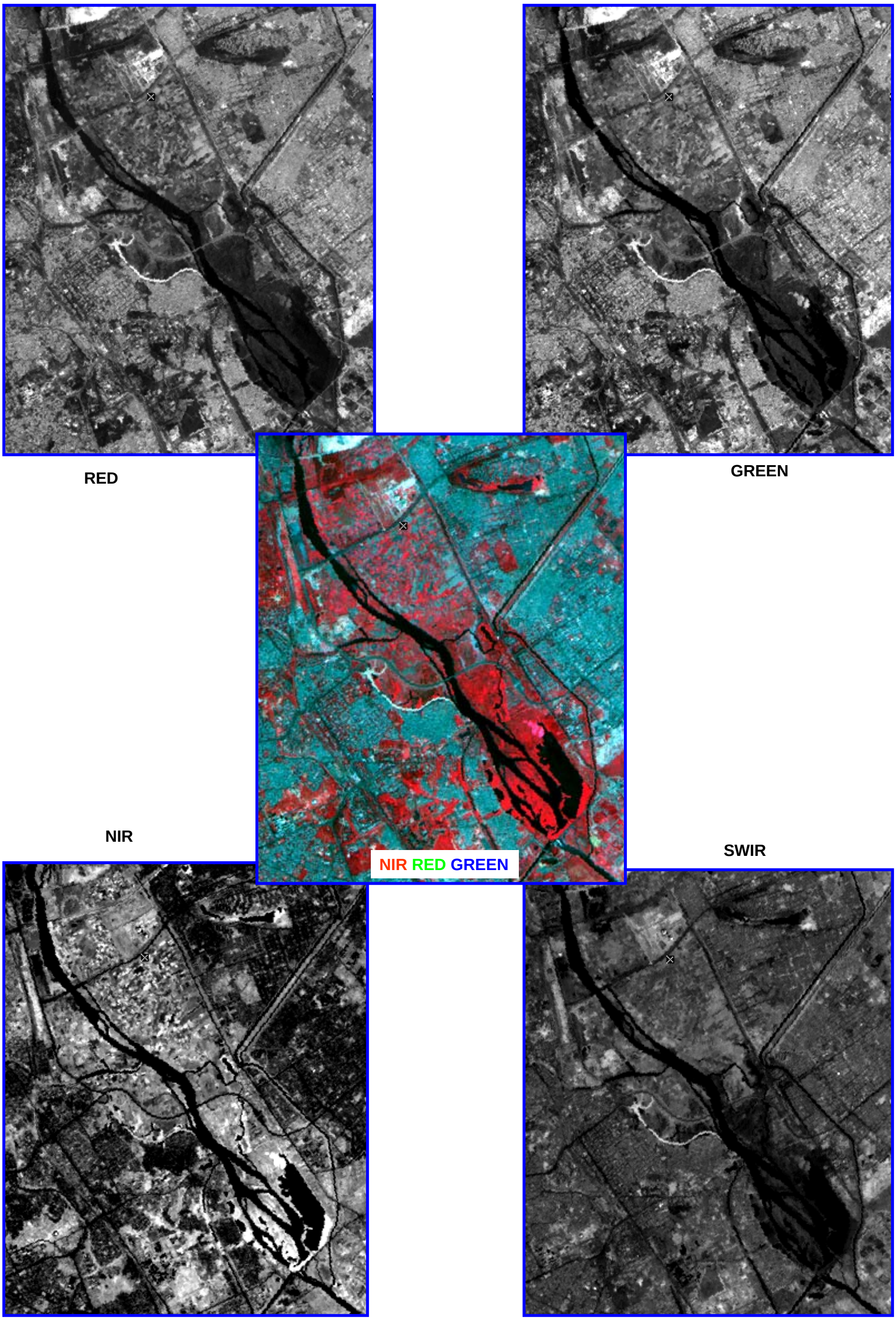


Figure 2: Various land features as they appear in four spectral bands and in a typical three band FCC.

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 place 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 (IRS) satellite. 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). 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 in 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 Delhi.

2.1 Wetland Classification System

In the present project, Modified National Wetland Classification system is used for wetland delineation and mapping comprising 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 included as wetland class. Definitions of wetland categories used in the project is 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. 2007). 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 as well as natural hierarchy (State-district- 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 extent 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 level 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) 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).

In the case of coastal wetlands only wetland extent is given.

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

Delhi situated on the banks of river Yamuna. It is the national capital of India lying between 28° 55' to 28° 53' N latitude and 76° 55' to 77° 22' E longitude. Uttar Pradesh and Haryana are two neighbors of Delhi. It is bounded by Haryana on the north, west and south and on the east by UP with the river Yamuna flowing on its eastern boarder in a north – south direction. The area of Delhi state is 2966 sq. kms. The hills and ridges formed of the Delhi quartzes nowhere attain an elevation over 150m above the ground surface with in the territory. The most significant physiographic feature in this area is the Delhi ridge which emerges out of the alluvium on the right bank of the Yamuna River near Timmerpur in the north of the old Delhi. The meandering of the Yamuna river has left a deep imprint on the physiography of plains. The plains are considerably wider and fertile and the soil in this region is generally a light sandy, loam and lends itself well to agriculture pursuits. Figure 3 shows location map of the Delhi state.

The plains can be divided into Delhi, New Delhi and Delhi Cantonment. The other regions of Delhi namely the Yamuna plains are flood-prone while the ridge which is the most dominating feature in this region is surrounded by the Aravallis. Delhi comprises of 200 villages which are heavily populated. Yamuna is an important river in Delhi which fertilizes the alluvial soil.

Delhi's climate is extreme. It is very cold in winter and terribly hot in summer. It is generally dry except for two-three months of humidity. The cold season begins in November and is at its peak in the first half of the January. In April and June the temperatures rise as high as 45° C. Temperatures fall to 2o° C.

Yamuna river is perhaps the only water body that fulfills the day to day requirements of the residents of Delhi. The cleanliness of the river is of a major concern for the government as industrial waste gets accumulated in the river. The other major sources of water include the Agra Canal, Hindu Canal and the Western Canal

The forest area of Delhi is covered by the Northern Tropical Thorn Forests. These forests are covered with large trees and shrubs. Wild life sanctuaries like the Asola Bhatti wild life sanctuary protect flora and fauna of the region.

Delhi is divided into nine districts. They are North, Central, East, West, South, New Delhi, North-East, North-West, and South-East. Each district is headed by a Deputy Commissioner. All Deputy Commissioners report to the Divisional Magistrate. Every district has three sub-divisions headed by a sub-divisional magistrate.

Satellite data (IRS LISS IV and LISS III) has been analyzed for delineating wetlands in the state. Mapping have been carried out at 1:25,000 scale for Delhi and surrounding 10km buffer area. The state is covered by fifteen 1:25,000 scale SOI topographical maps that form the spatial framework for mapping (Figure 4).

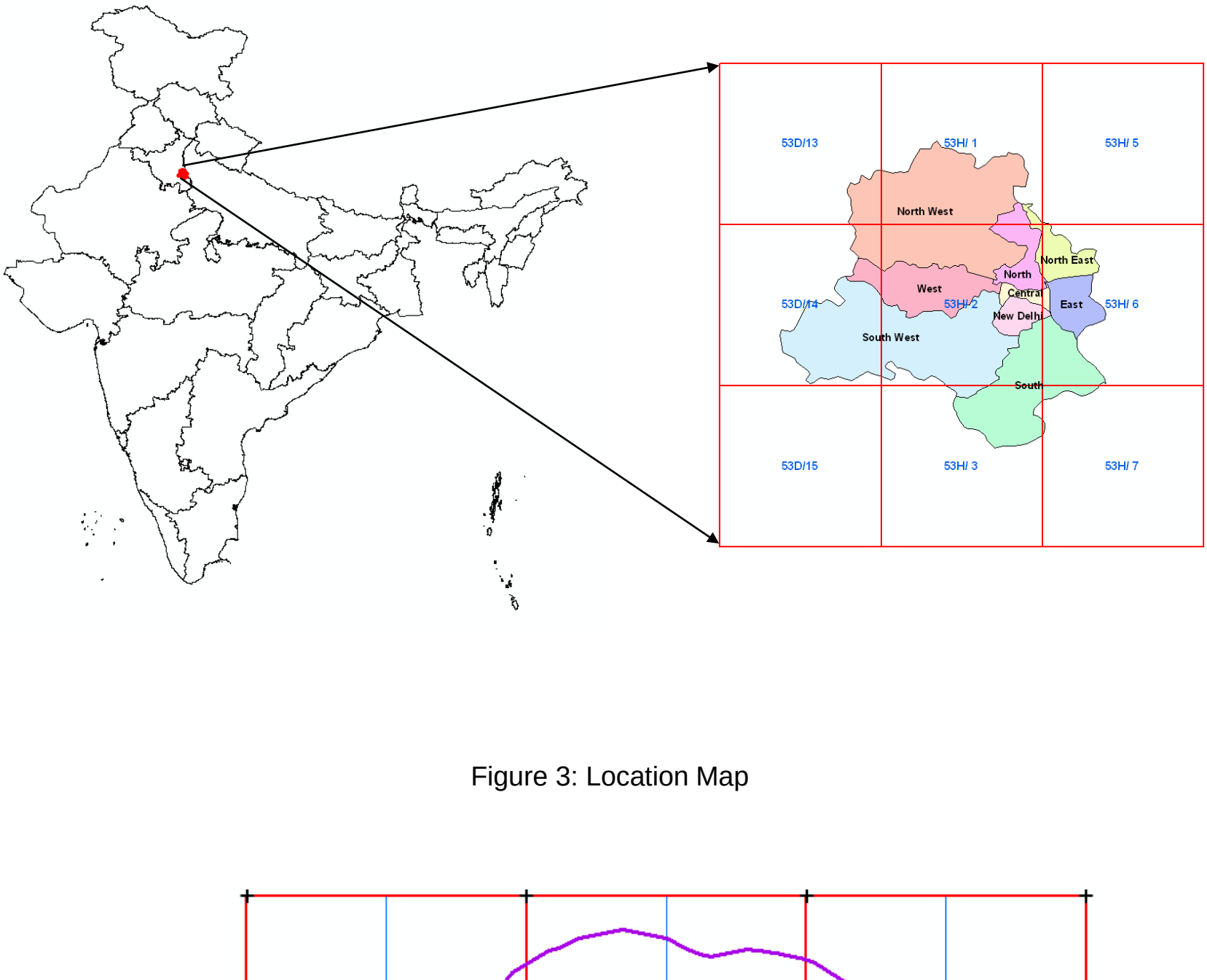


Figure 3: Location Map

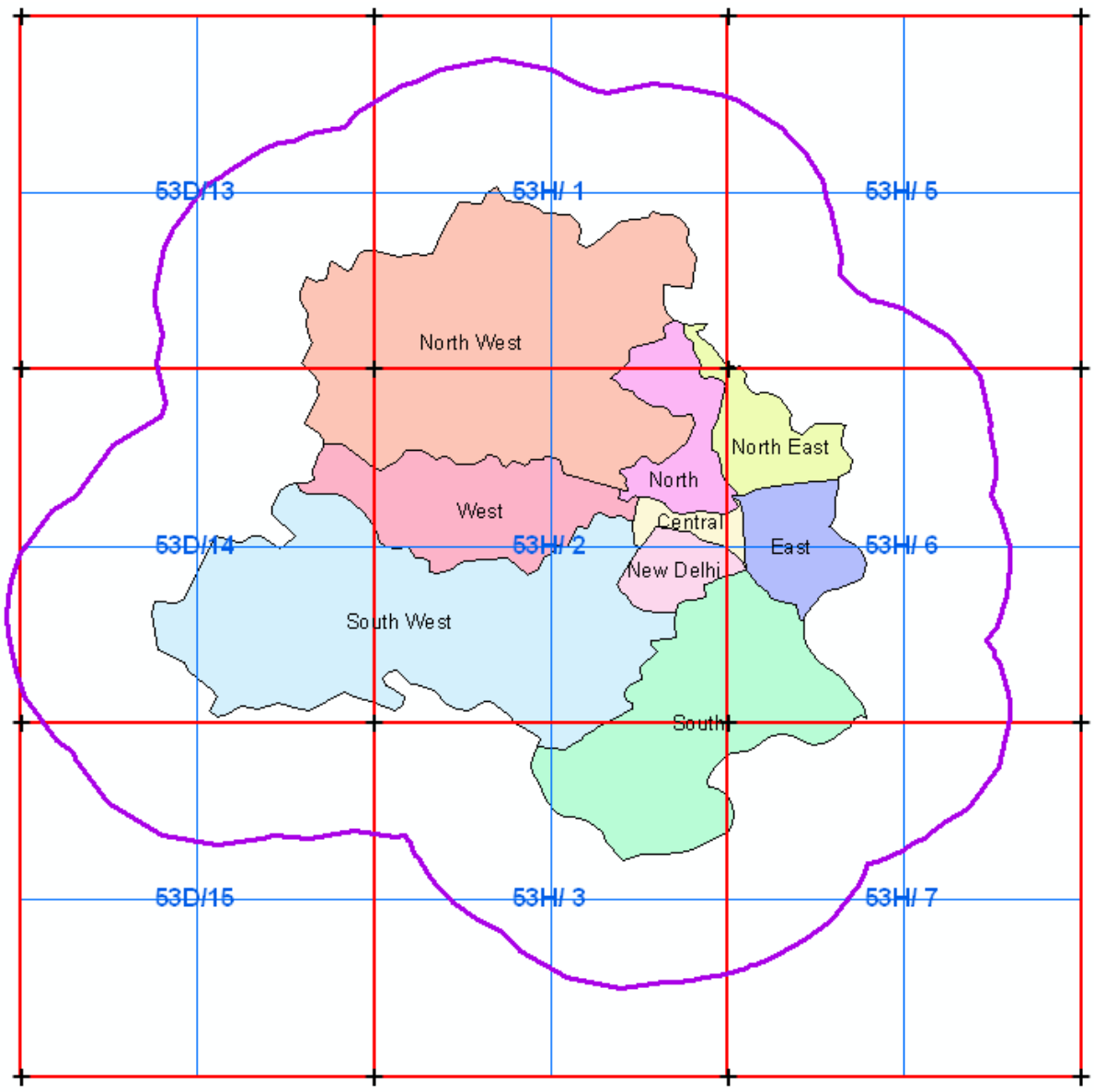


Figure 4: Spatial Framework of Delhi and surrounding area

4.0 DATA USED

Remote sensing data

IRS P6 LISS IV and LISS III data have been used to map the wetlands. The spatial resolution of LISS-IV data is suitable for 1:25,000 scale mapping. The state of Delhi is covered in 2 IRS LISS III scene (Figure 5). Two date data, one acquired during March and another during January were used to capture the pre-monsoon and post-monsoon hydrological variability of the wetlands respectively (Table-2). Figure 6 shows the overview of part of Delhi state as seen in the LISS IV FCC of post- monsoon pre-monsoon data respectively.

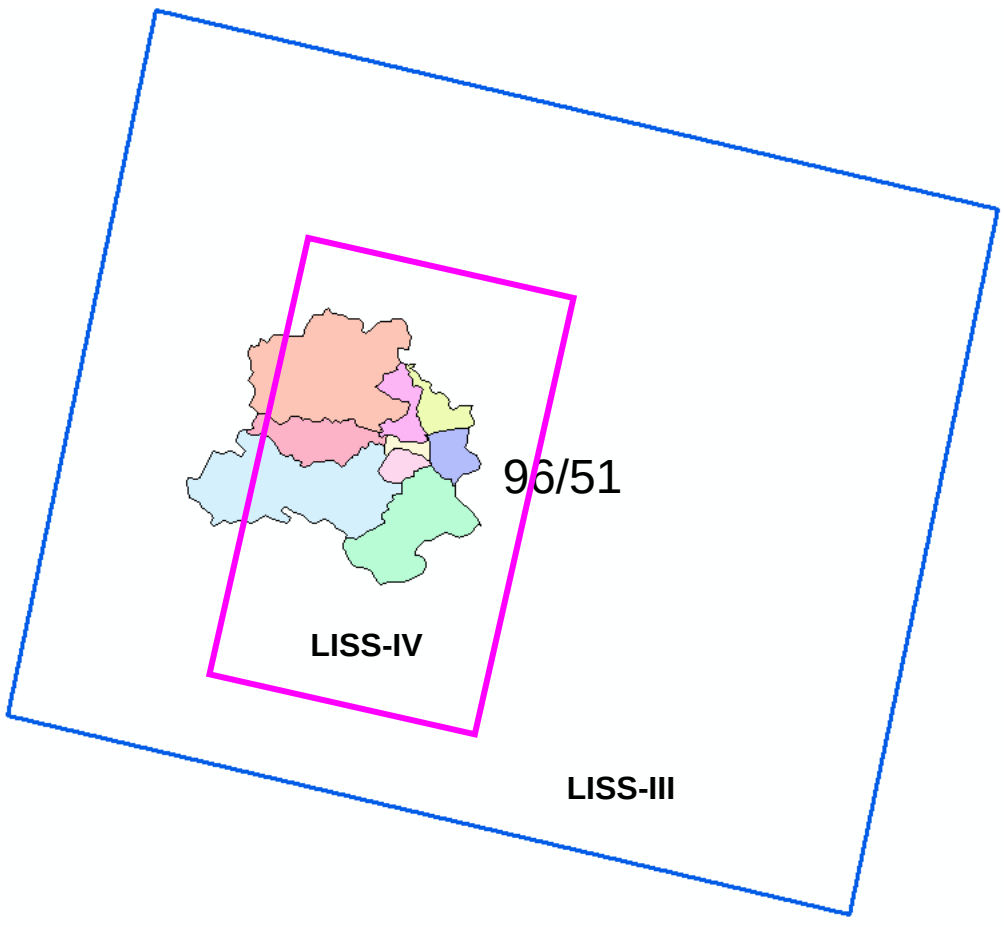


Figure 5: IRS P6 LISS-III and LISS-IV coverage of Delhi

Table-2: Satellite data used

Sr. No.	Sensor	Path-Row	Date of acquisition	
			Post-monsoon	Pre-monsoon
1.	IRS P6 LISS-III	96-51	October 10, 2006	May 14, 2007
2.	IRS P6 LISS-IV		September 17, 2007	

Ground truth data

Remote sensing techniques require certain amount of field observation called “ground truth” in order to convert into meaningful information. Such work involves visiting a number of test sites, usually taking the satellite data. The location of the features is recorded using the GPS. The standard proforma as per the NWIA manual was used to record the field data. Field photographs are also taken to record the water quality (subjective), status of aquatic vegetation and water spread. All field verification work has been done during October and November 2008.

Other data

Survey of India topographical maps (SOI) were used for reference purpose. Lineage data of National Wetland Maps at 1:250,000 scale was 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 softwares.

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 15' x 15' grid 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 Delhi state 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 archived image. The second date data was then registered with the first date data. LISS-IV data was referenced using LISS-III data and GPS survey 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)

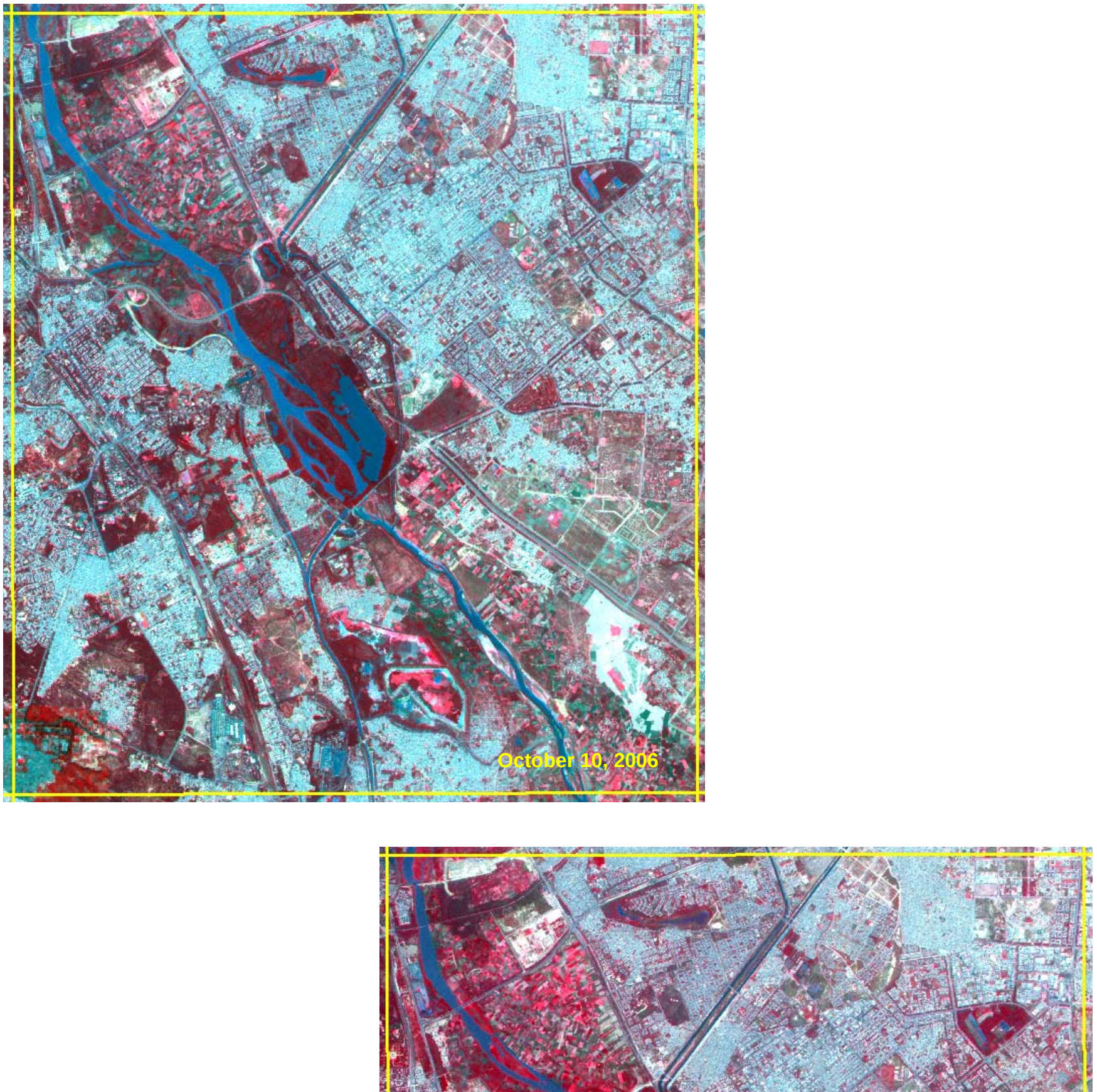


Figure 6: IRS LISS-IV FCC (Post-monsoon and Pre-monsoon): Part of Delhi

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.

- Extraction of open water :

  MNDWI was used within the wetland mask to delineate the water and no-water areas.

- 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.

- Turbidity information extraction :

  NDTI and MNDWI image was used to generate qualitative turbidity level (high, moderate and low) based on signature statistics and standard deviations. In the False Colour Composite (FCC) these generally appear in different hues as given in Table-3.

Table 3: Qualitative turbidity ratings

Sr. No.	Qualitative Turbidity	Conditional criteria	Hue on False Colour Composite (FCC)
1.	Low	> $+1\sigma$	Dark blue/blackish
2.	Moderate	> -1σ to <= $+1\sigma$	Medium blue
3.	High/Bottom reflectance	<= $\mu - 1\sigma$	Light blue/whitish blue

5.4 Conversion of the 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 digitization.

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.

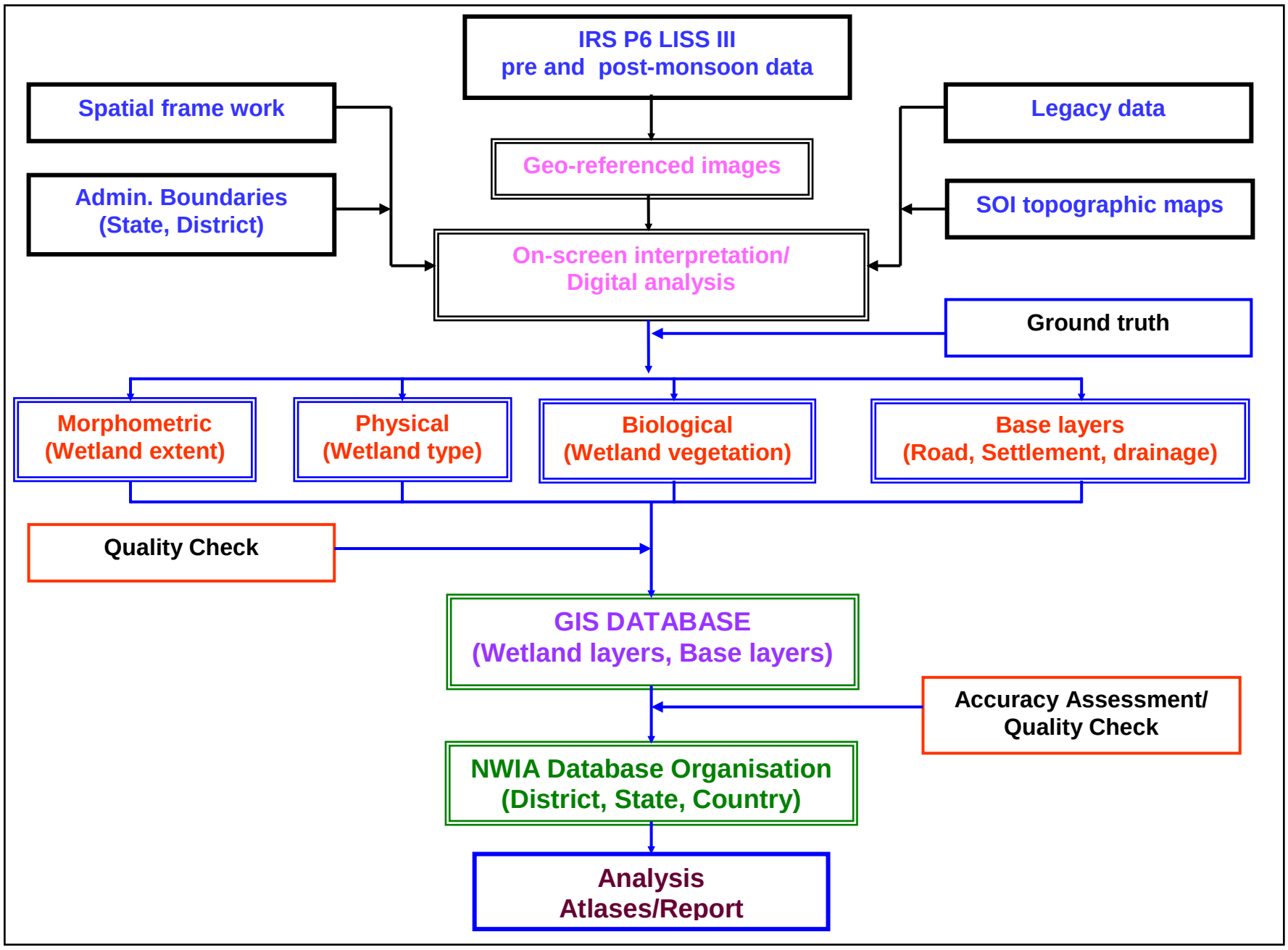


Figure 7: Flow chart of the methodology used

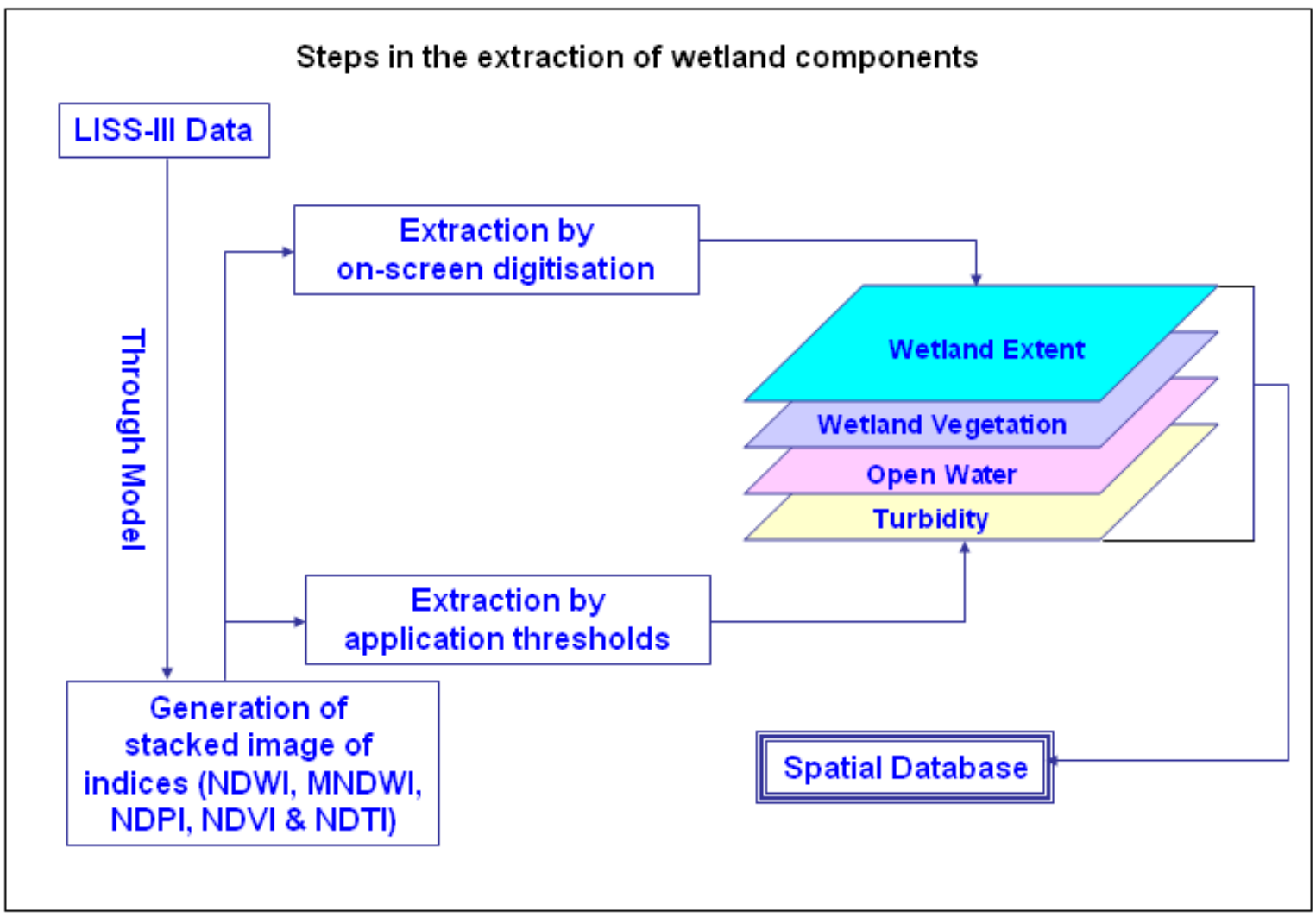


Figure 8: Steps in the extraction of wetland components

6.0 ACCURACY ASSESSMENT

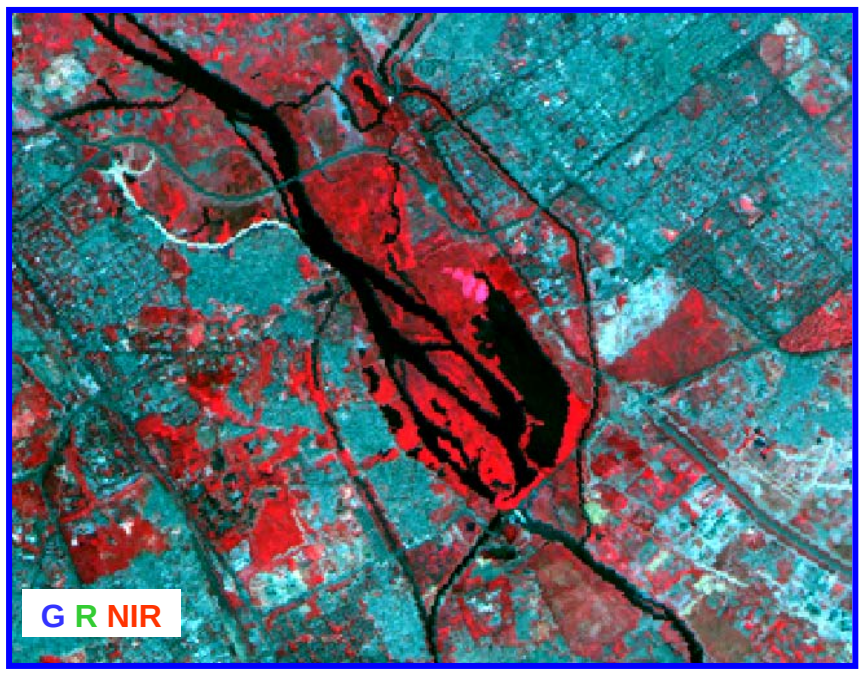
A comprehensive accuracy assessment protocol has been followed for determining the quality of information derived from remotely sensed data. Accuracy assessment involves determination of thematic (classification) as well as locational accuracy. In addition, GIS database(s) contents have been also evaluated 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.

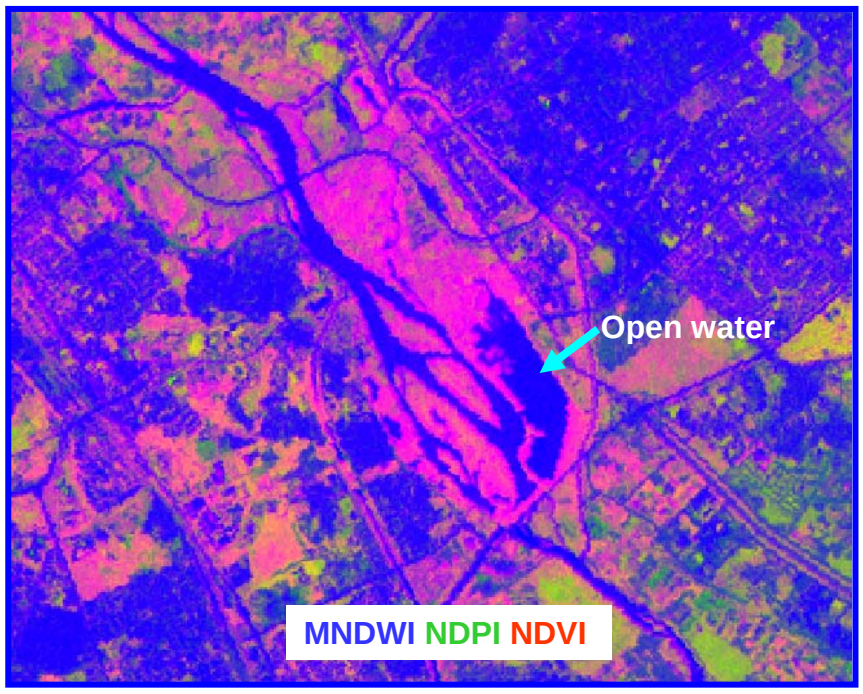
This study used well established, time-tested, fully documented data collection conventions. It employed skilled and trained personnel for image interpretation, processing and digital database creation. All interpreted imageries were reviewed by technical expert team for accuracy and code. The reviewing 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.

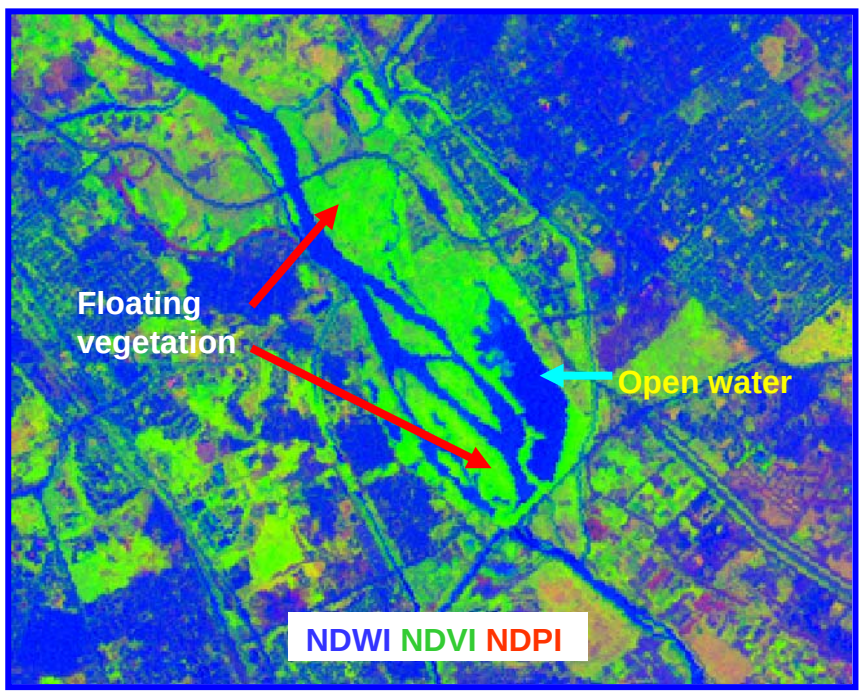
6.1 Data verification and quality assurance of output digital data files

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.

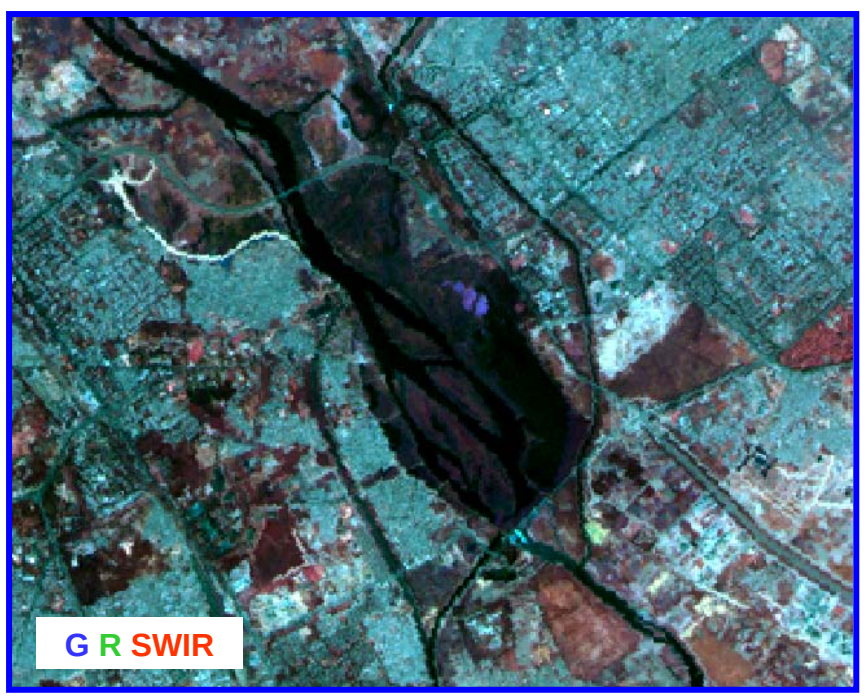


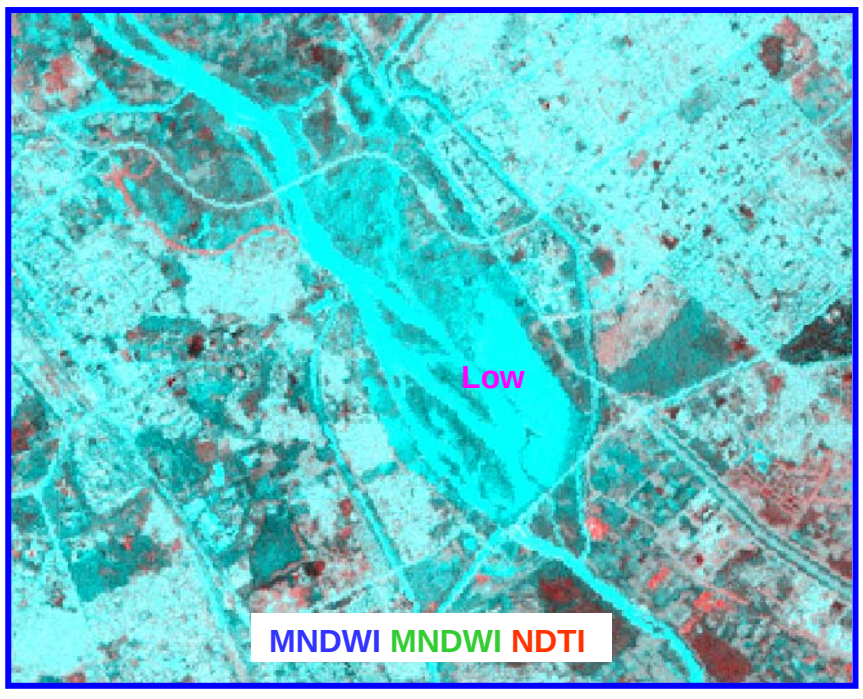


Useful for wetland boundary extraction/delineation



Useful for wetland vegetation & open water features





Okhla Dam,
IRS LISS III data, 10 October 2006

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

MAPS AND STATISTICS

7.0 WETLANDS OF DELHI

Area estimates of various wetland categories for Delhi have been carried out using GIS layers of wetland boundary, water-spread, aquatic vegetation and turbidity. Total 441 wetlands have been mapped at 1:50,000 scale in the state. In addition, 132 wetlands (smaller than 0.50 ha) have also been identified. Total wetland area estimated is 2556 ha that is around 0.86 per cent of the geographic area (Table 4). The major wetland types are river/stream (1116 ha), tanks/ponds (518 ha), waterlogged (natural/man-made) accounting for 23.2 percent of the wetlands (577 ha) and reservoirs (230 ha). Graphical distribution of wetland type is shown in Figure 10.

Analysis of wetland status in terms of open water and aquatic vegetation showed that around 50 and 60 percent of wetland area is under open water category during post monsoon and pre-monsoon respectively. Aquatic vegetation comprised of various types hydrophytes which include mainly grasses in the periphery of the banks and on exposed sand beds and also on different mounts where as water hyacinth is a dominant species in open water region. It is observed that water hyacinth is showed luxuriant growth in waters which are mainly originated through sewage. Ipomia aquatic is also observed the euphotic regions mainly in the banks of the rivers and other wetlands. Aquatic vegetation (floating/emergent) occupies around 30 and 35 per cent of wetland area during post-and pre-monsoon respectively.

Turbidity is a measure of opaque ness and it is used to study the physical property of water-transparency. High turbidity is associated with more particulate matter which includes organic molecules and inorganic sediments. The dispersion of sediments depends of the flow water currents and internal secchi (waves). Depending upon the wind action on the surface of the water of the stream/ drain flow (input to wetlands) sediments gets dispersed and plumes are formed which are enable to remote sensing sensors. Based on the reflective properties of sediments the qualitative turbidity ratings were assigned to the open waters. It has been observed during field observations that most of the wetlands are infested by aquatic vegetation and the water beneath the vegetation was dark black in color with foul odour. It clearly indicate that wetland which are highly infested by organic sewage have their own assimilation power to purify the water(reduction in Biological Oxygen Demand) and it take a long time to purify the same in natural conditions but this process could be enhanced by artificial aeration. Some of the wetlands have shown moderate and low turbidity this is mainly attributed to algal population on the surface of water and some time due to shadow of angiosperm (terrestrial vegetation) on banks of wetlands. Wetland beds (Bottom reflection), which are mainly comprised of organic material also reveals low turbidity signatures but efforts were made to remove the ambiguity using different indices.

Table 4: Area estimates of wetlands in the Delhi

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	11	106	4.15	100	60
2	1102	Ox-bow lakes/ Cut-off meanders	-	-	-	-	-
3	1103	High altitude wetlands	-	-	-	-	-
4	1104	Riverine wetlands	5	15	0.59	13	14
5	1105	Waterlogged	10	86	3.36	54	65
6	1106	River/Stream	26	1116	43.66	826	845
	1200	**Inland Wetlands -Man-made**					
7	1201	Reservoirs/Barrages	8	230	9.00	124	153
8	1202	Tanks/Ponds	352	466	18.23	441	418
9	1203	Waterlogged	29	471	18.43	85	145
10	1204	Salt pans	-	-	-	-	-
		Sub-Total	**441**	**2490**	**97.42**	**1643**	**1700**
		Wetlands (<0.50 ha), mainly Tanks	132	66	2.58	-	-
		Total	**573**	**2556**	**100.00**	**1643**	**1700**

Area under Aquatic Vegetation	714	741

Area under turbidity levels		
Low	24	8
Moderate	1373	1455
High	246	237

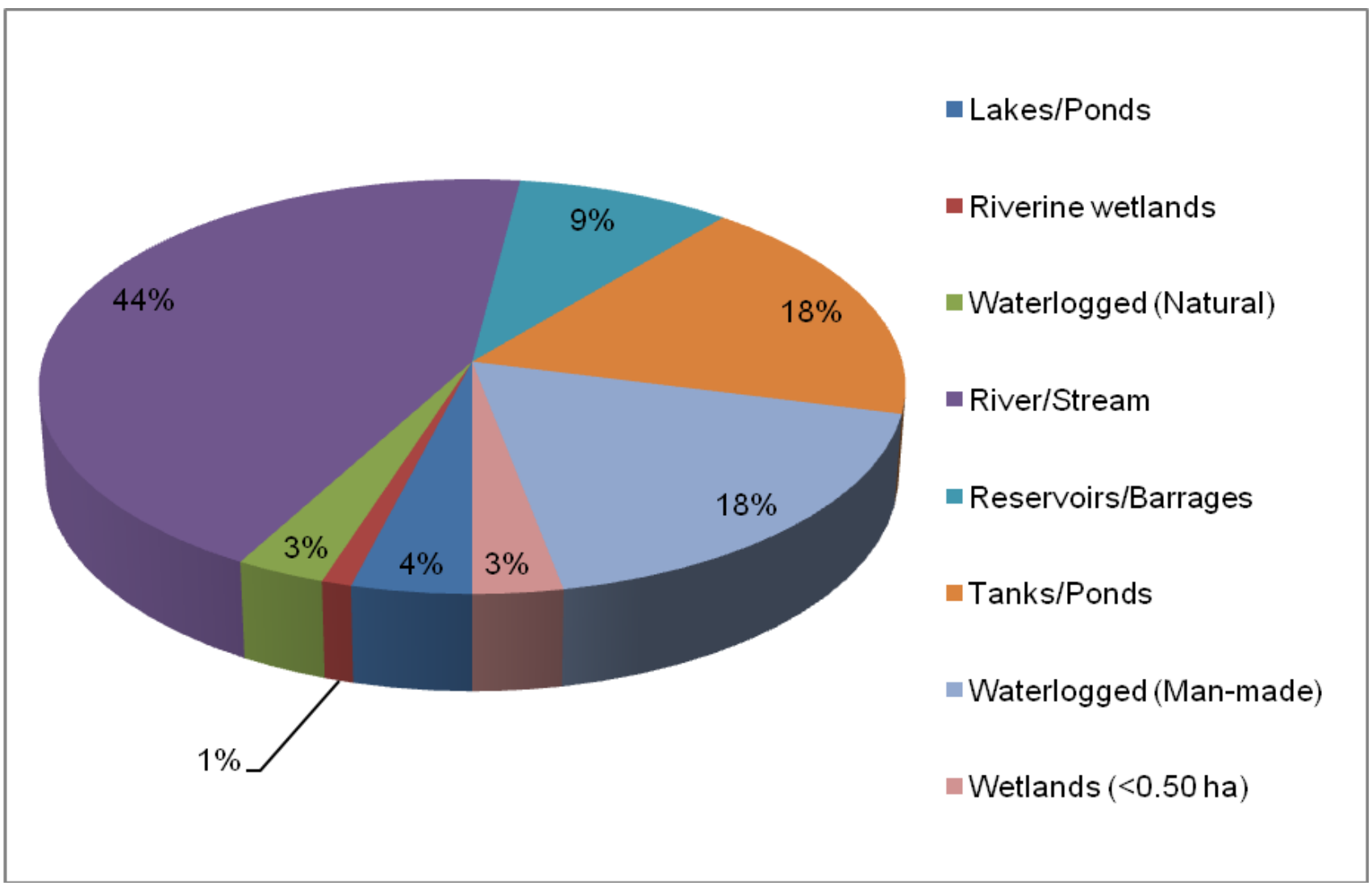


Figure 10: Type-wise wetland distribution in the Delhi

7.1 DISTRICT-WISE WETLAND MAPS AND STATISTICS

Delhi is divided into nine districts. They are North, Central, East, West, South, New Delhi, North-East, North-West, and South-East. Each district is headed by a Deputy Commissioner. All Deputy Commissioners report to the Divisional Magistrate. Every district has three sub-divisions headed by a sub-divisional magistrate.

District-wise distribution of wetlands showed that total wetland per cent area (0.86) is much less compare to country average. North district has 7.47 per cent of geographic area under wetland. The other three districts are: South, East and North East with around 3.69, 2.58 and 2.32 per cent area under wetland respectively. New Delhi and South West districts have the lowest area under wetland. Wetland category of Reservoirs/Barrages was observed only in South Delhi and East Delhi districts, mainly due to the presence of the Okhla Dam. District-wise wetland area estimates is given in Table-5.

South West and North West district have 44 and 47 small wetlands (< 0.50 ha) respectively, While other districts have less wetlands. Wetland statistics followed by wetland map and corresponding satellite data for each district is given to have a fairly good idea about the distribution pattern and density of wetlands in the district.

Table-5: District-wise wetland highlights

Sr. No.	District	Geographic Area (sq. km)	Wetland Area (ha)	% of total wetland area	% of district geographic area
1	North West	440	500	20	1.14
2	North	60	448	18	7.47
3	North East	60	139	5	2.32
4	East	64	165	6	2.58
5	New Delhi	1483	38	1	0.03
6	Central	60	112	4	1.87
7	West	129	79	3	0.61
8	South West	420	154	6	0.37
9	South	250	923	36	3.69
	Total	**2966**	**2556**	**100**	

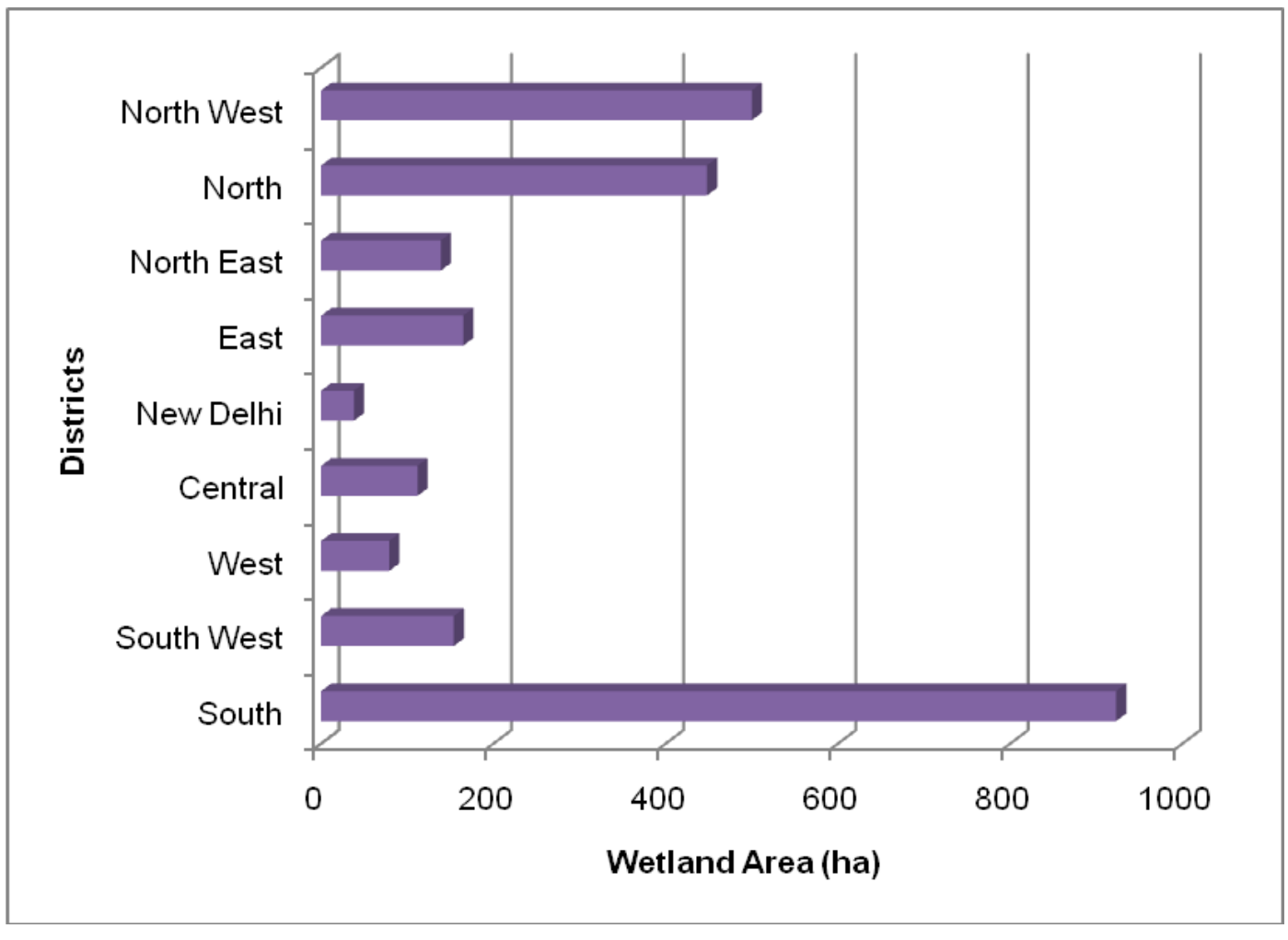
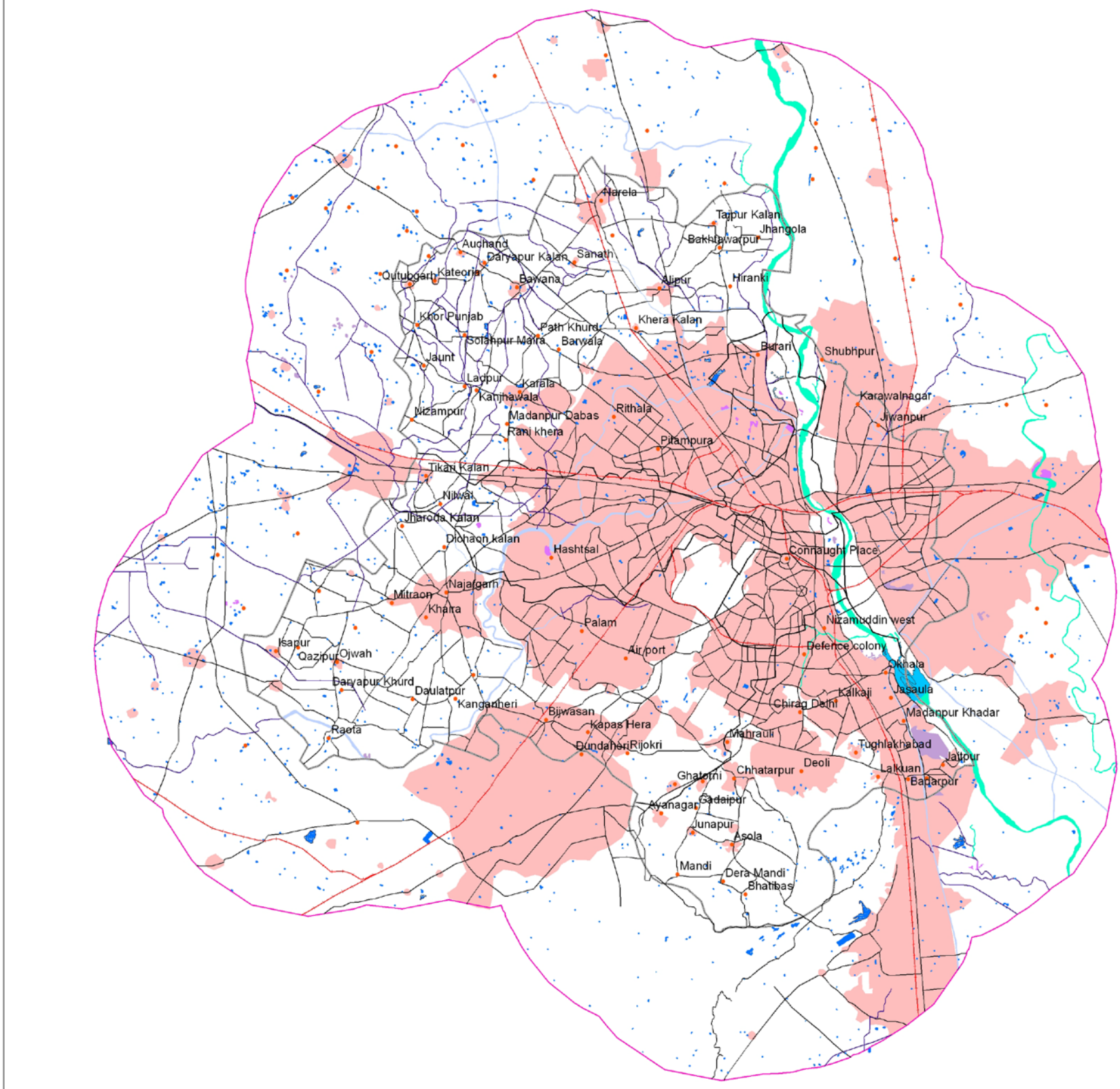


Figure 11: District-wise wetland distribution

State : Delhi

WETLAND MAP

10 km buffer area

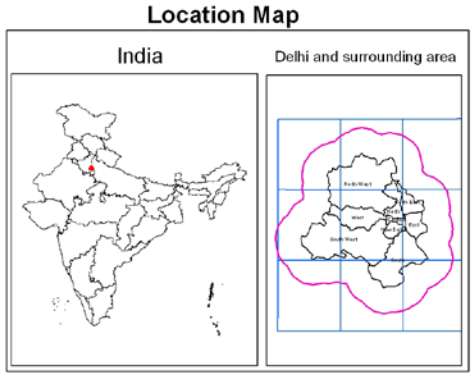


Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			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 (<0.50 ha)
- Settlements
- Drainage (line)
- Canal
- Roads
- Railways
- Town/Settlements
- District Boundary
- State Boundary
- International Boundary

Location Map



0 2.5 5 10 Kilometers

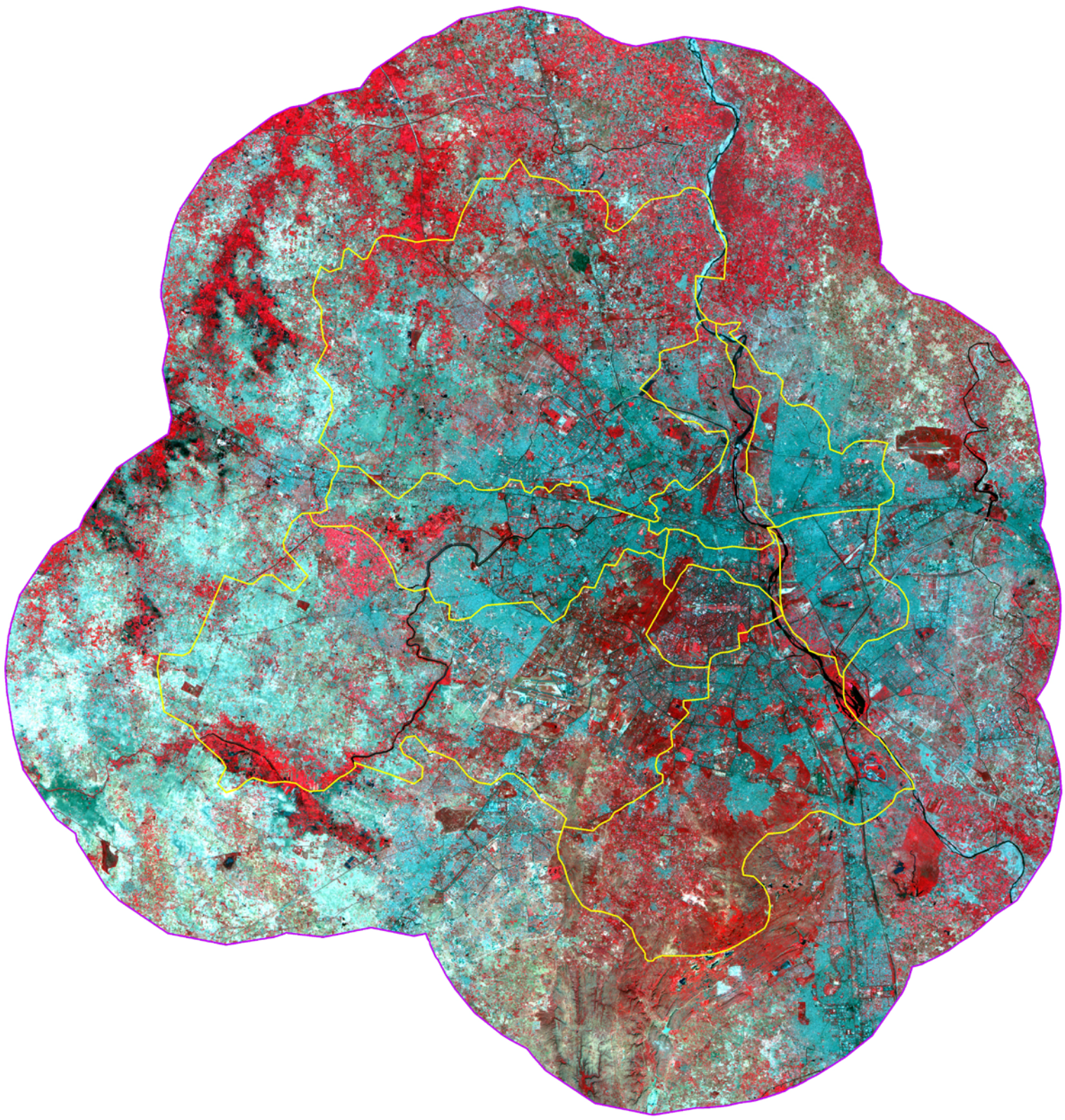
Data Source :
IRS P6 LISS III and LISS IV data
(Pre-monsoon and Post-monsoon Season 2006-07)

Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

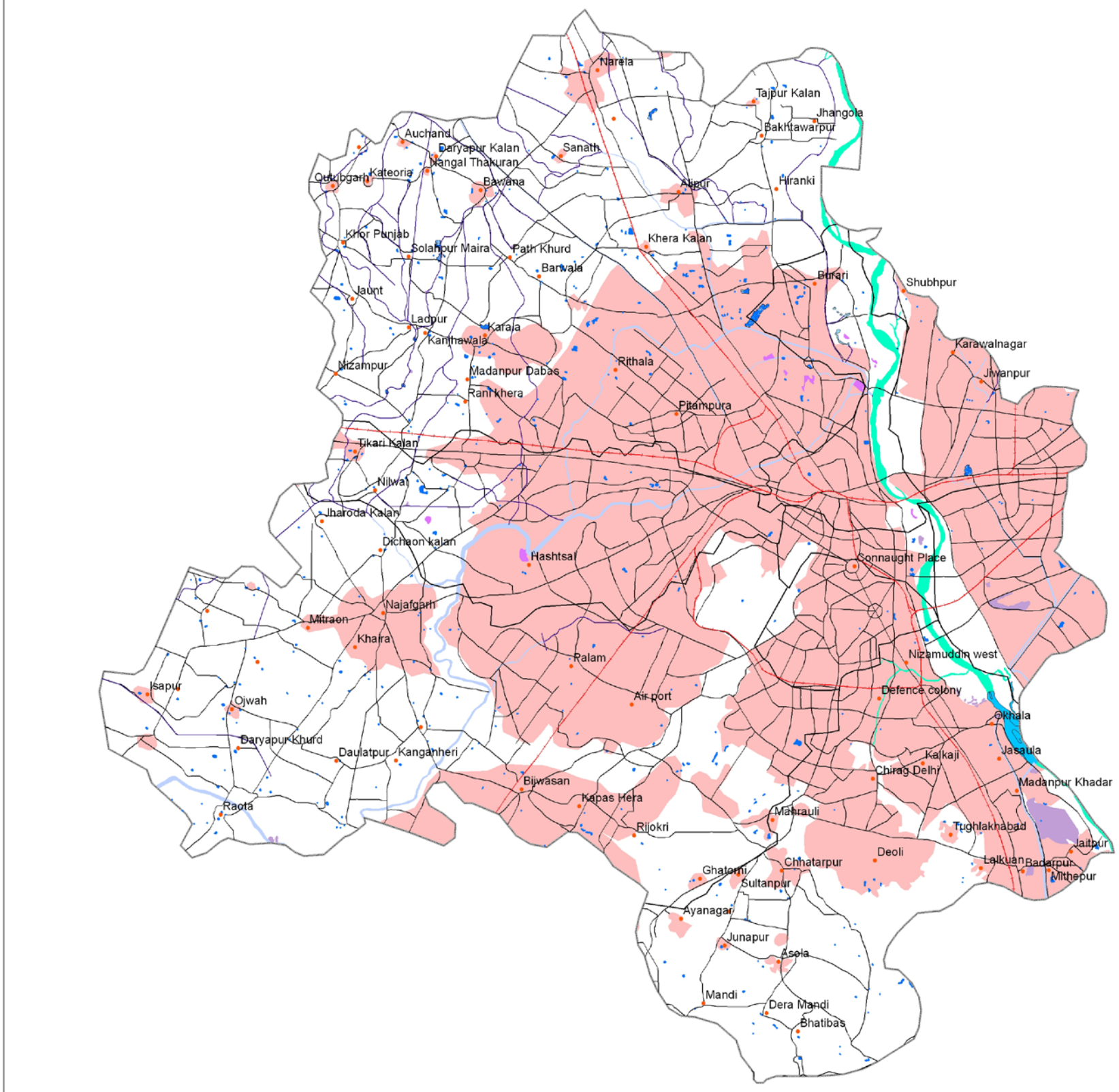
10 km buffer area



IRS P6 LISS-III post monsoon data (2006)

State : Delhi

WETLAND MAP



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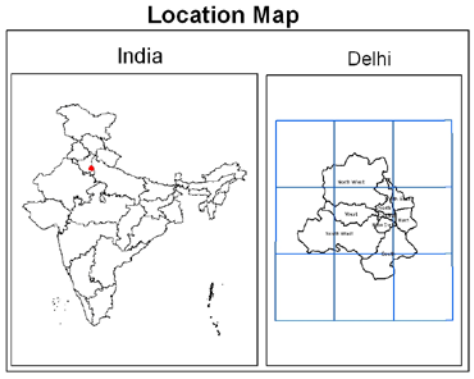
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral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

Legend

- Wetlands (<0.50 ha)
- Settlements
- Drainage (line)
- Canal
- Roads
- Railways
- Town/Settlements
- District Boundary
- State Boundary
- International Boundary

Location Map



0 2 4 8 Kilometers

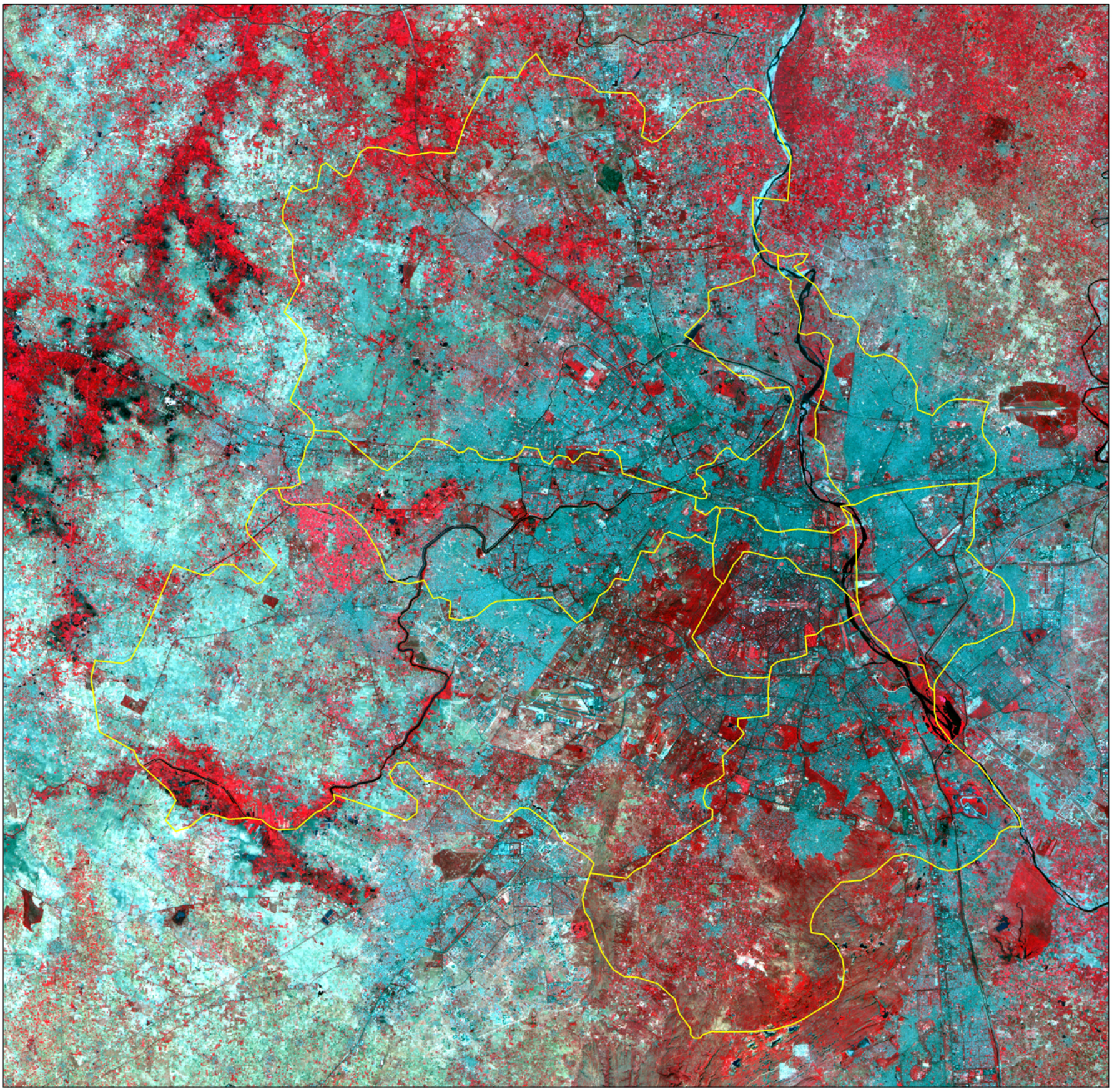
Data Source :
IRS P6 LISS III and LISS IV data
(Pre-monsoon and Post-monsoon Season 2006-07)

Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

Delhi



IRS P6 LISS-III post monsoon data (2006)

7.1.1 Wetland Distribution in North West

The total geographical area of the district is 440 Km^2. The total population of the district is 28, 47,395 (census 2001). Population density of the district is 6,472 persons per km^2.

The wetland area estimated is 500 ha, accounting for 1.14 per cent of geographic area. The wetland types found are Lakes/Ponds, Waterlogged area (Natural), Reservoirs/Barrages, Tanks/Ponds and River/Stream. Small wetlands, which are less than minimum mapable units (MMU), are 47 in the district. The dominant type of wetland found in the state are Tanks/ponds, River/Stream and Lakes/Ponds which account for around 38,, 34 and 12 percent of the total wetland area of the district respectively. Around 72 percent area of wetlands is under open water and 11 per cent having aquatic vegetation (floating and emergent type) during post-monsoon.

Details of the wetland statistics of the district is given in Table 6.

Table 6: Area estimates of wetlands in the North West

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	10	60	12.01	54	39
2	1102	Ox-bow lakes/ Cut-off meanders	-	-	-	-	-
3	1103	High altitude wetlands	-	-	-	-	-
4	1104	Riverine wetlands	-	-	-	-	-
5	1105	Waterlogged	4	48	9.61	35	34
6	1106	River/Stream	7	169	33.83	73	69
	1200	**Inland Wetlands -Man-made**					
7	1201	Reservoirs/Barrages	-	-	-	-	-
8	1202	Tanks/Ponds	132	189	37.84	186	171
9	1203	Waterlogged	8	10	2.00	10	10
10	1204	Salt pans	-	-	-	-	-
		Sub-Total	**161**	**476**	**95.30**	**358**	**323**
		Wetlands (<0.50 ha), mainly Tanks	47	24	4.70	-	-
		Total	**208**	**500**	**100.00**	**358**	**323**

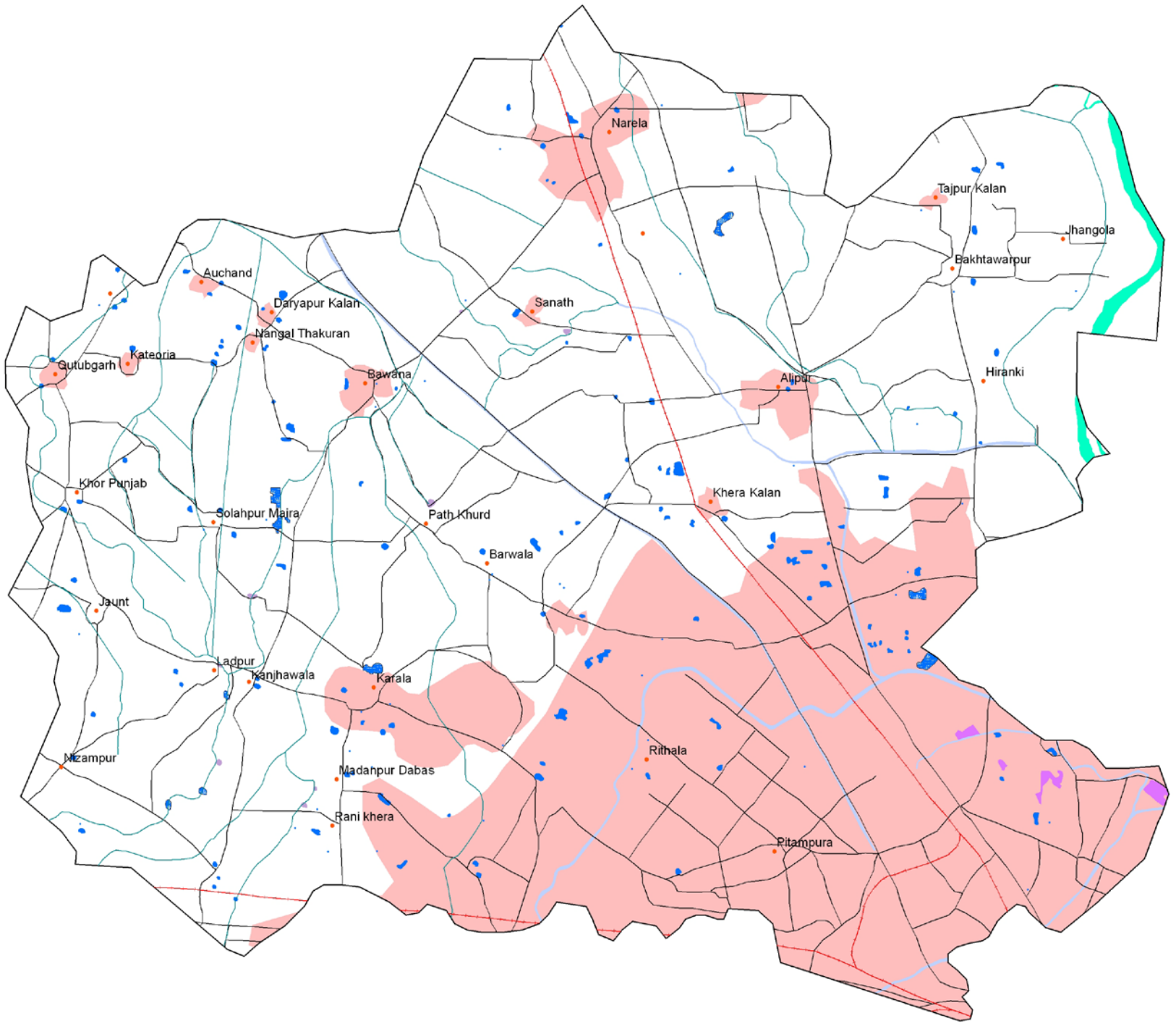
Area under Aquatic Vegetation	56	35

Area under turbidity levels		
Low	8	8
Moderate	235	210
High	115	105

State : Delhi

WETLAND MAP

District : North West

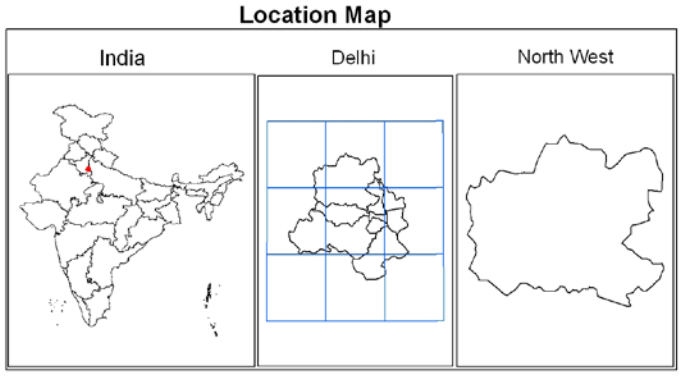


Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			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 (<0.50 ha)
- Settlements
- Drainage (line)
- Canal
- Roads
- Railways
- Town/Settlements
- District Boundary
- State Boundary
- International Boundary

Location Map



0 1 2 4 Kilometers

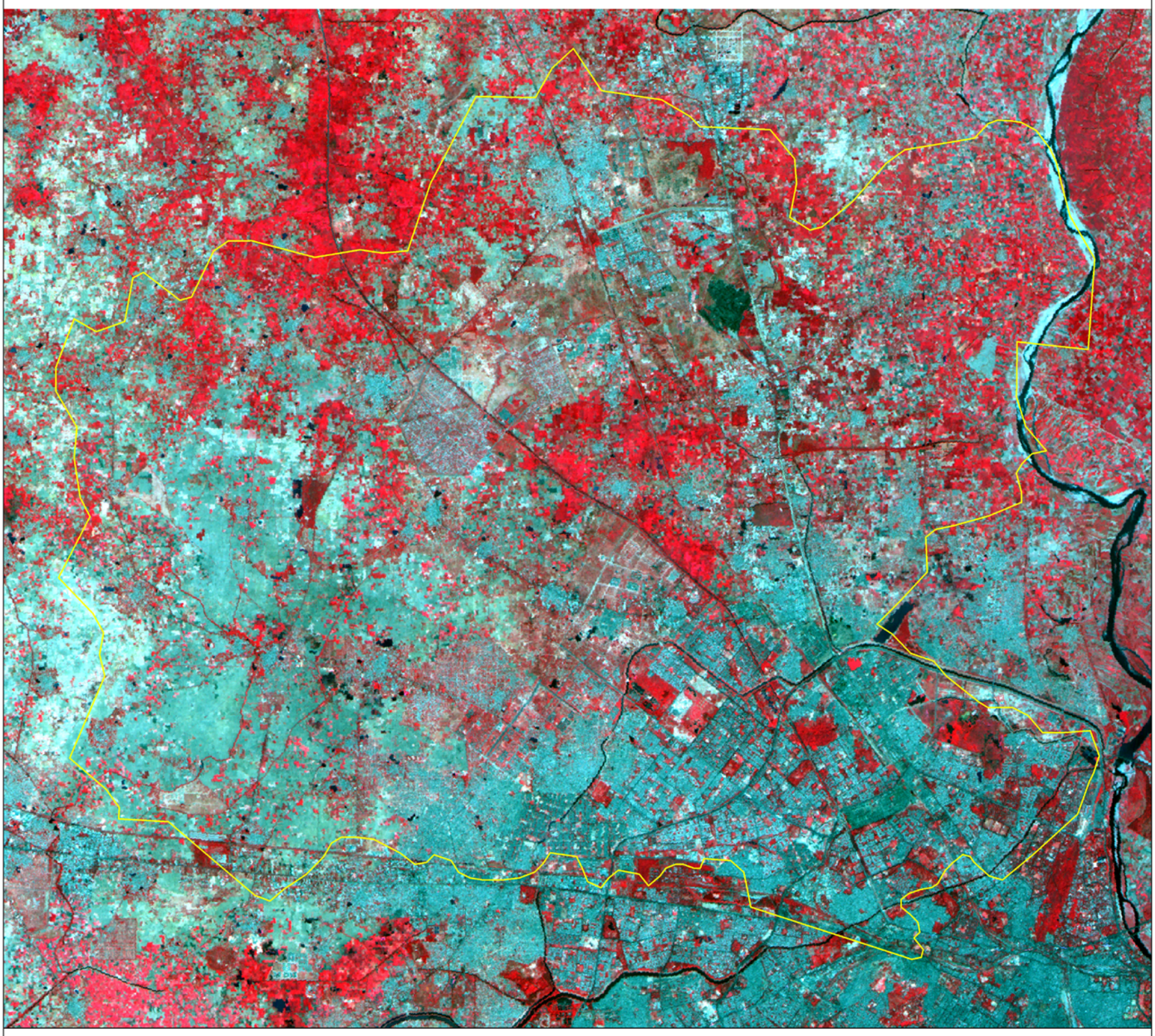
Data Source :
IRS P6 LISS III and LISS IV data
(Pre-monsoon and Post-monsoon Season 2006-07)

Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

North West



IRS P6 LISS-III post monsoon data (2006)

7.1.2 Wetland Distribution in North

North Delhi is bounded by the Yamuna River on the east, and is the northern-most part of the State. The total geographical area of the district is 60 Km^2. The total population of the district is 7,79,788 (census 2001). Population density of the district is 13,019 persons per $km^{2.}$ The total wetland area estimated is 448 ha. Details are given in table 7.

Table 7: Area estimates of wetlands in the North

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	1	30	6.70	30	21
2	1102	Ox-bow lakes/ Cut-off meanders	-	-	-	-	-
3	1103	High altitude wetlands	-	-	-	-	-
4	1104	Riverine wetlands	5	15	3.35	13	14
5	1105	Waterlogged	6	11	2.46	11	4
6	1106	River/Stream	8	372	83.13	293	293
	1200	**Inland Wetlands -Man-made**					
7	1201	Reservoirs/Barrages	-	-	-	-	-
8	1202	Tanks/Ponds	11	17	3.80	14	9
9	1203	Waterlogged	-	-	-	-	-
10	1204	Salt pans	-	-	-	-	-
		Sub-Total	**31**	**445**	**99.44**	**361**	**341**
		Wetlands (<0.50 ha), mainly Tanks	5	3	0.56	-	-
		Total	**36**	**448**	**100.00**	**361**	**341**

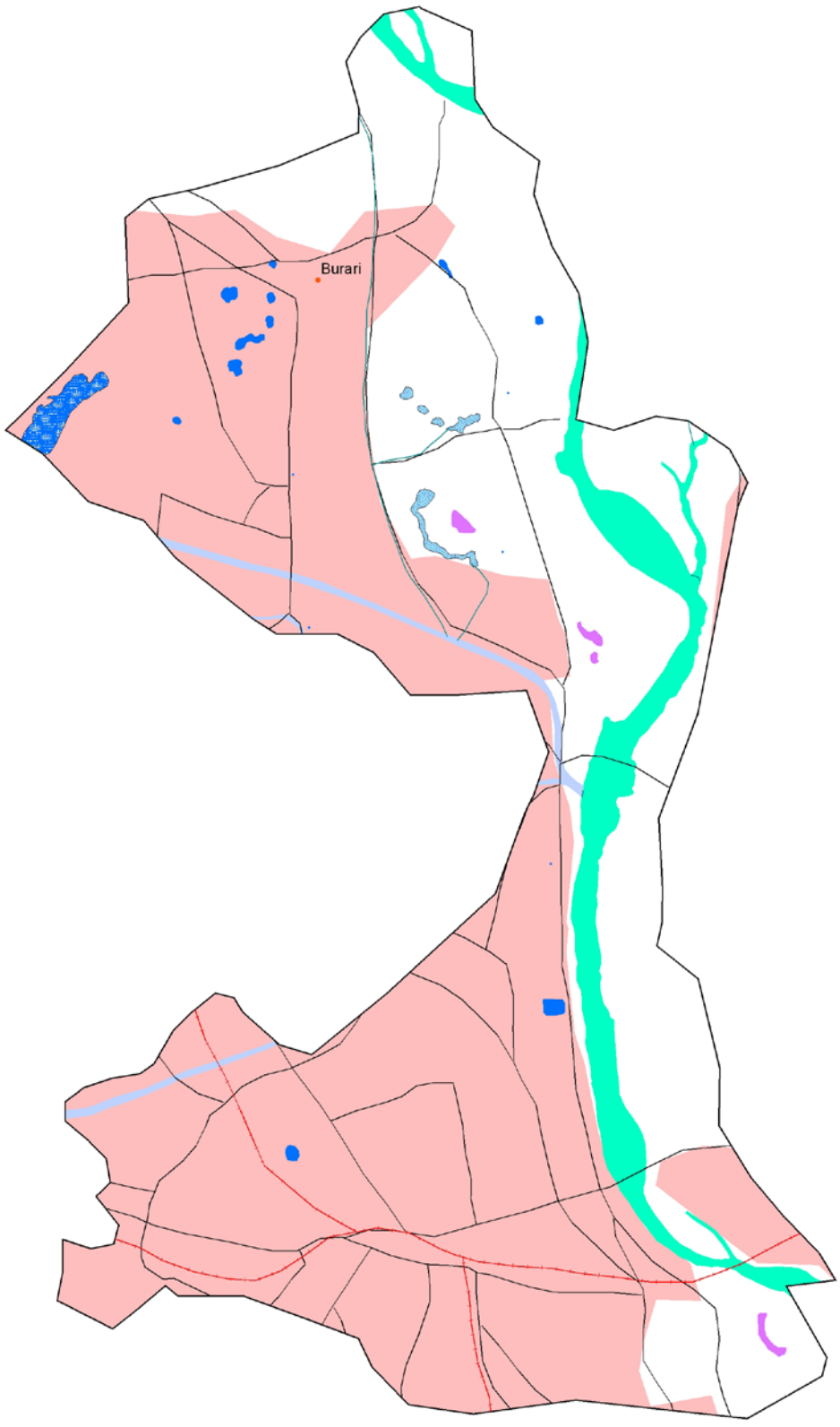
Area under Aquatic Vegetation	69	105

Area under turbidity levels		
Low	-	-
Moderate	351	338
High	10	3

State : Delhi

WETLAND MAP

District : North

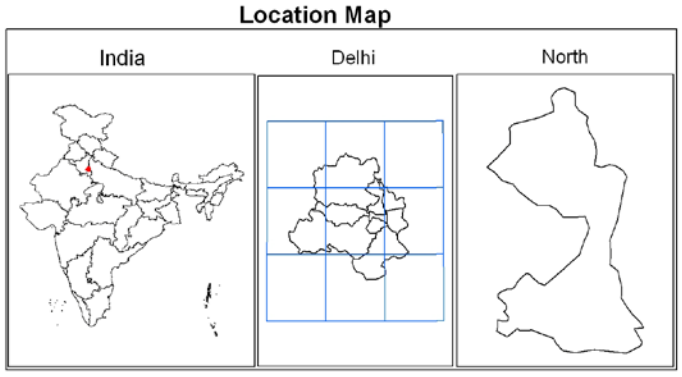


Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			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 (<0.50 ha)
- Settlements
- Drainage (line)
- Canal
- Roads
- Railways
- Town/Settlements
- District Boundary
- State Boundary
- International Boundary

Location Map



0 0.5 1 2 Kilometers

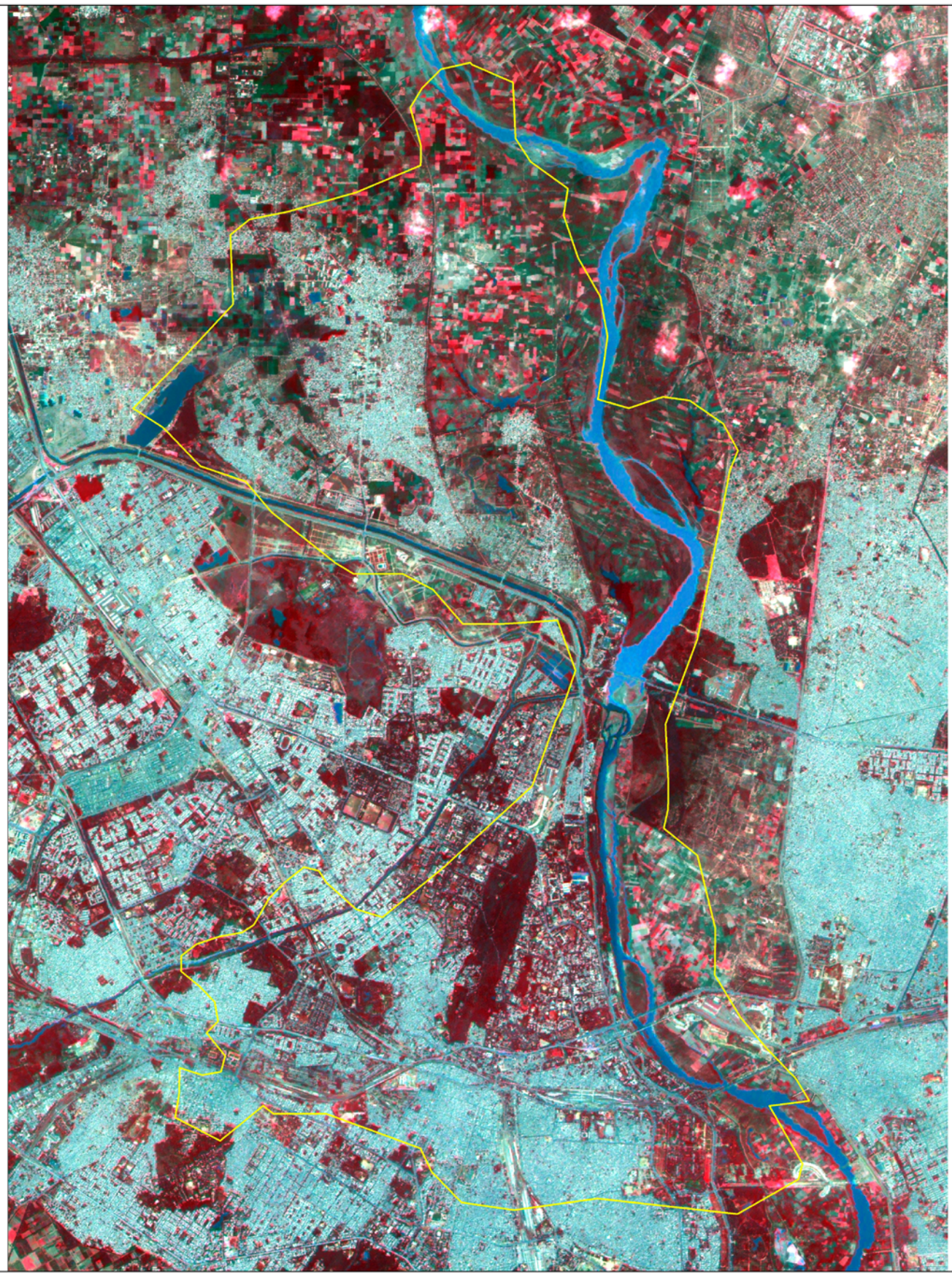
Data Source :
IRS P6 LISS III and LISS IV data
(Pre-monsoon and Post-monsoon Season 2006-07)

Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

North



IRS P6 LISS- IV post monsoon data (2007)

7.1.3 Wetland Distribution in North East

North East Delhi is bounded by the Yamuna River on the west and it shares a common boundary with Ghaziabad District of Uttar Pradesh state to the north. The total geographical area of the district is 60 Km^2. The total population of the district is 1,763,712 (census 2001). Population density of the district is 29,397 persons per km^2. The wetland area estimated is 139 ha. Details are given in table 8.

Table 8: Area estimates of wetlands in the North East

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	1	16	11.51	16	0
2	1102	Ox-bow lakes/ Cut-off meanders	-	-	-	-	-
3	1103	High altitude wetlands	-	-	-	-	-
4	1104	Riverine wetlands	-	-	-	-	-
5	1105	Waterlogged	-	-	-	-	-
6	1106	River/Stream	7	113	81.29	81	99
	1200	**Inland Wetlands -Man-made**					
7	1201	Reservoirs/Barrages	-	-	-	-	-
8	1202	Tanks/Ponds	8	6	4.32	6	5
9	1203	Waterlogged	-	-	-	-	-
10	1204	Salt pans	-	-	-	-	-
		Sub-Total	**16**	**135**	**97.12**	**103**	**104**
		Wetlands (<0.50 ha), mainly Tanks	8	4	2.88	-	-
		Total	**24**	**139**	**100.00**	**103**	**104**

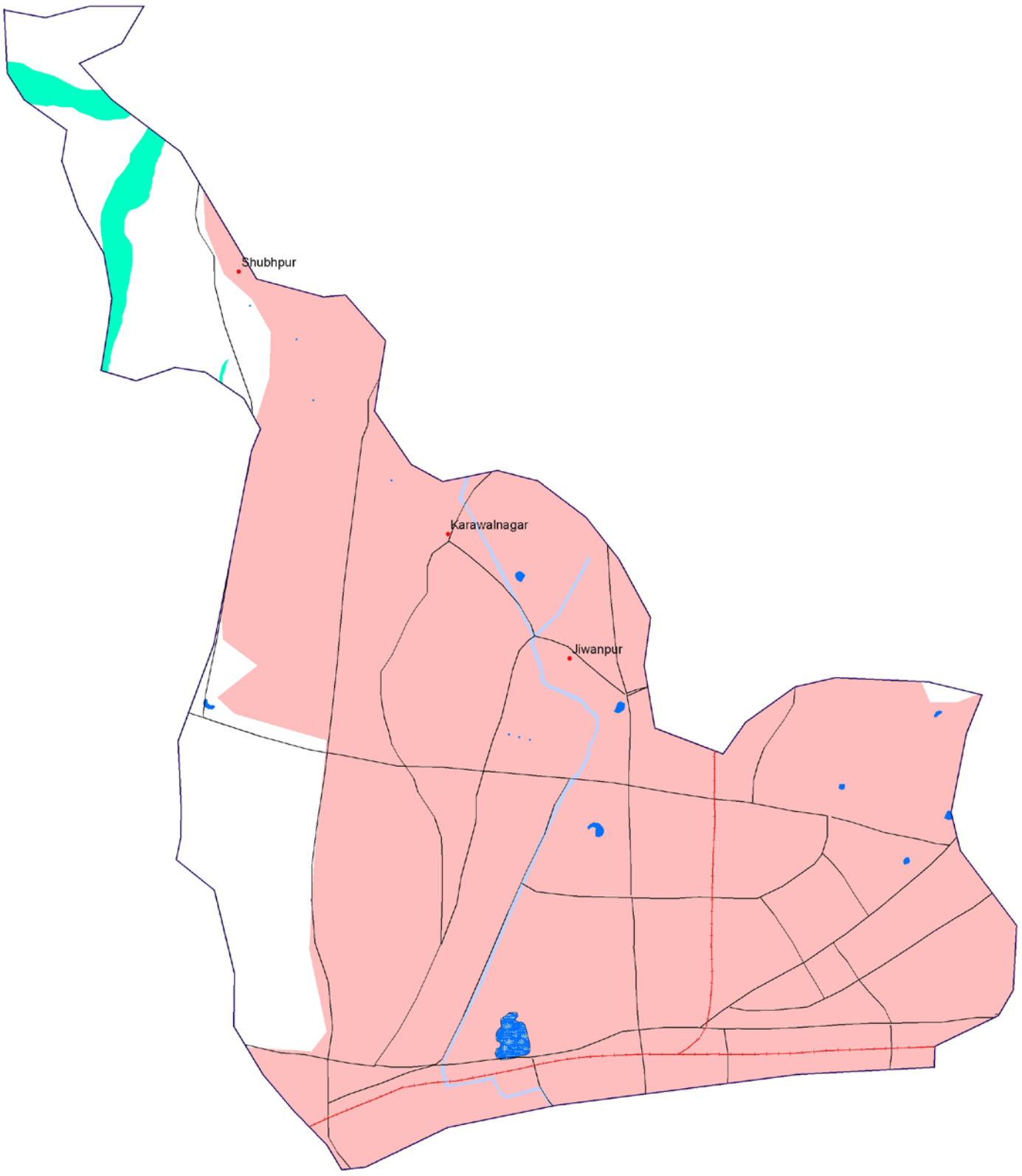
Area under Aquatic Vegetation	14	29

Area under turbidity levels		
Low	16	-
Moderate	85	102
High	2	2

State : Delhi

WETLAND MAP

District : North East

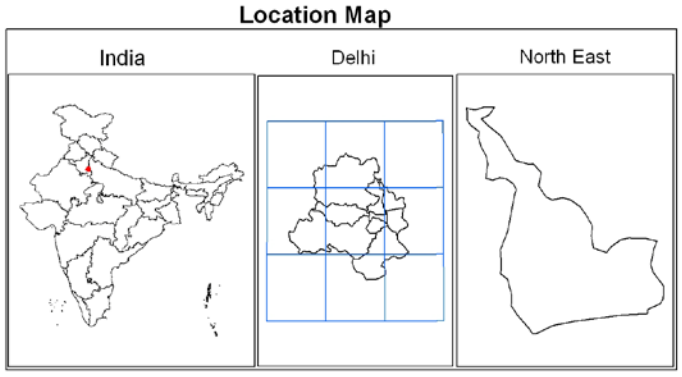


Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			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 (<0.50 ha)
- Settlements
- Drainage (line)
- Canal
- Roads
- Railways
- Town/Settlements
- District Boundary
- State Boundary
- International Boundary

Location Map



0 0.5 1 2 Kilometers

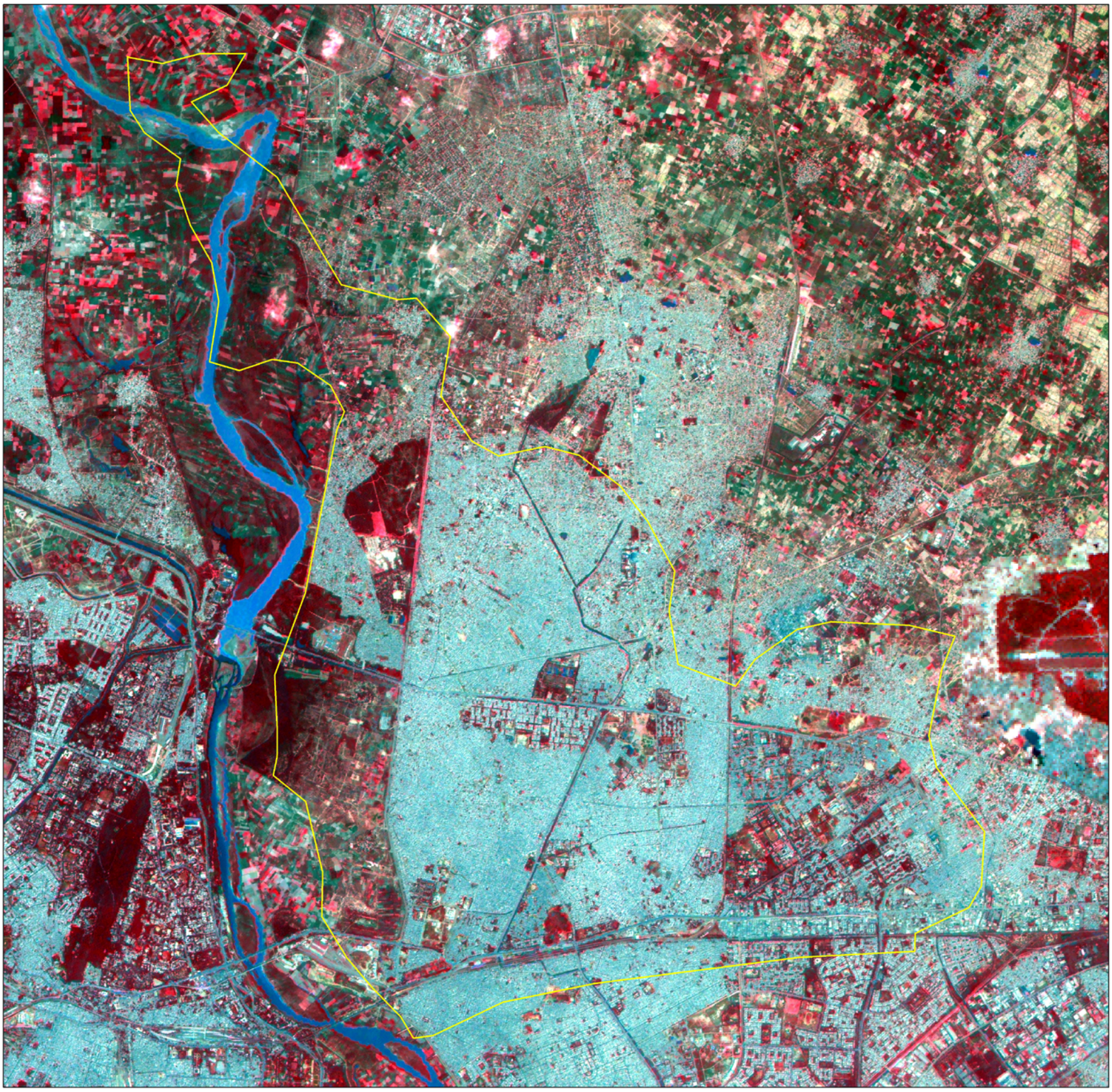
Data Source :
IRS P6 LISS III and LISS IV data
(Pre-monsoon and Post-monsoon Season 2006-07)

Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

North East



IRS P6 LISS- IV post monsoon data (2007)

7.1.4 Wetland Distribution in East

East Delhi is bounded by the Yamuna River on the west, Ghaziabad District of Uttar Pradesh state to the east and Gautam Buddha Nagar District of Uttar Pradesh to the southeast.The total geographical area of the district is 64 Km^2. The total population of the district is 4,48,770 (census 2001). Population density of the district is 22,638 persons per km^2. The wetland area estimated is 165 ha. Details are given in table 9.

Table 9: Area estimates of wetlands in the East

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	1102	Ox-bow lakes/ Cut-off meanders	-	-	-	-	-
3	1103	High altitude wetlands	-	-	-	-	-
4	1104	Riverine wetlands	-	-	-	-	-
5	1105	Waterlogged	-	-	-	-	-
6	1106	River/Stream	5	79	48.02	67	67
	1200	**Inland Wetlands -Man-made**					
7	1201	Reservoirs/Barrages	1	4	2.43	4	4
8	1202	Tanks/Ponds	8	13	7.90	13	8
9	1203	Waterlogged	2	68	41.34	17	-
10	1204	Salt pans	-	-	-	-	-
		Sub-Total	**16**	**164**	**99.70**	**101**	**79**
		Wetlands (<0.50 ha), mainly Tanks	1	1	0.30	-	-
		Total	**17**	**165**	**100.00**	**101**	**79**

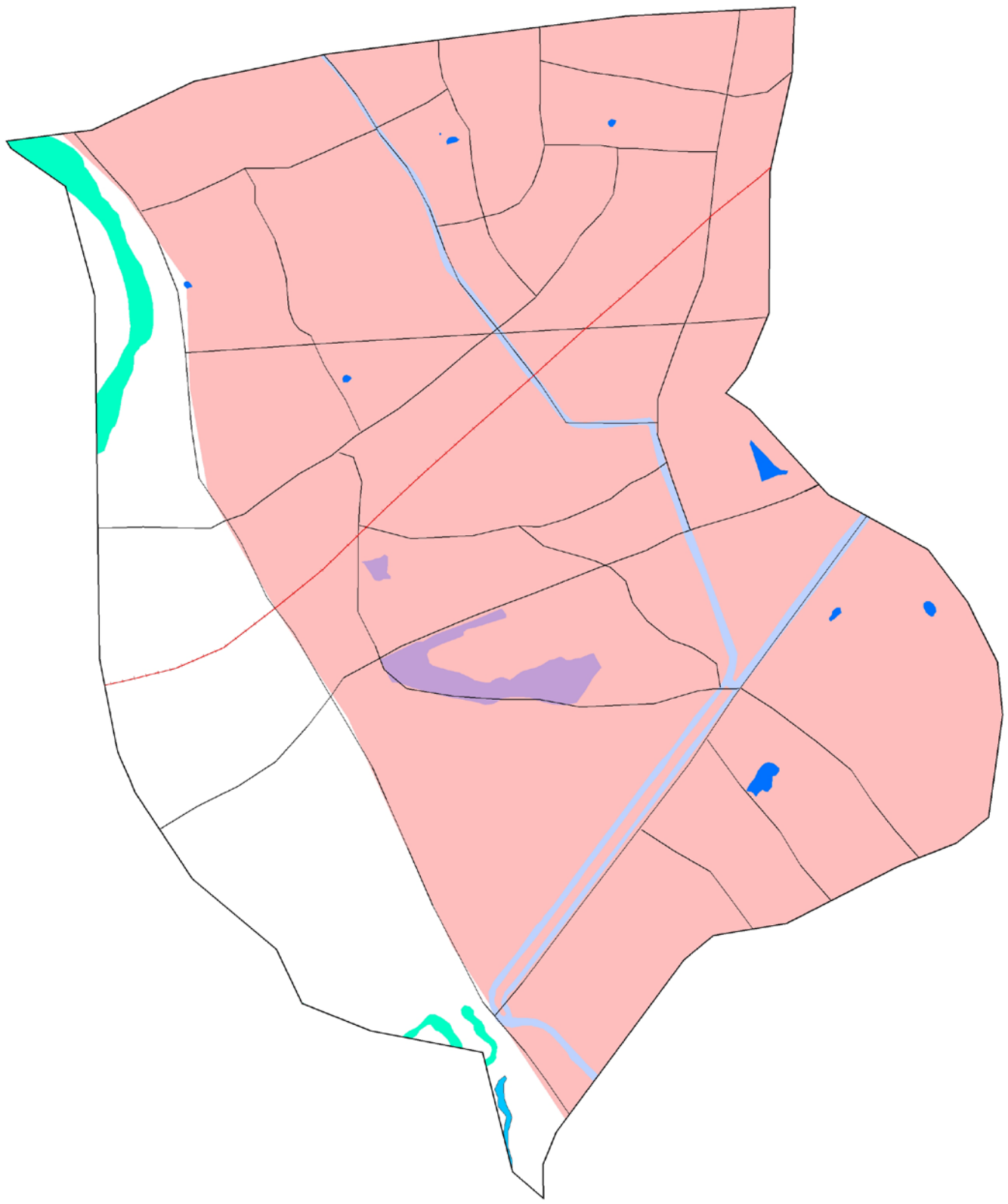
Area under Aquatic Vegetation	76	84

Area under turbidity levels		
Low	-	-
Moderate	100	78
High	1	1

State : Delhi

WETLAND MAP

District : East

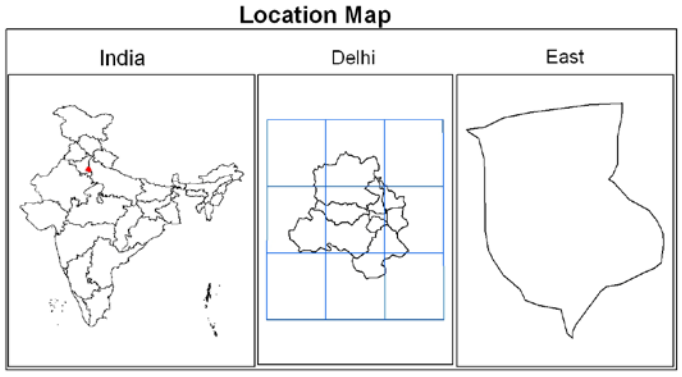


Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			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 (<0.50 ha)
- Settlements
- Drainage (line)
- Canal
- Roads
- Railways
- Town/Settlements
- District Boundary
- State Boundary
- International Boundary

Location Map



0 0.5 1 2 Kilometers

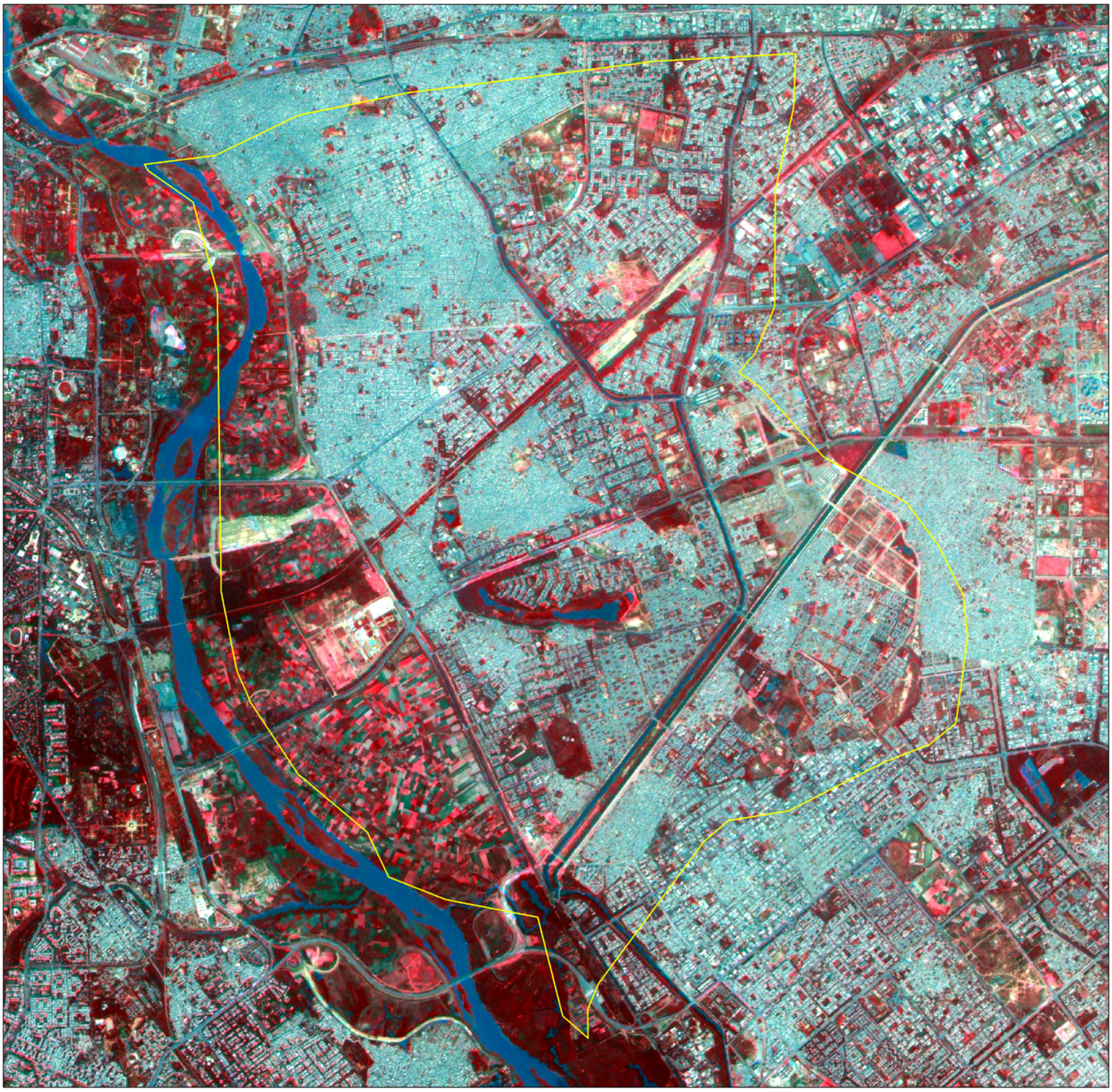
Data Source :
IRS P6 LISS III and LISS IV data
(Pre-monsoon and Post-monsoon Season 2006-07)

Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

East



IRS P6 LISS- IV post monsoon data (2007)

7.1.5 Wetland Distribution in New Delhi

New Delhi lies in the central part of the state. The total geographical area of the district is 1,483 Km^2. The total population of the district is 13,782,976 (census 2001). Population density of the district is 9,294 persons per km^2. The wetland area estimated is 38 ha.

Table 10: Area estimates of wetlands in the New Delhi

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	1102	Ox-bow lakes/ Cut-off meanders	-	-	-	-	-
3	1103	High altitude wetlands	-	-	-	-	-
4	1104	Riverine wetlands	-	-	-	-	-
5	1105	Waterlogged	-	-	-	-	-
6	1106	River/Stream	1	32	84.21	32	32
	1200	**Inland Wetlands -Man-made**					
7	1201	Reservoirs/Barrages	-	-	-	-	-
8	1202	Tanks/Ponds	3	5	13.16	2	5
9	1203	Waterlogged	-	-	-	-	-
10	1204	Salt pans	-	-	-	-	-
		Sub-Total	**4**	**37**	**97.37**	**34**	**37**
		Wetlands (<0.50 ha), mainly Tanks	2	1	2.63	-	-
		Total	**6**	**38**	**100.00**	**34**	**37**

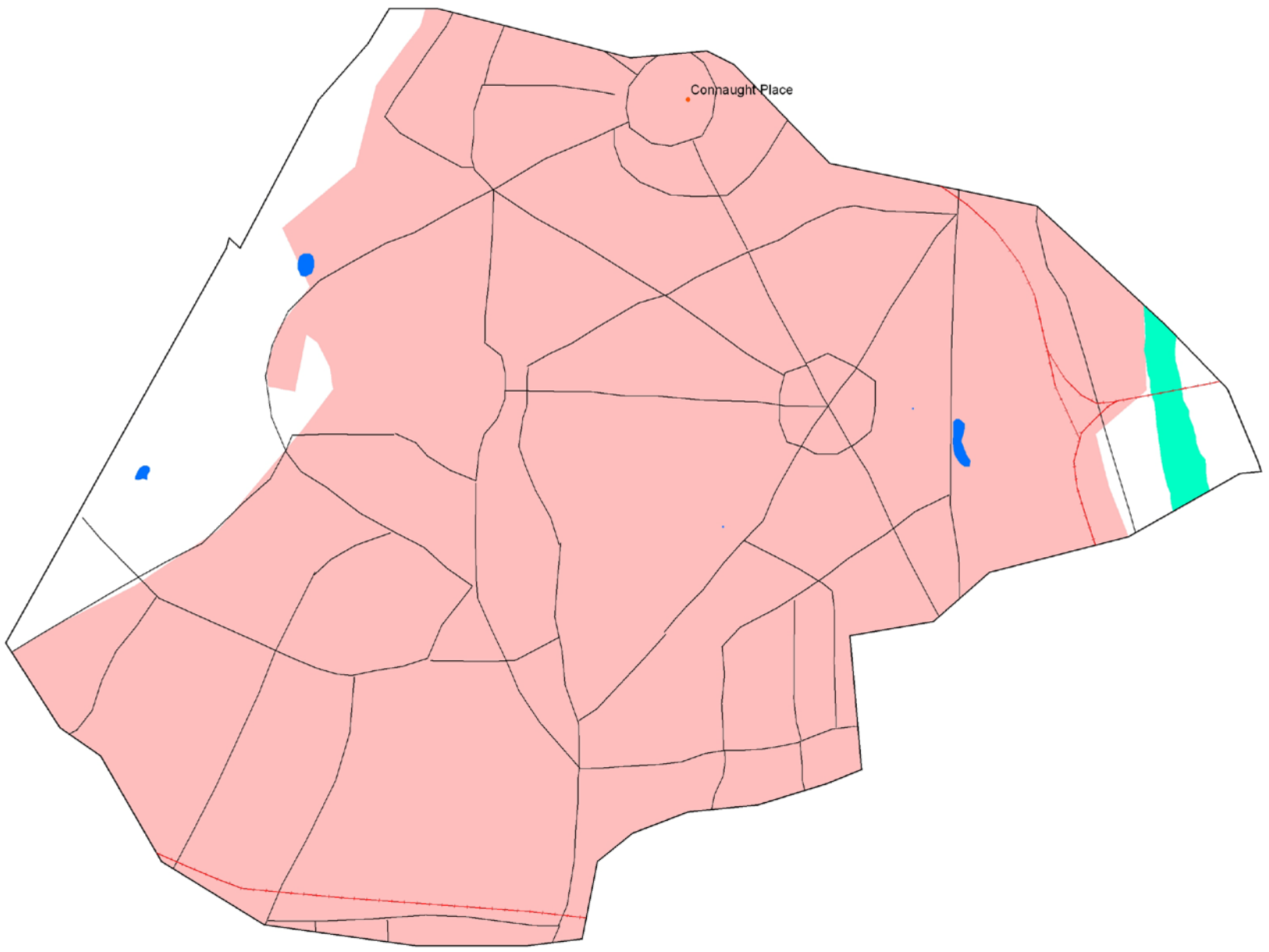
Area under Aquatic Vegetation	-	-

Area under turbidity levels		
Low	-	-
Moderate	32	33
High	2	4

State : Delhi

WETLAND MAP

District : New Delhi

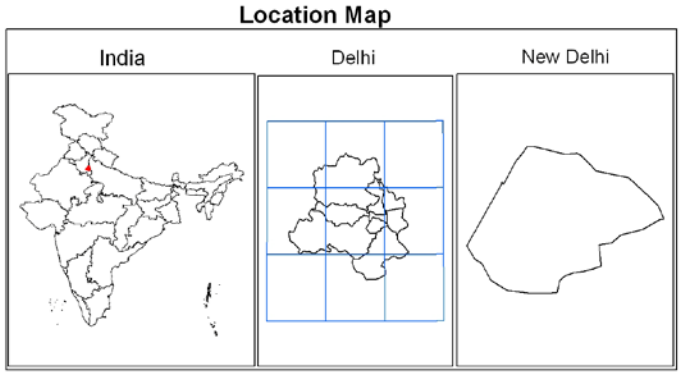


Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			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 (<0.50 ha)
- Settlements
- Drainage (line)
- Canal
- Roads
- Railways
- Town/Settlements
- District Boundary
- State Boundary
- International Boundary

Location Map



0 0.5 1 2 Kilometers

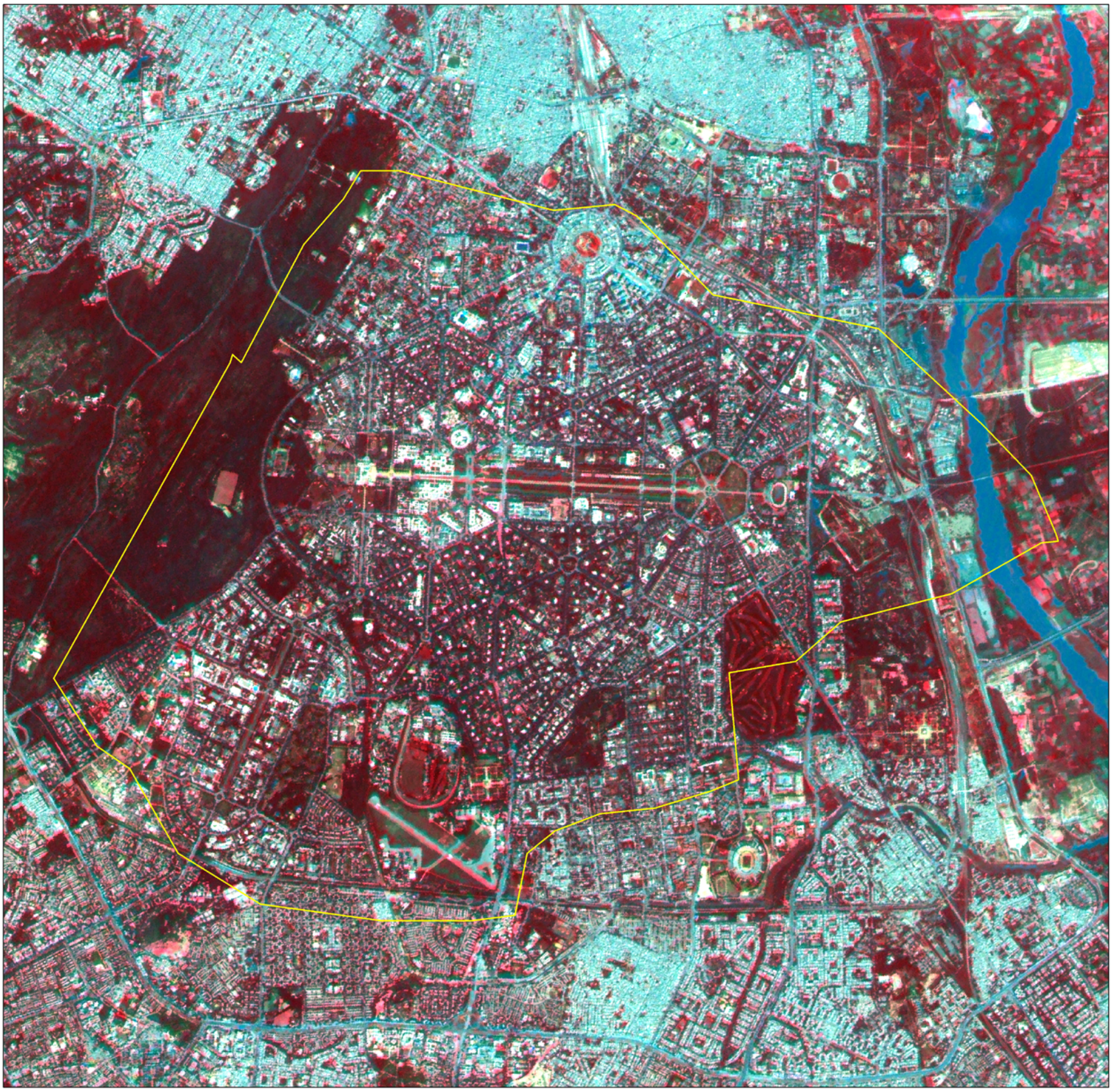
Data Source :
IRS P6 LISS III and LISS IV data
(Pre-monsoon and Post-monsoon Season 2006-07)

Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

New Delhi



IRS P6 LISS- IV post monsoon data (2006)

7.1.6 Wetland Distribution in Central

It is bounded by the Yamuna River on the east, and by the districts of North Delhi to the north, West Delhi and South West Delhi to the west, New Delhi to the south, and East Delhi to the east across the Yamuna.The total geographical area of the district is 60 Km^2. The total population of the district is 7,79,788 (census 2001). Population density of the district is 13,019 persons per km^2. The wetland area estimated is 112 ha. Details are given in table 11.

Table 11: Area estimates of wetlands in the Central

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	1102	Ox-bow lakes/ Cut-off meanders	-	-	-	-	-
3	1103	High altitude wetlands	-	-	-	-	-
4	1104	Riverine wetlands	-	-	-	-	-
5	1105	Waterlogged	-	-	-	-	-
6	1106	River/Stream	4	94	83.93	74	74
	1200	**Inland Wetlands -Man-made**					
7	1201	Reservoirs/Barrages	-	-	-	-	-
8	1202	Tanks/Ponds	5	10	8.93	8	10
9	1203	Waterlogged	1	8	7.14	2	8
10	1204	Salt pans	-	-	-	-	-
		Sub-Total	**10**	**112**	**100.00**	**84**	**92**
		Wetlands (<0.50 ha), mainly Tanks	-	-	-	-	-
		Total	**10**	**112**	**100.00**	**84**	**92**

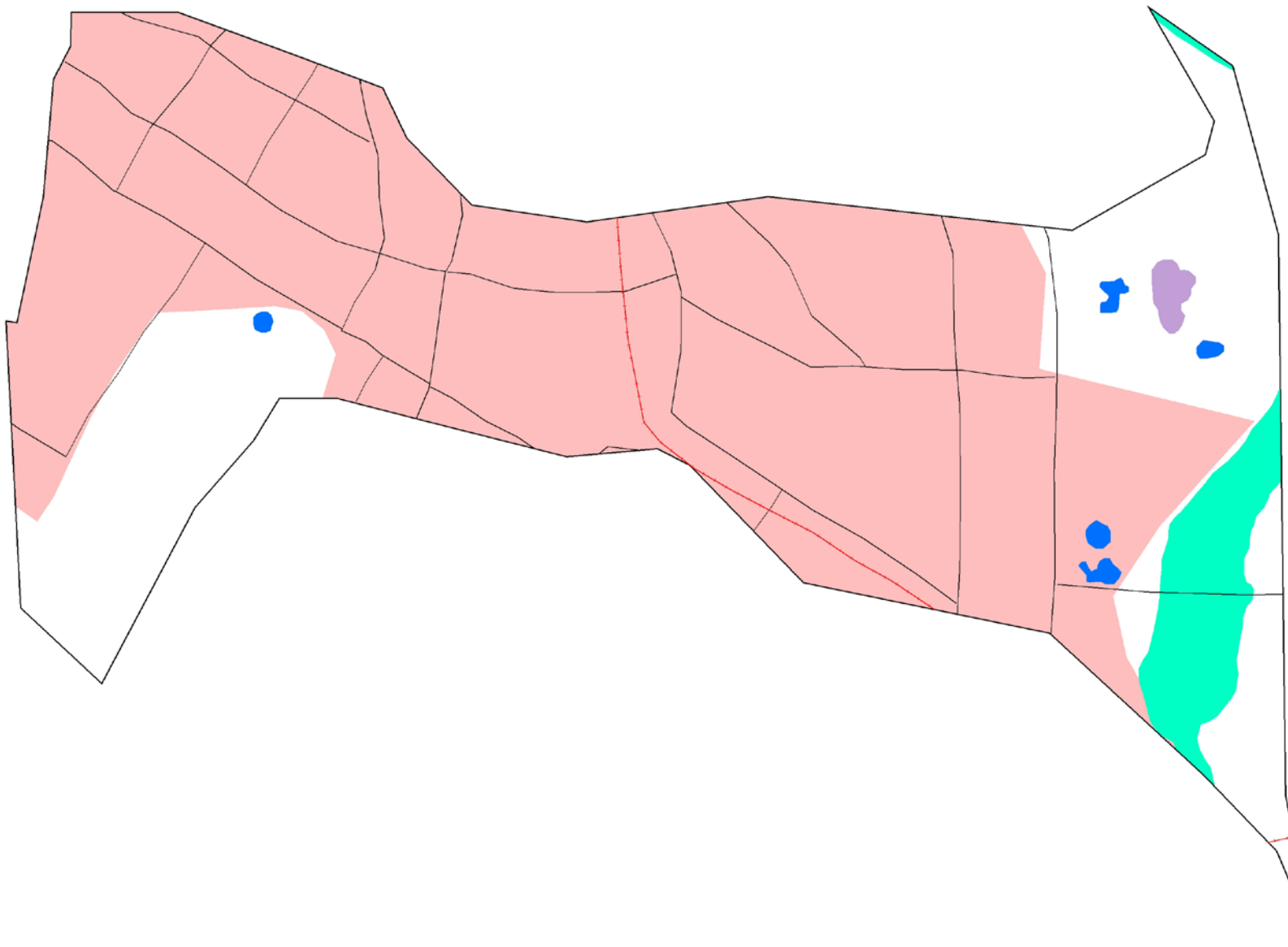
Area under Aquatic Vegetation	27	19

Area under turbidity levels		
Low	-	-
Moderate	77	82
High	7	10

State : Delhi

WETLAND MAP

District : Central

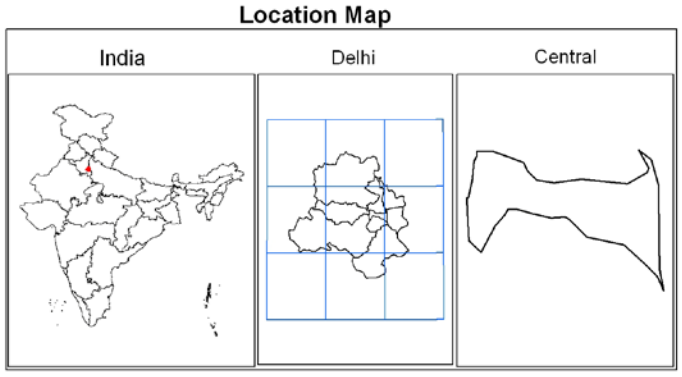


Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			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 (<0.50 ha)
- Settlements
- Drainage (line)
- Canal
- Roads
- Railways
- Town/Settlements
- District Boundary
- State Boundary
- International Boundary

Location Map



0 0.5 1 2 Kilometers

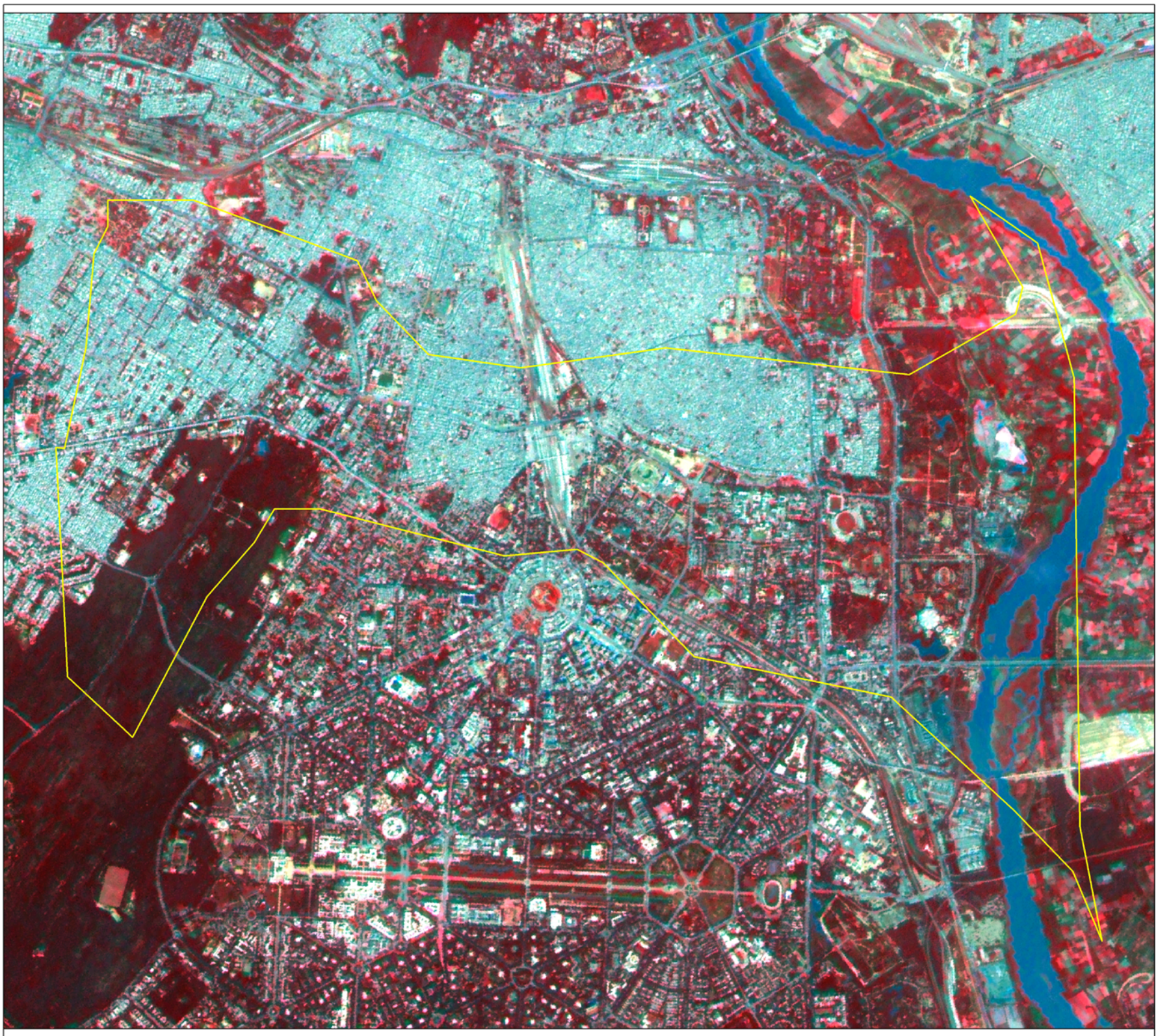
Data Source :
IRS P6 LISS III and LISS IV data
(Pre-monsoon and Post-monsoon Season 2006-07)

Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

Central



IRS P6 LISS - IV post monsoon data (2007)

7.1.7 Wetland Distribution in West

West Delhi is bound by the districts of North West Delhi to the north, North Delhi and Central Delhi to the east, South West Delhi to the south, and Jhajjar District of Haryana state to the west. The total geographical area of the district is 129 Km^2. The total population of the district is 2,119,641 (census 2001). Population density of the district is 16,431 persons per km^2. The wetland area estimated is 79 ha. Details are given in table 12.

Table 12: Area estimates of wetlands in the West

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	1102	Ox-bow lakes/ Cut-off meanders	-	-	-	-	-
3	1103	High altitude wetlands	-	-	-	-	-
4	1104	Riverine wetlands	-	-	-	-	-
5	1105	Waterlogged	2	27	34.18	8	27
6	1106	River/Stream	-	-	-	-	-
	1200	**Inland Wetlands -Man-made**					
7	1201	Reservoirs/Barrages	-	-	-	-	-
8	1202	Tanks/Ponds	27	42	53.16	42	30
9	1203	Waterlogged	3	5	6.33	5	5
10	1204	Salt pans	-	-	-	-	-
		Sub-Total	**32**	**74**	**93.67**	**55**	**62**
		Wetlands (<0.50 ha), mainly Tanks	10	5	6.33	-	-
		Total	**42**	**79**	**100.00**	**55**	**62**

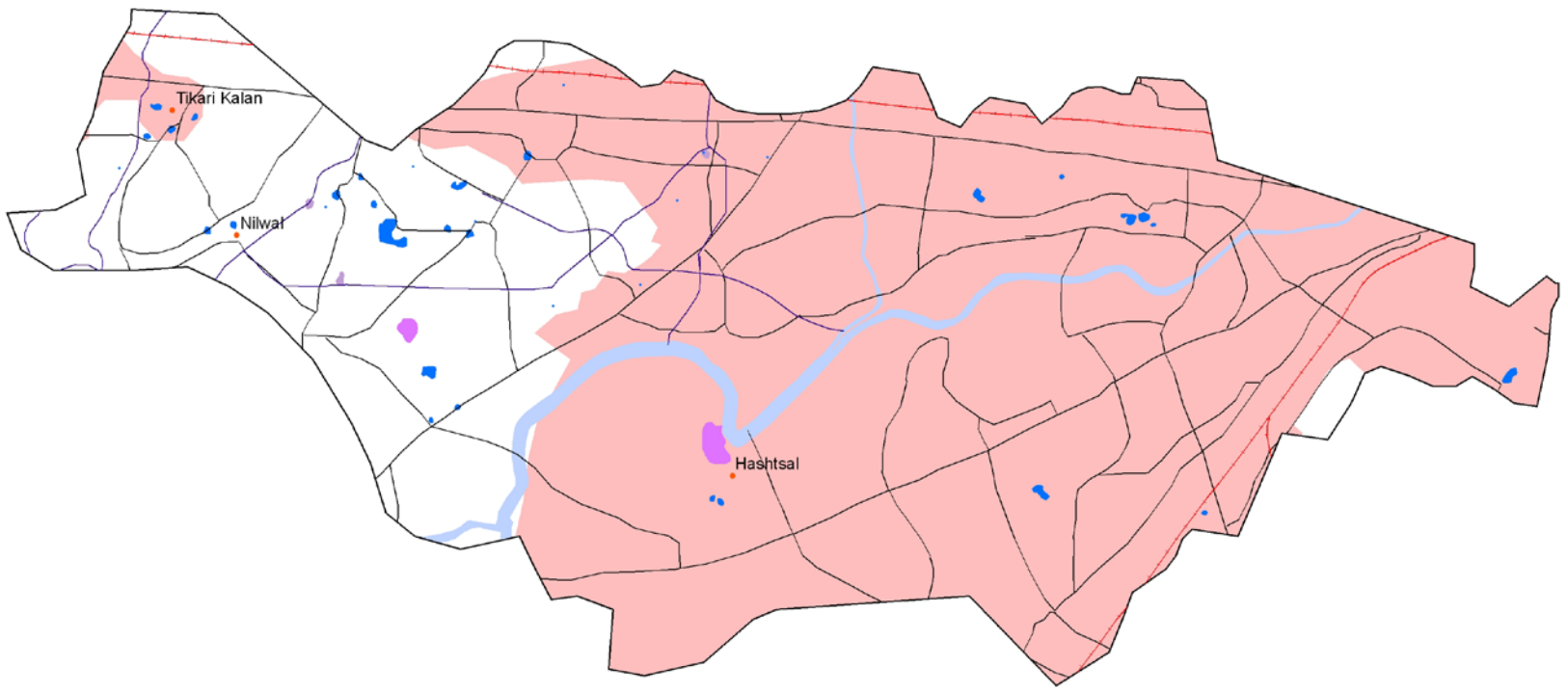
Area under Aquatic Vegetation	19	12

Area under turbidity levels		
Low	-	-
Moderate	31	40
High	24	22

State : Delhi

WETLAND MAP

District : West

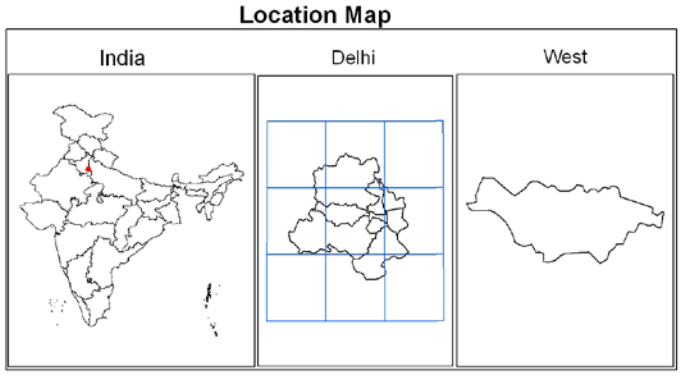


Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			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 (<0.50 ha)
- Settlements
- Drainage (line)
- Canal
- Roads
- Railways
- Town/Settlements
- District Boundary
- State Boundary
- International Boundary

Location Map



0 1 2 4 Kilometers

Data Source :
IRS P6 LISS III and LISS IV 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 : Delhi

West

IRS P6 LISS-III post monsoon data (2006)

7.1.8 Wetland Distribution in South West

South West Delhi is bounded by the districts of West Delhi to the north, Central Delhi to the northeast, New Delhi and South Delhi to the east, Gurgaon District of Haryana state to the south, and Jhajjar District of Haryana to the west. The total geographical area of the district is 420 Km^2. The total population of the district is 1,749,492 (census 2001). Population density of the district is 4,166 persons per km^2. The wetland area estimated is 154 ha. Details are given in table 13.

Table 13: Area estimates of wetlands in the South West

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	1102	Ox-bow lakes/ Cut-off meanders	-	-	-	-	-
3	1103	High altitude wetlands	-	-	-	-	-
4	1104	Riverine wetlands	-	-	-	-	-
5	1105	Waterlogged	-	-	-	-	-
6	1106	River/Stream	-	-	-	-	-
	1200	**Inland Wetlands -Man-made**					
7	1201	Reservoirs/Barrages	-	-	-	-	-
8	1202	Tanks/Ponds	106	123	79.87	113	119
9	1203	Waterlogged	2	9	5.84	9	9
10	1204	Salt pans	-	-	-	-	-
		Sub-Total	**108**	**132**	**85.71**	**122**	**128**
		Wetlands (<0.50 ha), mainly Tanks	44	22	14.29	-	-
		Total	**152**	**154**	**100.00**	**122**	**128**

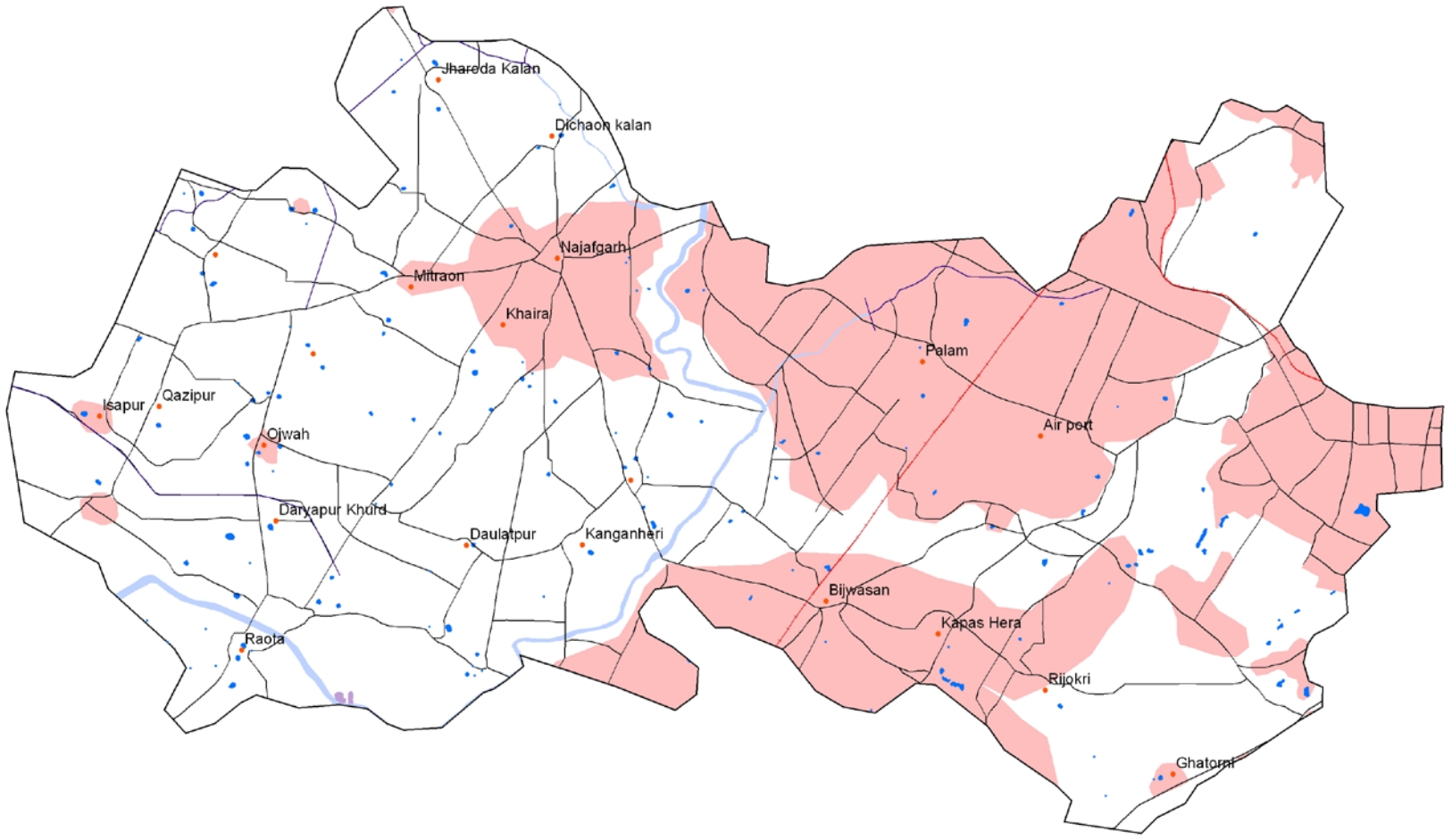
Area under Aquatic Vegetation	51	3

Area under turbidity levels		
Low	-	-
Moderate	64	68
High	58	60

State : Delhi

WETLAND MAP

District : South West

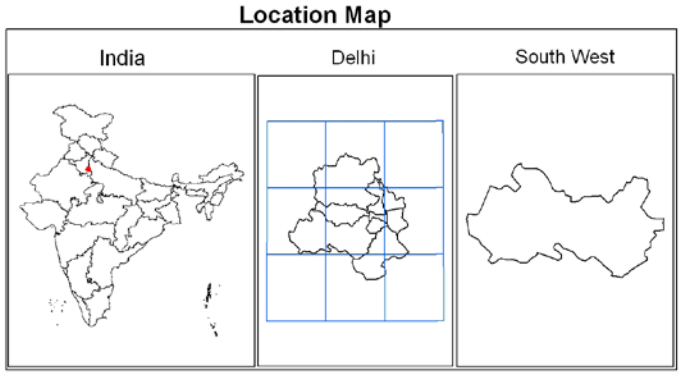


Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			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 (<0.50 ha)
- Settlements
- Drainage (line)
- Canal
- Roads
- Railways
- Town/Settlements
- District Boundary
- State Boundary
- International Boundary

Location Map



0 1 2 4 Kilometers

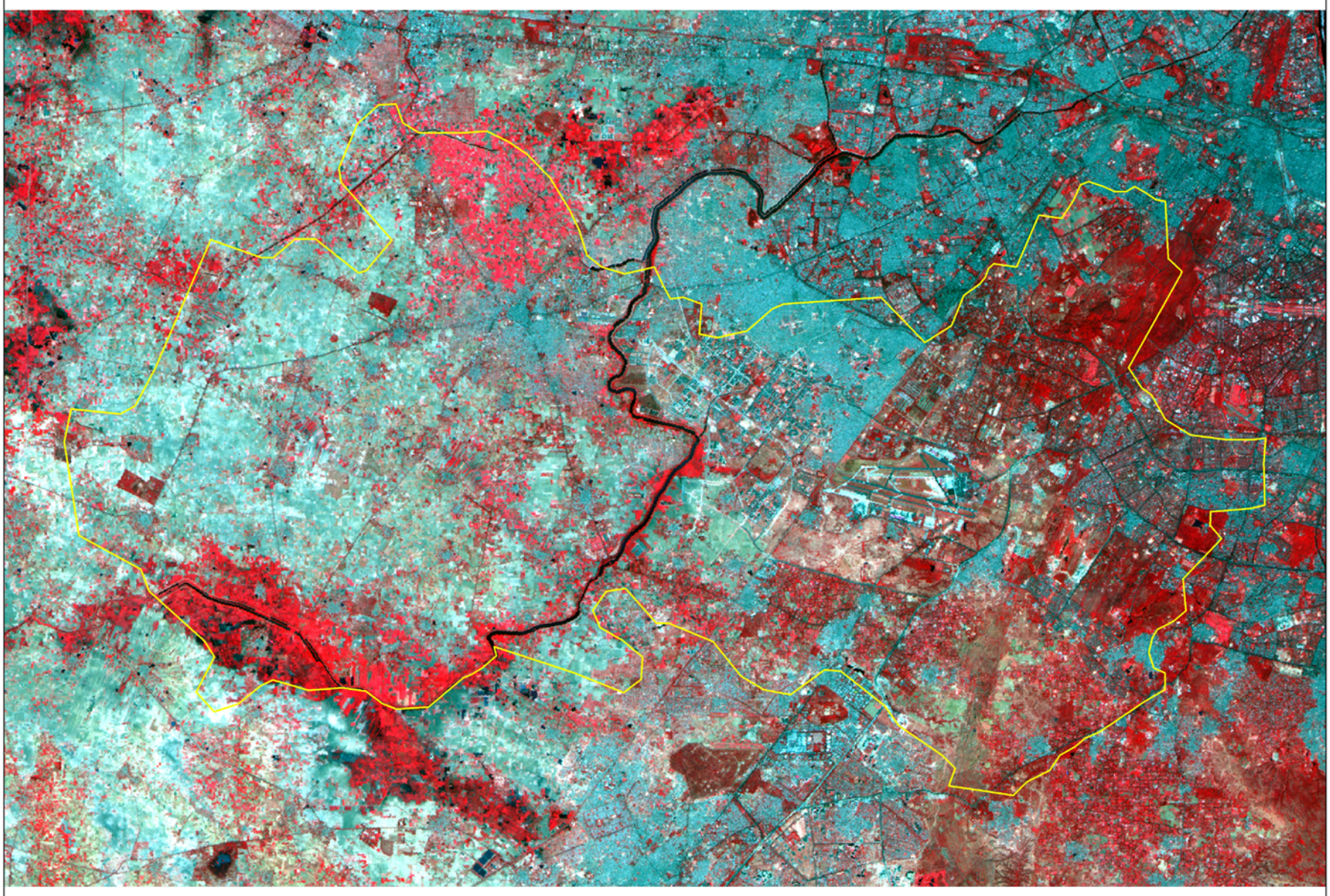
Data Source :
IRS P6 LISS III and LISS IV data
(Pre-monsoon and Post-monsoon Season 2006-07)

Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

South West



IRS P6 LISS-III post monsoon data (2006)

7.1.9 Wetland Distribution in South

It is bounded by the Yamuna River to the east, and by the districts of New Delhi to the north, East Delhi to the northeast across the Yamuna, Gautam Buddha Nagar District of Uttar Pradesh state to the east across the Yamuna, Faridabad District of Haryana state to the southeast, Gurgaon District of Haryana to the southwest, and South West Delhi to the west. The total geographical area of the district is 250 Km^2. The total population of the district is 2,258,367 (census 2001). Population density of the district is 9,034 persons per km^2. The wetland area estimated is 923 ha with major part of Okhla Barrage in it. Details are given in table 14.

Table 14: Area estimates of wetlands in the South

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	1102	Ox-bow lakes/ Cut-off meanders	-	-	-	-	-
3	1103	High altitude wetlands	-	-	-	-	-
4	1104	Riverine wetlands	-	-	-	-	-
5	1105	Waterlogged	-	-	-	-	-
6	1106	River/Stream	9	257	27.86	206	211
	1200	**Inland Wetlands -Man-made**					
7	1201	Reservoirs/Barrages	8	226	24.50	120	149
8	1202	Tanks/Ponds	52	61	6.61	57	61
9	1203	Waterlogged	13	371	40.22	42	113
10	1204	Salt pans	-	-	-	-	-
		Sub-Total	**82**	**915**	**99.19**	**425**	**534**
		Wetlands (<0.50 ha), mainly Tanks	15	8	0.81	-	-
		Total	**97**	**923**	**100.00**	**425**	**534**

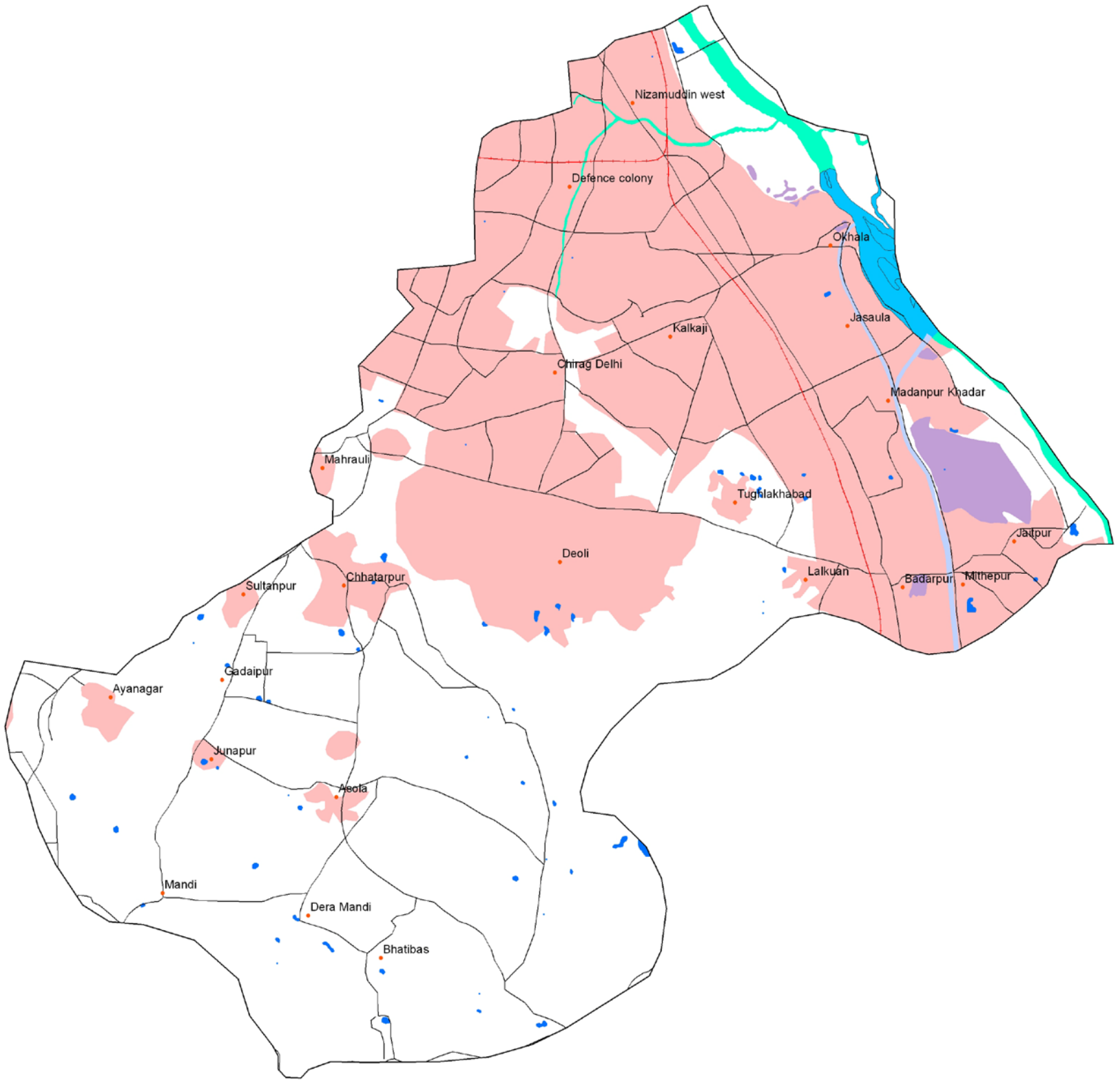
Area under Aquatic Vegetation	402	454

Area under turbidity levels		
Low	-	-
Moderate	398	504
High	27	30

State : Delhi

WETLAND MAP

District : South

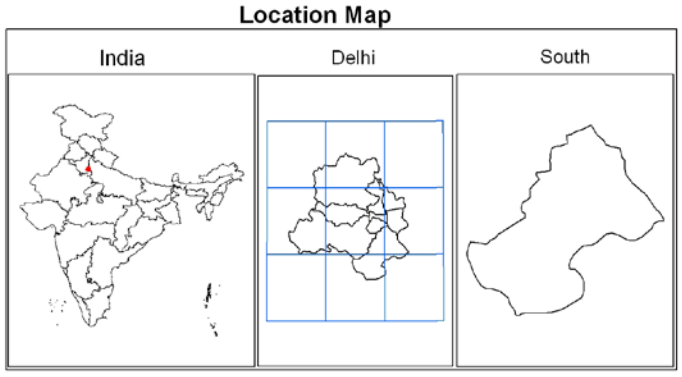


Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			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 (<0.50 ha)
- Settlements
- Drainage (line)
- Canal
- Roads
- Railways
- Town/Settlements
- District Boundary
- State Boundary
- International Boundary

Location Map



0 1.5 3 6 Kilometers

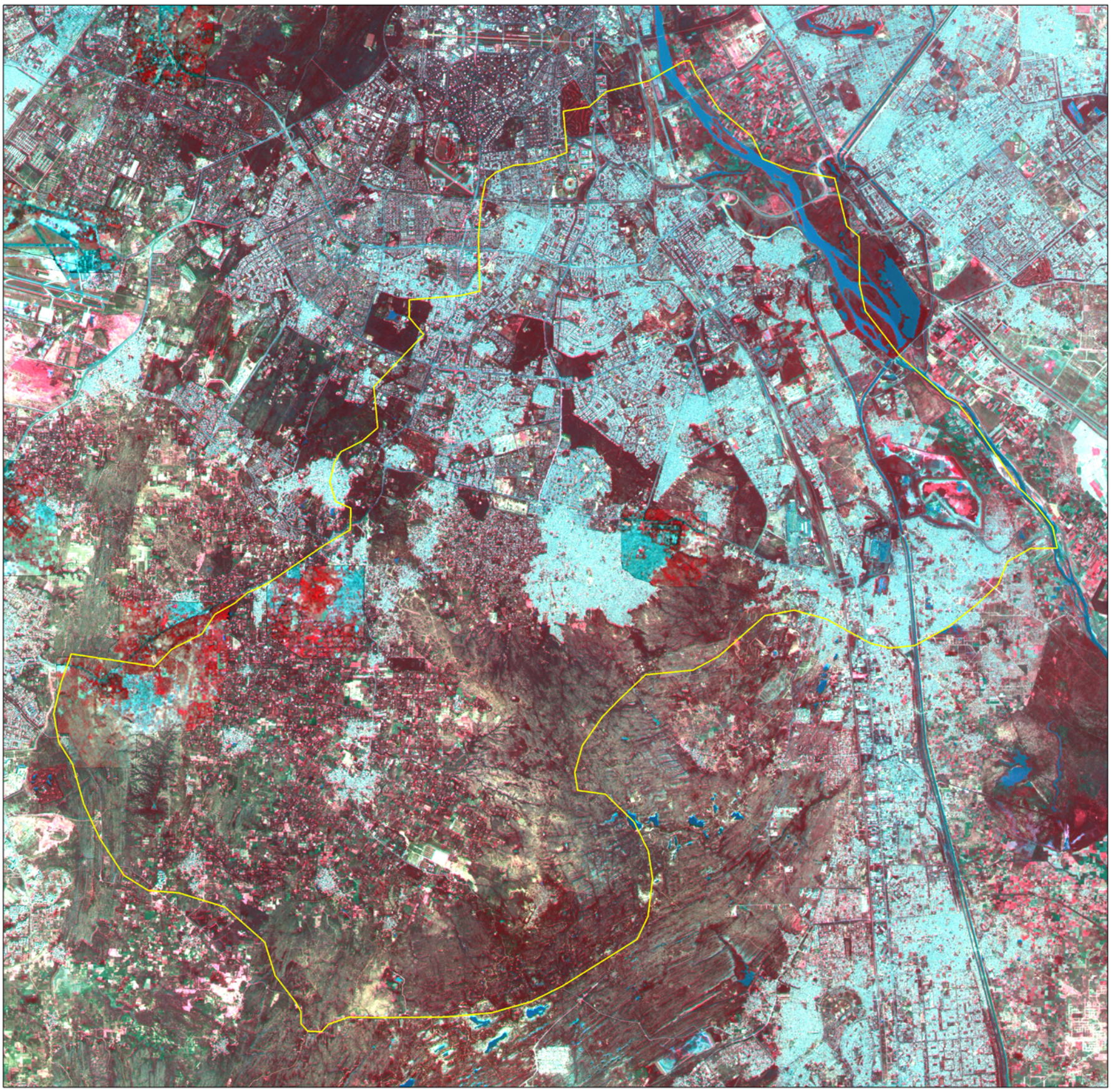
Data Source :
IRS P6 LISS III and LISS IV data
(Pre-monsoon and Post-monsoon Season 2006-07)

Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

South



IRS P6 LISS- IV post monsoon data (2007)

MAJOR WETLAND TYPES

8.0 MAJOR WETLAND TYPES OF DELHI

Major wetland types observed in the state are Reservoir, Waterlogged, and Tanks/Ponds. Details are given in Plate-1. Ground truth data was collected for selected wetland sites. The standard Performa was used to record the field data. Field photographs are also taken to record the water quality (subjective), status of aquatic vegetation and water spread. The location of the features was recorded using GPS. Field photographs of different wetland types are shown in Plates 2a and 2b.

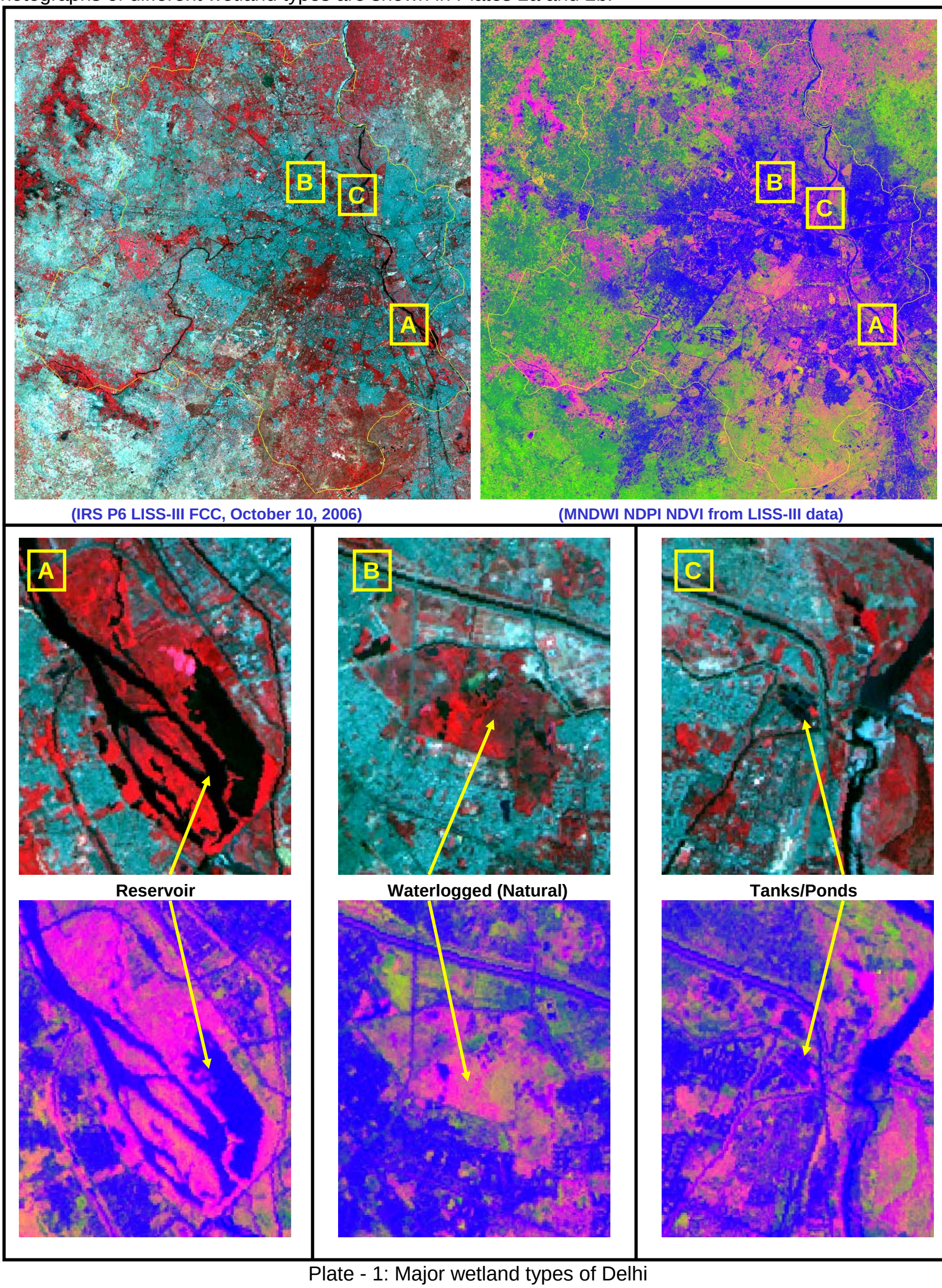


Plate - 1: Major wetland types of Delhi

Sr. No.	Description	Field photograph
1.	**Wetland Type**: Reservoir **Location**: Longitude: 77^0 17’ 20” E Latitude : 28^0 34’ 39” N **Turbidity**: Moderate **Aquatic vegetation**: Eichhornia crassipes	
2.	**Wetland Type**: Tanks/Ponds **Location**: Longitude: 77^0 13’ 34” E Latitude : 28^0 42’ 42” N **Turbidity**: Moderate Treated Sewage is pumped into oxidation ponds for developing aquaculture activity and irrigation facilities on the outskirts of Delhi state.	
3.	**Wetland Type**: Tanks/Ponds **Location:** Longitude : 77^0 00’ 15” E Latitude : 28^0 34’ 03” N **Turbidity**: Moderate Village tanks and ponds are used for multipurpose. Formation of algal blooms in winter and summer is a common phenomenon. Floating garbage mainly polythene bags are found in and around tanks and ponds. They move at the mercy of wind.	
4.	**Wetland Type**: Waterlogged Area (Natural) **Location**: Longitude: 77^0 10’ 28” E Latitude : 28^0 44’ 13” N Urbanization, mainly developmental activities such as infrastructure led to fragmentation of wetlands.	

Plate 2a: Field photographs and ground truth data of different wetland types and their health in Delhi

Sr. No.	Description	Field photograph
5.	**Wetland Type**: Yamuna River **Location**: Longitude: 77^0 17’ 27” E Latitude : 28^0 34’ 18” N **Turbidity**: Moderate Speed boats/ Recreational activity may enhance oxidation process of river water.	
6.	**Wetland Type**: Tanks/Ponds **Location**: Longitude: 77^0 13’ 34” E Latitude : 28^0 42’ 42” N **Aquatic vegetation**: Thypa grass and Caster plants around abounded mines are being used for infrastructure development.	
7.	**Wetland Type**: Tanks/Ponds **Location**: Longitude: 77^0 00’ 15” E Latitude : 28^0 34’ 03” N **Turbidity**: Moderate **Aquatic vegetation**: Thypa grass and Eichhornia crassipes	
8.	**Wetland Type**: River Location: Longitude: 77^0 13’ 52” E Latitude : 28^0 41’ 49” N Eutrophication: scum/foam formation along the bank of Yamuna river indicates the process decomposition along the banks of the river.	

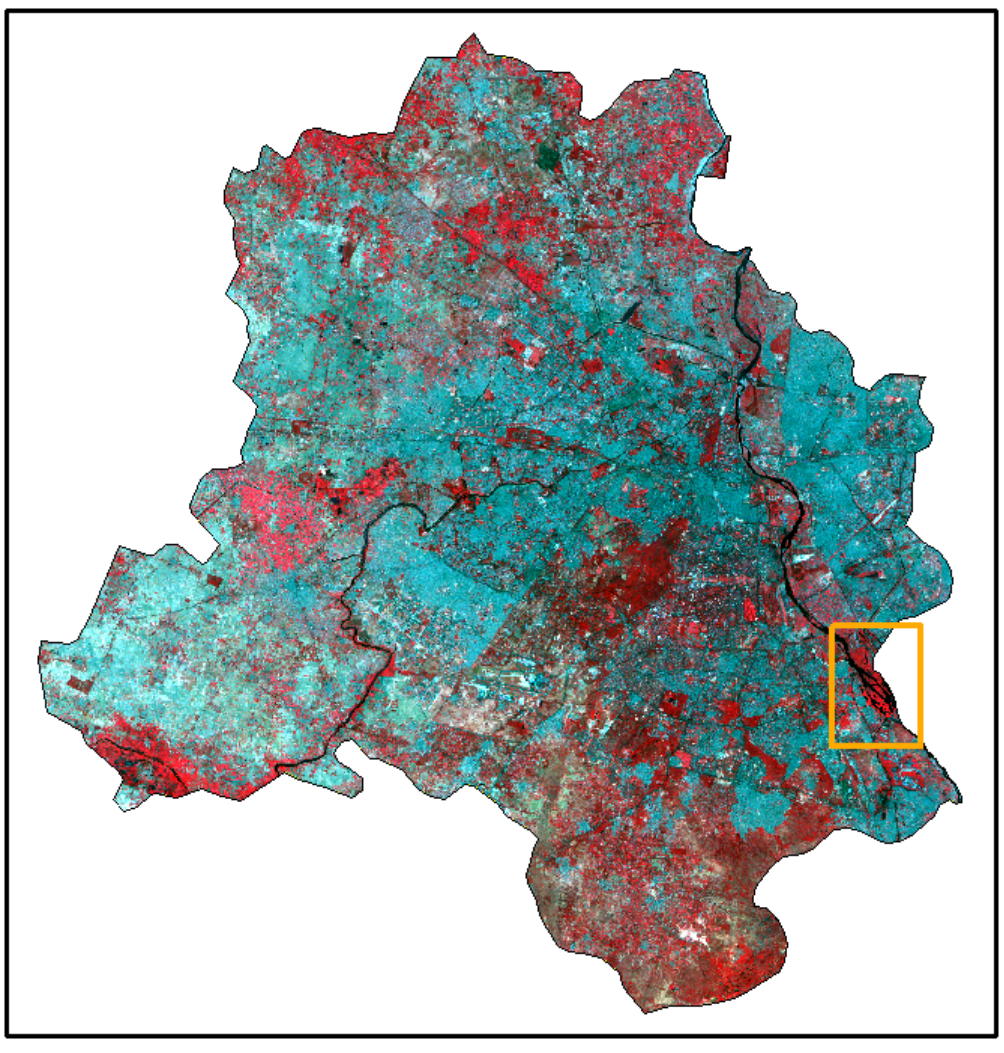
Plate 2b: Field photographs and ground truth data of different wetland types and their health in Delhi

IMPORTANT WETLANDS OF DELHI

9.0 IMPORTANT WETLANDS OF DELHI

River Yamuna is the main source of water for Delhi state. In order to meet the requirement there are many impoundments on the river. Okhla Barrage is one of the major man-made constructions to impound the water. Because of this the lotic wetland changed into lotic and lentic wetlands forming many new wetlands attracting for recreation, fishing, and new habitats for resident avi-fauna. Details of Okhla Barrage is shown in Plate 3. Plate 4 shows a 5 km buffer area of Barrage to show the satellite wetlands. These wetlands are dominated by Typha grass which is growing profusely in most of waterlogged areas/ flood prone areas of river. It is used as fodder as well as making huts in the river bed (islands). An overview of IRS LISS III FCC showing 5 km buffer area of Okhla Barrage shown in Plate 5.

Name	**Okhla Barrage**
Location	Between 28^0 32' N and 28^0 34' N latitudes and 77^0 17'E and 77^0 19 'E longitudes
Area	479 ha
Altitude	200 m
	The expanse of water and its depth varies with the season. There are some slums (encroachment) within the river who are engaged in fishing activity.
Climate	Average annual rainfall: 714 mm Temperature: 5^o to 45^o C.
Turbidity	Moderate: It is manly due to suspended material of plant origin, domestic sewage and industrial effluents. It has been reported that 320, 000 kl of untreated sewage discharged daily into river. Industrial effluents containing high concentration of DDT, heavy metals, and organophosphates finds it way to Yamuna River.
Vegetation	The Important vegetation includes Eichhornia crassipes, Phragmites karka, Thypha grass and Limna sps. Thypha is dominated in the periophery of the river banks where as phragmatis on and around islands. The most dominaent aquativegetation in open waters of the river and barrage is Eichornia sps. (Water Hycinth) which is an indicator of enrichment of nutrition (Eutrophication). Ipomea aquatic is also observed on the banks of river.
Fauna	The diversity of invertebrate and vertebrate fauna is very less. Avifauna is common egrets, herons, Bee eaters.



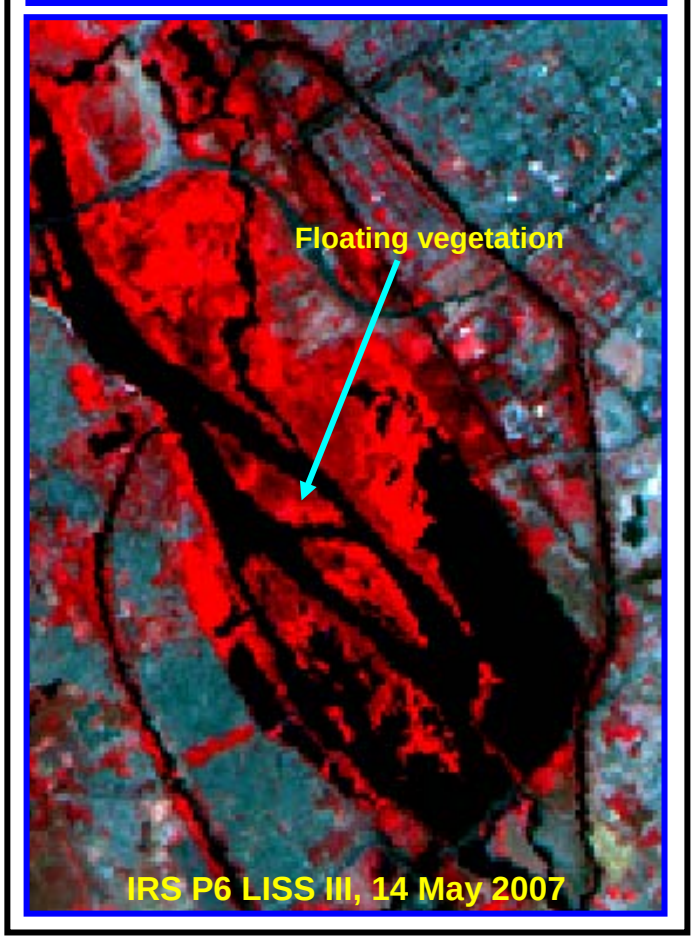
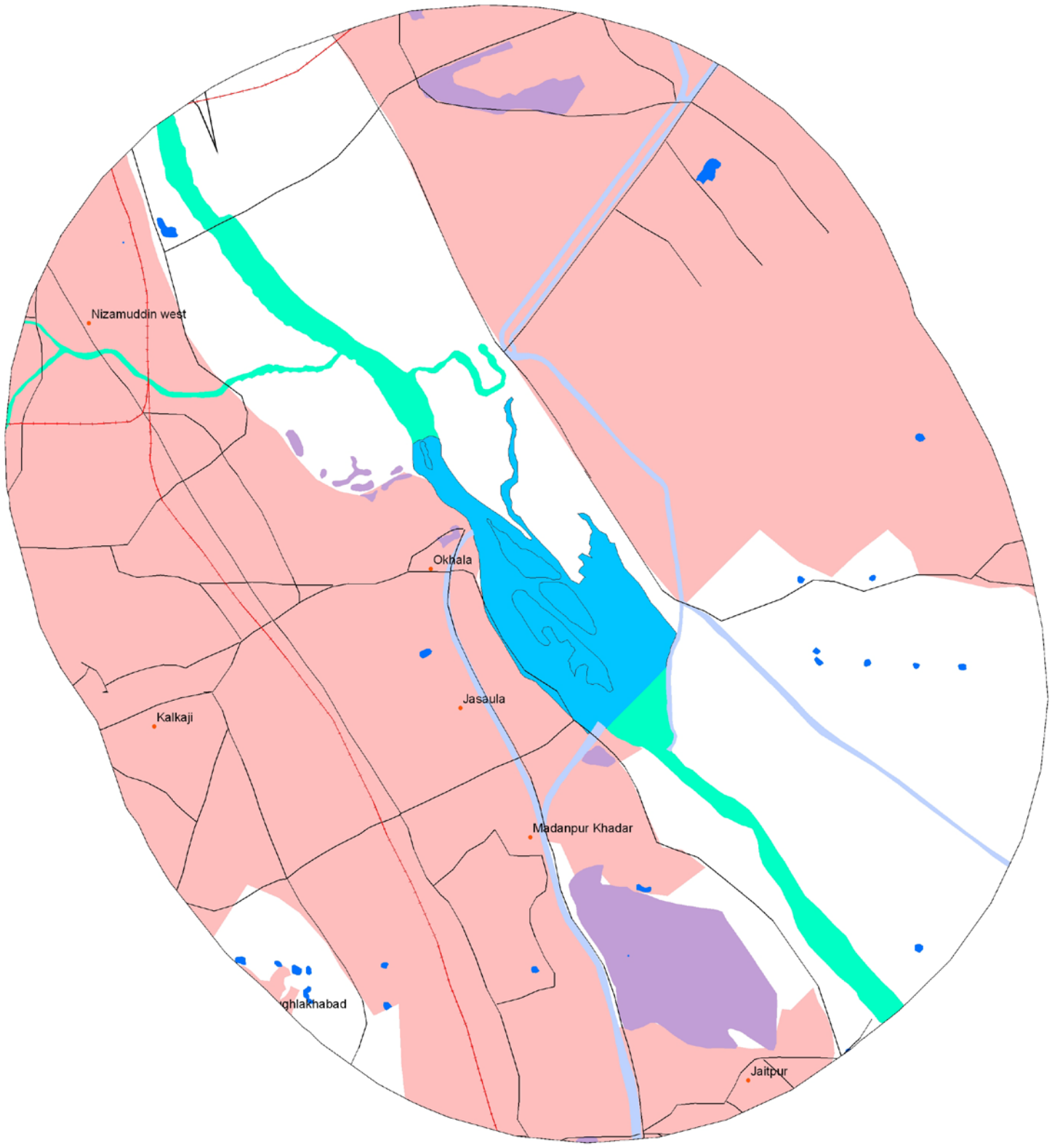


Plate 3: Okhla Dam

State : Delhi

WETLAND MAP

Okhla Barrage



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 (<0.50 ha)
- Settlements
- Drainage (line)
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- Roads
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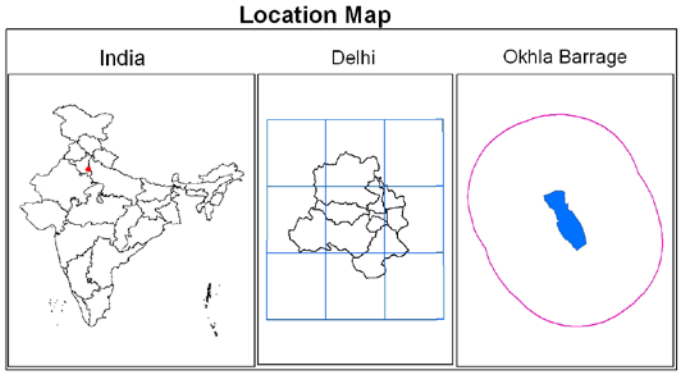
- District Boundary
- State Boundary
- International Boundary

Location Map



0 1 2 4 Kilometers

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

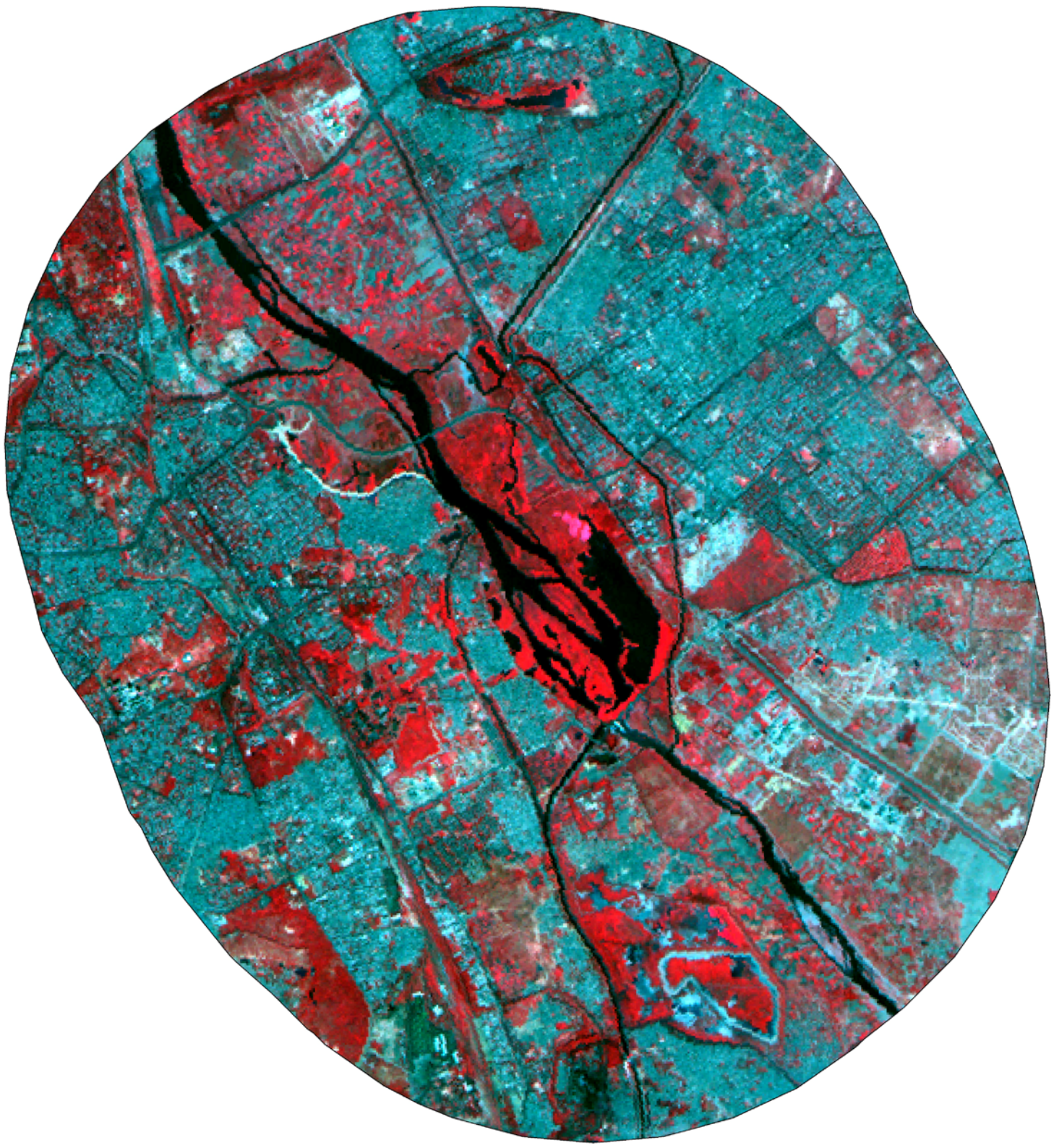
Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

Plate 4: Wetland map - 5 km buffer area of Okhla Barrage

State : Delhi

Okhla Barrage



IRS P6 LISS-III post monsoon data (2006)

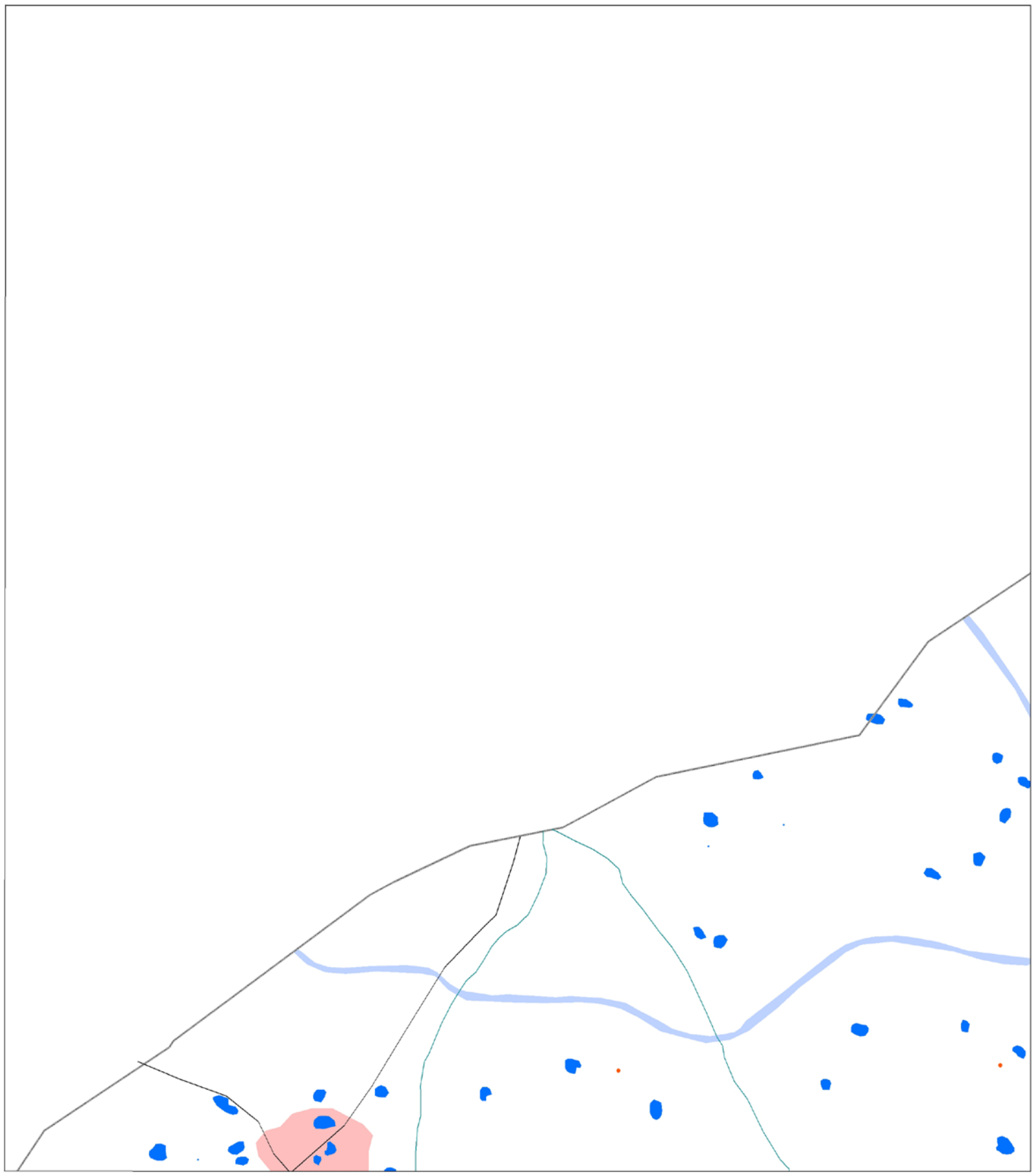
Plate 5: IRS LISS III FCC - 5 km buffer area of Okhla Barrage

SOI MAP SHEET-WISE WETLAND MAPS

State : Delhi

WETLAND MAP

Map No. : 53D/13NE



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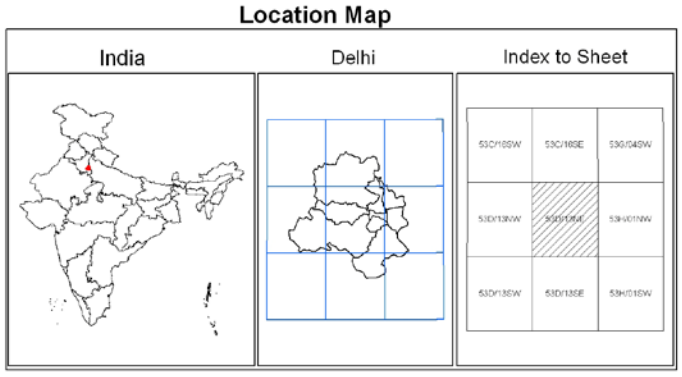
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral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

Legend

- Wetlands (<0.50 ha)
- Settlements
- Drainage (line)
- Canal
- Roads
- Railways
- Town/Settlements
- District Boundary
- State Boundary
- International Boundary

Location Map



0 0.5 1 2 Kilometers

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

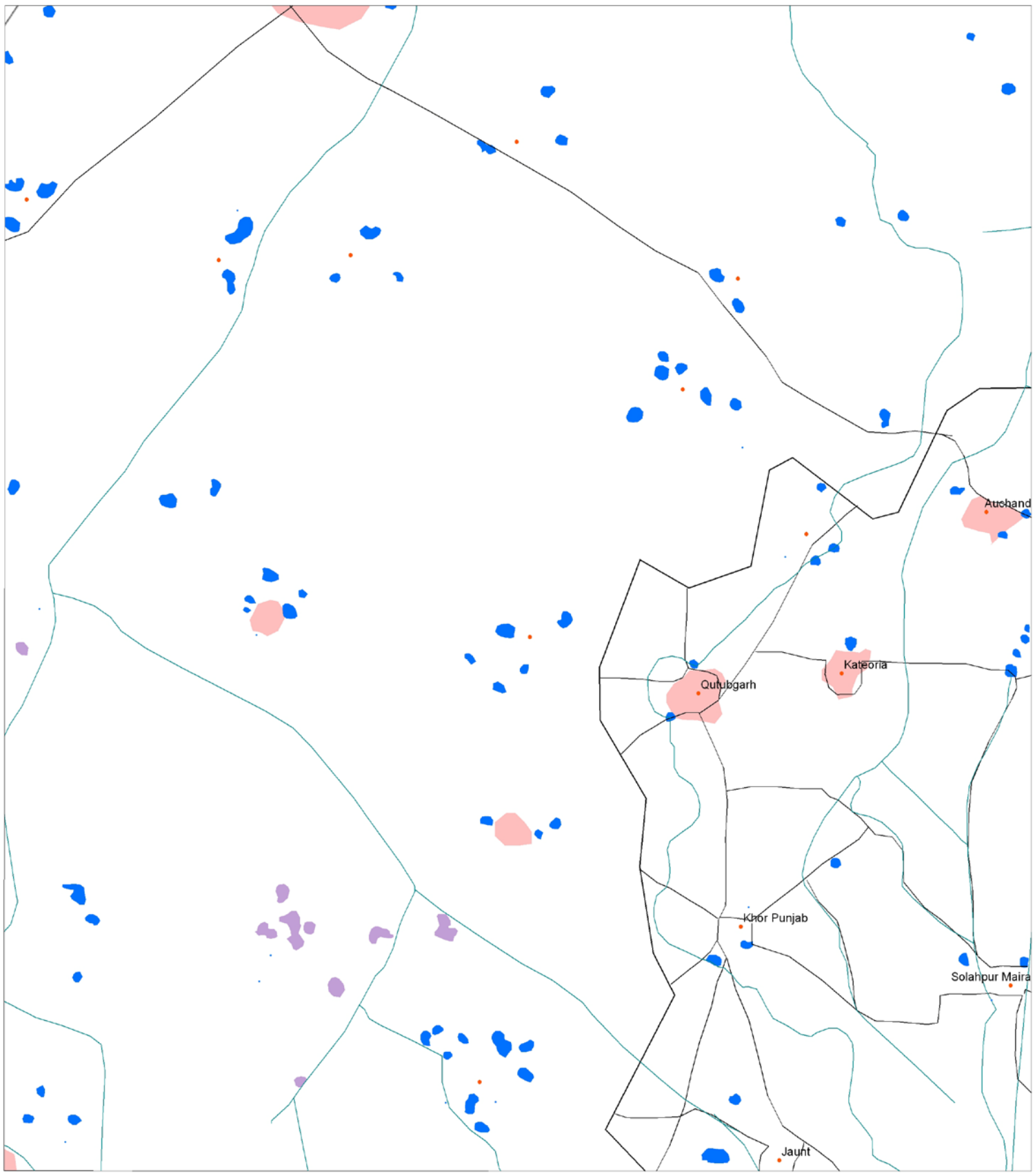
Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

WETLAND MAP

Map No. : 53D/13SE



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
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		Coastal Wetlands		
			Natural	
	2101			Lagoons
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	2103			Sand/Beach
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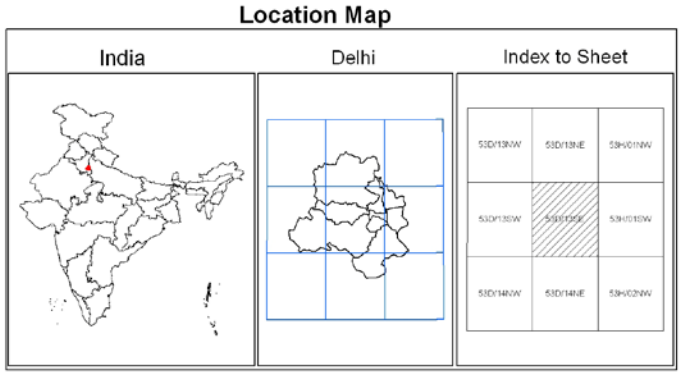
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- Wetlands (<0.50 ha)
- Settlements
- Drainage (line)
- Canal
- Roads
- Railways
- Town/Settlements
- District Boundary
- State Boundary
- International Boundary

Location Map



0 0.5 1 2 Kilometers

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

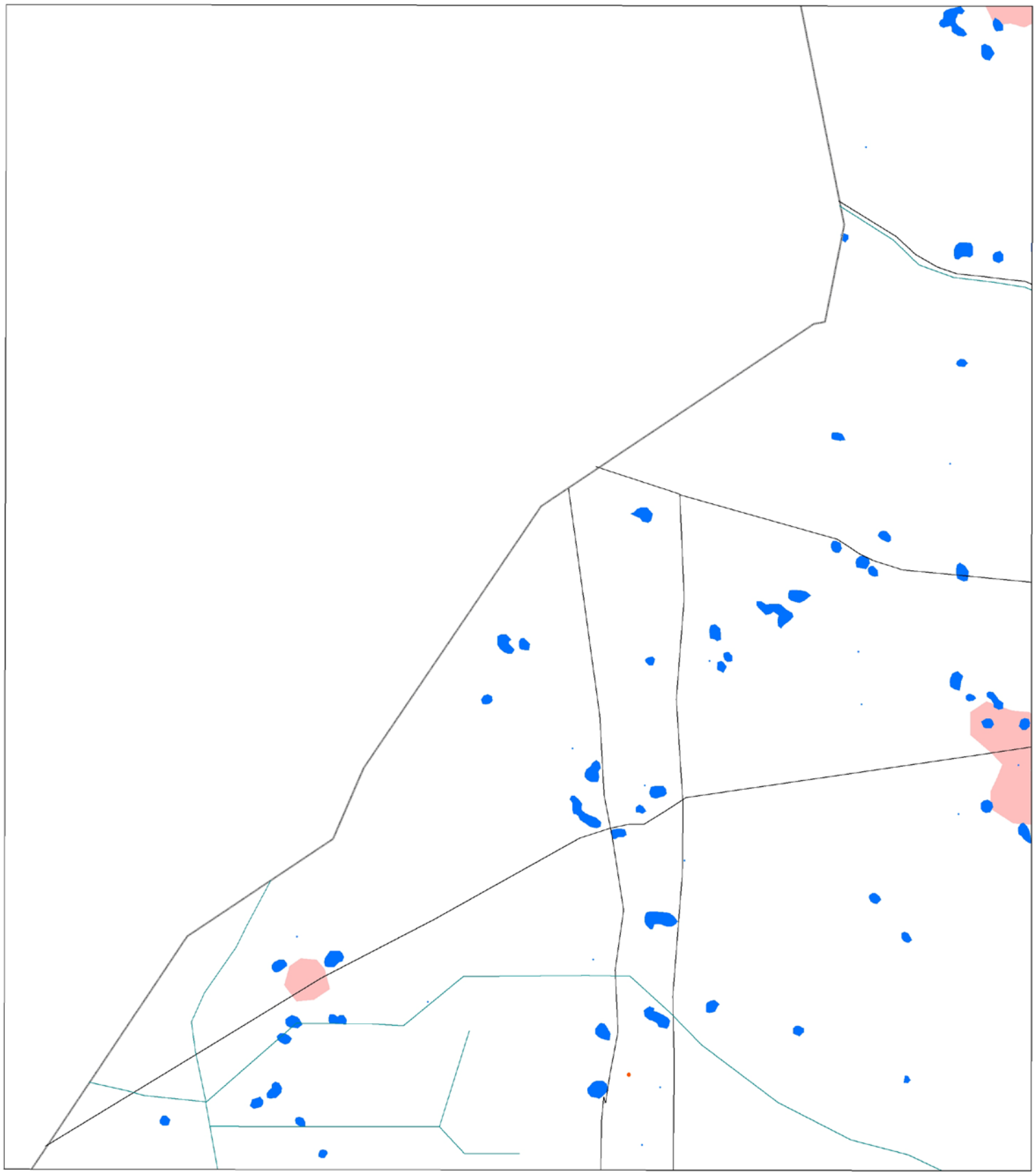
Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

WETLAND MAP

Map No. : 53D/14NW



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 (<0.50 ha)
- Settlements
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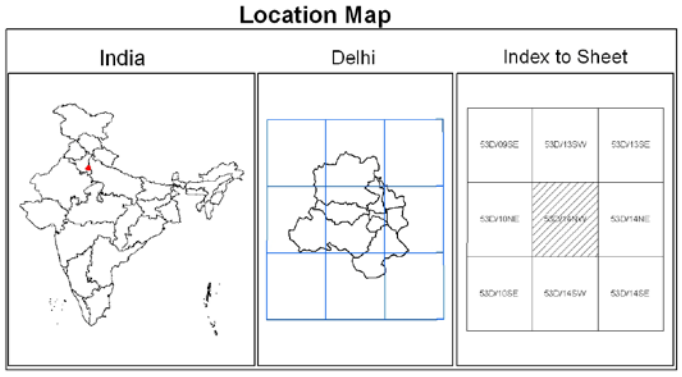
- Canal
- Roads
- Railways
- Town/Settlements
- District Boundary
- State Boundary
- International Boundary

Location Map



0 0.5 1 2 Kilometers

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

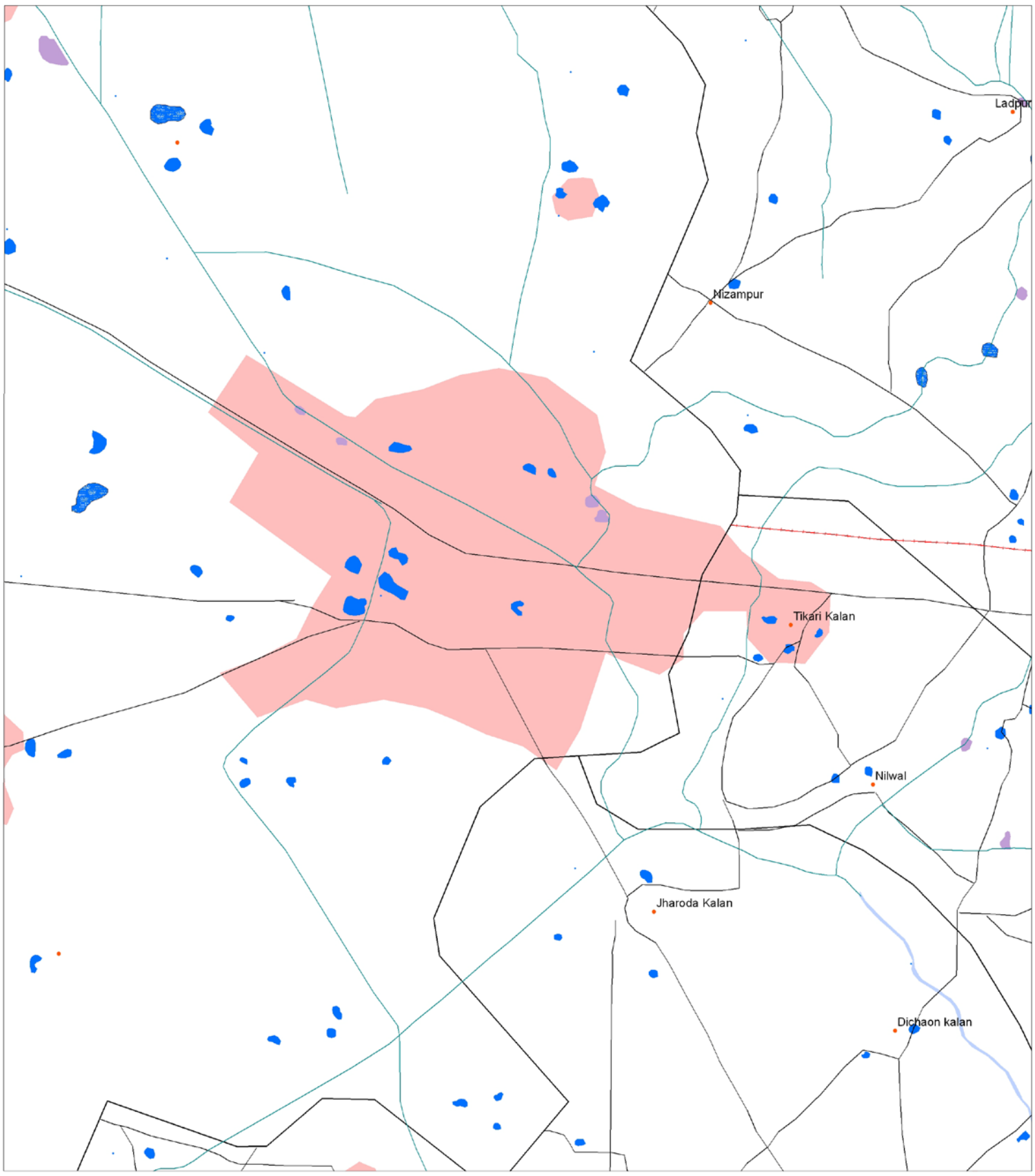
Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

WETLAND MAP

Map No. : 53D/14NE



Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
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	1101			Lakes/Ponds
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	2106			Mangroves
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Legend

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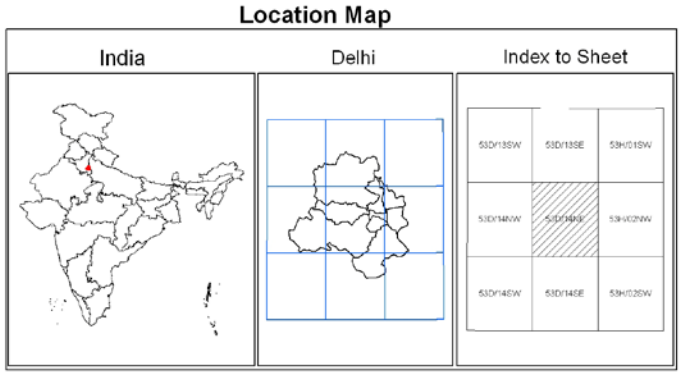
Location Map



0 0.5 1 2 Kilometers

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

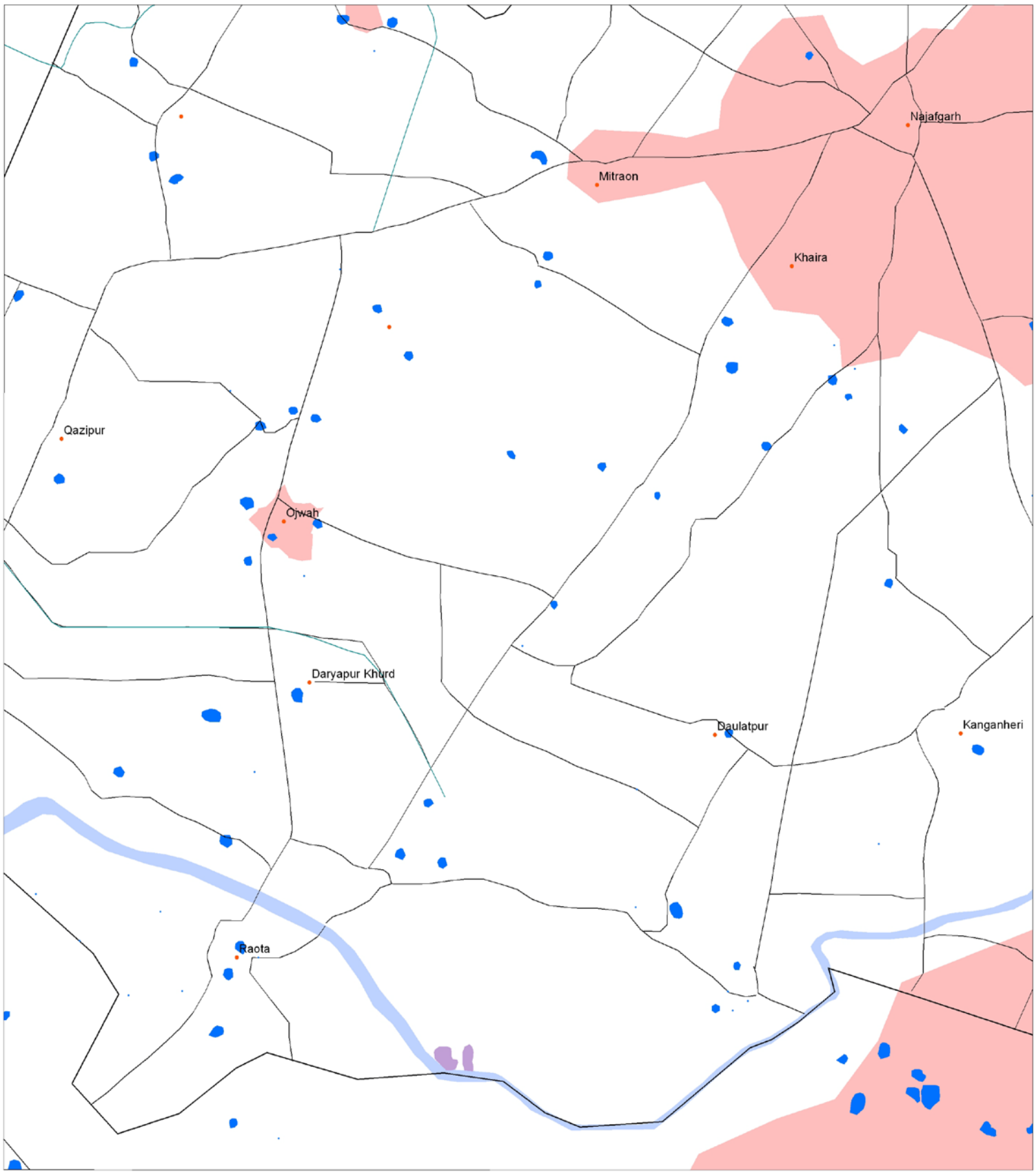
Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

WETLAND MAP

Map No. : 53D/14SE



Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
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Legend

- Wetlands (<0.50 ha)
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- District Boundary
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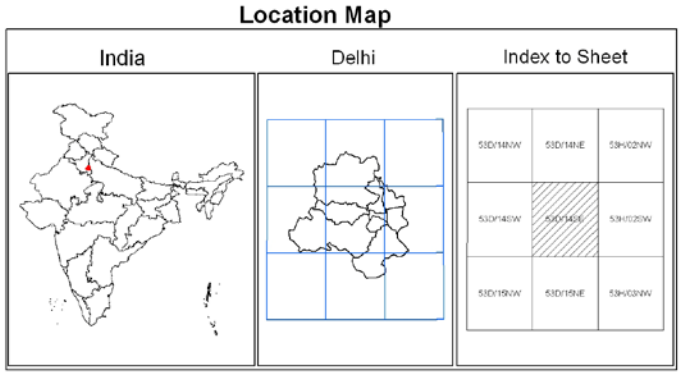
- International Boundary

Location Map



0 0.5 1 2 Kilometers

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

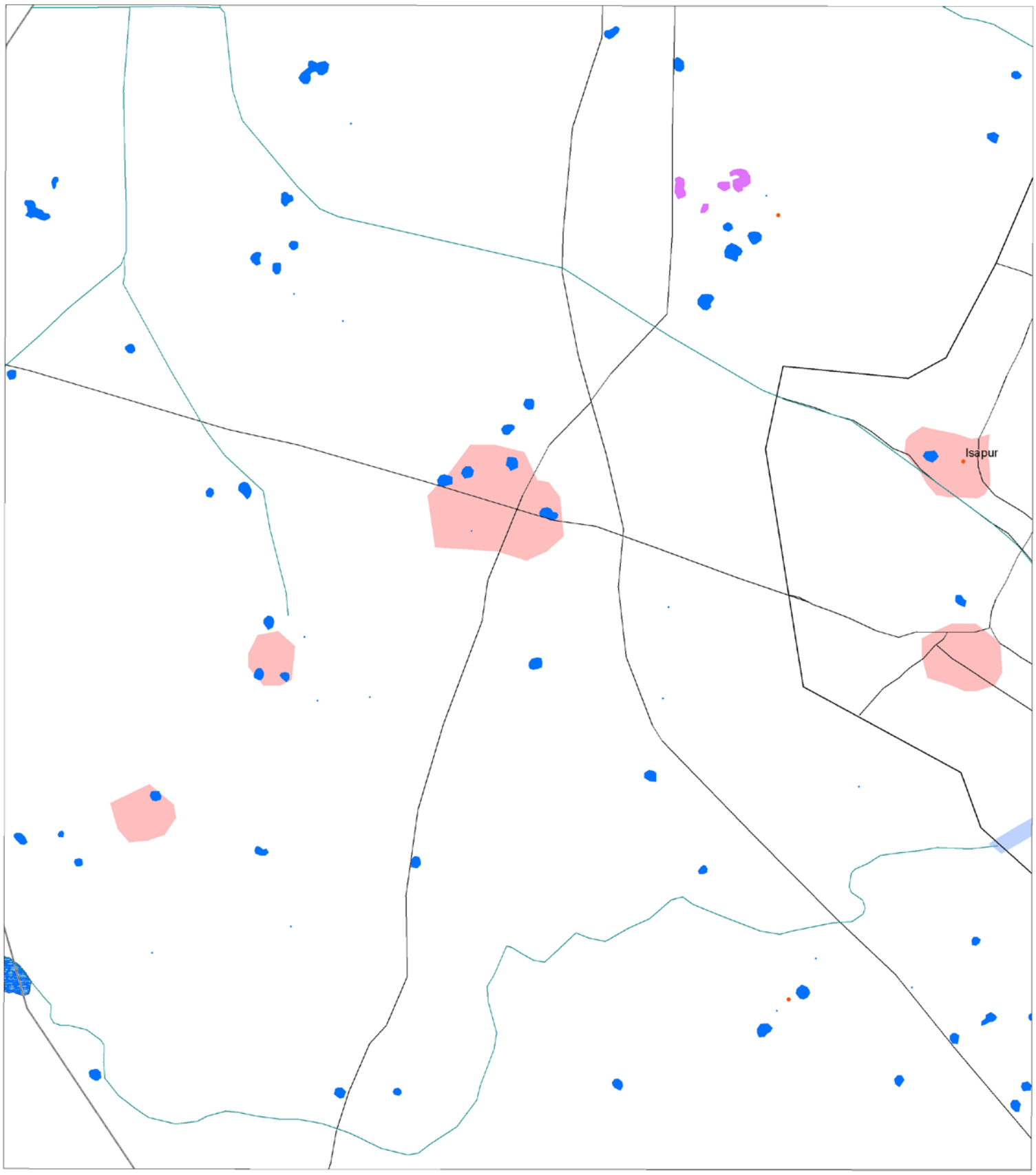
Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

WETLAND MAP

Map No. : 53D/14SW



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
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			Man-made	
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	2202			Aquaculture ponds

Legend

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- Railways
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- District Boundary
- State Boundary
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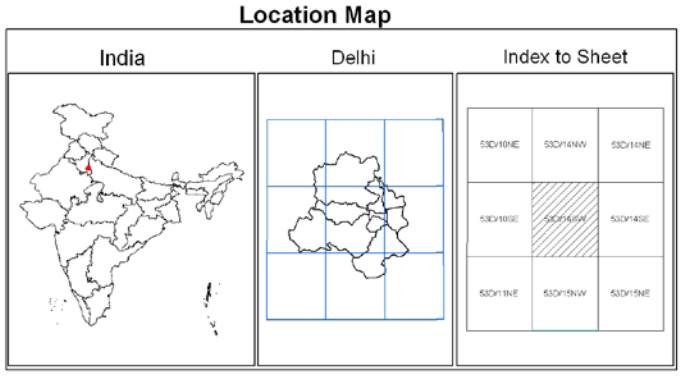
Location Map



0 0.5 1 2 Kilometers

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

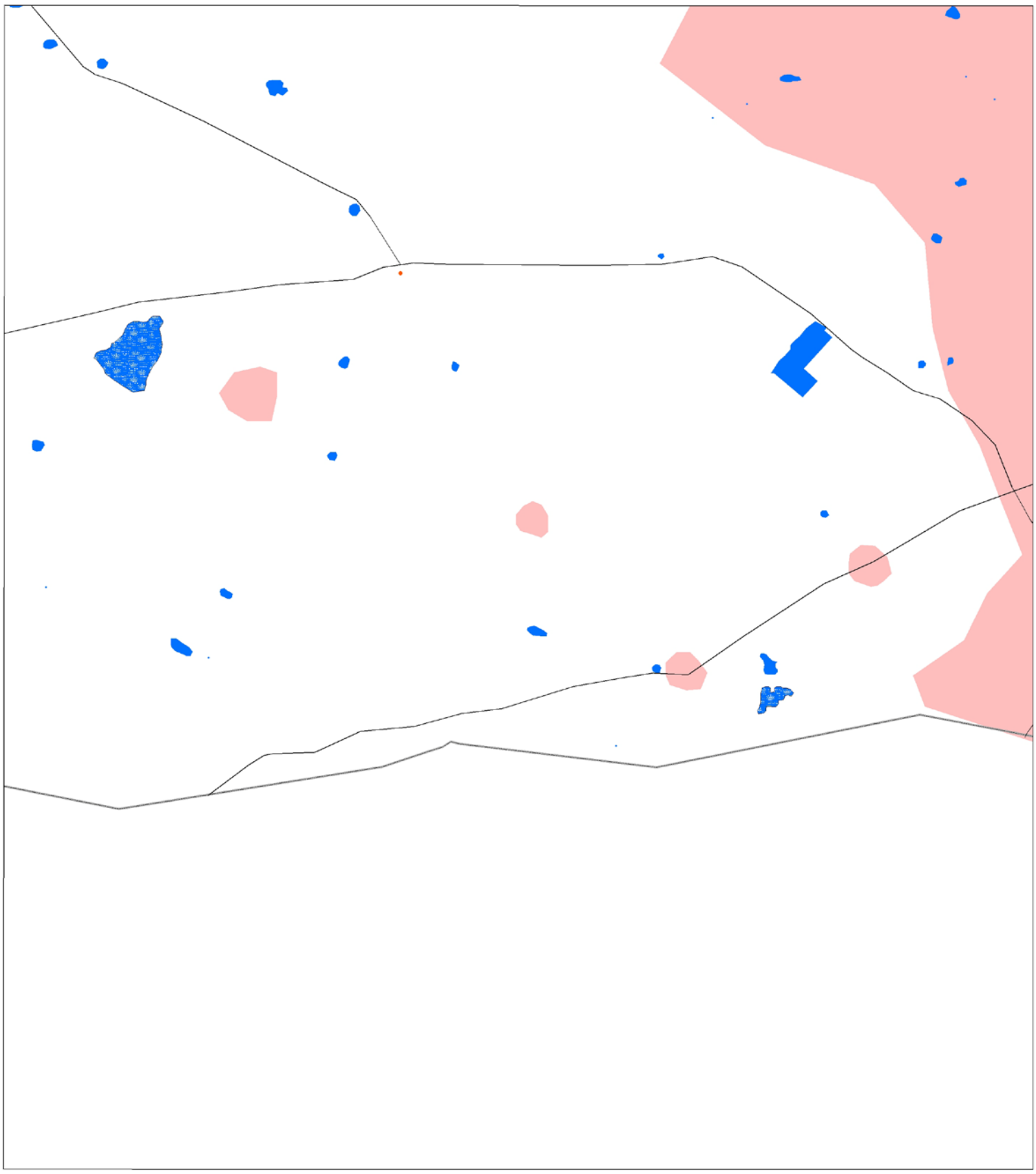
Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

WETLAND MAP

Map No. : 53D/15NE



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
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Legend

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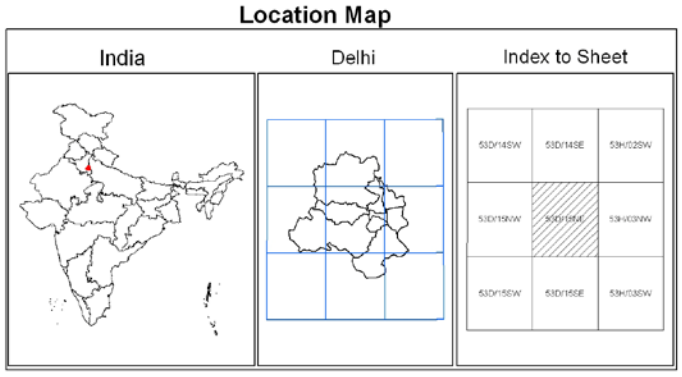
Location Map



0 0.5 1 2 Kilometers

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

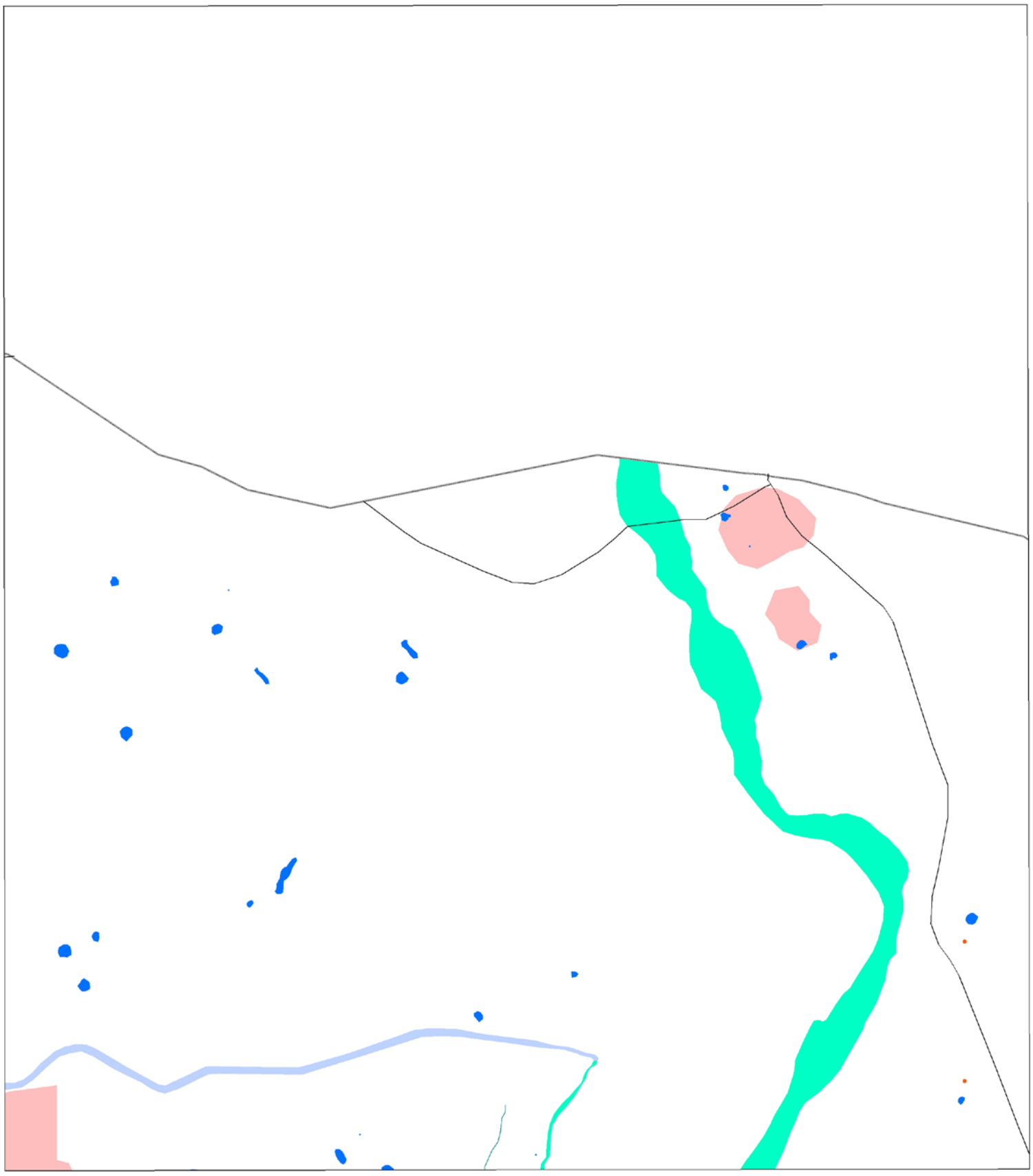
Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

WETLAND MAP

Map No. : 53H/01NE



Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
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Legend

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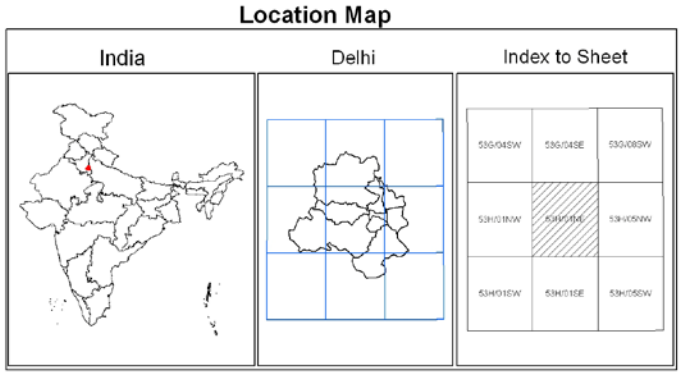
Location Map



0 0.5 1 2 Kilometers

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

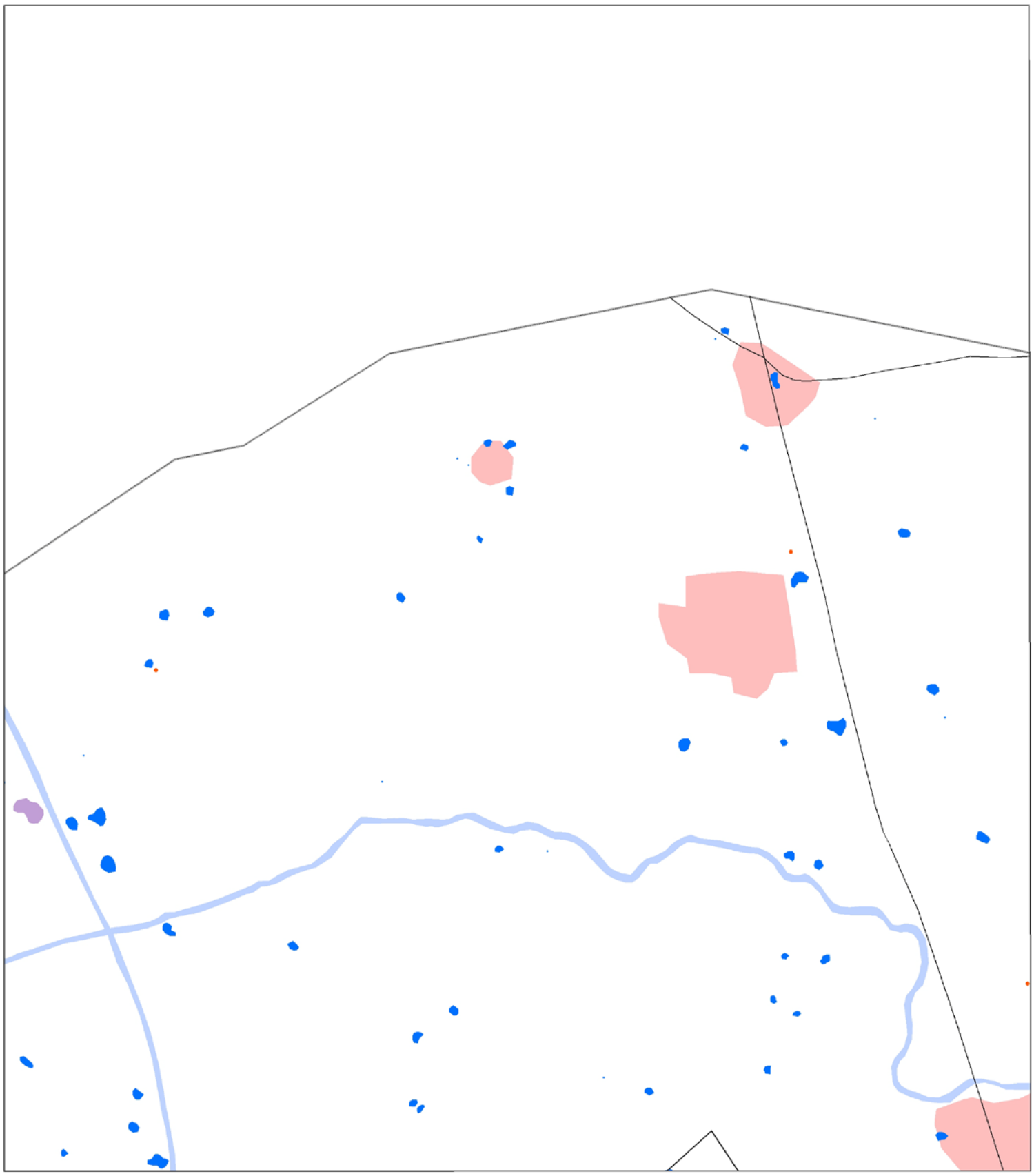
Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

WETLAND MAP

Map No. : 53H/01NW



Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
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Legend

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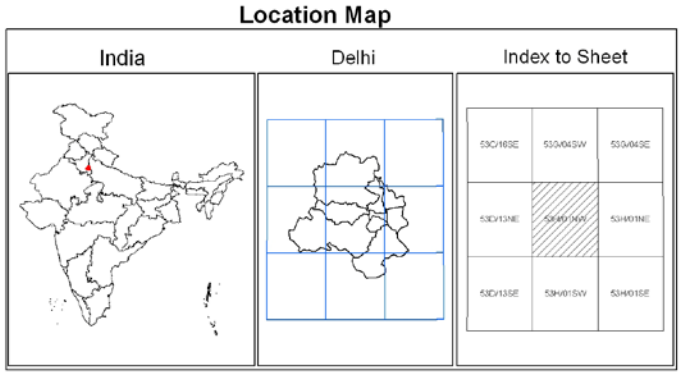
Location Map



0 0.5 1 2 Kilometers

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

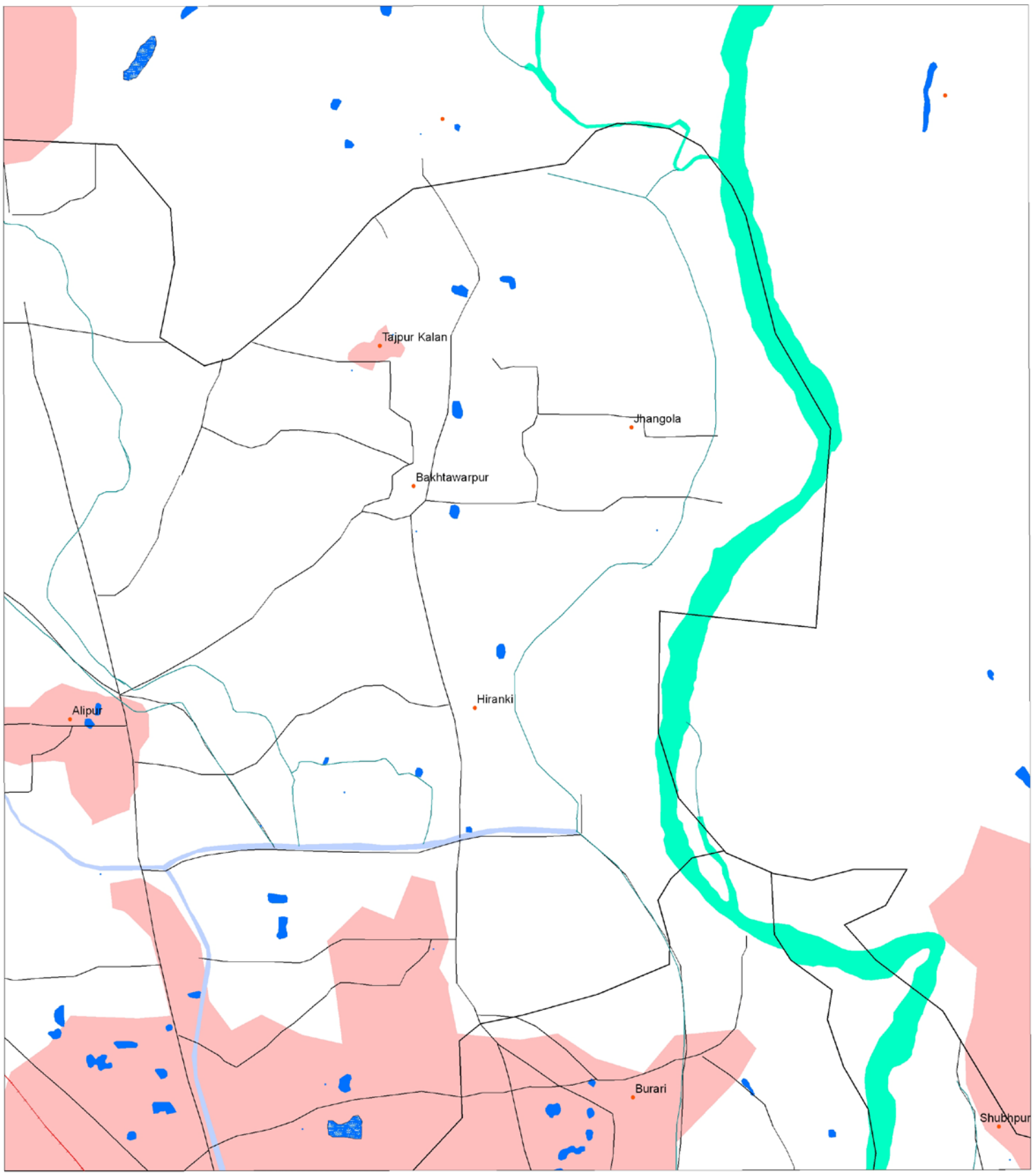
Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

WETLAND MAP

Map No. : 53H/01SE



Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
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	1101			Lakes/Ponds
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Legend

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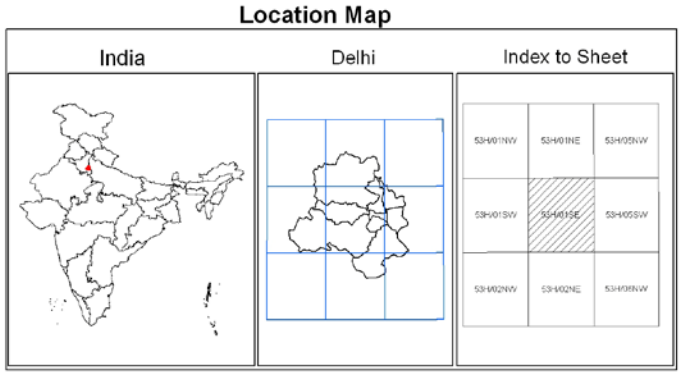


0 0.5 1 2 Kilometers

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

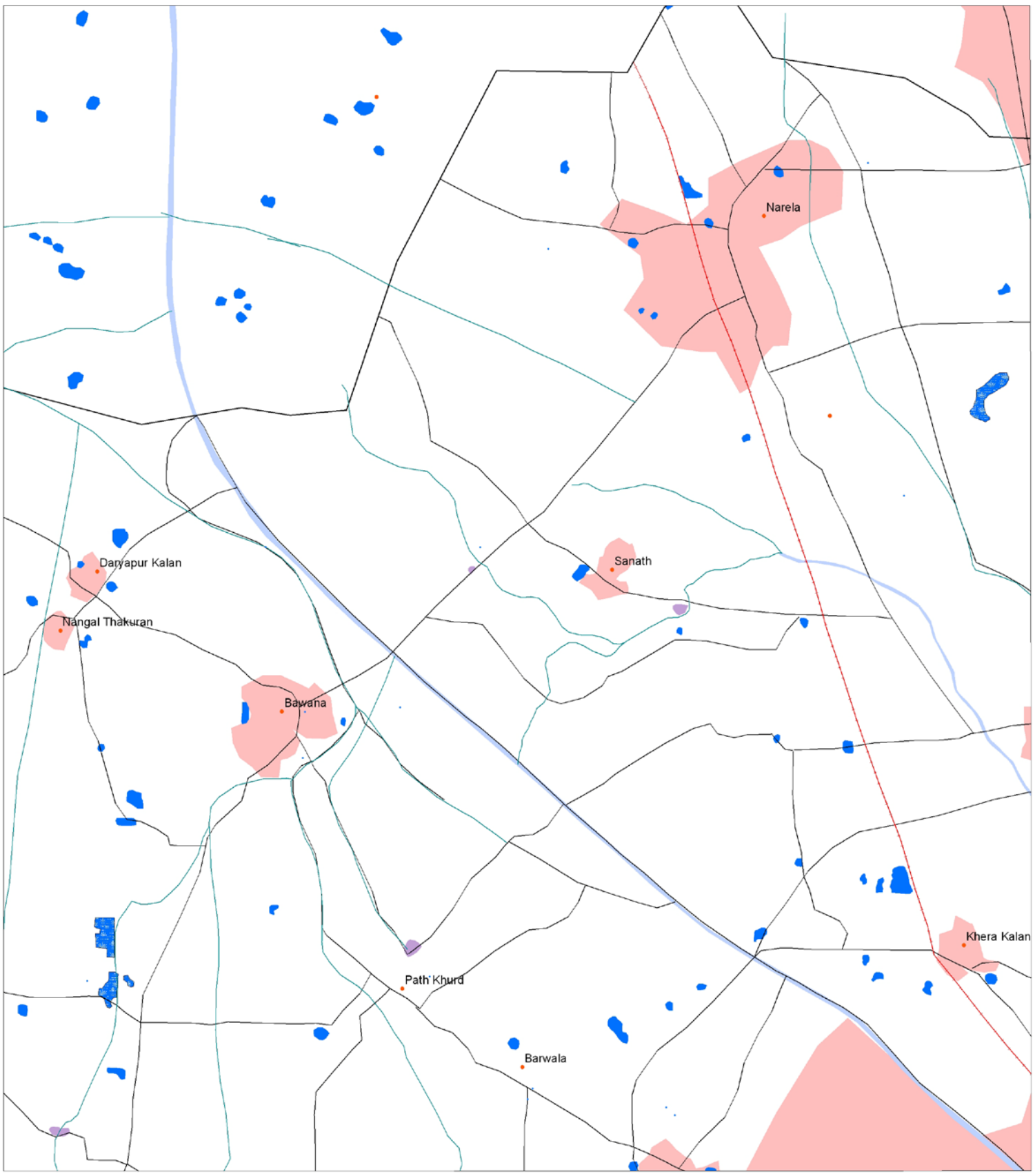
Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

WETLAND MAP

Map No. : 53H/01SW



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Legend

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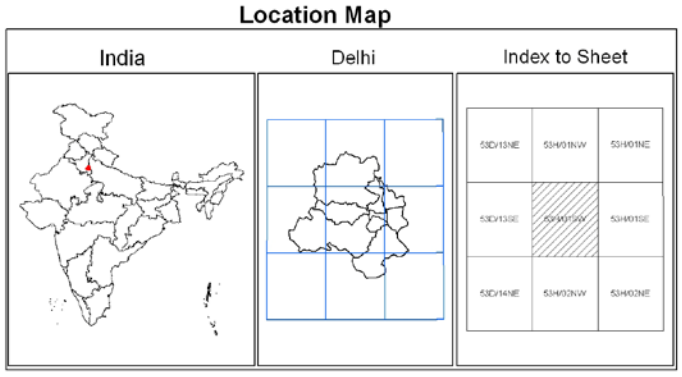

0 0.5 1 2 Kilometers

Data Source :
IRS P6 LISS III and LISS IV data
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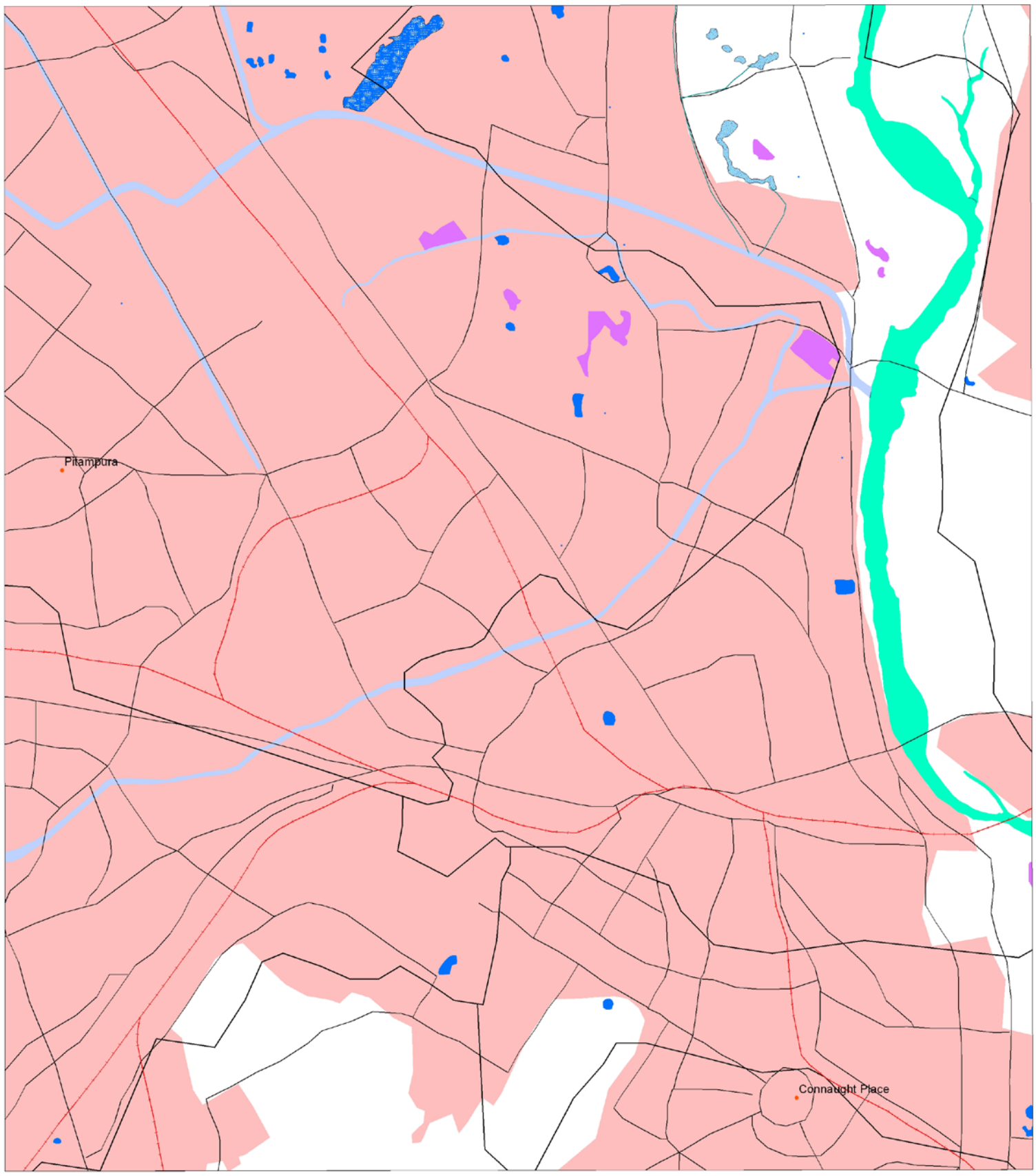
Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

WETLAND MAP

Map No. : 53H/02NE



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	1101			Lakes/Ponds
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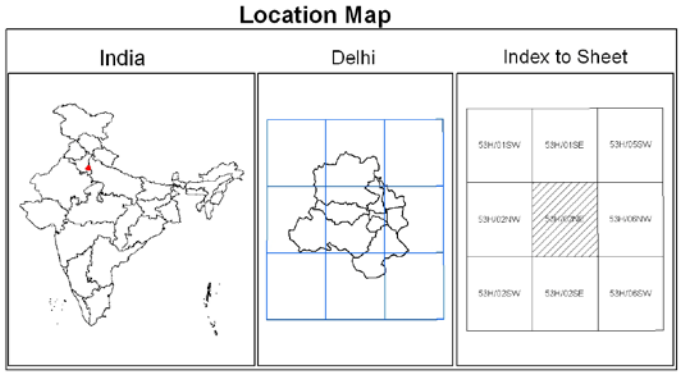

0 0.5 1 2 Kilometers

Data Source :
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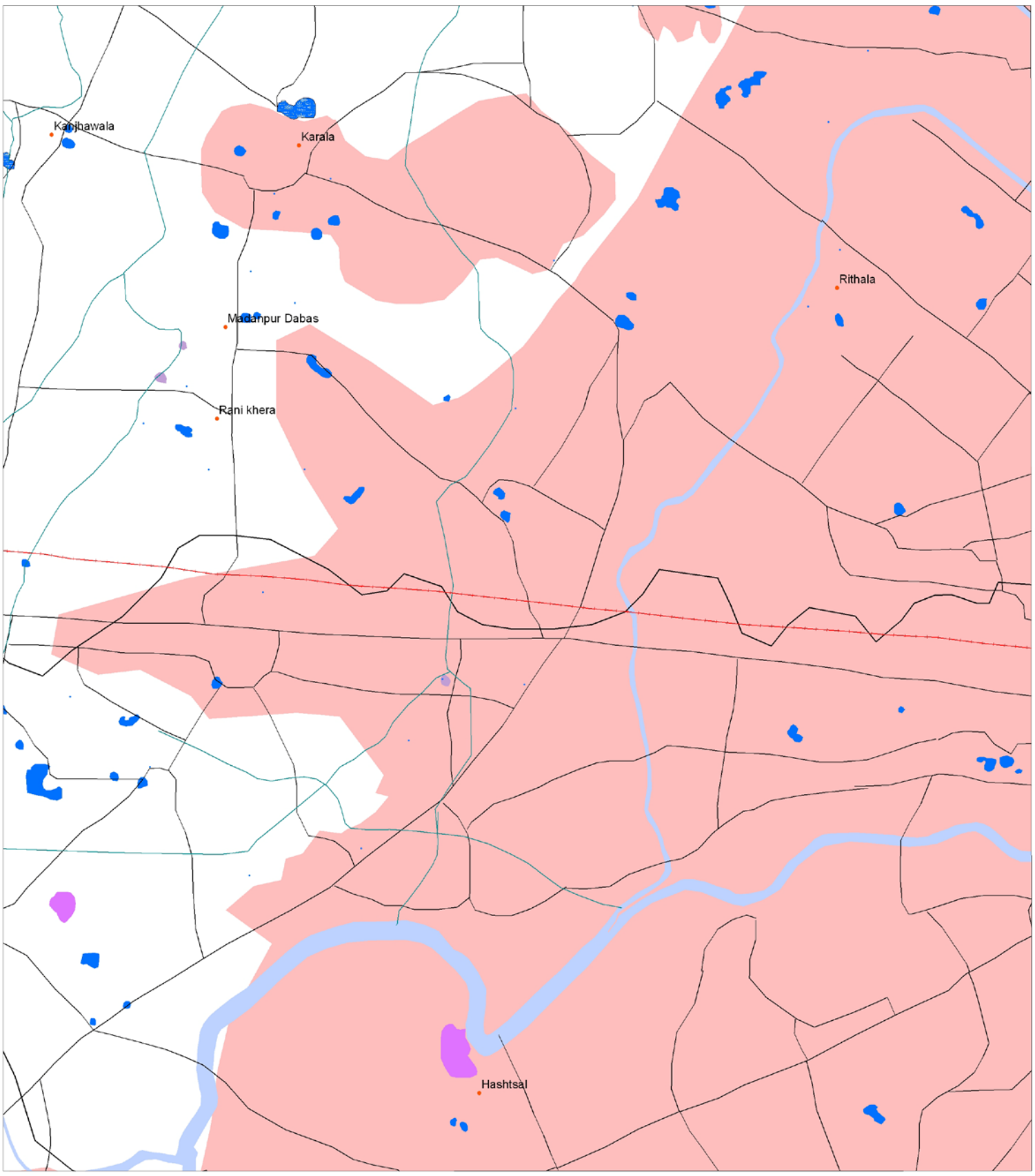
State : Delhi

WETLAND MAP

Map No. : 53H/02NW



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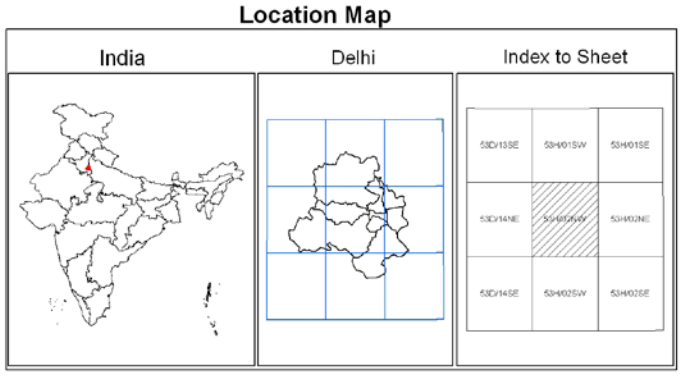

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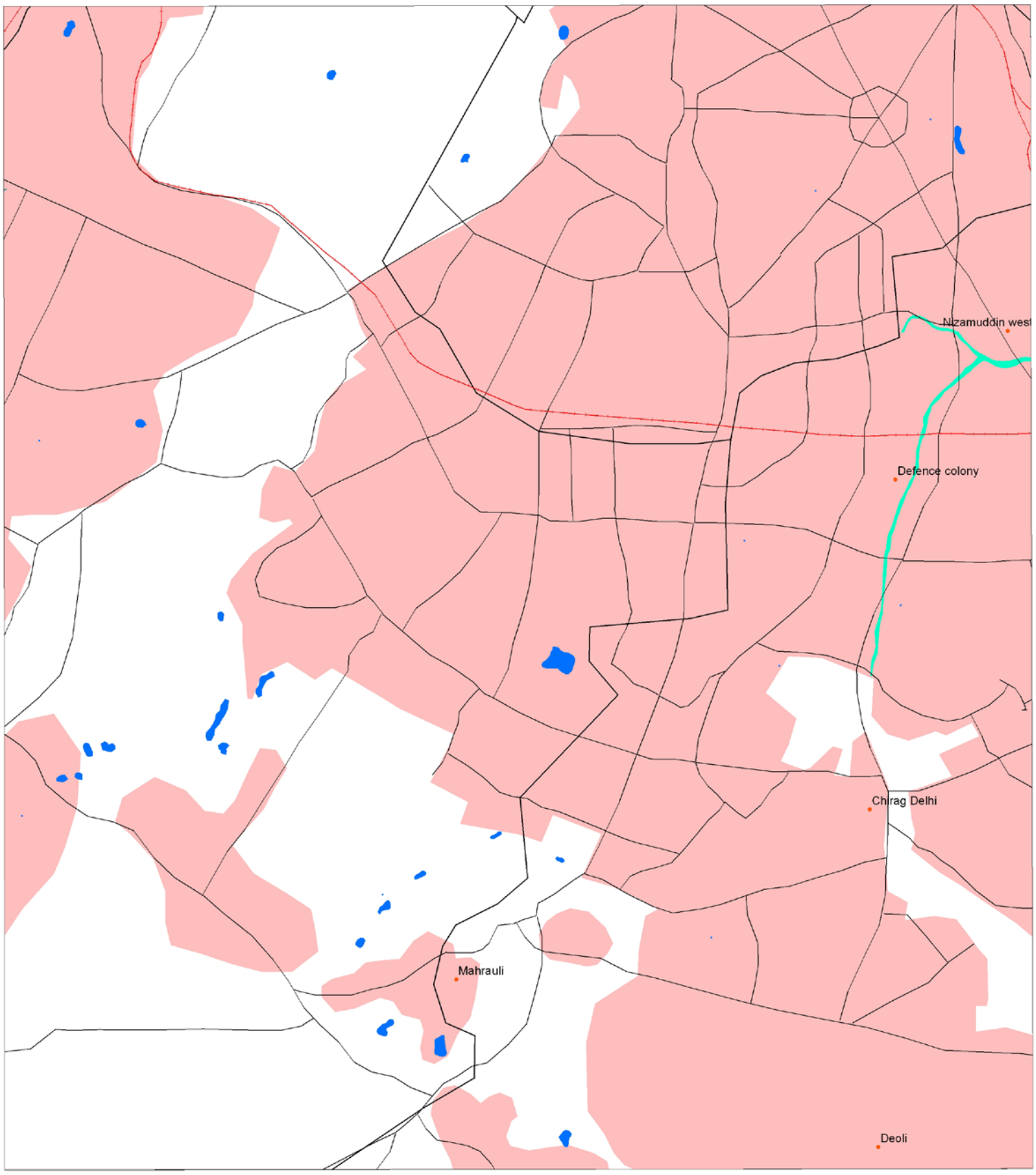
WETLAND MAP

Map No. : 53H/02SE

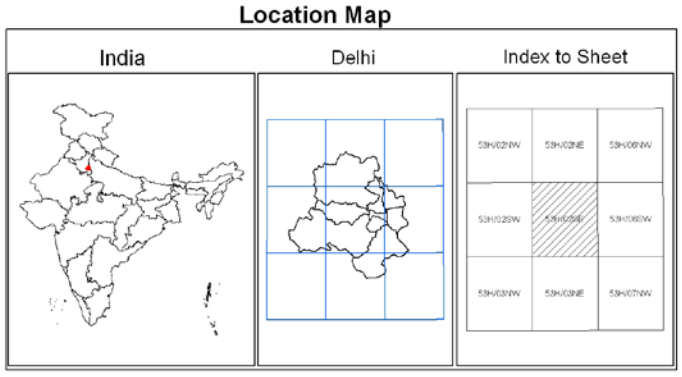


Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			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 (<0.50 ha)
- Settlements
- Drainage (line)
- Canal
- Roads
- Railways
- Town/Settlements
- District Boundary
- State Boundary
- International Boundary

Location Map



0 0.5 1 2 Kilometers

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

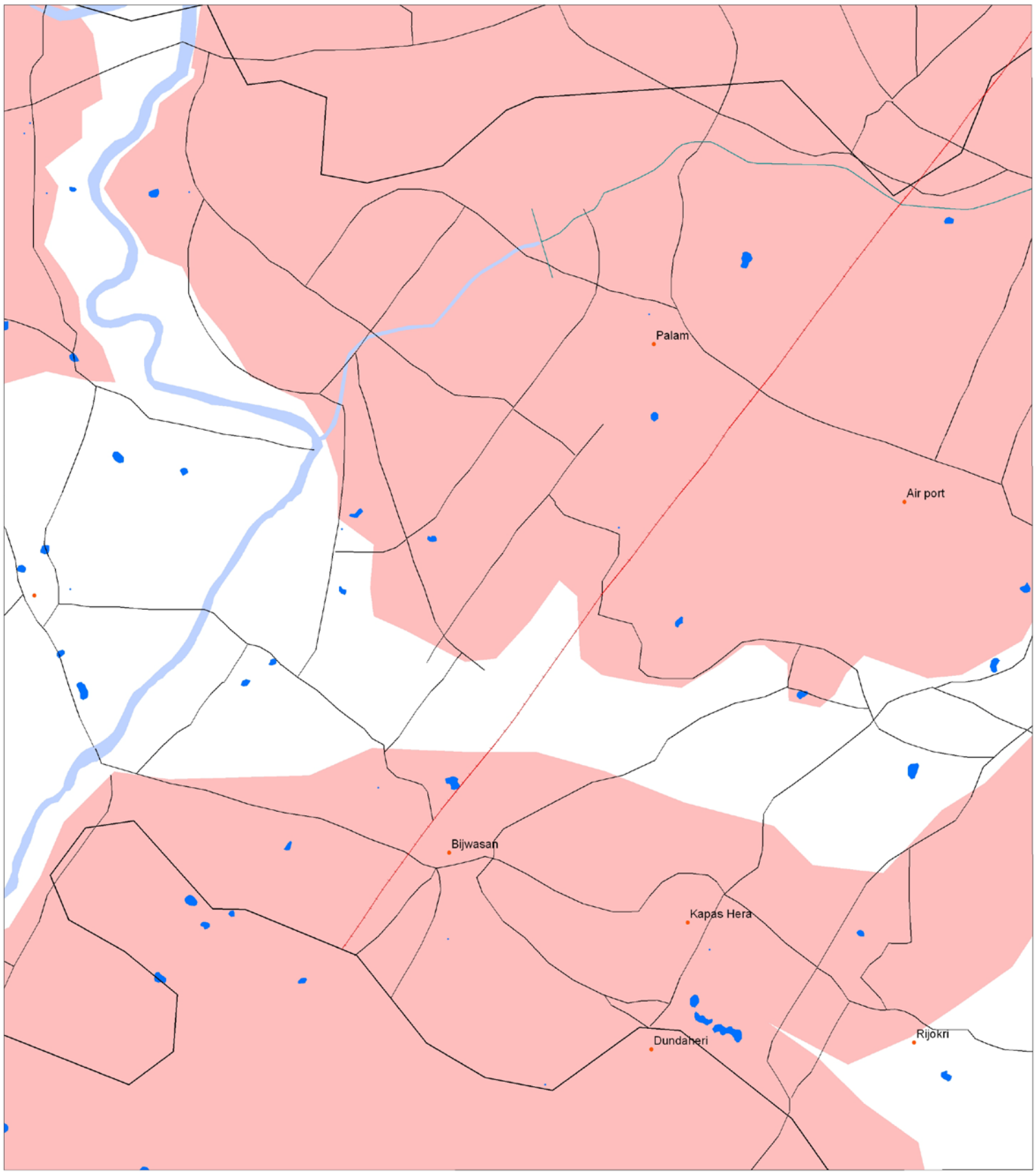
Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

WETLAND MAP

Map No. : 53H/02SW



Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
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	1101			Lakes/Ponds
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Legend

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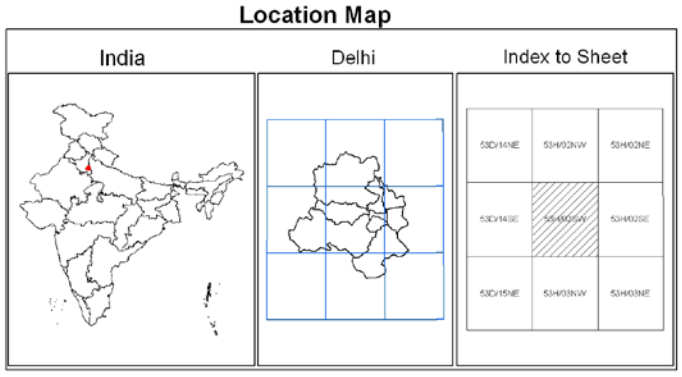
Location Map



0 0.5 1 2 Kilometers

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

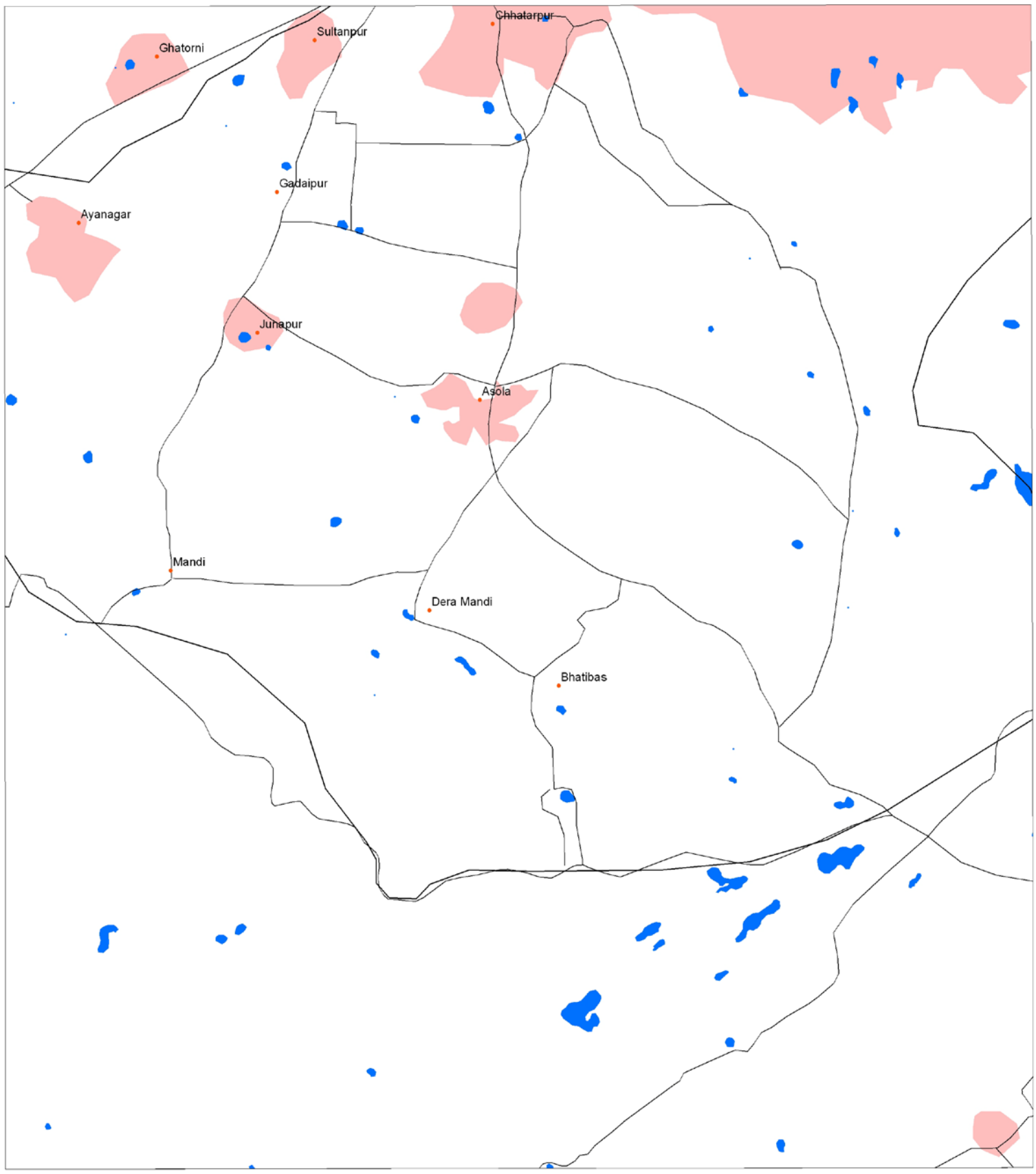
Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

WETLAND MAP

Map No. : 53H/03NE



Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
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Legend

- Wetlands (<0.50 ha)
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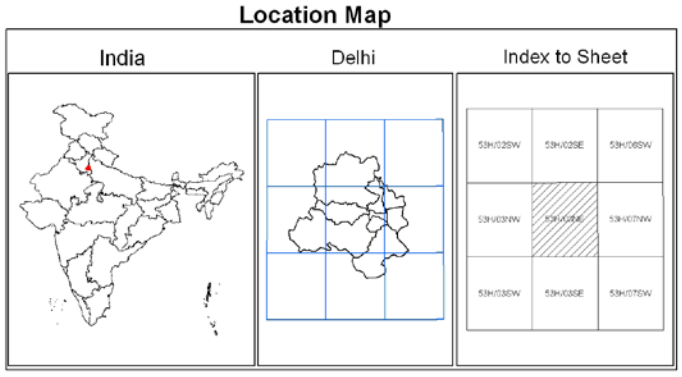
- Railways
- Town/Settlements
- District Boundary
- State Boundary
- International Boundary

Location Map



0 0.5 1 2 Kilometers

Data Source :
IRS P6 LISS III and LISS IV data
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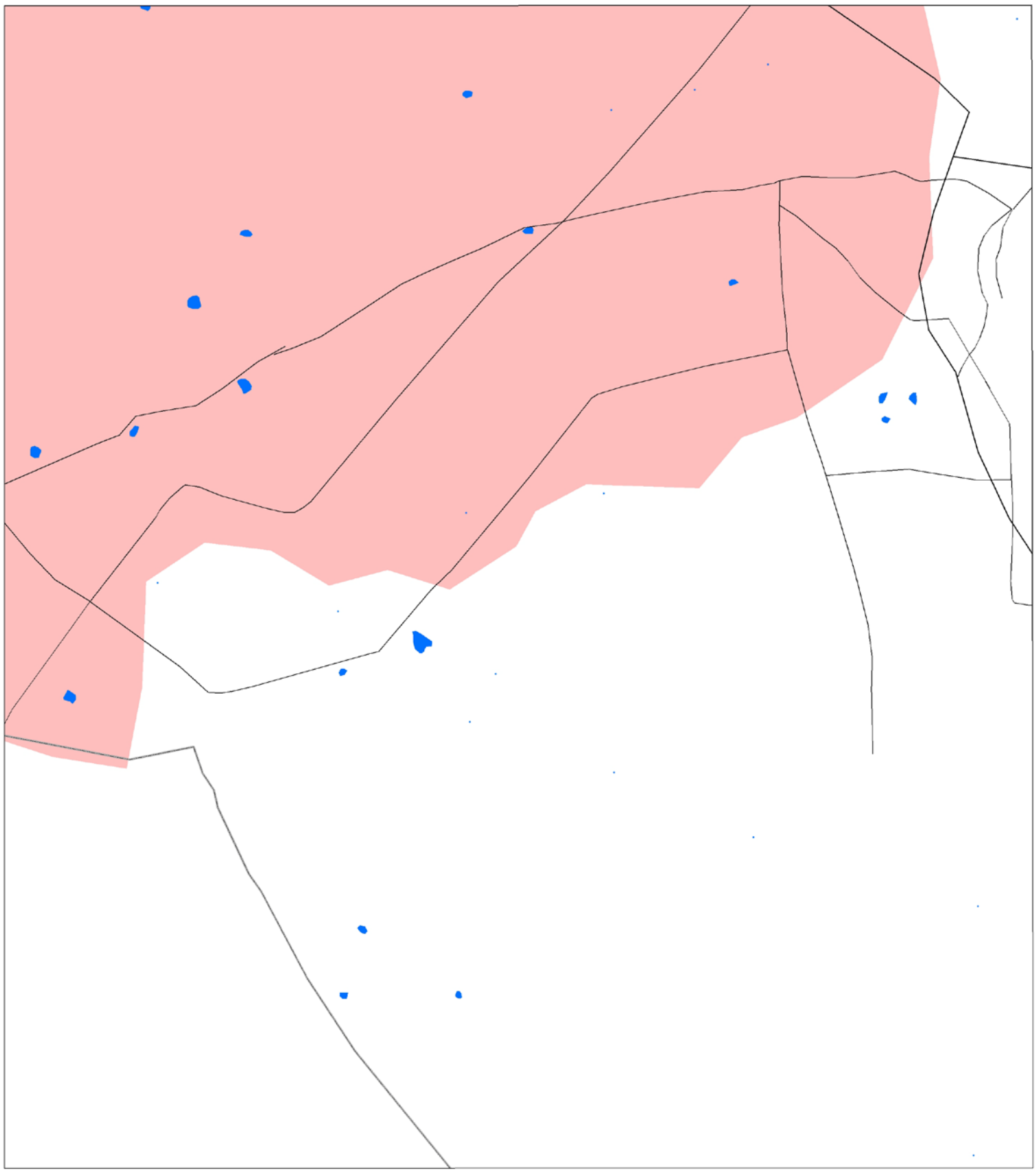
Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

WETLAND MAP

Map No. : 53H/03NW



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
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	1203			Waterlogged
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	2101			Lagoons
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Legend

- Wetlands (<0.50 ha)
- Settlements
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- District Boundary
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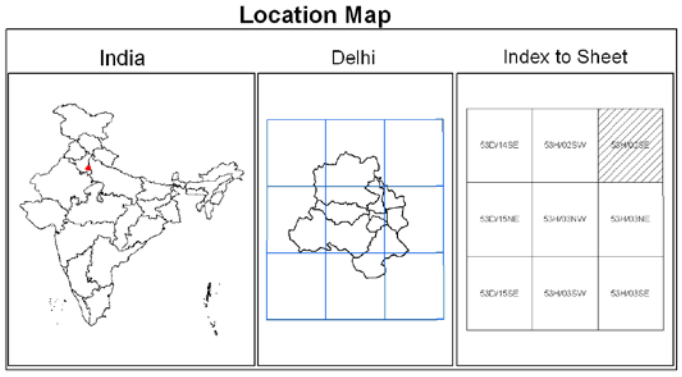
- International Boundary

Location Map



0 0.5 1 2 Kilometers

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

Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
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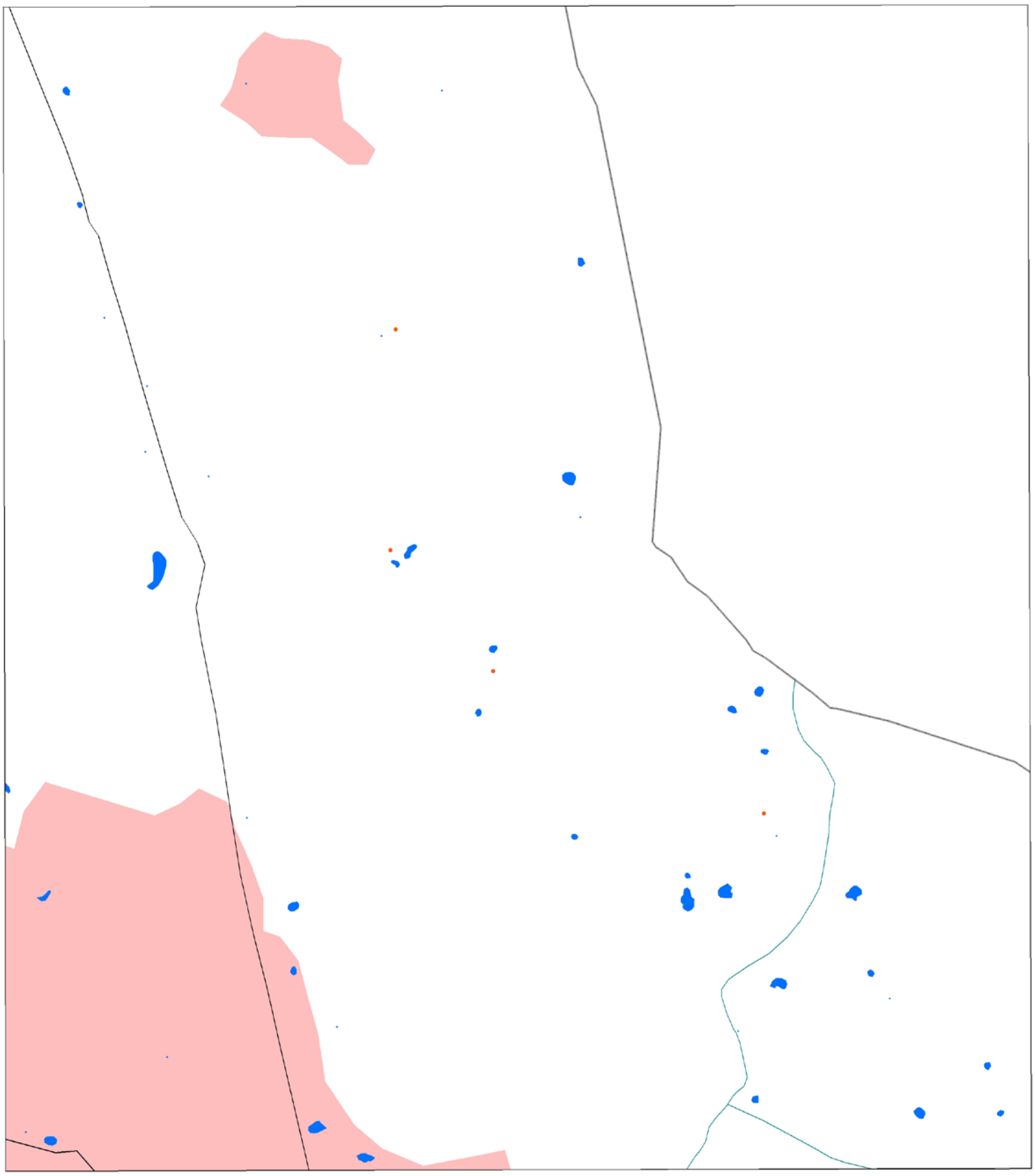
Government of India

State : Delhi

WETLAND MAP

Map No. : 53H/05SW



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
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			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
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Legend

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- Settlements
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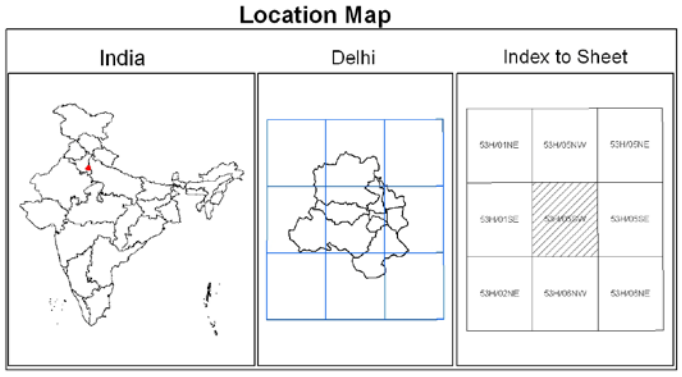
- Railways
- Town/Settlements
- District Boundary
- State Boundary
- International Boundary

Location Map



0 0.5 1 2 Kilometers

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

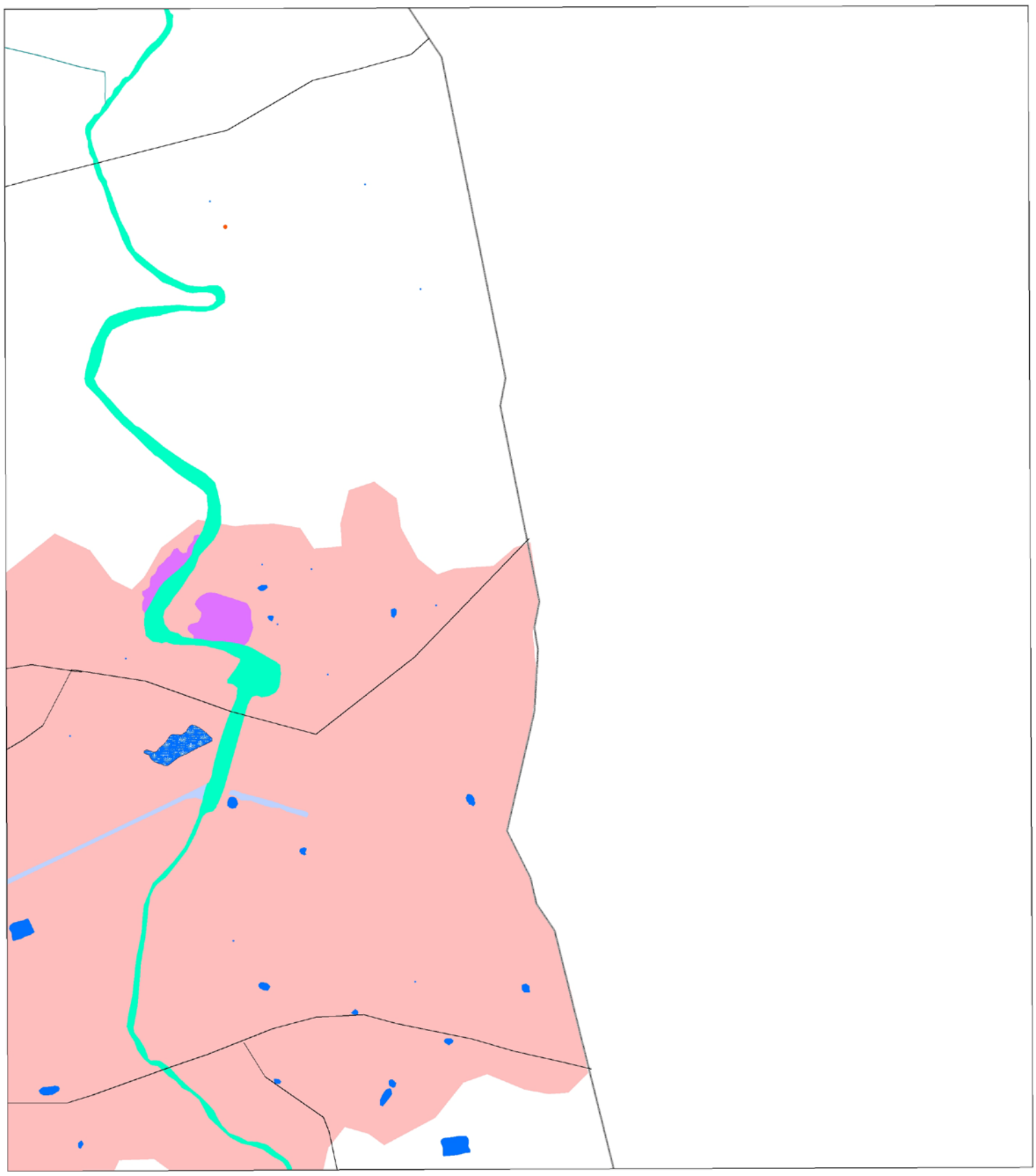
Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

WETLAND MAP

Map No. : 53H/06NE



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
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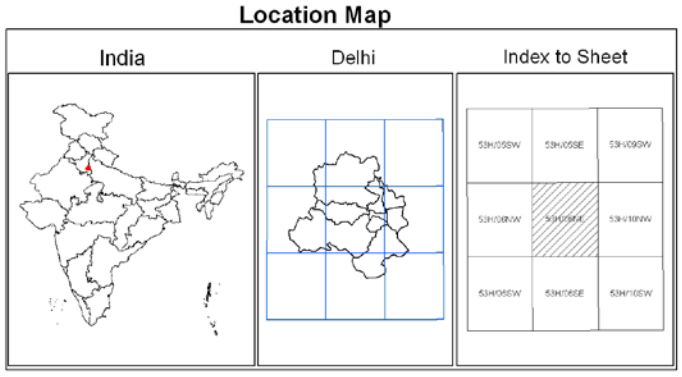
Location Map



0 0.5 1 2 Kilometers

Data Source :
IRS P6 LISS III and LISS IV data
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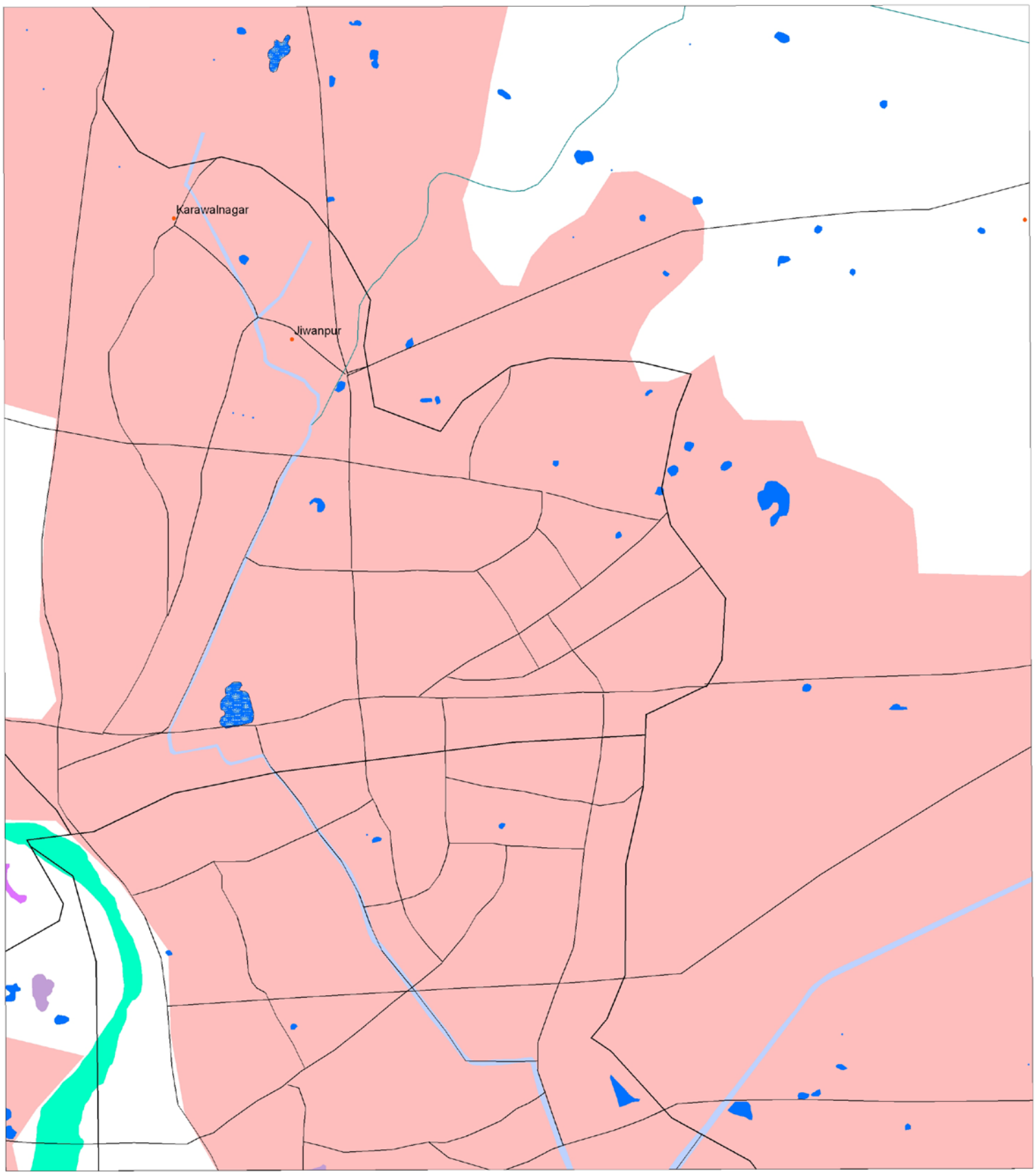
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

WETLAND MAP

Map No. : 53H/06NW



Symbol	Typecode	Level I	Level II	Level III
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	1101			Lakes/Ponds
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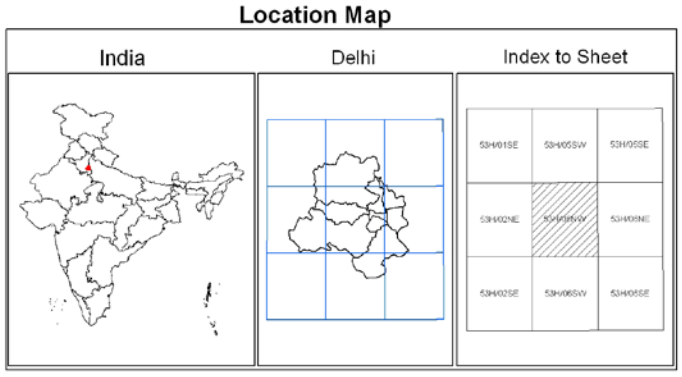


0 0.5 1 2 Kilometers

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

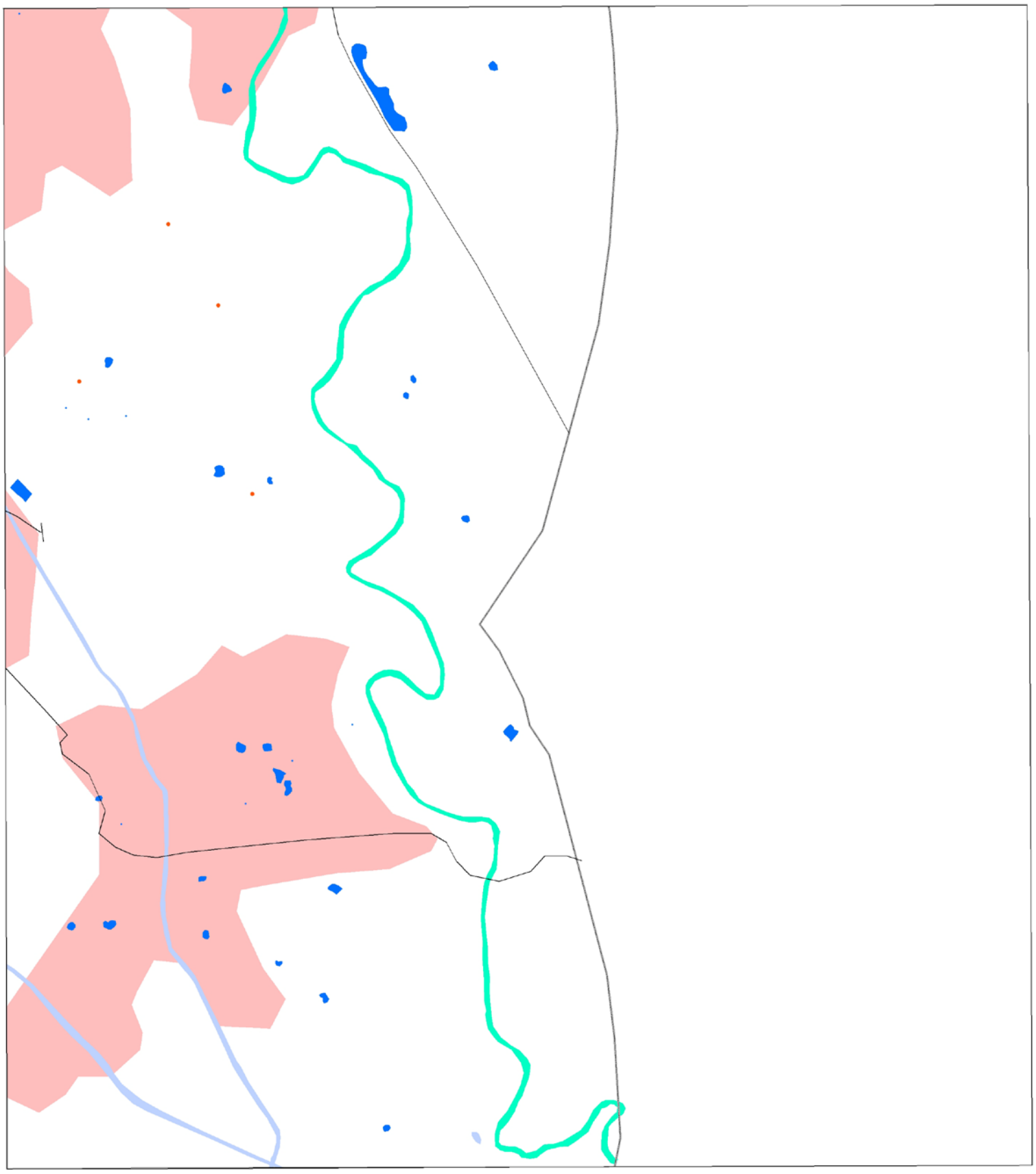
Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

WETLAND MAP

Map No. : 53H/06SE



Symbol	Typecode	Level I	Level II	Level III
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	1101			Lakes/Ponds
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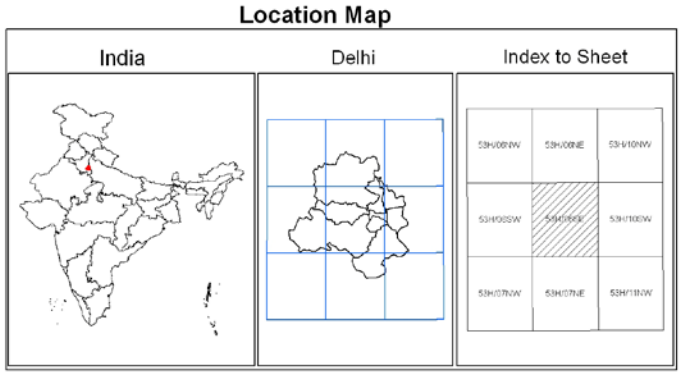

0 0.5 1 2 Kilometers

Data Source :
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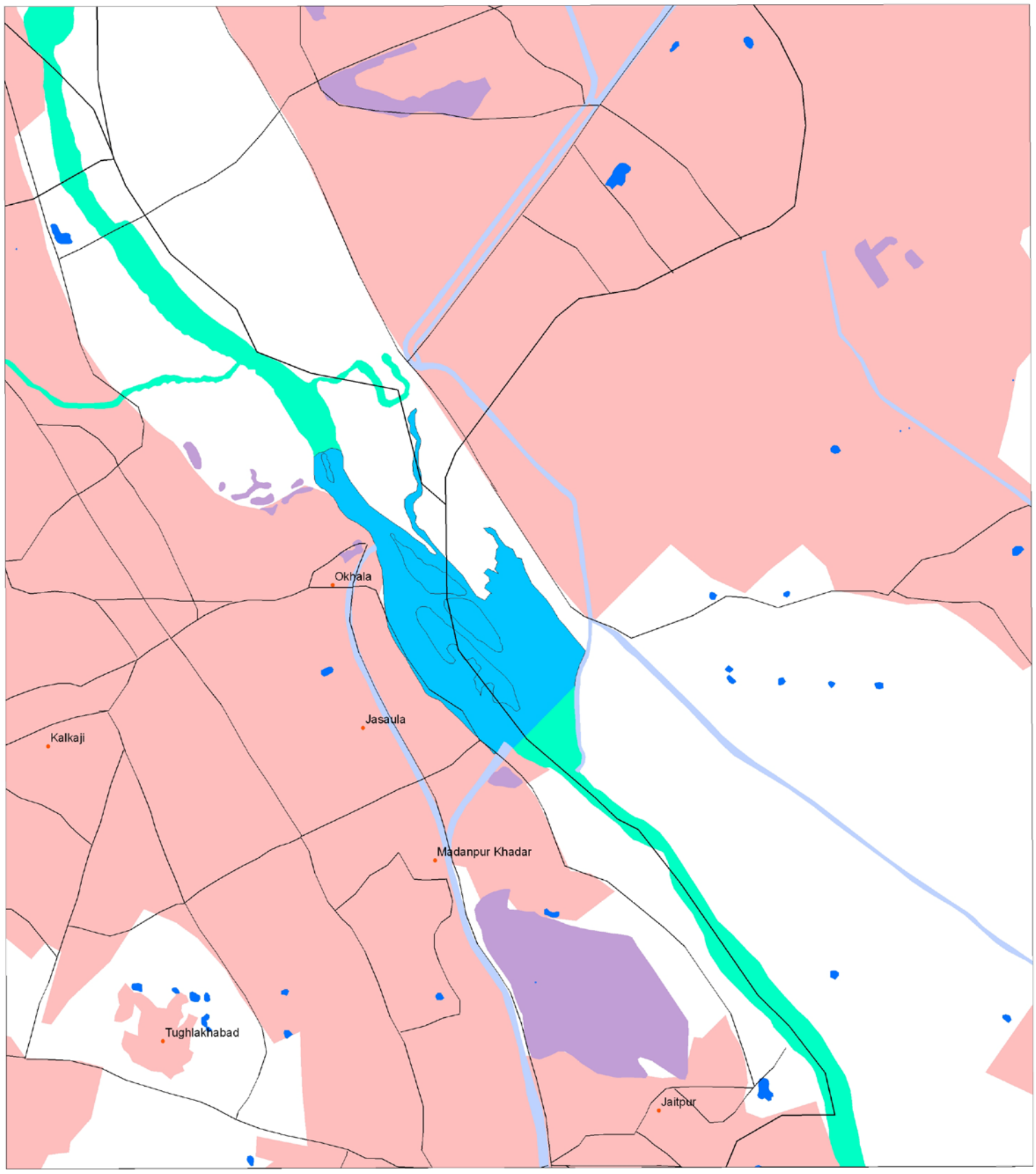
Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Delhi

WETLAND MAP

Map No. : 53H/06SW



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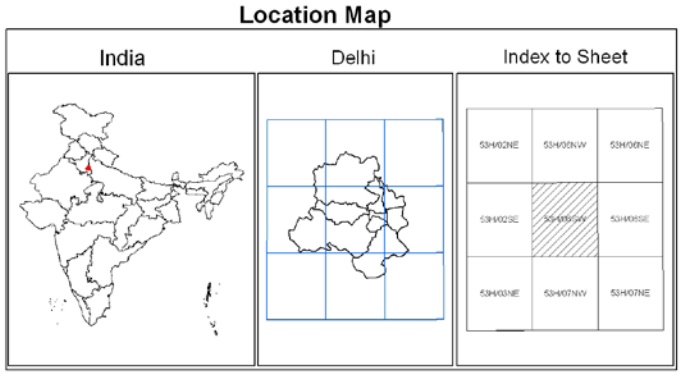

0 0.5 1 2 Kilometers

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Prepared By :
Space Applications Centre (ISRO), Ahmedabad

Sponsored By:
Ministry of Environment and Forests
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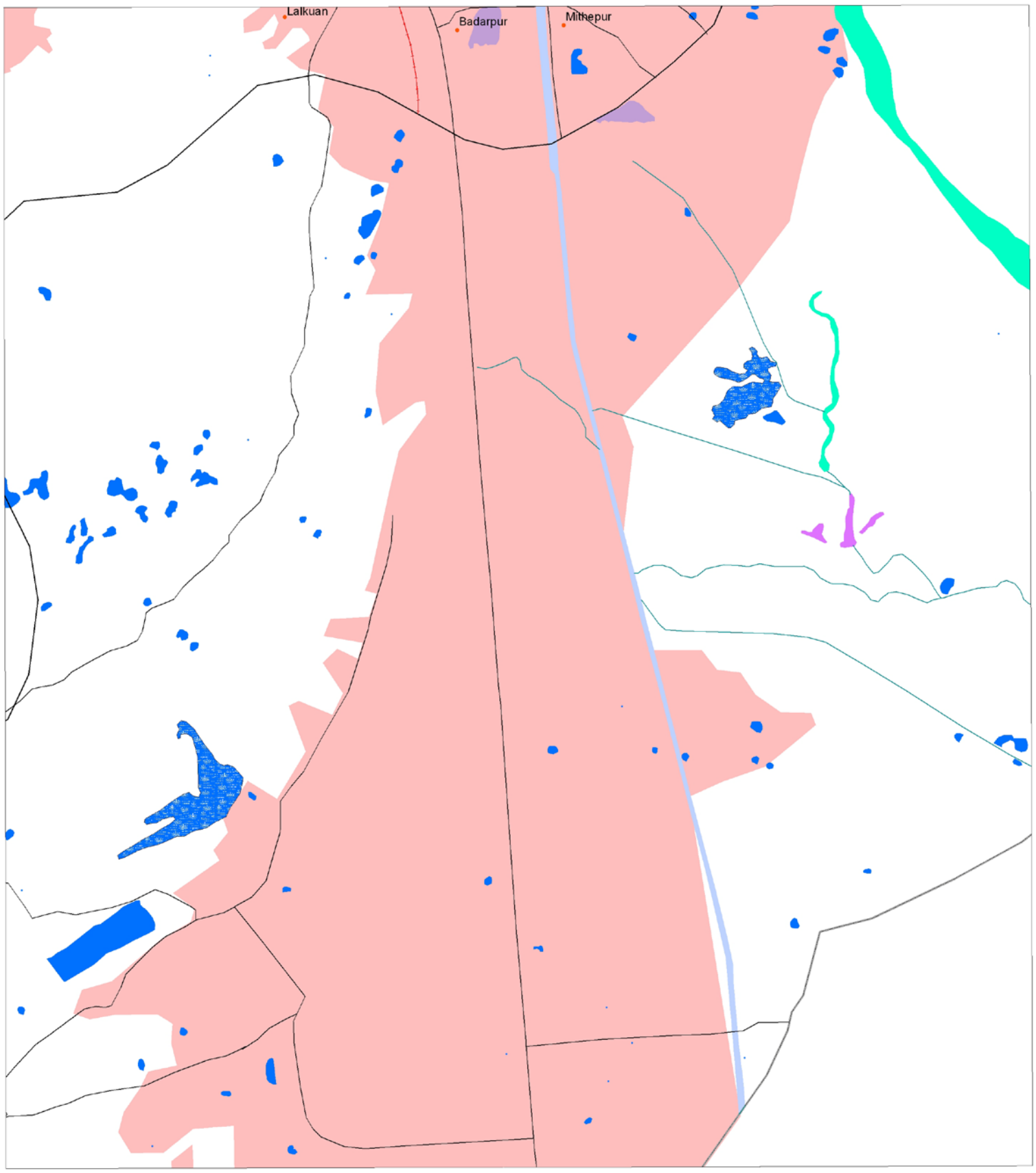
State : Delhi

WETLAND MAP

Map No. : 53H/07NW



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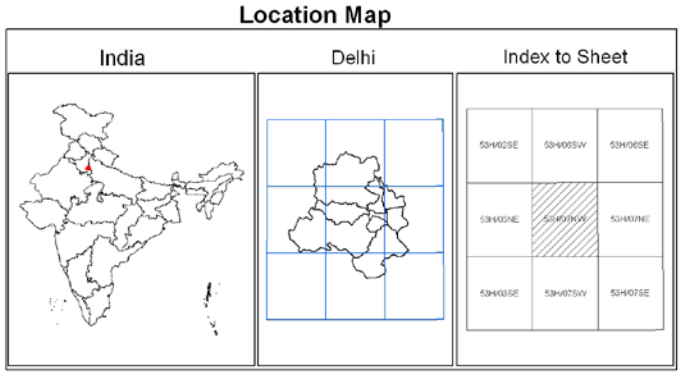

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Prepared By :
Space Applications Centre (ISRO), Ahmedabad

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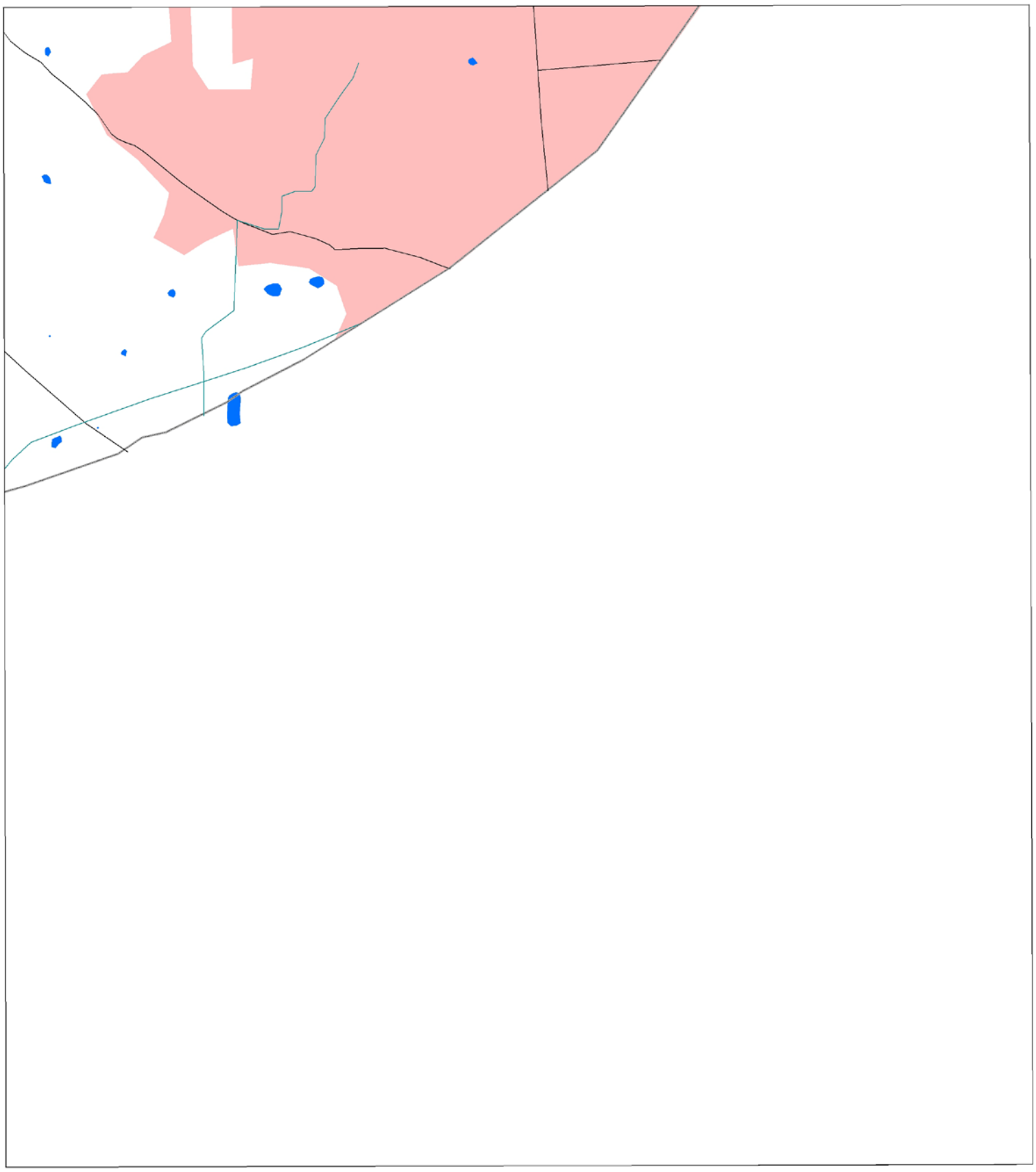
WETLAND MAP

Map No. : 53H/07SW



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		Inland Wetlands		
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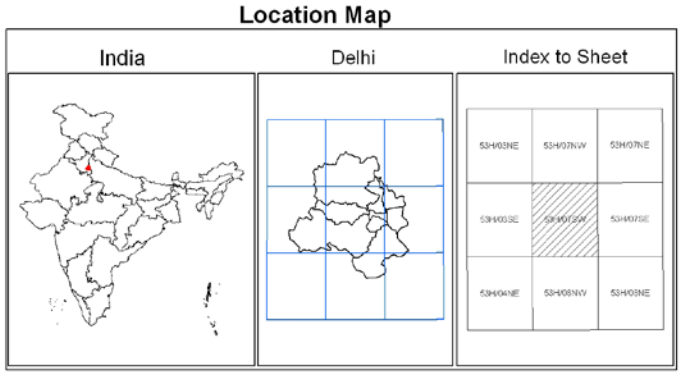

0 0.5 1 2 Kilometers

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Prepared By :
Space Applications Centre (ISRO), Ahmedabad

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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:

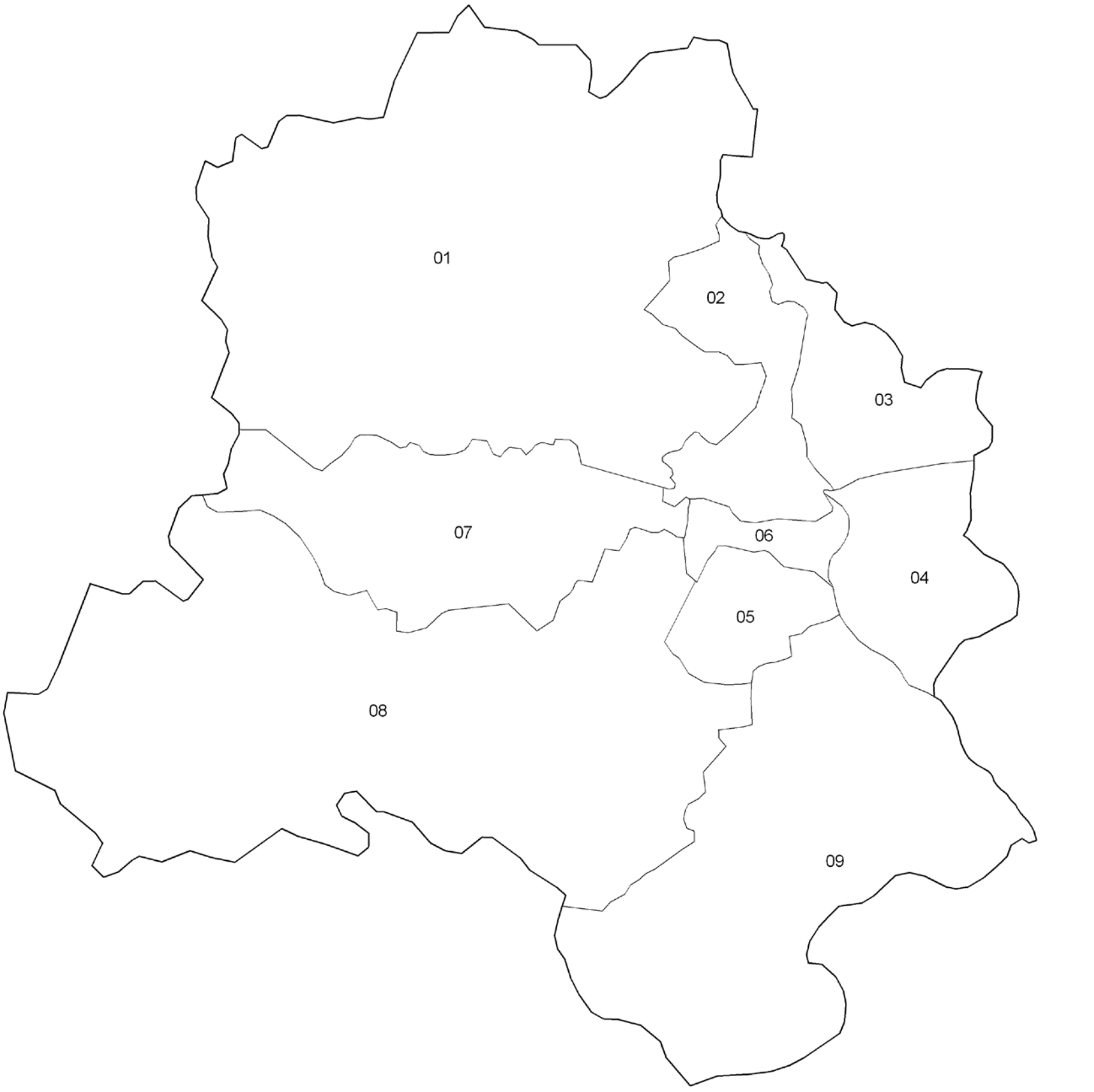
Wetland type code	Definition and description
1000	**Inland Wetlands**
1100	**Natural**
1101	**Lakes**: Larger bodies of standing water occupying distinct basins (Reid *et al*, 1976). These wetlands occur in natural depressions and normally fed by streams/rivers. On satellite images lakes appear in different hues of blue interspersed with pink (aquatic vegetation), islands (white if unvegetated, 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 (Margarate *et al*, 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 (Margarate et al, 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 (Margarate *et al*, 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 Encyclopaedia of Environmental Sciences, 1974), **Ash pond/Cooling pond** (The water body created for discharging effluents in industry, especially in thermal power plants (Encyclopaedic Directory of Environment, 1988) and **Cooling pond**: An artificial lake used for the natural cooling of condenser-cooling water serving a conventional power station (Encyclopaedic 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 waterlogging 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 (Margarate *et al*, 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 unvegetated 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 unvegetated 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 foraminefera. 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 (Margarate *et al*, 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 (Encyclopaedic Directory of Environment, 1988). Aquaculture ponds are geometrical in shape usually square or rectangular. Tone is blue.

Annexure – II
Details of District information followed in the atlas

State : Delhi

District Boundary Map



List of Districts

District Code	District Name
01	North West
02	North
03	North East
04	East
05	New Delhi
06	Central
07	West
08	South West
09	South

Legend
State Boundary
District Boundary

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

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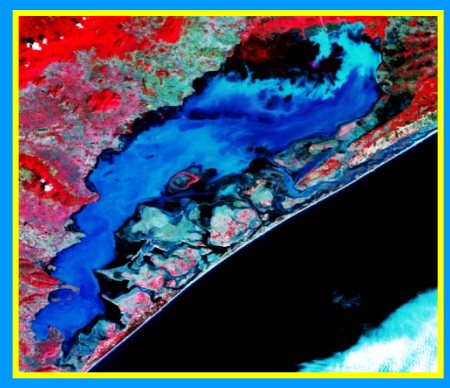

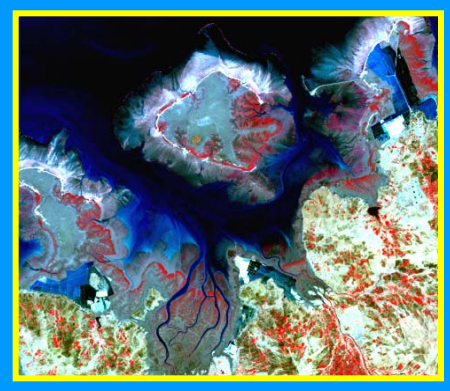

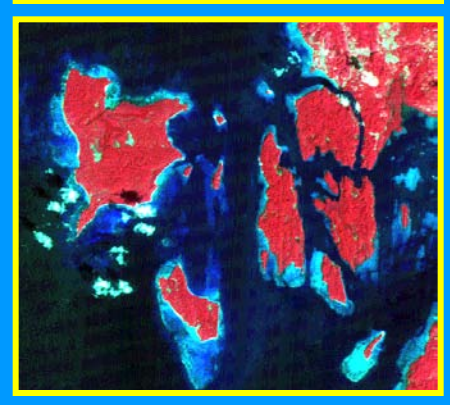

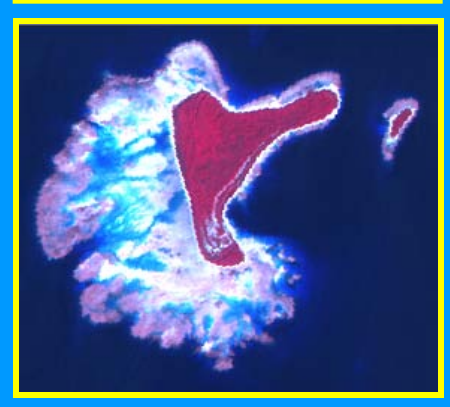

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