Comprehensive Management Plan for Pallikaranai Marsh

2014-2019

Conservation Authority for Pallikaranai Marsh

Care Earth Trust

2014

Acknowledgement

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One of the most fascinating aspects about the conservation of Pallikaranai Marsh is the unstinted support received from various people and organisations. The Save Palliakaranai Marshland Forum, which is a forum comprising of resident welfare organisations, NGOs, academics and the media has been a part of the efforts for close to a decade now. Their support to the cause as well as the formulation of the Plan is acknowledged with thanks. Likewise, members of the PEC of the Conservation Authority for Pallikaranai Marsh provided their inputs to the plan readily. We are grateful to them.

About Care Earth Trust and the Contributors to the Management Plan

Care Earth Trust is a Chennai, India based Technical Non-Governmental Organization that was founded in the year 2000 with the mission of conserving biodiversity for human well-being through research, advocacy and capacity building. The organization was awarded the prestigious **Indira Gandhi Paryavaran Puraskar** for the year 2009, by the Ministry of Environment and Forests, Government of India and the **TieCon Social Entrepreneurship Award for the year 2014** by The Indus Entrepreneurs**.**

The following are the objectives of Care Earth:

1. To provide scientific services in the area of biodiversity inventorying and monitoring
2. To assess human impacts on environment and recommend strategies and action for improvement
3. To undertake training and capacity building initiatives for the conservation of biodiversity
4. To develop and disseminate resource material on all components of biodiversity
5. To facilitate the rescue and rehabilitation of stray, sick and abandoned animals

Over the last twelve years, Care Earth has evolved to be an equal opportunity, non-discriminating organization. The Trust is constituted of and governed by people who are not only subject experts, but are also well known for their integrity and commitment to science and human welfare.

Trustees: Dr P S Easa, Prof N V Joshi, Dr R J Ranjit Daniels and Dr Jayshree Vencatesan

Infrastructure

Care Earth has a full service administrative office in Chennai with state of the art facilities for research and development, equipment such as computers with advanced software for computing and data analysis, and communication facilities. Extension facilities of Care Earth include a dedicated farm of 24 acres for palms and Cycads at Wallajahbad, Kanchipuram district, a field station at Bhavanisagar, Erode district and a rehabilitation centre for animals at Iyyencheri, Kanchipuram district.

Care Earth, as an institution and the Trustees, as members, are represented as

1. Member – Empowered Panel of the National Wildlife Board, Government of India
2. Member of the Working Group on Mapping Ecologically Sensitive, Significant, and Salient Areas of Western Ghats, for the Ministry of Environment and Forests, Government of India
3. Invited member – Western Ghats Expert Ecology Panel, set up by the Ministry of Environment and Forests, Government of India
4. Member of the Working Group: Forests and Livelihoods, Planning Commission of India
5. Member of the Tiger Conservation Authority, Tamil Nadu Forest Department, Government of Tamil Nadu
6. Member of the CAMPA, Tamil Nadu Forest Department and Working Group on Forests and Environment, Government of Tamil Nadu
7. Member of the Conservation Authority for Pallikaranai Marsh, Government of Tamil Nadu.
8. Member of the Working Group on Forests, State Planning Commission, Government of Tamil Nadu
9. Member, Tamil Nadu State Wildlife Advisory Board, Government of Tamil Nadu
10. Member, Kerala State Wildlife Advisory Board, Government of Kerala.
11. Member, Asian Elephant Specialist Group, IUCN/SSC
12. Member, Project Elephant Steering Committee, Government of India
13. Member, State Wildlife Advisory Board, Government of Chattisgarh

14. Member, Elephant Task Force, Ministry of Environment and Forests, Government of India
15. Member, Committee for studying the Human Wildlife Conflict related issues in Kerala, Government of Kerala
16. Member – Approval Committee of Tiger Conservation Plan for Tiger Reserves of South India, Ministry of Environment and Forests, Government of India.
17. Consultant to the National Biodiversity Authority, Government of India to revise the National Biodiversity Action Plan of India for submission to the Conference of Parties (CPO11) held at Hyderabad, 2012.
18. Consultant to the National Biodiversity Authority, Government of India to revise the National Targets for submission to the Conference of Parties (COP12)

Care Earth's publications (in addition to individual peer reviewed publications)

- Field guides to Birds, Amphibians and Freshwater Fishes by Dr R J Ranjit Daniels with Oxford University Press and the Indian Academy of Sciences
- Booklets for the Tamil Nadu Forest Department on various topics
- Booklets for Tamilnadu Biodiversity Board on Endangered Plants and Animals of Tamilnadu
- A comprehensive book on Western Ghats: People. Biodiversity and Conservation, published by Rupa and Company
- Technical Reports and papers listed in the website of Care Earth.

Care Earth's engagement with the judiciary

Care Earth is the expert member on two High Level Committees established by the Hon'ble High Court of Madras to oversee the restoration of major wetlands of Tamil Nadu viz. Adyar Creek and the Pallikaranai Marsh.

Academic Guidance

Care Earth has guided directly, or through technical support, 48 student dissertations. These include University of Freiburg, Germany, Oxford University, UK, University of

Illinois – Urbana Champaign, USA, Centre for Environment Planning and Development, Ahmedabad, Queens University, Belfast, Ireland and local universities such as Anna University and Madras University. It has a technical collaboration with IIT-Madras on studies pertaining to Pallikaranai Marsh.

Pioneering Projects of Care Earth Trust: trustees as individual experts and institutional expertise

1. Drafted the first ever management plan for the Nilgiri Biosphere Reserve for the Man and Biosphere Programme (1995) UNESCO
2. Drafted the country's first report to comply with Article 6 of the Convention on Biological Diversity for the Ministry of Environment and Forests, Government of India
3. Drafted the National Biodiversity Strategy and Action Plan for the Western Ghats Eco region for the Ministry of Environment and Forests, Government of India
4. Drafted the Biodiversity Strategy and Action Plan for Bangladesh for the Asia office of the World Conservation Union
5. Drafted the guidelines for the preparation of Biodiversity Strategy and Action Plans for south Asia for the Asia office of the World Conservation Union

Long term engagement with the Conservation of the Western and Eastern Ghats

- Coordinated the preparation of the **National Biodiversity Strategy and Action Plan for the Western Ghats Eco region** for the Ministry of Environment and Forests, GOI, the output of which is the benchmark for data on the Western Ghats (2000)
- Studied the **Impact of pesticide use on amphibians in the Anamalai Hills, Tamilnadu.** Project supported by International Conservation Union; one of the key indicators was the development of simple tools using frogs as indicators and provided the same to UPASI and other planters in Valparai for monitoring the health of the ecosystem Impact of Pesticides in Valparai (2002)
- Study on **Forests as refugia for human impacted plant species**. Supported by Smithsonian Tropical Research Institute, the study focused on the multiplicity of

uses and users of plant species in the Mudumalai WLS, Tamilnadu. One of the key outputs of the project was the restoration of 79 acres of wetlands that were encroached upon by the local community within the sanctuary(2003)

- Preparation of the base document for enabling the declaration of **Kotachadri Ecologically Sensitive Area in Karnataka** (2005)
- Two research projects of the TN Forest Department (2006): Defining methodologies to assess **Agroforestry practices in various districts of Tamil Nadu** and the Market Dynamics of Non-Timber Forest Produce in Tamil Nadu.
- **Species recovery plan for the Nilgiri Tahr.** Project supported by the Tamil Nadu Forest Department and Ministry of Environment and Forests, Government of India (2009)
- Research project titled '**Distribution and Dynamics of the *Phoenix* species in Eastern Ghats of Tamil Nadu** (2010). Supported by the Forest Utilisation Division of the Tamil Nadu Forest Department

Three research projects supported by the Tamil Nadu Forest Department (2008-2009)

- A study on the **harvesting techniques adopted for the collection of Nelli (Gooseberry) in Sathyamangalam Forest Division** by NTFP collectors and the impact on the growth and health of the trees
- A study **the protection and rehabilitation measures carried out by the Tamil Nadu Forest Department in the abandoned mining areas** within Reserve Forests of Tambaram Range
- A study on the **distribution and dynamics of *Phyllanthus* species in Sathyamangalam Forest Division of Tamil Nadu**
- Expert Consultation for the Government of Tamil Nadu/ JICA for preparation of the project proposal on Biodiversity, Tribal Development and Social Issues for the **Project Tamil Nadu Biodiversity Conservation and Greening Project** (2010)
- Project on **'Building a grassroots constituency to conserve River Moyar in the Mysore-Nilgiri Corridor'** (2009-2011) and **'*In situ* Conservation of the**

Critically Endangered Vultures of the Moyar Valley '(2011-2013). Project executed in partnership with Arulagam, Coimbatore with the support of the Critical Ecosystem Partnership Fund, Conservation International. Resulted in the contribution of information on conservation priorities to the management plan for Nilgiris North Forest Division, Tamilnadu and led to the development of a standardized, participatory methodology for assessing riverine habitats.

- Project titled **'Status of NTFP collection and trade in Tamil Nadu; with specific reference to the Eastern Ghats (2011).** One year study supported by the Forest Utilisation Division of the Tamil Nadu Forest Department.
- Project on **'Linking scales*:* Mainstreaming the Conservation Agenda in the Western Ghats of Tamil Nadu** (2013-15) with the support of the Critical Ecosystem Partnership Fund, Conservation International. The project is being implemented with the guidance of the Principal Secretary, Planning and Development, Principal Secretary – Environment and Forests and the State Land Use Board, to develop a Vision Document for the Conservation of the Western Ghats of Tamilnadu.
- Study on '**Bird Community Diversity in the Eastern Ghats of Tamil Nadu'** (2012-14) with the support of the Ministry of Environment and Forests, Government of India. The study documents bird community diversity in some of the lesser known patches within the Western Ghats of Tamilnadu.
- Project titled **'A state wide survey of select NTFP species** viz. Tamarind, Gallnut, Amla and Phoenix grass to evolve sustainable harvest methods and protocols (2013-15). Supported by the Research Division, Tamilnadu Forest Department. Project expected to evolve sustainable harvest protocols for the listed NTFP.
- Project titled '**Deciphering Land Use and Land Cover Change in the Western Districts of Tamilnadu"** (2014) State Land Use Research Board, State Planning Commission, Government of Tamilnadu. The study focuses on identifying proximate and distal drivers of land use land cover change around Protected Areas.

Care Earth's engagement in developing Landscape-level management plans for Bird Sanctuaries and Wildlife Sanctuaries

Name of the project	**Wetland Participatory Management Planning and Preparation of Wetland Action Plan for Vedanthangal and Karikili Bird Sanctuaries, Kanchipuram district**
Donor/Funding Agency	Tamilnadu Forest Department, Wildlife Warden - Chennai
Duration	Six months (2013)
Team Leader	Jayshree Vencatesan
Nature of the project	Development of a Management and Action Plan based on primary and secondary studies; situational analysis and consultation
Collaborators/Advisors	S Balachandran / BNHS
Name of the project	**Wetland Participatory Management Planning and Preparation of Wetland Action Plan for Vellode Bird Sanctuary – Erode district**
Donor/Funding Agency	Tamilnadu Forest Department, DFO-Erode
Duration	Six months (2013)
Team Leader	Jayshree Vencatesan
Nature of the project	Development of a Management and Action Plan based on primary and secondary studies; situational analysis and consultation
Collaborators/Advisors	S Balachandran / BNHS
Name of the project	**Wetland Participatory Management Planning and Preparation of Wetland Action Plan for Kanjirakulam, Chitrangudi, Melselvanoor and Keelselvanoor BS , Ramanathapuram district**
Donor/Funding Agency	Tamilnadu Forest Department, Wildlife Warden - Ramanathanpuram
Duration	Six months (2013)
Team Leader	Jayshree Vencatesan
Nature of the project	Development of a Management and Action Plan based on primary and secondary studies; situational analysis and consultation
Collaborators/Advisors	S Balachandran / BNHS

Name of the project	**Wetland Participatory Management Planning and Preparation of Wetland Action Plan for Vettangudi BS, Sivaganga District**
Donor/Funding Agency	Tamilnadu Forest Department, DFO-Sivaganga
Duration	Six months (2013)
Team Leader	Jayshree Vencatesan
Nature of the project	Development of a Management and Action Plan based on primary and secondary studies; situational analysis and consultation
Collaborators/Advisors	S Balachandran / BNHS
Name of the project	**Development of a Water Management Strategy – Sathyamangalam FD**
Donor/Funding Agency	Tamilnadu Forest Department, DFO-Sathyamangalam
Duration	One Year (2013)
Team Leader	Jayshree Vencatesan
Nature of the project	Development of a Management and Action Plan based on primary and secondary studies; notably hydrology and wildlife management; and situational analysis and consultation
Collaborators/Advisors	Dr R Jagannathan, HOD – Department of Geography, Madras University
Name of the project	**Development of a Water Management Strategy – Erode FD**
Donor/Funding Agency	Tamilnadu Forest Department, DFO-Erode
Duration	One Year (2013)
Team Leader	Jayshree Vencatesan
Nature of the project	Development of a Management and Action Plan based on primary and secondary studies; notably hydrology and wildlife management; and situational analysis and consultation
Collaborators/Advisors	Dr R Jagannathan, HOD – Department of Geography, Madras University
Name of the project	**Development of a Water Management Strategy – Megamalai WLS**
Donor/Funding Agency	Tamilnadu Forest Department, WLW-Megamalai
Duration	One Year (2013)
Team Leader	Jayshree Vencatesan
Nature of the project	Development of a Management and Action Plan based on primary and secondary studies; notably hydrology and wildlife management; and situational analysis and consultation
Collaborators/Advisors	Dr R Jagannathan, HOD – Department of Geography, Madras University

Name of the project	**Development of a Water Management Strategy – Guindy National Park**
Donor/Funding Agency	Tamilnadu Forest Department, WLW-Chennai
Duration	One Year (2013)
Team Leader	Jayshree Vencatesan
Nature of the project	Development of a Management and Action Plan based on primary and secondary studies; notably hydrology and wildlife management; and situational analysis and consultation
Collaborators/Advisors	Dr R Jagannathan, HOD – Department of Geography, Madras University
Name of the project	**Training and Capacity Building for the Management of Wetlands and Bird Sanctuaries of Tamilnadu**
Donor/Funding Agency	Tamilnadu Biodiversity Conservation and Greening Project (TBGP) Tamilnadu Forest Department
Duration	Six months (2013)
Team Leader	Jayshree Vencatesan
Nature of the project	Training, Capacity building, development of proceedings, Terms of Reference and Framework for developing Wetland Action Plans for the Bird Sanctuaries of Tamilnadu
Collaborators/Advisors	Drs S Balachandran, R J R Daniels
Name of the project	**Wetland Participatory Management Planning and Preparation of Wetland Action Plan for Vaduvoor and Udayamarthandapuram BS, Tiruvarur district**
Donor/Funding Agency	Tamilnadu Forest Department, DFO-Tiruvarur
Duration	Six months (2013)
Team Leader	Jayshree Vencatesan
Nature of the project	Development of a Management and Action Plan based on primary and secondary studies; situational analysis and consultation
Collaborators/Advisors	S Balachandran / BNHS
Duration	Six months (2013)
Team Leader	Jayshree Vencatesan
Nature of the project	Development of a Management and Action Plan based on primary and secondary studies; situational analysis and consultation
Collaborators/Advisors	S Balachandran / BNHS
Name of the project	**Development of the Ecological Management Plan for the Indian Institute of Technology – Mandi (HImachal Pradesh)**
Funding Agency	IIT-Mandi, MoHRD
Duration	2011
Team Leader	R J Ranjit Daniels
Nature of the project	Development of a Management Plan focusing on River Beas
Collaborators/Advisors	Mr R S Katwal IFS (Former CWLW, TNFD)

Name of the project	**Developing the Environmental Management Plan for Paatashala at Vallipuram (River Cheyyar floodplain).**
Donor/Funding Agency	The School - Krishnamurthy Foundation of India, Chennai.
Duration	2011
Team Leader	Jayshree Vencatesan
Nature of the project	Development of an Environmental Management Plan
Collaborators/Advisors	

Name of the project	**Management Plan for Thiruppadaimaruthur Birds Conservation Reserve of River Tamiraparani, Tirunelveli**
Donor/Funding Agency	Tamilnadu Forest Department
Duration	One year (2009)
Team Leader	Jayshree Vencatesan
Nature of the project	Preparation of the Management Plan for the country's first Birds Conservation Reserve

Institutional and Individual Contributors to the Development of the Management Plan

1. Dr R Jagannathan, Head of the Department, Geography, Madras University, Chennai

2. Mr Dharmesh Shah, Global Alliance for Incinerator Alternatives (GAIA)

3. Dr S Balachandran, Deputy Director, Bird Migration Study Centre, Bombay Natural History Society

4. Dr Indumathi Nambi, Associate Professor – Environmental Engineering, Indian Institute of Technology-Madras and her colleagues

5. Mr. Balchand Parayath and Mr. Raj Cherubal, Directors, Chennai CityConnect Foundation

6. The Executive Committee of Chennai City Connect

7. Mr Mahesh Radhakrishnan of MOAD for developing the Ribbon Walk Project Design

6. Mr V Srinivasan and Mr Kumara Raja of Save Pallikaranai Marsh Forum

7. The Director and staff – CCAC, Anna University

8. Ms. Thea-lina Muller and Dr Franziska Steinbruch of the Indo-German Centre for Sustainability at IIT Madras

Executive Summary

Water security, including both availability and quality, is a major and increasing concern in many parts of the world. Wetlands are solutions to water security and they provide multiple ecosystem services. Both maintaining and restoring wetlands can lead to cost savings in comparison to man-made infrastructural solutions. Wetlands are some of the most bio-diverse ecosystems in the world, providing essential habitats for many species. Wetlands are essential to human well-being and their loss can have negative ecological and economic impacts.

Wetlands can be described as lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by standing water that does not exceed 6 meters. Wetland management requires taking into account the intimate relationship between wetlands and the surrounding landscape. Wetlands can be managed by removing the stressors on the ecological character of existing wetlands or by restoration where degradation has occurred.

Tamil Nadu has 6.92% of its total geographical area under wetlands. There are 17 major river basins in Tamil Nadu and Pallikaranai Marsh is part of Chennai River Basin, more specifically a part of the Adayar River. The Pallikaranai Marsh is located in suburban Chennai, in Kanchipuram district which now comes under Greater Chennai. Pallikaranai Marsh is one of the last remaining natural wetlands of Chennai city located between 12.949371°N latitude and 80.218184°E longitude. The marsh is bound in the East by Old Mahabalipuram Road, in the West by Tambaram-Velachery road, Velachery village in the North and by Medavakkam-Karapakkam road in the South. It drains an area of about 250 km^2, through two outlets *viz.*, Okkiyam Madavu and the Kovalam creek and falls into Bay of Bengal and the topography of the marsh is such that it always retains some storage. The marsh area had a spread of 6000 ha (60 km^2) around 1960s which has now reduced to 593 ha. In 2007, the Government of Tamil Nadu notified the southern portion of the marsh, spanning 317 ha, initially as a Reserved Land which was later upgraded to a Reserve Forest. The marsh has been reduced and fragmented, due to construction of institutes, the Perungudi dump-yard

and Sewage treatment plant, IT corridors, residential complexes, etc. Pallikaranai is one of the 94 wetlands identified under National Wetland Conservation and Management Programme (NWCMP) of the Government of India.

Pallikarnai Marshland in Chennai is one of the most important wetlands in India. It is natural and unique in its hydrology. It is home to a large number of species of plants and animals. It is, however, under various kinds of threats; threats that are largely due to the rapidly changing surrounding urban landscape of Chennai. The threats are also due lack of awareness on the ecological value of natural wetlands.

A large part of south Chennai was historically a flood plain comprised of Pallikaranai Marsh, smaller satellite wetlands, large tracts of pasture land and patches of dry forests. The smaller wetlands that surrounded the Marsh served as the only source of irrigation for the area. The first known external manipulation of this system was the laying of the Buckingham Canal. Further, the presence of the freshwater aquifer running parallel to the coast contributed rather significantly to the expansion of the city's boundaries in the south. One of the fundamental factors facilitating the degradation was the categorization of the marsh as a pasture land and the absence of a State Land Use Policy. The marsh has been reduced to around one-tenth of its original extent on account of unplanned urbanization, destructive reclamation and dumping of solid and liquid waste generated by the urban society. The uniquely heterogeneous hydrology and ecology of the Pallikaranai Marsh makes it one of the most diverse natural habitats of the country. It supports 349 species of flora and fauna including 133 species of birds, 10 species of mammals, 21 species of reptiles, 10 species of amphibians, 50 species of fishes, 9 species of molluscs, 5 species of crustaceans, and 7 species of butterflies and about 114 species of plants including 29 species of grass. Various habitat types found in Pallikaranai Marsh include, open water pockets, islands and mounds, shallow waters and mud flats, emergent sedges, reeds and grassy bank areas, and flooded live and dead timber.

During the past 50 years nearly 90 percent of the Pallikaranai Marsh has been lost. Within this loss, large tracts of the marsh especially those along the residential areas of

Thoraipakkam, Pallikaranai and Perungudi have been converted into residential colonies. Roads, infrastructure, municipal landfills, sewage treatment facilities, etc. have fragmented the marsh into smaller portions and impacted the natural drainage pattern. Further, large tracts of the marsh have been invaded by invasive species of plants notably *Prosopis juliflora* and Water Hyacinth. During the period 2001-2008 the landscape underwent a significant transformation in terms of being modified into residential and industrial zones. Following the declaration of a large part of the marsh as a protected area, the unprotected area has been converted rather rapidly into human occupied zones. The overall wetland area both within the designated marsh area and the adjoining habitations has reduced considerably and the reduction in the area under open water within the marsh is of serious concern. Density of habitation is at the maximum on the northern and north-western portions of the marsh, which are also the zones that are impacted intensively during flooding. The marsh is under severe human pressure on all directions, except for the south which has the presence of an associated wetland thereby offering a semblance of buffer zone attributes. Keeping in view the long-term conservation and management of the Pallikarnai Marshland a comprehensive management plan has been drafted.

The Comprehensive Management Plan for Pallikaranai is based on the notion of Adaptive Management, which is a flexible, inclusive and knowledge-based approach. This plan accords equal consideration to people and nature and in a manner is a reconciliation of conservation and development goals. In view of the significance and long term anthropogenic degradation of the Pallikaranai Marsh, it is recommended that while the first five years are considered as the building blocks for the process, definition of certain goals, notably those pertaining to habitat improvement need to be addressed in blocks of five years. It is also important that quarterly reviews of progress be undertaken to ensure mid-course correction and establish benchmarks for monitoring achievements.

Multi-institutional collaboration has been co-opted into the process of formulating the current plan. Consultative processes engaging the stakeholders were conducted to factor in local considerations and continuous engagement through institutions such as the Conservation Authority for Pallikaranai Marsh. The wetland-specific Adaptive Management Framework adapted from Teal and Weishar (2005) has been used and this is discussed in detail in Chapter 2.

The Adaptive Management targets formulated on the basis of ongoing research and review of literature include, (i) maintain current wetland area, (ii) restore adequate water retention in wetland and surrounding watershed(s), (iii) eliminate groundwater depletion, (iv) reduce ecological risk in wetland to acceptable levels, (v) attain sufficient social valuation of wetland, (vi) restore species diversity, and (vii) maintain individual species.

The methodology for the development of the comprehensive management plan broadly included review, analysis and consolidation, scientific assessments and evaluation using standardized methods and tools, consultative processes and community/stakeholder engagement including SWOT-Analysis, reconciliation and engagement and conservation prioritization and formulation of Action Plans.

The main vision of the Comprehensive Management Plan is protection, restoration and conservation of wetlands for the cause of biodiversity conservation and human well-being. The most critical aspect of the current plan is its shift from being a ‘Management Plan for a Reserve Forest to a Comprehensive Management Plan for a Wetland for a five year period’. A three pronged strategy has been defined for the management of the Pallikaranai Marsh, which focuses on consolidation, protection, restoration and conservation. In the case of Pallikaranai Marsh, the primary focus is on the hydrological aspects of the wetland; notably not allowing the wetland to degrade to a water deficit, exceedingly dry entity.

The strategy of consolidation and protection is focused both on the currently protected area and the additional area of marsh being included in the ambit of protection through allotments from other line departments and the Chennai Corporation and the Revenue Department. The plan also recognizes that further addition to the RF area is possible to a maximum of 620 ha. The strategy also includes, the identification of ecological boundaries, as well as additional areas that need to be brought under regulation /protection for ensuring the integrity of the Pallikaranai Marsh.

The wetland area of about 2650 ha in 1990s has shrunk rather rapidly to less than 500 ha in 2012-13, due to the actual decrease in wetland area, the degradation of adjoining wetlands within the landscape and the loss of hydrological processes as a consequence. Ongoing research has indicated that about 700-800 tankers extract water within 3 km of the Pallikaranai marsh either by directly pumping water from the wetlands or through bore-wells, which needs to be managed as it is unsustainable as well as unregulated.

The area around Pallikaranai Marsh was historically the natural water holding zone for the city of Chennai. For defining the boundaries of Pallikaranai Marsh and considering watersheds as units of demarcation, the landscape under question is 231 sq. km, in which the remnant Pallikaranai Marsh is centrally located. The wetlands around the Marsh as well as the remnant forests such as the Nanmangalam RF are thus ecological extensions of the marsh. This entails that the watershed, christened the South Chennai Flood Plain, is redefined as the management unit, and all natural habitats that are currently present either in full or as remnants be accorded protection. Hence, it is important to focus on protecting the hydrology of the South Chennai Wetland Complex.

Analyzing the hydrology of Pallikarani Marsh, the construction of the Buckingham Canal was a key feature in connecting the easterly wetland of Okkiyam Thoraipakkam to the Marsh. The southern canal which originated in Ottiyambakam wetland and drained north through Perumbakkam has been compromised. Analyses show that Pallikaranai Marsh and its wetland complexes are part of one watershed that is spread over an area of 231 km.

The East coast is part of a small, yet distinct watershed. Buffering the two watersheds is yet another watershed of an extent of 10 ha which is what rendered historical connectivity to the Adayar River. While the adjoining wetlands discharge water into the marsh either as an overflow or through the drainage network, the presence of a stream that cuts across the marsh from the south-western parts of the landscape, to the north eastern part of the landscape is of critical significance for the south west – north east flow of freshwater into the system. The saline water intrusion was through the coastal watershed, with south to north drainage, with only the excess water draining into the marsh. The conservation of the marsh is hence critically linked to the protection of the watershed which hosts the Adyar River, as well the entire watershed of which it is a part.

The focus of ecological restoration for Pallikaranai Marsh is the wetland habitat. The Pallikaranai Marsh has about 550 ha dedicated for the restoration programme in blocks, strips or patches. For the restoration of Pallikaranai Marsh, four sub themes of restoration have been identified and these are as follows: ecological, environmental, interventional and hydrological. One of the foremost strategic interventions is to improve wetland area to maximize hydrological efficiency. This can be done by reclamation of large parts of the marsh on the northern, western and eastern peripheries to enable the development of residential and industrial complexes. The intervention within the designated marsh area in terms of roads, establishment of institutions and the presence of the Perungudi MSW dump have contributed not only to the overall reduction in the area and spread of the marsh, but have also altered the hydrology of the marsh.

Changes on the southern aspect of the marsh like establishment of institutions and industries, road construction and presence of ELCOT city have contributed to the flip of the marsh into grassland overrun by Invasive Alien Species. It is proposed that all areas identified as wetland/marsh areas must be protected by annexing the same to the existing Pallikaranai Marshland RF and areas outside the ambit of being part of RF, notably the 30 wetlands identified as being components of the South Chennai Wetland Complex need to be brought under the purview of the Conservation Authority for Pallikaranai Marsh.

The Chennai River Restoration Trust (CRRT) needs to be brought into the CAP or collaborate as a partner while developing its programmes and efforts need to be taken to ensure that ELCOT as well as the private industrial holdings, allow the small pockets of remnant wetlands within the campus to continue status quo, and also take an active part in the protection and campus restoration of the Pallikaranai Marsh. Guidelines for the real estate developers in the landscape need to be distinct, highlighting the dos and don’ts. Existing buildings located within the marsh have evolved to become refuges and breeding habitats for some of the large wetland birds and hence should not expand infrastructure.

For the purpose of restoring wetland attributes for supporting biodiversity various habitat types like mudflats, islands, emergent sedges and open water need to be preserved. It is also suggested to identify and restore wetland areas under Invasive Alien Species of plants. All the invasive woody vegetation including *Prosopis* should be removed from within the wetland to prevent excessive water loss due to evapo-transpiration. To restore the diversity of habitats within the Pallikaranai Marsh it is important to manage the aquatic vegetation notably *Typha* reed.

Seven species are Invasive Alien fish are known from the Marshland. Of these the Giant African Catfish and the Armored Catfish are a matter of serious concern. The marshland is open to further invasions by alien fish species. One species that is likely to invade is the Pacu. All three species of Tilapia introduced into the country for fisheries are now thriving in Pallikaranai Marsh which are likely to become abundant in the absence of local harvesting. Small-sized fish that are important in the aquatic food web are diverse and abundant. The presence of diadromous fish in the marshland indicates its connectedness to the Bay of Bengal. Fish that thrive in shallow water like panchax, mosquito fish and others are common in the marshland which can help in the control of mosquitoes locally. It is suggested that monitoring the relative abundance of the IAS and the air-breathing fish will be useful in tracking the water quality of the marshland. To maintain the fish diversity in the marshland, habitat management through monitoring the depth and DO levels of the water and by maintaining the connectivity with the sea and also locally within the various segments of the marshland is important. Management of shallow water micro-habitats also needs to be addressed.

For restoration of the groundwater system of the landscape a joint team of the line departments should undertake screening studies at a river basin or regional aquifer scale, to assess the potential for interaction between wetlands and groundwater. The Pallikaranai Marsh adjoins the south Chennai aquifer that runs parallel to the old Mahabalipuram Road. The aquifer originates from the south of Thiruvanmiyur and extends up to Kovalam Creek in the south. A study shows that there could be lowering in the groundwater level due to industrialization and the high groundwater pumping. The recharge from the rainfall was estimated to be 290 mm per year representing 28% of the average annual precipitation. A separate study shows the decrease in the holding capacity of the Pallikaranai Marshland due to construction on the Marshland which could be a reason for the reduction in the groundwater recharging capacity of the Marshland.

Considering the geology, groundwater recharging amount, rainfall amount the effective recharge in cu meters over the period 2001 to 2013 has been presented in the Plan. It has been found that due to changes in the Marshland its retention capacity is rapidly decreased and will lead to extreme floods in Chennai with precipitation sums which are already under the 95% confidence interval. To facilitate the seasonal hydrology of the system it has been suggested that all drainage systems in and out of the Palliakaranai Marsh must be brought under the joint purview of the Public Works Department and the TN Forest Department. Further, culverts on the Thoraipakkam-Keelkattalai Road must be maintained on a regular basis as opposed to the post monsoon intervention and flow channels in ELCOT city can be maintained as a joint venture between ELCOT and TNFD. Management of the mouth of Okkiyam Madavu can be handled jointly by the TNFD and PWD and no further structural intervention in any form should be allowed within the designated marsh area.

The major sources of pollution in Pallikaranai Marsh are large quantities of untreated and partially treated sewage water and Perugudi MSW dump, spread over an expanse of 78 ha. Pallikaranai marsh is largely affected by organic waste disposal and contamination as is indicated by the high levels of Chloride and Sulphate and alarmingly high concentrations of the heavy metals known to be carcinogenic in nature.

Groundwater in several pockets around the marshlands is now contaminated and the rich organic content of the municipal waste degrades over time to release highly acid and toxic leachate. Further an air sample taken during a routine fire at the dump revealed the presence of 27 toxic chemicals including 3 carcinogens. High amounts banned chemicals like DDT and hexachlorocyclohexane have also been reported from the Marsh. The waste dump is adjacent to a Reserve Forest and in the migratory path of many birds which are at high risk and for which the recommended action is closure. Planned closure followed by a through remediation is proposed. In order to streamline the assessment process the Superfund Accelerated Cleanup Model (SACM) method suggested by the United States Environment Protection Agency's (USEPA) is proposed. The site investigation activity checklist (UNEP 2005) can be used as a guideline for carrying out Remedial Investigation and Feasibility Studies (RI/FS) at Perungudi.

A robust public consultation component has to be included in the process of remediation. It is also crucial to ascertain that the nodal waste management agency has a clear plan to phase out its dependence on Perungudi for waste disposal. Institutional Control by waste diversion through decentralized management in Kodambakkam, Teynampet, Adyar and other areas that send their waste to Perungudi is proposed. The immediate priority should ideally be containment of pollutants before moving on to the remediation phase. For Perungudi the *ex situ* approach is recommended as the site is on an ecologically sensitive area which requires the most stringent decontamination process possible. Natural Cap/Catch can also be used for remediation which includes biodegradation by plant uptake, anaerobic degradation by micro-organisms and adsorption to organic matter. A proper closure plan should precede a remediation plan and before a disposal facility stops receiving wastes which includes stabilization of critical slopes, leachate collection and treatment, fire control and waste picker resettlement action plan. Further, a long-term monitoring plan will be required as part of the remediation design and implementation. The significance of public participation is also essential and should be incorporated into the process wherever practically possible. An alternate system of waste management that does not rely on disposal but rather on recovery of resources at source should be initiated in all the zones that rely on Perungudi.

A GIS based interventional model has been developed for Pallikaranai Marsh at a resolution of 10 ha grids for supporting the restoration initiatives. This model has delineated the entire marsh, irrespective of its legal status or administrative jurisdiction into equal sized 10 ha grids and interventions has been proposed as part of the restoration strategy for the Pallikaranai Marsh.

Defining the ecological significance of Pallikaranai Marsh, it is a part of the vast Bay of Bengal Large Marine Ecosystem. There are around 130 species of birds and more than 50 species of fish in the Pallikaranai Marshland. The fish and fish-eating birds are the flagship species that characterize wetland ecosystems. Pallikaranai Marsh also serves, as a feeding ground to a number of visitors. Migrants like the sandpipers and teals are common and Blackwinged Stilts may usually be found in a small number at the northern edge of the water.

The fish fauna of Pallikarnai Marshland is dominated by species that are capable of withstanding lower dissolved oxygen levels. The higher relative abundance of invasive alien species such as the mosquito fish and tilapia is evident. The community of fish found in the wetland is such that the species represent various feeding guilds and together sustain a very complex underwater food web and fish availability is rather substantial. Therefore large numbers of fish-eating birds such as cormorants, pelicans, storks, herons, egrets and terns inhabit the marshland. Annual fish availability is guaranteed by two important ecological factors - the meta-population dynamics and complex underwater food web.

The influence of the Bay of Bengal Large Marine Ecosystem has been significant on the marshland affecting hydrology and biodiversity and may also be responsible for the diversity of certain species of migratory waders. Population and diversity of waders and shorebirds in the marshland start building up after the northeast monsoon and peak during December-March seasons when the water recedes and becomes shallower. In addition to this there are the ducks and other swimming birds like the grebe. Given the inference that the ecological web that sustains the Pallikaranai Marshland is relatively intact, it is important that future interventions, direct or indirect, do not upset the existing balance. Major interventions that might affect the ecology of the marshland are that which concern the hydrology.

Occurrence of six near- threatened and 1 vulnerable species of birds emphasize the global importance of Pallikaranai Marsh. Up to 1400 individuals of Grey headed Lapwing an uncommon migrant species to southern India have been recorded at Pallikaranai. The global importance of this wetland is well understood in providing the wintering ground for the vulnerable migratory wader the Great Knot, and several uncommon (Red Knot, Large Whistling Duck, Grey-headed Lapwing) and near-threatened species. It supports over 40,000 birds at a time during the migratory season and over 5000 birds during the non- migratory season and thus easily qualifies as an important Ramsar site.

Historically, the marshland received copious volumes of freshwater. However, currently much of the runoff water has been diverted through narrow channels and closed storm-water drains offering less scope for free oxidation as the water flows. Based on the assumption that the minimum hydrological flows will be interfered with by the rapidly changing land use around the marshland it is foreseen that the pattern of sedimentation, mudflat and shore formation will be very dynamic that habitat management for shore and wading birds will be a major future challenge.

The dynamics of sedimentation will also affect water-land ratio leading to shifts in the vegetation mosaics and also create newer habitat niches for invasive terrestrial plants like *Prosopis juliflora*. In Pallikarnai Marshland, the invasion of *Prosopis juliflora* has been rather rapid along the northeast boundary and this may be attributed to the substrate created by the solid waste disposal from the Perungudi side. Other species of plants that have the potential of interfering with the hydrology and the land-water ratio of the marshland are the cattail, water lettuce, duckweed and water hyacinth. Managing these plants therefore need appropriate strategies and are not completely eliminated. Considering the dynamic nature of the surrounding landscape, it is important to monitor not just the diversity and abundance of birds, but also the dynamics of micro-habitats within the protected area and the shifting mosaics of major habitats in the entire watershed-landscape that sustains the marshland.

Tree-cover within the watershed-landscape needs to be carefully assessed and monitored. Shifts in the community organization of wetland birds; the ratio of fish-eating birds and non-fish-eating wetland birds is the key to monitoring the health of the Pallikarnai Marshland. Fish diversity and abundance in the wetland have to be carefully managed so that the breeding birds find adequate food within the sanctuary. For this, it is important that during the dry season, the catfish is harvested and eliminated. It is also important to manage eutrophication in the sanctuary.

It has been proposed that Pallikaranai Marsh would be an ideal site for a public space. Two watch towers have been recently constructed by the Forest Department to make bird watching easier and binoculars are available for bird watching. A project titled Ribbon Walk has been proposed for Pallikaranai Marsh on the Thoraipakkam – Keelkattalai Radial Road, whose design elements and cost estimates are provided. It is proposed to develop and construct a dedicated Wetland Centre at Pallikaranai Marsh whose key features would include education and awareness, training and capacity building, research and monitoring. For enabling local communities' participation in the management and conservation of Pallikaranai Marsh establishment of a Local Interest Group (LIG) through a well-entrenched Eco-tourism programme, for engaging in protection and conservation is proposed. Hence, it would be necessary to collaborate and discuss these requirements with the resident welfare groups for efficient management of the marsh. Creation of a Nature Guides Corp should also be taken up the LIG.

The LIG could evolve a cycle trail in parts around the marsh. This includes maintenance of roads and making available cycles on rent. Such an effort could be further strengthened by declaring the marsh a 'no-plastic zone.' The possibility of regulated extraction of *Typha* grass and the conversion of the same into eco-friendly products could also be explored. Another effort could be the commemoration of local conservation efforts as a carnival during birding seasons. Framework for studies and assessments, wetland inventory, wetland disease management has also been discussed in detail. Establishment of a Wetland Authority for the State of Tamil Nadu is proposed.

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1. Introduction

1.1 Wetlands and their characteristics

Wetlands are “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 metres” (Ramsar Convention, 1971). Wetlands are more popularly defined as ‘lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by standing water that does not exceed 6 meters’.

Wetland is also a term often used to describe an ecosystem arising from water inundation and whose soil and biotic processes are adapted to flooding. Wetlands across the globe are variable in their appearance and composition and include other ecosystems described as marshlands, swamps, and bogs (Keddy, 2010).

The Ramsar Classification of Wetland Types includes 42 types of wetlands, which belong to one of the three broad categories (Ramsar Convention Secretariat, 2011):

- Inland wetlands;
- Marine/coastal wetlands;
- Human-made wetlands.

Human-made wetlands covered by the Ramsar Convention include aquaculture, farm ponds and permanently or temporarily inundated agricultural land - such as rice paddies, salt pans, reservoirs, gravel pits, sewage farms and canals. There are a range of other wetland classifications used for different purposes, based on hydro-geomorphology and/or vegetation characteristics, such as:

- Marine (coastal wetlands, including coastal lagoons, rocky shores and coral reefs);
- Estuarine (including deltas, tidal marshes, and mangrove swamps);
- Lacustrine (wetlands associated with lakes);
- Riverine (rivers and wetlands along rivers and streams); and
- Palustrine (marshes, swamps and bogs).

The Ramsar Charter on Wetlands

1. The "nexus" between water, food and energy is one of the most fundamental relationships – and increasing challenges - for society.
2. Water security is a major and increasing concern in many parts of the world, including both the availability (including extreme events) and quality of water.
3. Global and local water cycles are strongly dependent on wetlands.
4. Without wetlands, the water cycle, carbon cycle and nutrient cycle would be significantly altered, mostly detrimentally. Yet policies and decisions do not sufficiently take into account these interconnections and interdependencies.
5. Wetlands are solutions to water security – they provide multiple ecosystem services supporting water security as well as offering many other benefits and values to society and the economy.
6. Values of both coastal and inland wetland ecosystem services are typically higher than for other ecosystem types.
7. Wetlands provide natural infrastructure that can help meet a range of policy objectives. Beyond water availability and quality, they are invaluable in supporting climate change mitigation and adaption, support health as well as livelihoods, local development and poverty eradication.
8. Maintaining and restoring wetlands in many cases also lead to cost savings when compared to manmade infrastructure solutions.
9. Despite their values and despite the potential policy synergies, wetlands have been, and continue to be, lost or degraded. This leads to biodiversity loss - as wetlands are some of the most biodiverse areas in the world, providing essential habitats for many species - and a loss of ecosystem services.
10. Wetland loss can lead to significant losses of human wellbeing, and have negative economic impacts on communities, countries and business, for example through exacerbating water security problems.
11. Wetlands and water-related ecosystem services need to become an integral part of water management in order to make the transition to a resource efficient, sustainable economy.
12. Action at all levels and by all stakeholders is needed if the opportunities and benefits of working with water and wetlands are to be fully realised and the consequences of continuing wetland loss appreciated and acted upon.

An estimated 1,386,000,000km^3 of water fills the earth. Of this, only 2.5% is fresh water. Two-thirds of the Earth's freshwater is locked up as ice. The freshwater that is held in lakes, rivers, wetlands, underground aquifers, soil pores, plant life and atmosphere – the Earth's major source of freshwater, amounts to a mere 0.77% of the total water that fills the earth.

1.2 Global wetland area

The global extent of coastal and inland wetlands is estimated to be in excess of 12.8 million km^2, but this is recognised as a considerable underestimate. Estimates for global area of inland (freshwater) wetlands vary considerably (from 5.3 – 9.5 million km^2), but are also considered underestimates (Finlayson et al. 1999). Much of the total area is **inland wetlands**: for example, 5.7 million km^2 of natural freshwater wetlands (including 3.85-4 million km^2 of peatlands); and 1.3 million km^2 of rice paddy (see Spiers 1999). Open water wetlands (both natural and human-made) cover a seasonal maximum of 5.66 million km^2 (Prigent et al. 2012). Areas of **coastal wetlands** are smaller, and include 0.5 million km^2 of major estuaries (MA 2005c); 0.566 million km^2 of major deltas (Coleman et al. 2008); 0.138-0.147 million km^2 of mangroves (FAO 2007; Giri et al. 2011); 0.177 million km^2 of seagrass beds (Green & Short 2003); and 0.392 million km^2 of salt marshes and up to 0.6 million km^2 of coral reefs (TEEB, 2013).

1.3 Current Status of Global Wetlands

Wetlands continue to face severe pressures, despite many benefits they provide to people and many conservation/restoration successes from recent efforts at local to national to global scales. Although there is no comprehensive assessment of the state of the world's remaining wetlands, many are recognised as having deteriorated in status and to be currently degraded. For instance, in 2012, out of the 127 governments reporting to the Ramsar Convention, 28% of the countries indicated that the overall status of their wetlands had deteriorated in the recent years while only 19% indicated improvement.

1.4 The water cycle and wetlands

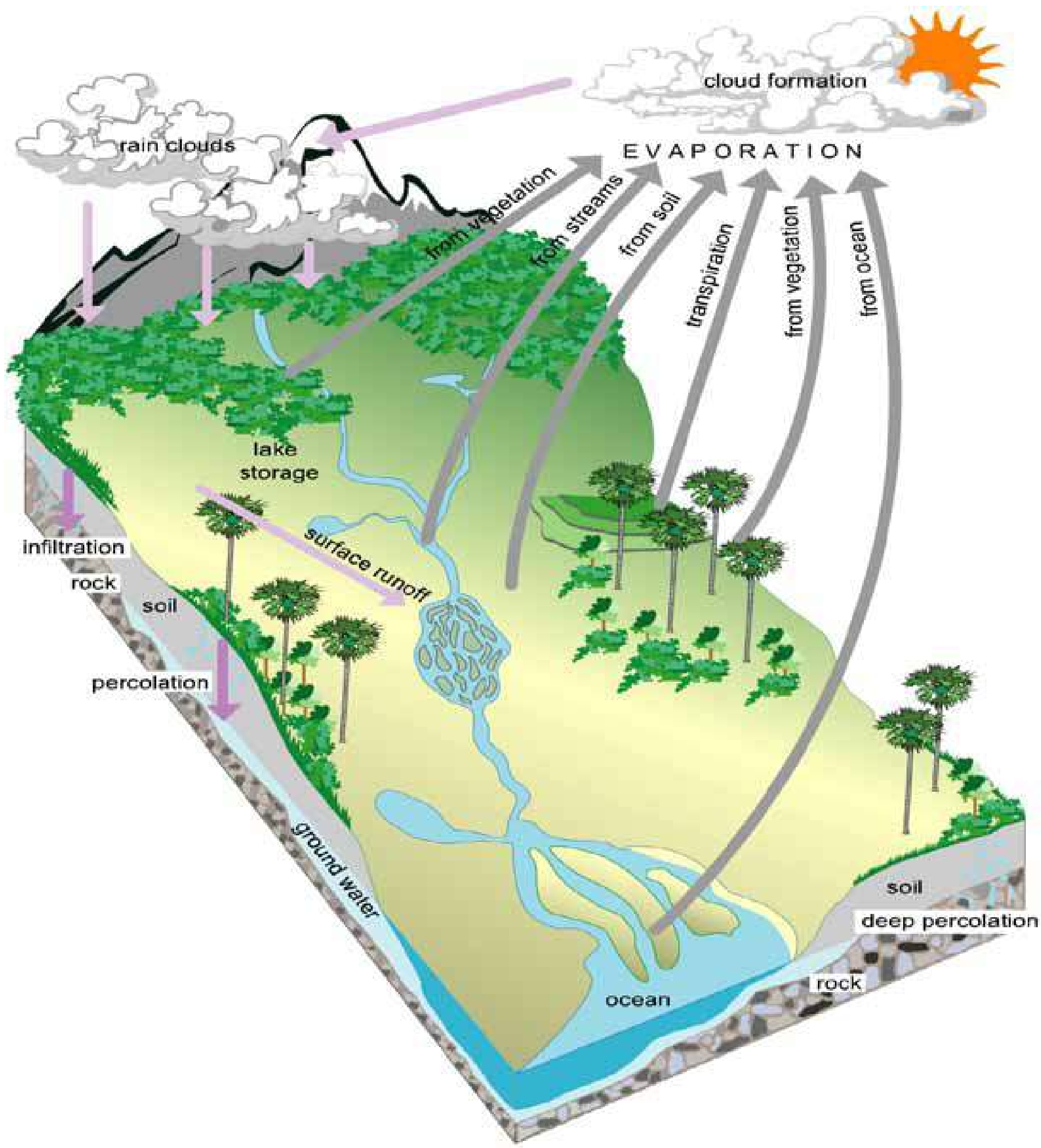
Water moves around the earth through the water cycle and wetlands are a crucial part of it. The water cycle is influenced by both physical (e.g. topography, geology) and ecological factors (e.g. transpiration from plants, the effects of land cover on water flows). The water cycle also underpins and is influenced by nutrient cycling (which influences water quality) and carbon cycling (which influences land cover and organic carbon in soils, including in high carbon ecosystems such as peatlands). This functioning supports the delivery of all ecosystem services from land (including those from land-based wetlands) and greatly influences those delivered by coastal ecosystems. Fig. 1.1 illustrates this cycle and highlights only some of the water-related and water dependent ecosystem services in play.

Wetlands are a conspicuous and important part of this cycle and therefore a key determinant of the type and level of ecosystem service delivered – particularly regarding surface water flows (most of which occur through wetlands). Whilst this report focuses on the role of wetlands in delivering ecosystem services, it is important to keep in mind this landscape/ecosystem setting of wetlands. Usually, but not always, wetlands receive water from the landscape and deliver it, generally through rivers, to the coast and onwards into the sea. There are exceptions: some wetlands deliver water back into the landscape (through groundwater and soil moisture recharge) while other inland wetlands can be the final destination of water. In some cases wetlands cannot be distinguished from land, e.g. wetlands dominated by vegetation cover (such as forested wetlands).

One major implication of this intimate relationship between wetlands and the landscape is that neither can be managed independently. In some cases, particularly in deltas, wetlands are responsible for creating land itself through sediment transfer.

Also, in many instances the services delivered by wetlands are underpinned by a combination of ecosystem functions arising from both within and beyond the wetland and the surrounding landscape. For example, the hydrology of wetlands is determined by the physical and ecological features of the wetland itself and that of the catchment within which it is located. A second important feature is the inter-connectivity between ecosystem components, particularly through wetlands, which results in disturbances in one area having a potential impact in another - often a long distance away. For example, the benefits of flood regulation provided by wetlands can be realised a long distance downstream, up to thousands of kilometres.

Figure 1.1 provides an overview of the hydrological pathways and the ecosystem services provided by the water cycle.



1.5 Wetlands and Ecosystem Services

Wetlands are the most important of life-supporting ecosystems that have sustained human lives and communities over the millennia. And as Sandra Postel and Stephen Carpenter have lucidly said in 1997 "it is no coincidence that early human civilizations sprang from river valleys and floodplains. Sufficient quantities of freshwater have underpinned the advancement of human societies since their beginning. Today, we rely on the solar-powered hydrological cycle not only for water supplies, but also for a wide range of goods and services, many of which are hidden and easy to take for granted".

Wetland ecosystems, including rivers, lakes, marshes, rice fields, and coastal areas, provide many services that contribute to human well-being and poverty alleviation (Table 1.1). Groups of people living near wetlands are highly dependent on these services and are directly harmed by their degradation. Two of the most important wetland ecosystem services affecting human well-being involve fish supply and water availability. Inland fisheries are of particular importance in developing countries and they are sometimes the primary source of animal protein for rural communities. Groundwater, often recharged through wetlands, plays an important role in water supply, with many people dependent on it as a source of drinking water.

"Wise Use" of Wetlands

The "wise use" concept adopted by the Ramsar Convention's Contracting Parties is widely recognised as the longest established example amongst intergovernmental processes of the implementation of ecosystem-based landscape scale approaches to the conservation and sustainable development of natural resources, including wetlands (Finlayson et al., 2012). Wise use of wetlands is now defined by Ramsar as *"the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development"* In turn, "ecological character" is *"the combination of ecosystem components, processes and services that characterize the wetland at any given point of time"*. Wise use and the maintenance of the ecological character of wetlands form the guiding principles for wetland management planning under the Ramsar Convention.

Table.1.1: Ecosystem services provided by wetlands

Services	Specifics and examples
Provisioning (providing direct services)	
Food	Production of fish, molluscs, fruits, cereals, other crops
Freshwater	Storage and retention of water for domestic, agricultural and industrial use
Fibre and fuel	Products of fuelwood, grasses, fibre, peat, fodder for cattle, wood for huts etc.
Biochemical	Medicines through plants and other biota
Genetic Material	Genes for resistance to pathogens, ornamental species etc.
Regulating	
Climate regulation	Source of and sink for greenhouse gases; influence of local and regional temperature, precipitation and other climatic processes
Water regulation (hydrological flows)	Ground water recharge and discharge
Water purification and waste treatment	Retention, recovery, and removal of excess nutrients and other pollutants
Erosion regulation	Retention of soils and sediments
Natural hazard regulation	Flood control, protection from storms
Pollination	Habitat for pollinators
Cultural	
Spiritual and inspirational	Abode of temples, other religious institutions, nominate deities, species, sacred spaces etc.
Recreational	Opportunities for recreational activities, local public spaces
Aesthetic	Many people find beauty or aesthetic value in wetlands and the biodiversity they support, notably birds
Educational	Opportunities for formal and informal learning, notably on Nature and Conservation
Supporting	
Soil formation	Sediment retention and accumulation of organic matter
Nutrient cycling	Storage, recycling, processing and acquisition of nutrients.

(Millennium Ecosystem Assessment, 2005)

Of Water and Sustainable Development

- The availability of water in the appropriate quantity (including avoiding scarcity and overabundance), with the appropriate quality and at the appropriate time is a fundamental requirement for sustainable development.
- Water security is widely regarded as the key natural resource challenge facing humanity.
- Wetlands are crucial in maintaining the water cycle which, in turn, underpins all ecosystem services and therefore sustainable development.
- Wetlands provide vital water-related ecosystem services at different scales (e.g. clean water provision, waste water treatment, groundwater replenishment), which are critical for life and the economy.
- The restoration of wetlands and their water-related services offer significant opportunities to address water management problems with sustainable and cost-effective solutions.
- Wetlands provide a network of important natural infrastructures that deliver significant benefits to people.
- Wetlands provide ecosystem services that can support man-made infrastructures to deliver water supply, sewage treatment and energy - among other benefits.
- In many cases, wetlands can offer ecosystem services that deliver benefits to humans more cost effectively and sustainably than alternative man-made infrastructures.
- Wetlands restoration is already at the forefront of ecosystem restoration in most countries because of the hydrological functions of wetlands.
- Wetlands are of importance to the livelihood and cultural identity of many diverse, indigenous peoples.
- Water-related ecosystem services and wetlands are being degraded at an alarming pace. Loss and degradation of water and wetlands have an enormous social and economic impact (e.g. increased risk of floods, decreased water quality - in addition to impacts on health, cultural identity, and on livelihoods).

1.6 Consequences of non-protection of Wetlands

It is to be recognized, albeit with a sense of despair, that many water resource developments that have been undertaken to increase access to water have not given adequate consideration to harmful trade-offs with other services provided by wetlands, and many such conversions of wetlands have favoured provisioning services (notably food production) at the expense of losing or reducing delivery of regulating and supporting services from wetlands. Given the often high values, and the diversity, of ecosystem services provided by intact and /or protected wetlands and that a large proportion of these values are from water-related regulating services such as regulation of water flows, moderation of extreme events and water purification, the widespread and major losses of all types of inland and coastal wetlands have inevitably led to the increasing major loss of wetland ecosystem service value delivery to people. Permitting the remaining wetlands be converted or letting them degrade means further loss of their value to people. Such costs of inaction (or actions to convert wetlands) can be very high.

1.7 The economic benefits of restoring degraded wetlands

When wetlands have been allowed to be lost or degraded, there is a second category of the cost of such inaction: the cost of restoration. Overall, while costs of restoration can be high, and require long-term management investment, the resulting economic benefits to people can outweigh such costs. However, in general even with active restoration interventions, once wetlands have been disturbed, they either recover slowly (over decades or centuries) or move towards alternate states that differ from their original (pre-disturbance) state (Moreno-Mateos et al. 2012; Mossman et al. 2012). As loss and degradation of wetlands leads to loss of the economic benefits of ecosystem services, restoration of wetlands can restore some of those services and hence deliver high economic benefits. Removing the stressors or pressures on the ecological character of existing wetlands is the best practice for preventing further loss and degradation. When this is not feasible or when degradation has already occurred, wetland restoration must be considered as a potential response option.

A few wetland restoration efforts have failed due to, among other things, narrow objectives which focus on one benefit or a partial package of benefits. The inability to recognise or appreciate the potential for achieving multiple benefits across sectors has, in some cases, precluded cost-effective, participatory approaches to wetland restoration that may be more successful in recovering benefits and delivering more sustainable outcomes for people and the environment. Decision makers should recognise the full range of environmental, cultural and socio-economic benefits from wetland restoration, as the failure to recognize these multiple benefits often greatly undermines the rationale for wetland restoration and compromises future well-being (Alexander et al., 2012).

2. Adaptive Management Framework and Targets

2.1 Adaptive Management – the approach, application to wetland restoration and conservation

The Comprehensive Management Plan needs to be entrenched in the notion of Adaptive Management, which is a flexible, inclusive and knowledge based approach. This plan accords equal consideration to people and nature and in a manner is a reconciliation of conservation and development goals. Adaptive Management as an ideal approach has amongst others, been advocated by Prof Madhav Gadgil. In his preamble to the Peoples' Biodiversity Register of the Biodiversity Act, 2002 and Rules, 2004, it is stated:

"In fact, the emerging scientific understanding of complex systems tells us that a centralized, inflexible approach to management of living resources cannot be expected to work. The history of the wetland of Keoladev Ghana at Bharatpur in Rajasthan, home to numerous species of resident and migratory water birds illustrates this very well. The well-known ornithologist, Dr Salim Ali and his co-workers have spent decades studying this ecosystem. As a result of this work, Dr Salim Ali was convinced that the ecosystem would benefit as a water bird habitat by the exclusion of buffalo grazing. Government accepted this recommendation, and, with the constitution of a National Park in 1982, all grazing was banned. The result was a complete surprise. In the absence of buffaloes, a grass, Paspalum grew unchecked and choked the wetland, rendering it a far poorer habitat for the water birds. Scientists therefore advocate that ecosystem management must be flexible and at all times ready to make adjustments on the basis of continual monitoring of on-going changes. In contrast, the Government authorities made a rigid decision to permanently ban all grazing and minor forest produce collection from Keoladev Ghana, and having once committed themselves have felt obliged to continue the ban, even though it has become clear that buffalo grazing, in fact, helps enhance habitat quality for the water birds. The emerging scientific philosophy therefore is to shift

from such an inflexible system involving uniform prescriptions to a regime embodying systematic experimentation with more fine tuned prescriptions. Under such a regime, stoppage of grazing would have been tried out in one portion of the wetland, the effects monitored and the ban on grazing either extended or withdrawn depending on the consequences observed. This would be a flexible, knowledge based approach, a system of "adaptive management" appropriate to the new information age". ***Madhav Gadgil, 2005*** *in his preamble to the Peoples' Biodiversity Register for enabling the Biodiversity Act and Rules (2002)*

- The second principle pertains to the issue of periodicity. While the set period for any management plan is five years, in view of the significance and long term anthropogenic degradation of the Pallikaranai Marsh, it is recommended that while the first five years are considered as the building blocks for the process, definition of certain goals, notably those pertaining to habitat improvement need to be addressed in blocks of five years. It is also important that quarterly reviews of progress be undertaken to ensure mid course change or correction, and establish benchmarks for monitoring achievements.

- Multi institutional collaboration and engagement is yet another principle that is seen as being fit to the formulation of the plan. It is in this context that a number of institutions and individuals have been co-opted into the process of formulating the current plan, and it is hoped that subsequent initiatives would follow the same.

- Consultative processes are important to engage stakeholders in natural resource management and this is especially pertinent in the case of urban areas wherein local populations are devoid of a direct connect with natural resources and hence may be oblivious to its protection. On the other hand, this kind of a scenario provides an opportunity to build sensitivity and awareness amongst local people to ensure that natural resources and areas are appreciated and thereby protected. It is also important to factor in local considerations and inputs into the management plan as and when applicable.

- Continued engagement through established formats and institutions such as the Conservation Authority for Pallikaranai Marsh, especially the Project Executive Committee is yet another critical principle in the development and implementation of the management plan.

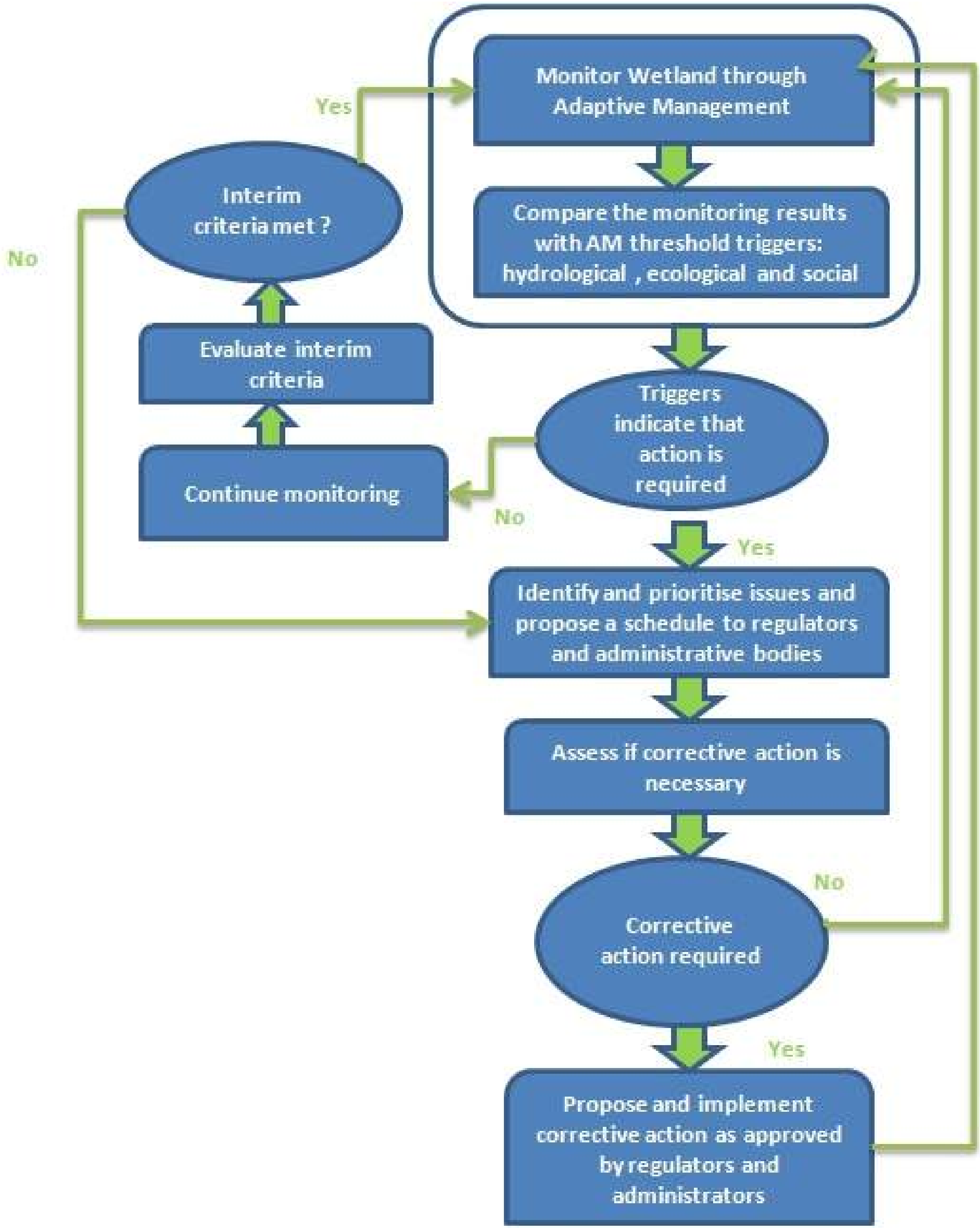
2.1.1 Adaptive Management

Adaptive management (AM) has been successfully utilized as a tool to help restore the ecological functioning of wetlands. It is an iterative process that involves decision-making regarding complex, uncertain situations in order to improve an existing situation. The gathering of information and system monitoring are key methods to refining AM's iterative process. Often adaptive management is misunderstood and confused with trial and error approaches. Adaptive management differs from these approaches due to its structure, explanation of goals, incorporation of alternative management objectives and outlining of data collection and evaluation (Allen et al, 2011). While AM frameworks provide a good process by which management issues and problems can be conceptualized, there is a rather 'accommodative' component in the approach in which there is an understanding that information may be incomplete and may be altogether incorrect.

2.1.2 Adaptive Management Framework

Most AM approaches tend to be either case specific or too general to be of use to be of any applied value. Hence the framework proposed by Teal and Weishar's (2005) terminating adaptive management framework for wetlands was selected because it provides a general wetland- and contamination-specific framework that can be localized for individual wetlands. Keeping local conditions and issues in view, the framework was modified by removing the final targets step of the process. Whereas adaptive management of wetlands often is intended to continue even after a certain level of wetland restoration has been reached (Care Earth and City Connect, 2011). The adapted framework is presented as Figure 2.1.

Figure 2.1 Wetland-specific adaptive management framework, adapted from Teal and Weishar (2005).



As stated in the earlier sections of the paper, AM is an iterative process, as can be noticed from the circular flow of Figure 2.1. Threshold triggers, as identified in second box, are defined as the measurement level of targets beyond which the targets are no longer acceptable for purposes of human and/or ecological health. Monitoring of determined targets and comparison of these targets with the threshold triggers should be ongoing in order to ensure that the targets are at acceptable levels.

Once a certain level of measurement has been reached or surpassed in a given wetland, the threshold trigger for that target would be reached and adaptive management would move from step 2 to 3 in Figure 2.1. At this point, action might be necessary to remediate or nullify the concern. Scientists and professionals involved in the implementation of adaptive management at the wetland will need to assess whether or not the situation indicates that a threshold trigger has been reached and action is required. Interim criteria would then be set to evaluate if the threshold trigger has been passed and if there are impacts on other components of the wetland, and a timeframe in which to evaluate the interim criteria would be defined. The interim criteria and the timeframe would be decided based upon techniques and information in peer-reviewed scientific literature, preferably from case studies in similar climate and ecological zones. If it is decided that action is not required, then monitoring will be continued and the interim criteria evaluated. If the criteria have been met, then the adaptive management process will reset, reiterate, and monitoring and comparison with triggers will continue. If the interim criteria are not met, it signals that the trigger thresholds from the second box have likely been met or surpassed and action is required.

If action is required, then further study must be undertaken to identify what the underlying issues might be that have caused the threshold triggers to be met. The scientists and professionals directly involved in the monitoring and implementation of the wetland's adaptive management should collaborate and produce a reasonable schedule of potential corrective actions to return the threshold targets to an appropriate level. The adaptive management practitioners–the professionals and scientists implementing adaptive management at the wetland– should choose potential corrective techniques that have strong support in peer-reviewed scientific literature and that have been applied in similar ecological zones or social conditions.

In the fourth box, the practitioners propose the identified issues and schedule to relevant regulators and administrative bodies/departments, who then must assess if the corrective action is necessary. A threshold trigger being reached does not immediately imply that correction is necessary. This is due to the fact that the change may not be a reflection upon the ecological health of the wetland, but rather due to extenuating factors, in which case the decision – makers may conclude that no changes are needed to address this trigger and that a new trigger threshold is needed. Similarly, corrective action might not be necessary if the results of a corrective action would result in what the decision-makers see as externalities with disproportionately high impacts. The assessment of corrective action in the fifth box should always consider the actions' potential externalities, including how actions impact other ecological components of the wetland and also the social, economic, and environmental health of the larger region. Decision-making should follow successful approaches and include when applicable such steps as public input sessions and consultation with relevant scientific authorities. If decision-makers find that corrective action is required, the identified actions should be implemented by the relevant scientists and professionals (seventh box of Figure 2.1). At this point, the adaptive management process would iterate again - monitoring would be resumed and targets would continue to be checked against their threshold triggers.

2. 2 Adaptive Management Targets

This section discusses adaptive management targets that can be used for wetlands. AM targets were chosen to highlight areas such as social, hydrological, and biological influences on contaminated wetlands. In addition to inputs obtained from ongoing action research programmes on wetlands of Tamilnadu by Care Earth, a review of literature of existing case studies was conducted in order to generate a comprehensive list of targets used in these adaptive management scenarios. From there, redundancies were consolidated and targets were grouped based on common themes. These themes were then consolidated into one general target each. The seven final AM targets, which are (1) maintain current wetland area, (2) restore adequate water retention in wetland and surrounding watershed(s), (3) eliminate groundwater depletion, (4) reduce ecological risk in wetland to acceptable levels, (5) attain sufficient social valuation of wetland, (6) restore species diversity, and (7) maintain individual species. It is to be noted that the economic targets have not been identified in view of the *de facto* significance of freshwater to economy.

2.2.1 Maintain Current Wetland Area

Wetland area is a key metric because it will determine whether efforts at preserving the current integrity of the wetland are successful. As has been discussed, wetlands perform significant environmental functions. Often, untested or ad-hoc interventions in wetlands lead to significant reduction in the wetlands' abilities to function since the integrity of the system is compromised. Wetland area is an effective general target because it can be and often has been measured over time. Some methods for doing this are through systematic field surveys supported by the study and analysis of satellite data; the availability of open source satellite data such as Google Earth is an added advantage. Landscape specific, time-series hydrological maps are effective for this metric.

2.2.2 Improve Water Retention of Wetland

Water retentiveness is the quality of a wetland that describes the amount of water it can retain. This is an important metric to assess a wetland's ability to mitigate flooding, which is a valuable wetland function. Wetlands mainly retain water in soil, vegetation and through ponding. Many calculations for flood mitigation have focused on surface waters; however, water retention in soil is also a significant portion of water retention in wetlands. This is because wetland soil is highly porous, being able to store anywhere between three to nine times its own weight (Ming et al, 2007). However, as soil, sediment and the surrounding vegetation become affected by contaminants, the wetlands' ability to retain water often diminishes (Castelle at al, 1992). There are many factors that play into this reduction. For example, if plants become contaminated, they may wither or lose their ability to take up excess water. Water retentiveness can also be affected by development. Generally, a one acre area of wetland can store anywhere from 5-5.5 million litres of water (EPA, 2013). Although this amount may vary depending on the soil type and vegetation of a wetland, it is an indication that wetland area also influences water storage capacity.

Hence a rather strong indicator of whether or not a wetland's retentiveness is decreasing or increasing is the quantity and magnitude of flooding within the wetland watershed over time. Examining precipitation, stream flow and flood frequency and magnitude data over time can assess this metric. One additional aspect to consider in improving water retention is the creation of artificial, buffer wetlands (or at times even deck storage) in the area that drains to the existing wetland. These wetlands would serve to mitigate flood reduction in much the same ways as natural wetlands. The use of porous soil would increase water uptake and the addition of vegetation would further slow overland flows and capture passing water (Aldous et al, 2012).

2.2.3 Minimize Groundwater Depletion

The interaction between wetlands and groundwater is often complicated. One major relationship is wetlands' ability to provide recharge to groundwater. Usually a wetland is connected to several other wetlands or larger water bodies that minimize the surface runoff into developed areas and control water flow. These water bodies, popularly referred to as reservoirs, are essentially water reserves that sustain the wetland and perform other functions such as flood mitigation for residents, industrial use and irrigation. Thus, reduced ground water recharge can also be linked back to a wetland's water retentiveness. If the wetland is not able to retain enough water for a sufficient period of time, the likelihood of recharge occurring will decrease. Also contributing to the depletion to a considerable extent is the intensive extraction of ground water through deep bore wells from the periphery of wetlands. Groundwater level is a concern because water movement through the system plays an important role in wetland ecology aspects such as plant community composition and organisation (Carter, 1986).

For an analysis of ground water depletion, the following data are important: historical groundwater level, types of groundwater usage, number of pumping wells and pumping rate. Historical groundwater data will provide information on groundwater level changes, which will help identify the current groundwater situation. Types of groundwater usage reflect the effects of urbanization on the wetland. This is because the usage is highly dependent on the types of demand from surrounding areas. The number of pumping wells and pumping rates provide the daily usage of groundwater related to the wetland.

2.2.4 Reduce Ecological Risk to Acceptable Levels

Ecological risk identifies and measures the level of contamination in the wetland. One way to assess the ecological risk is to identify the level of risk in a selected indicator species. An indicator is "an organism or ecological community so strictly associated with particular environmental conditions that its presence is indicative of the existence of these conditions" (Morrison, 1986). The term "indicator" can be applied either to a species that is selectively adapted to certain pollution conditions or organisms that bioaccumulate toxic substances (Angus, 2012). Once an indicator species for the wetland has been identified, an ecological risk assessment (ERA) can be conducted to assess the risk in that particular species. Ecological Risk Assessment evaluates the potential adverse effects that human activities have on the living organisms that make up ecosystems (US EPA, 1998). The risk assessment process provides a way to develop, organize and present scientific information so that it is relevant to environmental decisions" (US EPA, 2011)[1]. Data often required in order to conduct a successful ERA include information on the population, contamination levels and other habitat information for that species.

[1] ERA guidelines or studies are not available for India. The benchmarks suggested by the EIA notification are possibly a potential reference.

2.2.5 Species Diversity

Species composition is an indicator of ecological integrity, and hence species diversity is an absolute metric for assessing the wetland's level of ecological integrity (Pawson, 2010). In turn, knowledge of the wetland's ecological integrity will assist in the successful application of adaptive management to the site. For example, if the species diversity is much lower at one wetland than it is in the nearby baseline wetlands, it would be a signal that the ecological integrity of the first wetland is being compromised. Species diversity is tracked by noting the number of different species in the wetland as a function of time. In general, greater species diversity will correlate with higher wetland ecological integrity.

The common index used to measure species diversity is the Shannon-Weiner Index, which is as follows:

$$H' = -\sum p_i \ln p_i$$

Where, where *H'* is the Shannon–Weiner index of species diversity; *pi* is the proportion of individuals belonging to species *i, (pi* = n_i */ N*)

In the above equation n_i = number of individuals of species *i*; N = total individuals = $\sum n_i$; *S* = total species.

The maximum value of Shannon Weiner function, ln *S* is found when the distribution is even and its minimum value when the distribution is extremely skew. If *N* is large relative to S, the minimum value is approximately ln *(N / N –S)*. If the species are equally abundant then the H' value would be high. That is, the maximum diversity, H_{max} = ln *S*, where *S* is the total number of species (Fager, 1972).

2.2.6 Individual Species

In addition to species diversity, knowledge of individual species –including population levels and distribution over the area of the wetland over time– is another important target. Species diversity reveals the number of different species, but not necessarily the dynamics between species – for example, if the populations of native species are decreasing while the populations of invasive alien species are increasing. As invasive alien species can have significant negative impacts upon indicators of ecological integrity -such as reduction in native biodiversity and species composition- knowledge of individual species, including invasive species, at the wetland over time is key to understanding the wetland's ecological integrity and successfully applying an adaptive management scheme (Pawson et al, 2010). Metrics for the individual species target include information on invasive species, such as the number of different invasive species in a wetland, the percentage of the wetland area they cover, and how these dynamics change over time. Since a multitude of species may be present in a wetland, it can be more efficient to track data on indicator species (such as an identified flagship species) as opposed to all species.

2.2.7 Social –Cultural Valuation of Wetland

Another key target for the success of adaptive management efforts is the social cultural perception regarding the importance of the preservation and restoration of the wetland. Since the restoration and political prioritization of wetlands are supported by public awareness, measuring public awareness is an important target for assessing the social investment in wetlands. Several quantifiable ways to assess this are by tracking the number of appearances of the wetland in public media annually (i.e. newspapers, TV, internet forums, etc), the number of non-scientific visitors to the wetland per year, and through public awareness surveys.

The number of appearances of the wetland in public media is important because it signifies how often people are exposed to knowledge regarding the specific wetland. Further, the presences in public media are an indicator that it is a topic of interest in the surrounding areas and further reporting of events in the wetland can prompt action. The number of non-scientific visitors to the location per year is another important social indicator because a greater amount of tourism to the location would indicate a mindset that this location is a place worth visiting and is attractive within the community. An example of data for this target are tracking visitor numbers at a visitor centre or an information location at the wetland, and as wetland visits increase there would be a need for parking and accommodations for those visitors that also could be quantified as metrics. Finally, public interest surveys gauging public awareness regarding the current contamination and importance of the wetland provide further information regarding changes in opinion as adaptive management practice continues.

3. Scope, Purpose and Goal of the Current Initiative

The Pallikaranai Marsh is amongst the few and last remaining natural wetlands of south India. The Marsh that was till about 30 years ago spread over an area of more than 5000ha (50km^2) has been reduced to around one-tenth of its original extent due to the non-recognition of the area as a wetland, and thereby its utilization for a number of urban centric anthropogenic activities such as roads, development of residential and industrial settlements, establishment of institutions, disposal of municipal solid waste and sewage, etc.

Despite the onslaught, the Marsh has survived due to its unique ecology – in being partly saline and largely freshwater. This more or less flat low-lying land has sustained an ecosystem by draining the storm water from large areas of southeast Chennai into the Bay of Bengal. The most important link – in fact the aorta of the ecosystem, is the narrow canal at Okkiyanmadavu (a canal) that takes the Marsh's water into the sea. Despite the flow being interrupted by the Buckingham Canal during the past 100-150 years, the Okkiyanmadavu has been vital to the sustenance of the Pallikarnai Marsh by allowing the storm water to drain into the sea during the monsoons and letting the seawater enrich the ecosystem during the non-rainy months. The entire ecology of the Marsh is sustained by the seasonal hydrology in general and the mixing of sea and freshwater in particular. As is well-known, freshwater wetlands that are in the stage of marshes are unstable as they eventually transform to grasslands and then to scrub and forests due to the semi-aquatic and terrestrial plants that over-run the habitat. It is only the mixing of seawater that sustains marshes as very few plants are adapted to living in saltwater systems and as they cannot survive elsewhere have evolved 'life-styles' that mutually sustain the ecosystem and the living communities of plants and animals that depend on them. In other words, the freshwater-salt marsh ecosystem is one that is delicately balanced in nature and is sustained by a set of equally fragile ecological communities (Care Earth, 2002, 2005).

3.1 Conservation Authority for Pallikaranai Marsh

In keeping with the tradition of pioneering many initiatives, and in response to the request made by the residents of Chennai, the scientific community and naturalists, the Government of Tamilnadu declared a large part of the Pallikaranai marsh, spanning 317 ha. as a Reserved Land in the year 2007. This was followed by a number of initiatives to protect and restore the marsh, chief of which was the establishment of the country's first Conservation Authority of the Pallikaranai Marsh, with a two tier system of functioning that facilitates direct participation of the local resident welfare associations, experts and other relevant stakeholders in the protection and conservation of the Pallikaranai Marsh. A sum of Rs. 15 crores was allotted by the State Government for a period of five years beginning 2012 for taking up activities that would enable the restoration and conservation of the Pallikaranai Marsh. It was hence felt essential that a comprehensive management plan that would define the guiding principles and serve as a reference for enabling the protection, restoration and conservation of the Pallikaranai Marsh be developed. The location of Pallikaranai Marsh is provided as Fig. 3.1.

3.2 Scope and Purpose

On the basis of the aforestated guidelines, the following methodology was developed and utilised for the formulation of the Comprehensive Management Plan for the protection, restoration and conservation of Pallikaranai Marsh.

The CAP, in addition to being comprehensive and entrenched in the principles of adaptive management is mandated to facilitate 'Action Planning'. Action planning is the process that guides the day-to-day activities of a unit of management such as an organization, project or as in the current context, a Bird Sanctuary. It is the process of planning what needs to be done, when it needs to be done, by whom it needs to be done, and what resources or inputs are needed to do it. It is the process of operationalising the strategic objectives. The key words that define an action plan are strategic objectives, participatory planning, technical capacity, monitoring and dissemination.

In view of the above, the following broad methods were proposed and used:

1. Review, analysis and consolidation
2. Scientific assessments and evaluation using standardized methods and tools
3. Consultative processes and community/stakeholder engagement including SWOT-Analysis
4. Reconciliation and engagement and conservation prioritisation
5. Formulation of Action Plans

The specifics of the methodology are detailed in the following Table 3.1:

Table 3.1: Specifics of the methodology

Component	Methods and Tools
Review, analysis and consolidation	• Review of secondary data sources; generic to wetland management in India, global initiatives that are successful, and specific to the wetlands and Bird Sanctuaries of Tamilnadu • Analysis and synthesis; analysis of the above data sources to enable the formulation of a benchmark report or a synthesis document • Review of maps, toposheets and time series open source satellite imageries: to analyse and discern major changes in topography, landscape and habitat parameter; to establish benchmarks for defining ecological boundaries and administrative boundaries. • Review and consolidation of meteorological, geographical and geological data • Identification of gaps in research, data, others as applicable.

Component	Methods and tools
Scientific assessments and evaluation	**Ecological Assessments**
	• Ecological assessments: field research using standard methods and tools to assess and/or enumerate • Landscape features, heterogeneity, habitat diversity, character, quality, integrity, biological diversity focussing on birds, fish, mammals and select invertebrates and flora. • Hydrological features such as soil and water quality (natural and pollution load), nature of the wetland, water balance, water depth, potability, water quality parameters etc. • Research interface to identify data sets that need to be strengthened, creation of simple data sets, monitoring protocols, identification of bioindicators etc.
	Social Assessments
	• Socio-economic assessments using a combination of quantitative and qualitative methods to assess and / or enumerate • Demographic profile • Local economic conditions, livelihood profiles • Nature and interests of local human population • Conservation traditions, customary laws and regulation • Sacred species, totemic species • Human infrastructure, including roads, institutions etc • Development initiatives • And Tourism related issues.
	Interface Assessments
	• Interface assessments using a combination of quantitative and • qualitative methods to assess and / or enumerate • Ownership and jurisdiction of various government departments, • Identification of synergy and divergence in functioning and mandate • Assessment of natural resource dependency by the stakeholders • Time series change of land use and land cover change in and around the Marsh

Component	Methods and tools
Consultative processes and community/stakeholder engagement	• Participatory methods such as group discussions: focus, • Small and large as well as Participatory Analysis methods • To identify the range of stakeholders, their demographic arrangement • The existence, role and functions of local self governments • Presence and functioning of other interest groups, identification of synergies and conflicts and their drivers, creation of monitoring groups • Establishing joint mechanisms to draft the action plan, review and feedback
Reconciliation and engagement	Discussions, Consultative meetings with the stakeholders, senior officials of the department, District Forest Officer and his /her field team, other invited experts to present their inputs and advice and incorporate the same into the action plan, as appropriate Define the vision, mission, scope, mandate, goals, functions and responsibilities for the management of the wetland
Formulation of Action Plans	The Comprehensive Management Plans are formulated following a joint review, of which the following components are critical: Vision and mission of the wetland, thematic and subject components such as habitat description, characterization, habitat management, habitat improvement, hydrology, community engagement, involvement of local communities, identification of issues, concerns, problems associated with the management (SWOT Analysis) Identification of protection, restoration and conservation measures, identification of feasible units for implementation and demarcation on ground, identification of regular and periodic monitoring mechanisms and protocols for various components associated with management of the wetland: notably microhabitats, wild bird disease monitoring, documentation, identification of innovative local specific conservation measures that involve local communities and the financial outlay and allocation of resources, personnel and infrastructure for the wetland.

Figure 3.1 Location of Pallikaranai Marsh

3.3 Organisation of the Report

The Comprehensive Management Plan for Pallikaranai Marsh (hereinafter referred to as CMP) has been organised as follows:

1. The CMP in its introduction provides an overview on Wetlands, highlighting aspects such as the definition, broad wetland types of India, legal framework and conservation prioritisation of wetlands and ecosystem services provided by wetlands.
2. This is followed by a detailed discussion on the wetlands of Tamilnadu, wherein the wetland types typical of Tamilnadu, geo morphological characteristics of the State's wetlands, rainfall regimes and river basins are discussed.
3. The next section of the report is focussed on Kanchipuram district and greater Chennai, highlighting aspects of climatic conditions and resultant impact on rainfall patterns, climatic features, hydrological patterns and local knowledge systems.
4. A detailed description of Pallikaranai Marsh highlighting its status as a marsh in the midst of a metropolitan city, location, socio-economic attributes, biodiversity and hydrology constitutes the next section.
5. The final sections of the report discuss the CMP in detail. Sections or points that are deemed critical in the CMP have been highlighted in bold.

4. Wetlands of India – An Overview

According to the globally accepted definition of wetlands, diverse types of classes get included in the definition such as lagoon, beach, mangrove, coral reef, salt pan, aquaculture pond, waterlogged, ox-bow lake, reservoir, lake, tank inter-tidal mudflat etc. A classification system based on IUCN/RAMSAR definition and amenable from remotely sensed data has been used to categorise the wetlands by National wetland inventory and assessment, Government of India. A total 19 types of wetlands have been delineated using a hierarchical system that excludes rice fields. This classification categorises inland and coastal wetlands at level-I followed by natural and man-made wetlands as level-II, which were further categorised into 19 types of wetlands (Table 4.1).

Table 4.1: Classification of wetlands

Level – I	Level - II	Level – III	Code
Inland	Natural		1100
		Lake/Pond	1101
		Ox-bow Lake / Cut-off meander	1102
		High Altitude wetland	1103
		Riverine Wetland	1104
		Waterlogged	1105
		River/Stream	1106
	Man-made		
		Reservoir/Barrage	1201
		Tank/Pond	1202
		Waterlogged	1203
		Salt Pan	1204
Coastal	Natural		
		Lagoon	2101
		Creek	2102
		Sand/Beach	2103
		Intertidal Mud-flat	2104
		Salt Marsh	2105
		Mangrove	2106
		Coral	2107
	Man-made		
		Salt Pan	2201
		Aquaculture Pond	2202

4.1 Legal framework for wetland conservation in India

As of now there is no specific legal framework for wetland conservation, management and their wise use. Draft regulatory framework for conservation and management of wetlands is being finalized to be notified under the Environment (Protection) Act, 1986. At present conservation and wise use of wetlands is being ensured through following legal instruments:

• These include Forest Act, 1927, Forest (Conservation) Act, 1980, the Wildlife (Protection) Act, 1972, the Air (Prevention and Control of Pollution) Act, 1974, the Water Cess Act, 1977 and the umbrella provision of Environment (Protection) Act, 1986.

• The Coastal Regulation Zone Notification 2011 declaring the coastal stretches of seas, bays, estuaries, creeks, rivers and backwaters, which are influenced by tidal action as the Coastal Regulation Zone under the provision of Environment (Protection) Act, 1986. This proposes graded restriction on setting up and expansion of industries, including pressures from human activities.

• The Biodiversity Act, 2002, and the Biodiversity Rules, 2004, are aimed at safeguarding the floral and faunal biodiversity, and regulating their flow from the country to other countries for research and commercial use. Thus, their provisions also contribute towards conserving, maintaining, and augmenting the floral, faunal and avifaunal biodiversity of the country’s aquatic bodies.

- Policies- National Environment Policy, 2006; National Conservation Strategy and Policy Statement on Environment and Development, 1992; National Forest Policy, 1988.
- Plans- National Biodiversity Action Plan, 2008
- National Wetlands Conservation Programme

The Government of India has been implementing the National Wetlands Conservation Programme (NWCP) in close collaboration with the State/UT Governments since the year 1985-86. Under the programme, 115 wetlands (Annexure I) have been identified till now by the Ministry which require urgent conservation and management interventions.

4.2 Objectives of the Programme

The programme was initiated with the following objectives:-

1. to lay down policy guidelines for conservation and management of wetlands in the country;
2. to provide financial assistance for undertaking intensive conservation measures in the identified wetlands;
3. to monitor implementation of the programme; and
4. to prepare an inventory of Indian wetlands

The Central Government is responsible for overall coordination of wetland conservation programmes and initiatives at the international and national levels. The Central government is responsible for the following:

• Providing financial assistance for implementation of the approved items of the programme;
• Providing technical expertise and know-how including training of personnel;
• Issue of detailed guidelines covering all aspects of management; and
• Evaluation of the interventions made.

Criteria for identification of wetlands of national importance under NWCP are same as those prescribed under the 'Ramsar Convention on Wetlands' and are as given below:

Sites containing representative, rare or unique wetland types

(i) Criterion 1. If it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate bio-geographic region.

Criteria based on species

(ii) Criterion 2. If it supports vulnerable, endangered, or critically endangered species; or threatened ecological communities.

(iii) Criterion 3. If it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.

(iv) Criterion 4. If it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.

Specific criteria based on water birds

(v) Criterion 5. If it regularly supports 20,000 water birds or more

(vi) Criterion 6. If it regularly supports 1% of the individuals in a population of one species or subspecies of waterbirds.

Specific criteria based on fish

(vi) Criterion 7. If it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.

(vii) Criterion 8. If it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.

Specific criteria based on water/life and culture

(viii) Criterion 9. If it is an important source of food and water resource, increased possibilities for recreation and eco-tourism, improved scenic values, educational opportunities, conservation of cultural heritage (historic or religious sites).

Pallikaranai Marsh is one of the 94 designated wetlands for India under the National Wetland Conservation and Management Programme.

- Some wetland sites have been declared as Wildlife Sanctuaries and National Parks. In addition, certain wetlands have been designated as Ramsar Sites, which accord an international conservation status to the wetland. The Important Bird Area designation is yet to be identified for many prioritised wetlands.
- Guidelines for sustainable development and management of brackish water aquaculture have been drawn up by Tamil Nadu state government.

- Our National Environment Policy (NEP), approved by the Cabinet on 19 May 2006, recognizes the numerous ecological services rendered by wetlands; vide., The National Wetland Inventory and Assessment Project (NWIA) 2007.

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, and administrative boundaries).
- Creation of a seamless database of the states and country in GIS environment.
- Preparation of State-wise wetland atlases.

5. Wetlands of Tamil Nadu

5.1 Introduction

Tamil Nadu has 6.92% of its total geographical area under wetlands. The major wetland types are Lakes/Ponds, Tanks/Ponds, River/Stream, and Reservoirs. Area under mangroves is around 7315 ha. Coral reefs (3899 ha) exists mainly in Ramnathapuram district. Aquatic vegetation is observed in Lakes/Ponds, and Tanks/Ponds. The area under aquatic vegetation is more during pre monsoon than that of post monsoon. The open water spread is significantly lower during pre monsoon compared to post monsoon.

Table 5.1: Area estimate of wetlands in India

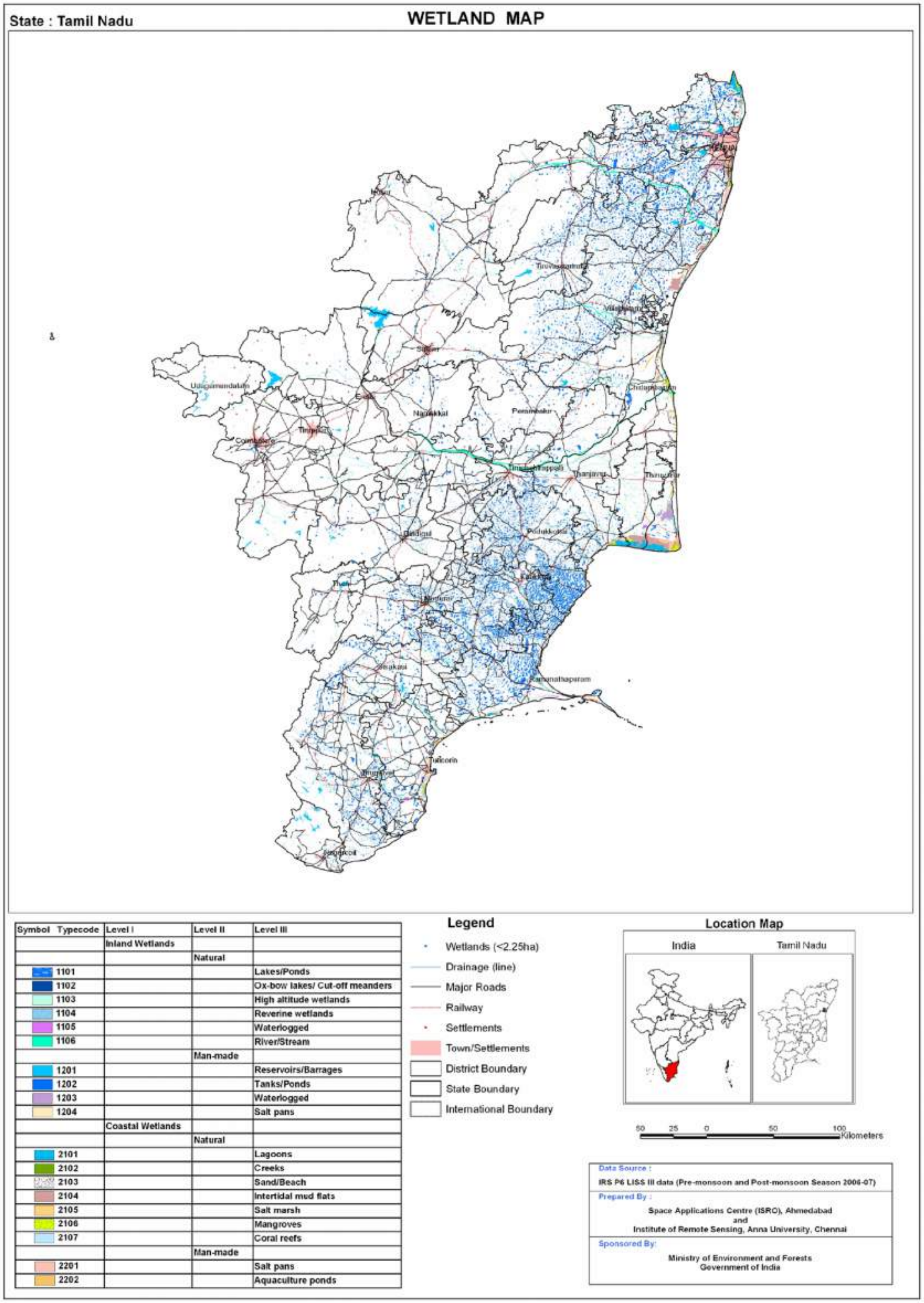
Area in ha

Sr. No.	Wettcode	Wetland Category	Number of Wetlands	Total Wetland Area	% of wetland area	Open Water: Post-monsoon Area	Open Water: Pre-monsoon Area
	1100	**Inland Wetlands - Natural**					
1	1101	Lakes/Ponds	4369	316091	35.02	236456	45436
2	1104	Riverine wetlands	2	127	0.01	121	41
3	1105	Waterlogged	44	3928	0.44	3382	2168
4	1106	River/Stream	194	136878	15.17	131049	131479
	1200	**Inland Wetlands -Man-made**					
5	1201	Reservoirs/Barrages	99	56419	6.25	46443	31064
6	1202	Tanks/Ponds	19343	237613	26.33	164346	23078
7	1203	Waterlogged	38	10811	1.20	9353	5816
		Total - Inland	**24089**	**761867**	**84.41**	**591150**	**239082**
	2100	**Coastal Wetlands - Natural**					
8	2101	Lagoons	74	25057	2.78	25041	22034
9	2102	Creeks	17	3404	0.38	3339	3403
10	2103	Sand/Beach	73	9798	1.09	-	-
11	2104	Intertidal mud flats	84	33164	3.67	-	-
12	2105	Salt Marsh	42	6108	0.68	5369	2596
13	2106	Mangroves	78	7315	0.81	-	-
14	2107	Coral Reefs	36	3899	0.43	-	-
	2200	**Coastal Wetlands - Man-made**					
15	2201	Salt pans	47	22889	2.54	22505	19733
16	2202	Aquaculture ponds	144	10739	1.19	10457	9420
		Total - Coastal	**595**	**122373**	**13.56**	**66711**	**57186**
		Sub-Total	**24684**	**884240**	**97.97**	**657861**	**296268**
		Wetlands (<2.25 ha), mainly Tanks	18294	18294	2.03	-	-
		Total	**42978**	**902534**	**100.00**	**657861**	**296268**

Area under Aquatic Vegetation	167273	531600

Area under turbidity levels		
Low	314273	70189
Moderate	247677	159206
High	95911	66873

Figure 5.1 Distribution of wetlands in Tamil Nadu



5.2 District-wise wetland area in Tamil Nadu

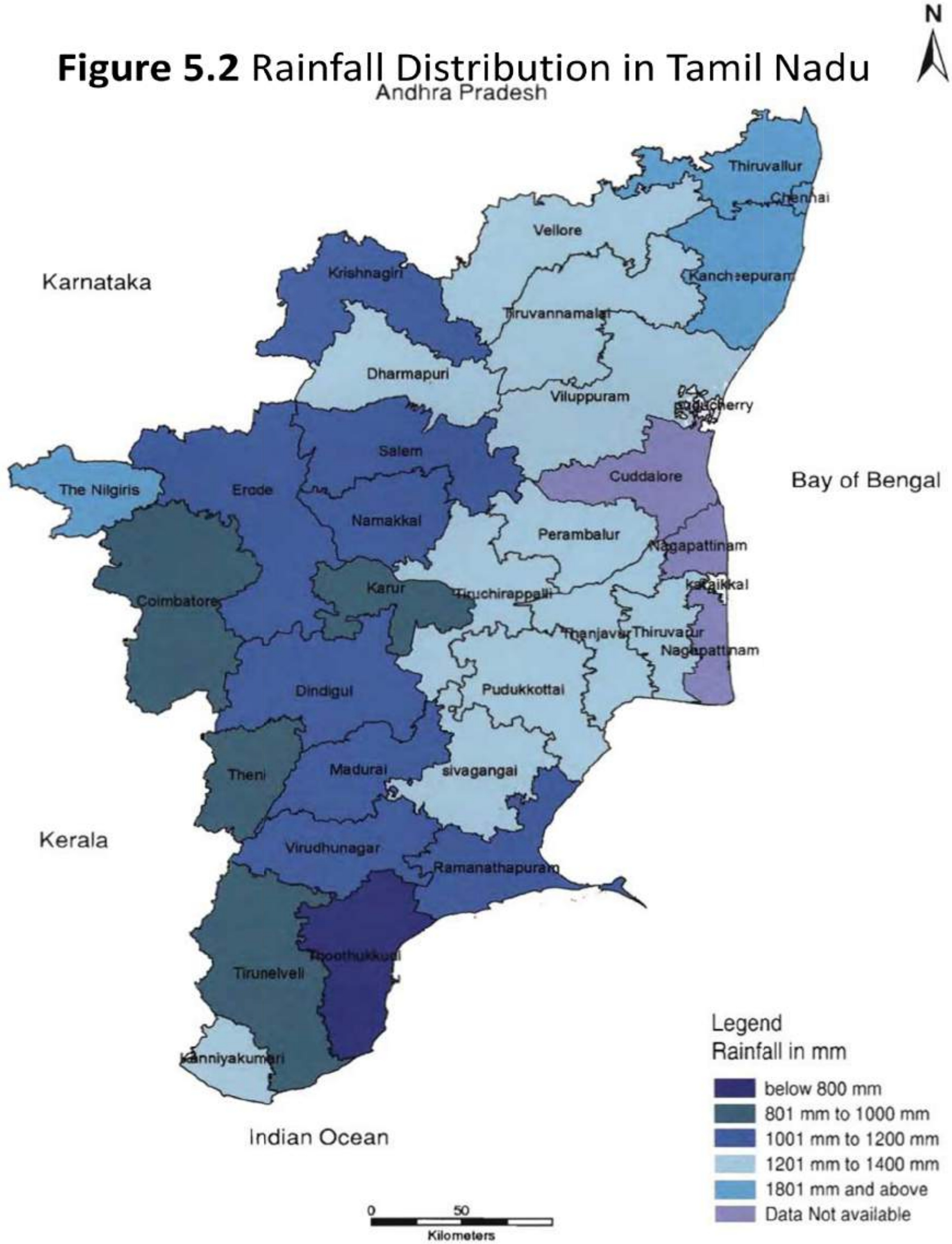
The wetlands occupy as high as 18.05% of geographic area (Ramnathapuram district), and as low as 1.08% (Coimbatore). In terms of total wetland area (% wetland area), Kanchipuram is the leading district (80445 ha, 8.91%) and Chennai is the least (917 ha, 0.10 %). Lakes/Ponds and Tanks/Ponds are the dominate wetland types in almost all districts. In coastal areas, Lagoons, Inter tidal mudflats and Saltpans are dominant wetland types.

Table 5.2: District-wise wetland area in Tamil Nadu

District	Geographic Area * (sq. km)	Wetland Area (ha)	% of total wetland area	% of district geographic area
Thiruvallur	3422	53863	5.97	15.74
Chennai	178	917	0.10	5.15
Kancheepuram	7857	80445	8.91	10.24
Vellore	6077	32640	3.62	5.37
Dharampuri	4498	18215	2.02	4.05
Thiruvannamalai	6191	48130	5.33	7.77
Viluppuram	7222	64105	7.10	8.88
Salem	5205	15270	1.69	2.93
Namakkal	3363	7687	0.85	2.29
Erode	8162	13570	1.50	1.66
The Nilgiris	2453	3127	0.35	1.27
Coimbatore	7469	8070	0.89	1.08
Dindigul	6267	13815	1.53	2.20
Karur	2896	16383	1.82	5.66
Tiruchirappalli	4404	18626	2.06	4.23
Perambalur	3690	8070	0.89	2.19
Ariyalur **	1942	11042	1.22	5.69
Cuddalore	3678	28135	3.12	7.65
Nagapattinam	2716	47833	5.30	17.61
Thiruvarur	2097	22591	2.50	10.77
Thanjavur	3348	34184	3.79	10.21
Pudukkottai	4663	72402	8.02	15.53
Sivaganga	4189	67172	7.44	16.04
Madurai	3742	24614	2.73	6.58
Theni	3242	5293	0.59	1.63
Virudhunagar	4232	29071	3.22	6.87
Ramanathapuram	4090	73808	8.18	18.05
Thoothukkudi	4621	37810	4.19	8.18
Tirunelveli	6823	37709	4.18	5.53
Kanniyakumari	1672	7937	0.88	4.75
Total	**130409**	**902534**	**100.00**	6.92

* Census 2001 data is used ** GIS data is used

Figure 5.2 Rainfall Distribution in Tamil Nadu



5.3 Rainfall of Tamil Nadu

Tamil Nadu falls under Tropical savannah climate (Köppen climate classification) and a small portion of the state falls under Humid subtropical climate. The climate of the state ranges from dry sub-humid to semi-arid. It is a state that is heavily dependent on monsoon rains. The state has three distinct periods of rainfall: advancing monsoon period, South West monsoon from June to September, with strong southwest winds; North East monsoon from October to December, with dominant northeast winds; dry season from January to May.

The normal annual rainfall of the state is about 945 mm (37.2 in) of which 48% is through the North East monsoon, and 32% through the South West monsoon. Since the state is entirely dependent on rains for recharging its water resources, monsoon failures lead to acute water scarcity and severe drought. Tamil Nadu is classified into seven agro-climatic zones: north-east, north-west, west, southern, high rainfall, high altitude hilly, and Cauvery Delta (the most fertile agricultural zone).

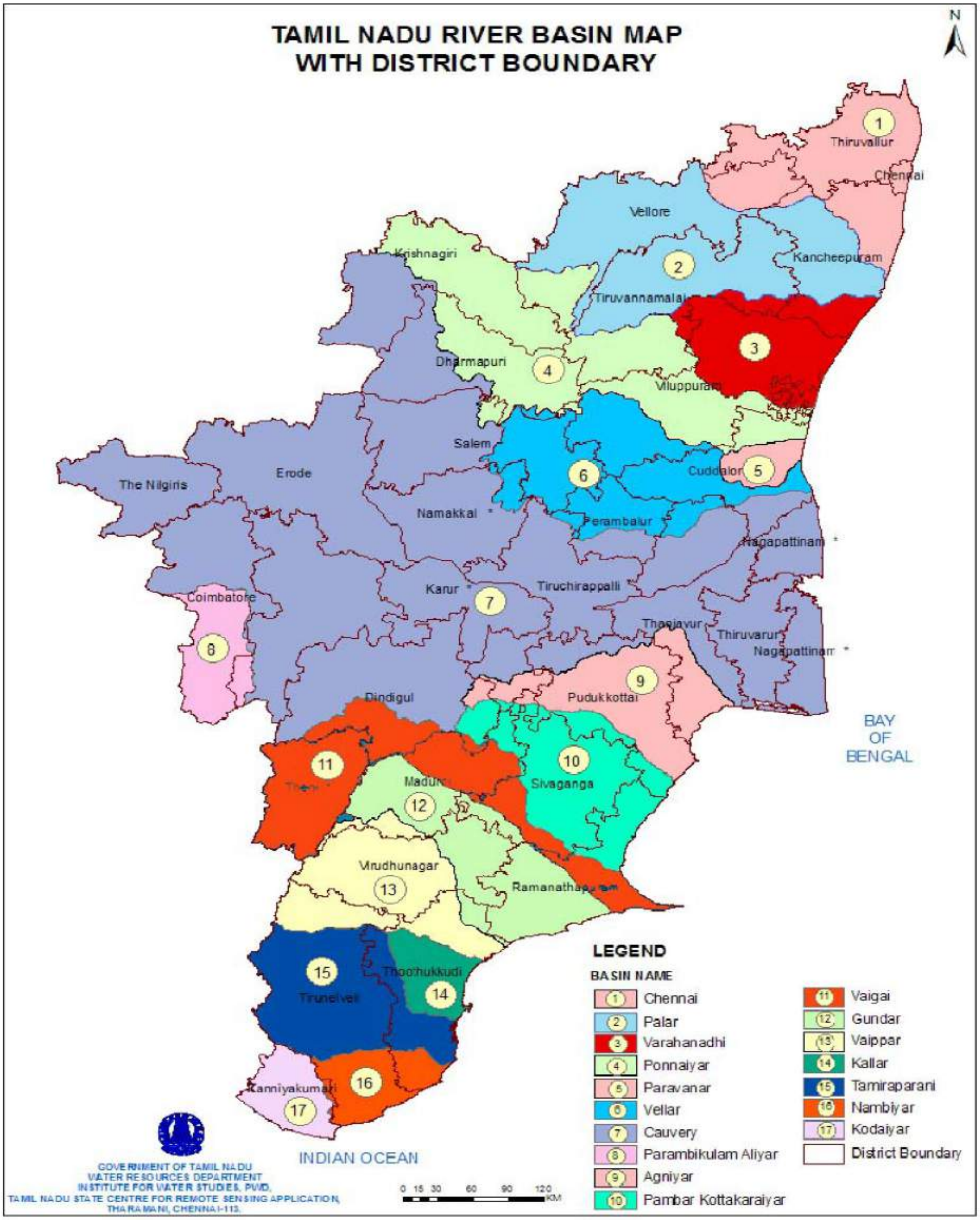
5.4 River Basins of Tamil Nadu

The river basins in Tamil Nadu are grouped into 17 major river basins, and they are as follows:

Table 5.3: Major River Basins in Tamil Nadu

Name of the Major River Basin Group	River Basins in the Group
1. Chennai Basin Group	1. Araniyar 2. Kusaithalaiyar 3. Cooum 4. Adayar
2. Palar	5. Palar
3. Varahanadhi	6. Ongur 7. Varahanadhi
4. Ponnaiyaar	8. Malattar 9. Ponnaiyaar 10. Gadilam
5. Vellar	11. Vellar
6. Paravanar	
7. Cauvery	12. Cauvery
8. Agniyar	13. Agniyar 14. Ambuliyar 15. Vellar
9. Pambar and Kottakaraiyar	16. Koluvanar 17. Pambar 18. Manimukthar 19. Kottakaraiyar
10. Vaigai	20. Vaigai
11. Gundar	21. Uthirakosamangaiyar 22. Gundar 23. Vembar
12. Vaippar	24. Vaippar
13. Kallar	25.Kallar 26. Korampallam Aru
14. Thambaraparani	27. Thambaraparani
15. Nambiyar	28. Karmaniar 29. Nambiyar 30. Hanumanadhi
16. Kodaiyar	31. Palayar 32. Valliyar 33. Kodaiyar
17. PAP	34.West flowing river

Figure 5.3 Map showing river basins in Tamil Nadu



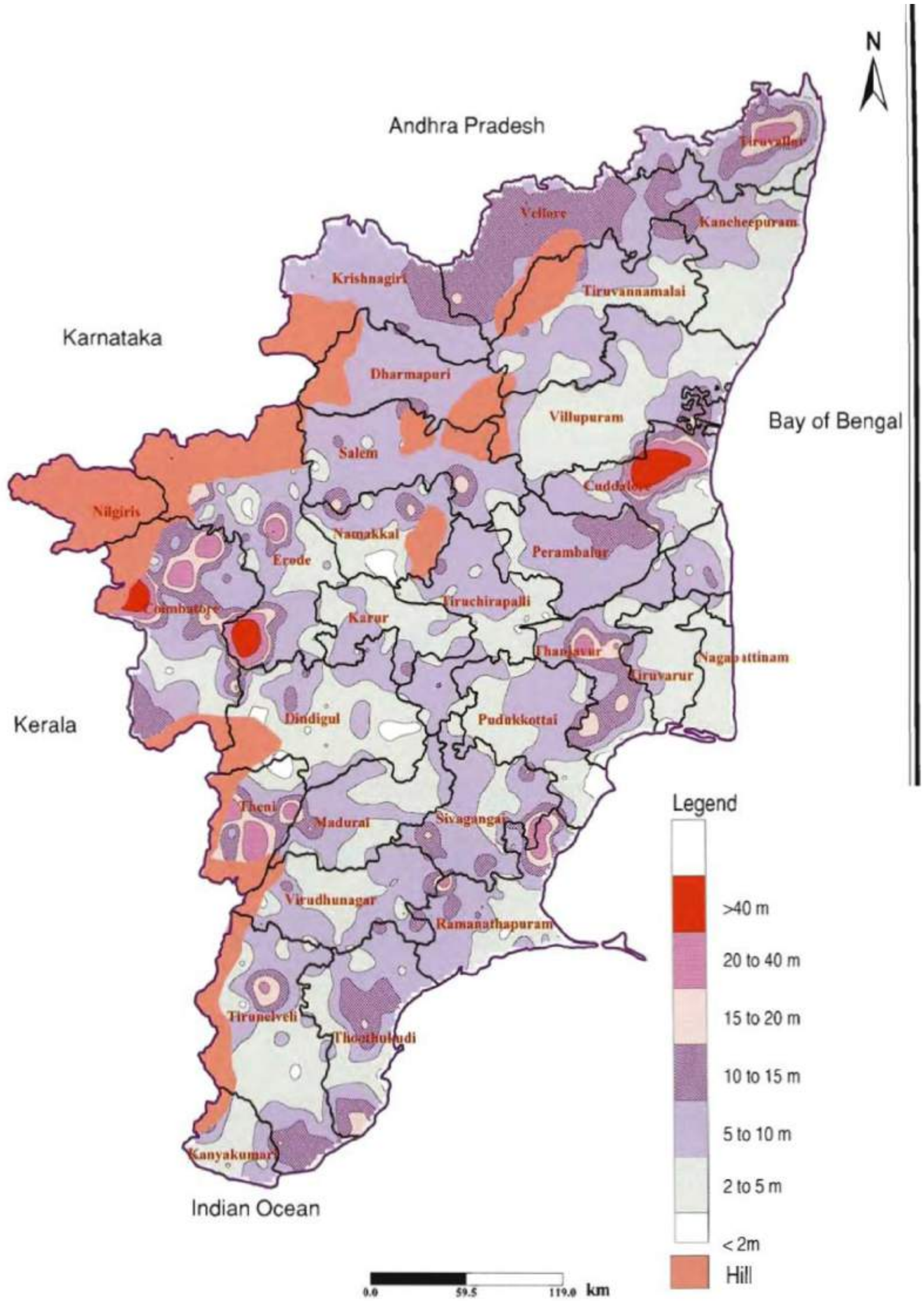
Area and rainfall of the river basins of Tamilnadu and Surface Water and Groundwater potential (MCM) of the River Basins of Tamilnadu.

Table 5. 4: Area and rainfall of the river basins of Tamilnadu

S.No	Name of the Major River Basin Group	Area of the basin (sq.km)	Normal Annual Rainfall (mm)	Normal Rain Volume (Km3)	System tanks	Non system tanks
1.	Chennai Basin Group	5542	1130	6.26	1304	215
2.	Palar	10911	940	10.03	661	
3.	Varahanadhi	4214	1250	4.55	131	1290
4.	Ponnaiyar	11257	920	11.17	1133	
5.	Vellar	7659	980		386	71
6.	Paravanar	760		8.39	2	9
7.	Cauvery	43867	930	45.32		
8.	Agniyar	4566	910	4.06	346	3629
9.	Pambar and Kottakaraiyar	5847	880	3.07	160	1161
10.	Vaigai	7031	900	6.97	521	976
11.	Gundar	5647	770	3.73	526	123
12.	Vaippar	5423	800	5.00	151	711
13.	Kallar	1879	600	1.04	15	184
14.	Thambaraparani	5969	1110	6.09		1300
15.	Nambiyar	2084	950	1.48	559	38
16.	Kodaiyar	1533	1720	2.64	2	1460
17.	PAP	3462	610	1.33		

S.No	Name of the Major River Basin Group	Surface water potential	Groundwater potential	Other sources	Total water potential
1.	Chennai Basin Group	906.00	1120.22		2026.22
2.	Palar	1758.00	2610.32		4368.32
3.	Varahanadhi	412.09	1482.07	4.00	1898.16
4.	Ponnaiyaar	1310.43	1560.00		2870.43
5.	Vellar	1065.00	1344.00	6.00	2415.00
6.	Paravanar	104.30	225.50	39.70	370.00
7.	Cauvery	5962.00	2869.00		8831.00
8.	Agniyar	585.00	920.00	499.00	2004.00
9.	Pambar and Kottakaraiyar	653.00	976.00		1629.00
10.	Vaigai	1579.00	993.00		2572.00
11.	Gundar	567.52	766.00		1334.00
12.	Vaippar	611.00	1167.00	4.82	1782.82
13.	Kallar	124.56	69.58	17.37	211.51
14.	Thambaraparani	1375.00	744.00		2119.00
15.	Nambiyar	203.87	274.74		478.61
16.	Kodaiyar	925.00	342.10		1267.10
17.	PAP	416.00	751.001		1167.00

Figure 5.4 Map showing Groundwater levels in different districts of Tamil Nadu



Source: TWAD Board, Chennai

The Pallikaranai Marsh is part of the Chennai River Basin. More specifically, it is part of the Adayar River, whose history is not only rather scantily known, but is also rather varied in terms of the original course and hydrology. Ground evidence in and around the marsh establish historical connectivity to a river, as indicated by the presence of a high number of water washed rocks. However, in the absence of robust geological studies, conclusive statements on the connectivity of the marsh to Adyar River have not been provided. However, the strong substantiation provided by the watershed maps developed for the region as part of the CAP validates the hypothesis. The data is presented and discussed in detail in subsequent sections of the report.

6. Wetlands of Kanchipuram district – Greater Chennai

The Pallikaranai Marsh is located in the region known as suburban Chennai, falling within the district of Kanchipuram. Historically the marsh was part of the erstwhile Chengai-Anna district. This region has recently been made part of the newly designated Greater Chennai. In terms of its ecological character, the marsh is typical of the wetlands of Kanchipuram district, which is one of the most well watered districts of Tamilnadu. Hence, the following section of the report discusses wetlands of Kanchipuram district as well as Greater Chennai.

6.1 Kanchipuram district

Kanchipuram district is situated on the northern East Coast of Tamil Nadu and is bounded in the west by Vellore and Thiruvannamalai district, in the north by Thiruvallur district and Chennai district, in the south by Villuppuram district in the east by Bay of Bengal. It lies between 11°00' to 12°00’ North latitudes and 77°28' to 78°50' East longitudes. The district has a total geographical area of 4393.37 sq km and coastline of 57 km. Kanchipuram, the temple town is the district headquarters. For administrative reasons, the district has been divided into 4 revenue divisions comprising of 11 taluks with 1137 revenue villages. Agriculture is the main occupation of the people with 47% of the population engaged in it. Paddy is the major crop cultivated in this district. Groundnuts, Sugarcane, Cereals & Millets and Pulses are the other major crops. The chief irrigation sources in the area are the tanks, wells, tube wells and canal. Tank irrigation is highest in Madurantakam block followed by Thirukalukkundram, Acharapakkam, Sriperumpudur, Tirupporur, Walajabad, Chittamur, Lattur, Kattankolathur, Lathur, Kundrathur, Kanchipuram, St. Thomas Mount blocks.

There are only a few hills of considerable elevation in the district. The southern part of Maduranthakam Taluk contains small hills. Palar River is one of the most important rivers running through the district. Kanchipuram district is part of the composite east flowing river basin and spread over a part of Palar and Cheyyar sub-basin.

The elevation of the area ranges from 100 m asl in the west to the sea level in the east. The major part of the area is characterised by an undulating topography with innumerable depressions, which are used as irrigation tanks.

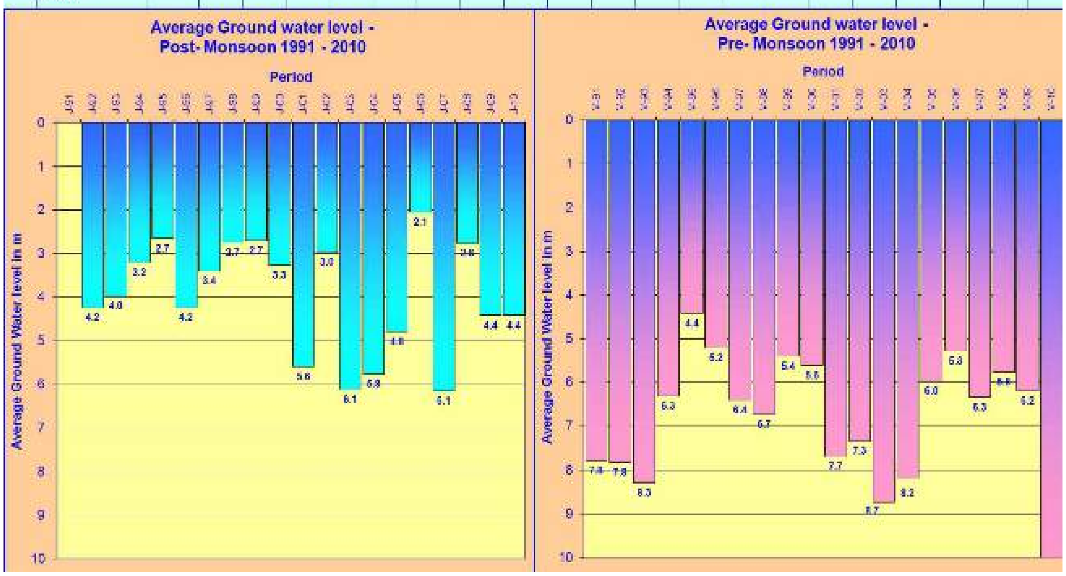
Soils have been classified into 1) clayey soil, 2) red sandy or red loamy soil 3) Red sandy brown clayey soil and 4) Alluvial soil. Of the above soils brown clayey soil is the most predominant, covering more than 71% of the areal extent of Kanchipuram district. Alluvial soils are found on the banks of Palar, Cheyyar and other rivers. The river alluvium is transported and is seen in coastal area of this district. Sandy coastal alluvial (arenacious soil) occurs along the seacoast as a narrow belt. The district is underlain by both sedimentary and fissured formations. The important aquifer system in the district are constituted by 1) unconsolidated and semi consolidated formations and 2) weathered, fissured and fractured crystalline rocks.

Ground water in phreatic aquifers in Kanchipuram in general, is colourless, odourless and slightly alkaline in nature. It is observed that the ground water is suitable for drinking and domestic uses in respect of all the constituents except total hardness and nitrate. With regard to irrigation suitability based on specific electrical conductance and Sodium Adsorption Ratio (SAR), it is observed that the ground water in the phreatic zone may cause high to very high salinity hazard and medium to high alkali hazard when used for irrigation. Proper soil management strategies are to be adopted in the major part of the district while using ground water for irrigation.

Figure 6.1 Groundwater levels in Kancheepuram district (1991-2010)

Kancheepuram District - Ground water level from 1991 - 2010

Sl. No	District	Average	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
2	Post Monsoon Ground water Level in m (January)	4.0		4.2	4.0	3.2	2.7	4.2	3.4	2.7	2.7	3.3	5.6	3.0	6.1	5.8	4.8	2.1	6.1	2.8	4.4	4.4
3	Pre Monsoon Ground water Level in m (May)	6.8	7.8	7.8	8.3	6.3	4.4	5.2	6.4	6.7	5.4	5.6	7.7	7.3	8.7	8.2	6.0	5.3	6.3	5.8	6.2	10.4



6.2 Climate: Kanchipuram district generally experiences hot and humid climatic conditions. Summer- Max. 36.6° C Min. 21.1° C, Winter- Max. 28.7° C Min. 19.8° C. The pre-monsoon rainfall is almost uniform throughout the district. The coastal taluks get more rains rather than the interior regions. This district is mainly dependent on the seasonal rains, the distress conditions prevail in the event of the failure of rains. Northeast and Southwest monsoon are the major contributors, 54% and 36%, respectively to the total annual rainfall. The southwest monsoon rainfall is highly erratic and summer rains are negligible. High relative humidity between 58 and 84% prevails throughout the year. Relative humidity is maximum in the morning and minimum in the evening. Higher rates of relative humidity are observed between November and January i.e., 83 to 84%. In the months of June, the humidity is lower i.e., around 58%. Average relative humidity in the morning and evening is 74% and 64% respectively.

6.3 Kanchipuram wetlands

The total area under wetland in the district is 80445 ha, which includes 487 small wetland (<2.25 ha). Lakes/Ponds occupy 44.03% of wetland area. The second major wetland type is Tanks/Ponds. There are 1178 Tanks/Ponds with 18372 ha area (22.84%). The other wetland types are: River/stream (12.02%), Salt Pans (5.24 %), Reservoirs (4.70 %) and Inter-tidal mudflats (4.63 %). Details of wetland statistics is given in the following Table 6.1. Aquatic vegetation is observed in Lakes/Ponds, and Tanks/Ponds. The area under aquatic vegetation is more during pre monsoon (45379 ha) than that of post monsoon (2965 ha). The open water-spread is significantly lower during pre monsoon (29962 ha) compared to post monsoon (70469 ha). The most critical lacuna of the National Wetland Atlas is the failure to include Pallikaranai Marsh as a wetland for the district.

Figure 6.2 Wetland distribution in Kanchipuram district

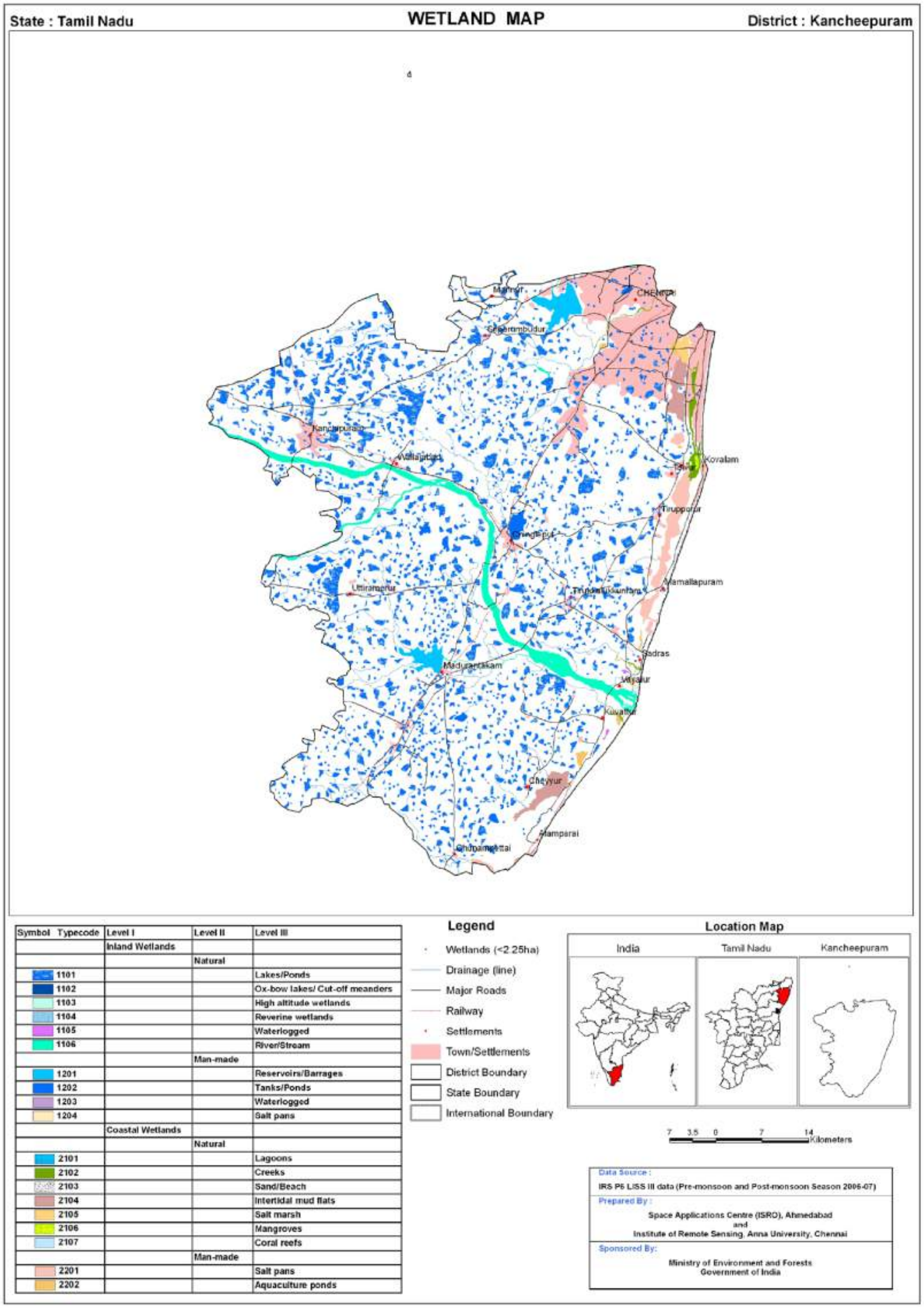


Table 6.1: Categories of Wetlands in Tamilnadu

S. 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	469	35421	44.03	33730	9664
2	1105	Waterlogged	5	120	0.15	120	-
3	1106	River/Stream	15	9669	12.02	8863	8629
	1200	**Inland Wetlands -Man-made**					
4	1201	Reservoirs/Barrages	2	3781	4.70	3740	2421
5	1202	Tanks/Ponds	1178	18372	22.84	17119	2668
6	1203	Waterlogged	1	103	0.13	98	27
		Total - Inland	**1670**	**67466**	**83.87**	**63670**	**23409**
	2100	**Coastal Wetlands - Natural**					
		Total	**4362**	**67172**	**100.00**	**46795**	**5573**
7	2102	Creeks	5	1385	1.72	1385	1385
8	2103	Sand/Beach	7	1601	1.99	-	-
9	2104	Intertidal mud flats	4	3725	4.63	-	-
10	2105	Salt Marsh	1	646	0.80	644	611
11	2106	Mangroves	2	115	0.14	-	-
	2200	**Coastal Wetlands - Man-made**					
12	2201	Salt pans	4	4215	5.24	3989	3917
13	2202	Aquaculture ponds	14	805	1.00	781	640
		Total - Coastal	**37**	**12492**	**15.53**	**6799**	**6553**
		Sub-Total	**1707**	**79958**	**99.39**	**70469**	**29962**
		Wetlands (<2.25 ha), mainly Tanks	487	487	0.61	-	-
		Total	**2194**	**80445**	**100.00**	**70469**	**29962**

Area under Aquatic Vegetation	2965	45379
Area under turbidity levels		
Low	48696	11097
Moderate	13397	11403
High	8376	7462

6.4 Wetlands of Greater Chennai

Chennai, formerly known as Madras is the capital of the state of Tamil Nadu and is India's fourth largest city. It is located on the Coromandel Coast of the Bay of Bengal with an estimated population of 42, 16,268 in 2012. The 400-year-old Chennai city is a fast expanding metropolis, being the capital city of the most urbanised state of India. It is the 34th largest city in the world, and is soon to be declared the 31st largest city of the world.

Infrastructure development and rapid expansion have led to the boundaries of Chennai to be redefined as Greater Chennai. The immediate proximity of neighbouring state of Andhra Pradesh in North and presence of Bay of Bengal in the East have limited the scope of development activities to the large pastures of open lands in West and South. These are the easily available spaces for infrastructure and industrial developments (Vencatesan, 2007). Chennai is a coastal city with a unique presence of wetlands, lakes, ponds, manmade tanks, marshes and swamps (shallow water system) backwater estuaries organized in the form of complexes. These water bodies move from West to East (Care Earth, 2005).

A growing concern on the need to conserve wetlands for posterity has led to a number of estimates being provided on the total number of wetlands that dotted Chennai and its neighbourhoods. While extreme guesstimates have placed about 3000 wetlands as being the original number, a more conservative estimate has been at 1000 plus wetlands. Sanjeevaraj (2002) reported that Chennai had around 150 small and large water bodies, but in recent years the number of wetlands has been reduced to 27. (2002).

Care Earth's assessment of the wetlands of Greater Chennai, based on a study of SOI toposheets of 1971 and composite imageries for the period 2009-11, revealed that Greater Chennai has 474 wetlands (minimum of 1 ha.) organized as complexes; of which 43 wetlands are of immense significance. These 43 wetlands are found organized as 25 complexes (Care Earth, 2012). This study has since been endorsed by the State Government and its departments of Public Works, Chennai Metropolitan Development

Authority and the Chennai River Restoration Trust as the official number of wetlands for the city.

6.5 Seasons and Precipitation Regimes of Chennai and its environs

One of the often cited reasons for poor availability of water is the low rainfall regimes of Chennai and its adjoining areas. Ironically though, south and west Chennai have been witnessing recurrent annual flooding since 2005 (Vencatesan, 2007). Analysis of the meteorological data for the past two hundred years (Drescher et al, 2007) for Chennai clearly shows that the annual flooding is not based on a long or medium-term trend reflecting increasing precipitation amounts. In fact there is no significant upwards or downwards trend that could be identified during the last 200 years. Further, as indicated by the rainfall map of the state of Tamil Nadu, Chennai and Kancheepuram district are classified as areas receiving 1000-1200 mm of average annual rainfall.

Also, the last 20 years are characterized by a consistent annual average of 1248 mm, with 'intense rainfall days' characterizing the North-East monsoon. Without a sustainable planning strategy especially facing the natural run-off due to single strong rainfall events, south and west Chennai would be prone to floods and water logging.

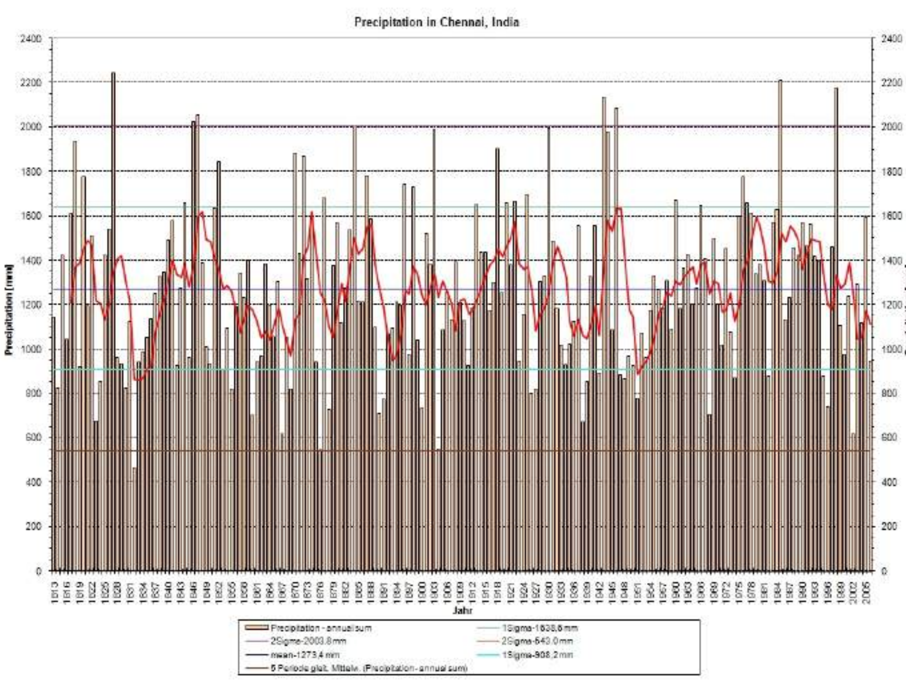


Figure 6.3 Precipitation trends for Chennai 1913-2005

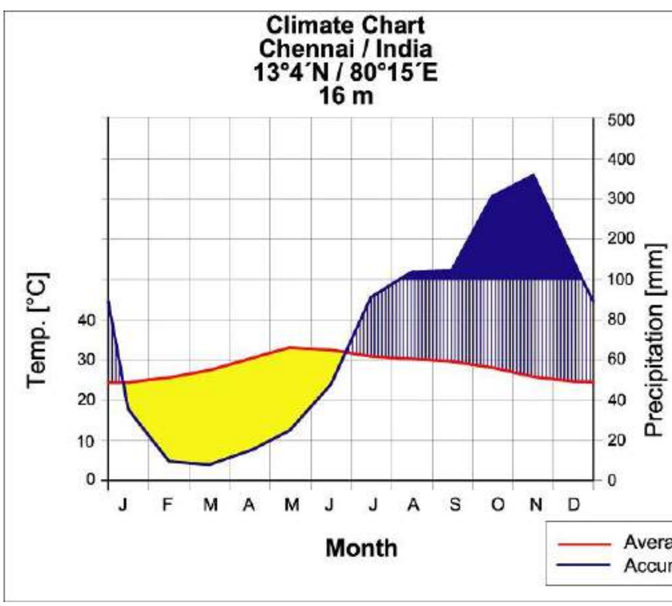
The landscape of which Chennai is a part is typical of tropical dissymmetric climate (Meher-Homji 1974). The mean annual maximum and minimum temperatures are 32.9°C and 24.3°C. The mean annual rainfall is 1215 mm (range 522 to 1235 mm; Manikandan 1931-60). Based on the rainfall pattern and water availability in the environment, three broad seasons have been defined for Chennai by Sankar Raman et al.

1. Dry season (January- march): January, February and march are the months of least mean rainfall- 25.8 mm 6.3 mm and 15.1 mm respectively. Dew is an important source of moisture during the season.

2. Summer or pre-monsoon (April- May): this season is characterized by high temperatures, and erratic rainfall. This regime is believed to determine the peculiar vegetation of the Coromandel Circar Coast (Meher-Homji 1974)

3. Monsoon or wet season (June- December): during the season Chennai receives rain from the south-west monsoon (June- December) and the north east monsoon (October-December). Maximum precipitation occurs during October –November from NE monsoon depressions in the Bay of Bengal. The general climatic trends for Chennai and its environs are depicted in the following diagram (Glaser et al, 2008).

Figure 6.4 Climate Chart of Chennai



Month	Temp. (°C)	Prec. (mm)
Jan	24,4	36
Febr	25,6	10
März	27,5	8
Apr	30,3	15
May	33,1	25
Jun	32,5	48
Jul	30,9	91
Aug	30,3	117
Sep	29,7	119
Oct	28,1	305
Nov	25,9	356
Dec	24,7	140

7. Pallikaranai Marsh

7.1 Profile of the Pallikaranai Marsh

Pallikaranai Marsh, located on the geo-coordinates of 12.949371°N latitude and 80.218184°E longitude, is one of the last remaining natural wetlands of the Chennai city. It is locally known by generic Tamil name ‘kazhuveli’ which means a marsh or water logged area (Vencatesan, 2007). The marsh is bound in the East by Old Mahabalipuram Road, in the West by Tambaram-Velachery road, Velachery village in the North and by Medavakkam-Karapakkam road in the South. It drains about 250 km^2 areas through two outlets viz., Okkiyam Madavu and the Kovalam creek and falls into Bay of Bengal. The topography of the marsh is such that it always retains some storage, thus forming a classic wetland ecosystem.

The marsh area had a spread of 6000 ha (60 km^2) around 1906s, of which there is a 90 percent loss of habitat resulting in the presence of only 593 ha of marsh (Care Earth, 2002). In 2007, the Government of Tamilnadu, responding to the science based advocacy programme of Care Earth and the civil society network that was forged as part of the advocacy programme, viz. Save Pallikaranai Marsh Forum, notified the southern portion of the marsh, spanning 317 ha, initially as a Reserved Land which was later upgraded to a Reserve Forest.

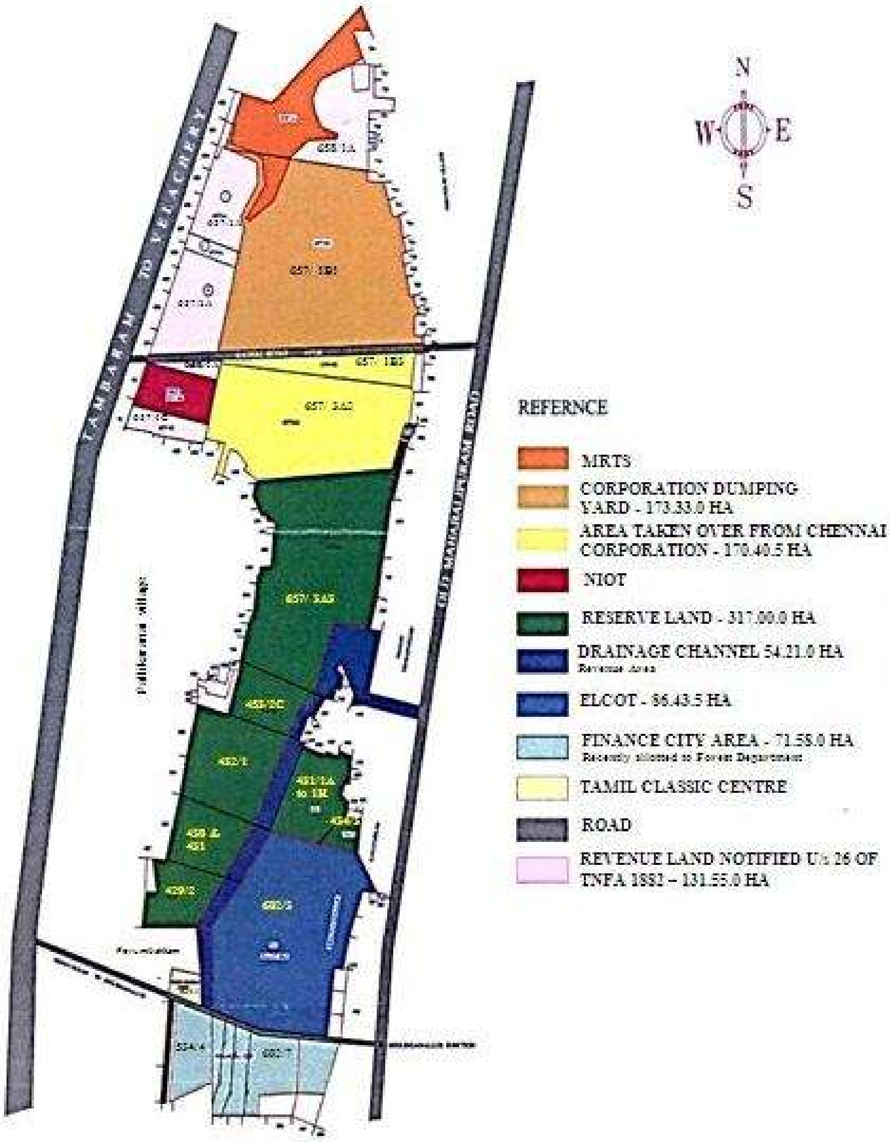
The Hon’ble Chief Minister of Tamilnadu who undertook an aerial survey of the flood-affected areas in South Chennai and suburbs on Nov’12, 2002, announced that the Government would initiate a move to declare Pallikaranai swamp area as a 'Reserve Forest' zone to prevent urban development in the sensitive eco-system. The Govt. of Tamilnadu has sanctioned Rs. 15.75 Crores in G.O.Ms. No. 184 E&F (FR5) Dept., dated: 15.12.2011 for the period of 5 years from 2011-12 to 2015-16 under state fund for the ecological restoration and conservation of Pallikaranai Marsh. Order was issued for the formation of a society named Conservation Authority of Pallikaranai Marshland to look after the entire affairs of this marshland in. G.O Ms. No. 103 E &F Dept. dated 31.03.2012.

The marsh has been reduced and fragmented, due to construction of institutes like NIOT (National Institute of Ocean Technology) and CWET (Centre for Wind Energy Technology), Perungudi dump-yard and Sewage treatment plant which occupy a major part of marsh land and on the other hand due to development of IT corridors, residential complexes, etc.

Pallikaranai is one of the 94 wetlands identified under National Wetland Conservation and Management Programme (NWCMP) of the Government of India and is also one of the three in the state of Tamil Nadu, the other two being Point Calimere and Kazhuveli. It is also one of the prioritized wetlands of Tamil Nadu. A project on 'Inland Wetlands of India' commissioned by the Ministry of Environment and Forests, Government of India in coordination with SACON and Care Earth had prioritized Pallikaranai marsh as one of the most significant wetlands in the country in the year 2001-02.

Details	Area (Ha.)
Area notified as RL (G.O.Ms. No. 52 E&F dated. 09.04.2007)	317.00.0
Area taken over from Chennai Corporation (TCR effected on 11.06.2013 & title transfer on 30.10.2013)	170.40.5
Revenue area declared U/s 26 of TNFA 1882 (Kancheepuram District Gazette No. 6 dated. 01.07.2013)	131.55.0
Finance City area & recently allotted to Forest Department (G.O. Ms. No. 147 Revenue Dept. dt. 12.05.14)	71.58
Corporation dumping yard	173.33.0
Total area (Department control)	690.53.5
Unused Marsh land area	112.36.0
Total available marshland	**802.89.5**

Figure 7.1 Present consolidation status of Pallikaranai Marsh



7.2 Ecological History of the Pallikaranai Marsh

A large part of south Chennai was historically a flood plain as evidenced by the soil type of the region, which is described as recent alluvium and granite gneiss. Spread over 50 sq. km, it comprised of a large Marsh (Pallikaranai Marsh), smaller satellite wetlands, large tracts of pasture land and patches of dry forests. The composite nature of the landscape is depicted in the following diagram wherein the entire landscape is defined as a coastal plain with intermittent and overlapping habitat types of cultivation, wetlands and scrub forests.

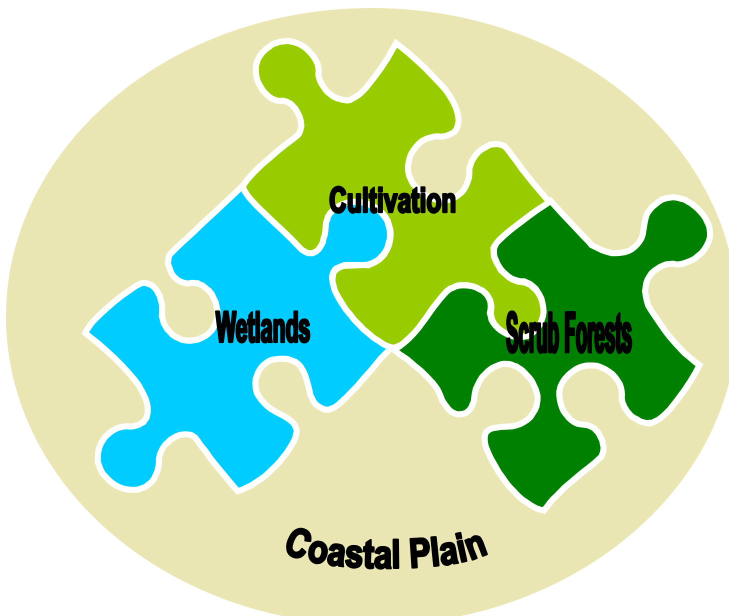


Figure 7.2 Habitat types of south Chennai Flood Plain

It is also of significance that the smaller wetlands that surrounded the Marsh served as the only source of irrigation for the area, which thrived on paddy and green leafy vegetable cultivation. This gave the Marsh a legendary status since the villages did not have wells or dug-out ponds, which are the norm in the northern districts of Tamil Nadu (TN).

The first known external manipulation of this system, which is part of the Coromandel Coast, was the laying of the Buckingham Canal. Devised as a navigation canal in 1806, of 421.55 km length, that connected Pedda Ganjam in Andhra Pradesh (AP) and Marakanam in TN, the canal served the primary purpose of ferrying salt. It is not well known that the canal was under private ownership and was then called the Cochrane Canal. In 1837, the Canal was taken over by the East India Company and renamed as the Government East Coast Canal. In 1876, it was rechristened the Buckingham Canal. The Buckingham Canal was devised as a salt water canal, tidal to a great extent in those parts where the river bars are open and utilized the numerous estuaries and backwaters along the East Coast.

The city of Chennai due to its immediate proximity to the neighbouring state of AP and the presence of the extensive Pulicat Estuarine Complex to the north, and the Bay of Bengal to the East, can expand only towards the west and south. The presence of the freshwater aquifer running parallel to the coast has contributed rather significantly to the expansion of the city's boundaries in the south – which is one of the many pointers to the presence and importance of the South Chennai Floodplain.

While unplanned and ad-hoc human interventions have contributed to the large scale decimation of the landscape, the fundamental factor facilitating the degradation has been the continuation of the rather archaic system of land classification wherein the Marsh was categorised as a pasture land; and the absence of a State Land Use Policy.

Lack of understanding about the importance of a marsh in an urban environment as a flood regulator and environmentally a high productive habitat has resulted in marsh being reduced to around one-tenth of its original extent on account of unplanned urbanization, destructive reclamation and dumping of solid and liquid waste generated by the urban society. According to the State Revenue records the marshland was classified as wasteland and so the Government of Tamil Nadu fragmented the marsh and large parts were reclaimed to be developed as residential and rehabilitation areas (Vencatesan, 2007).

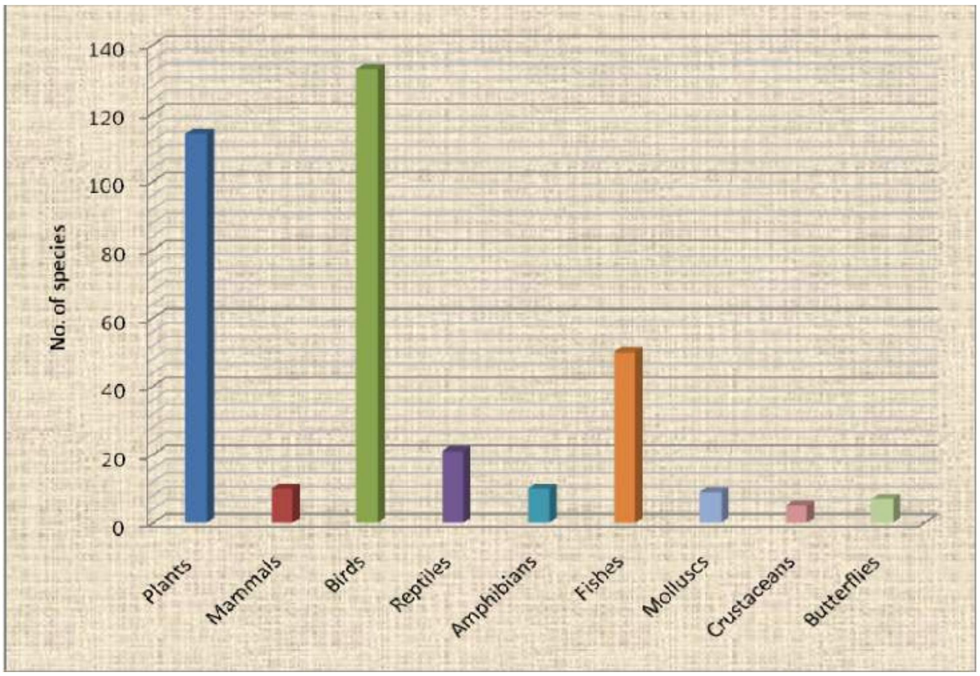
While tracing the revenue history of Madras Presidency, Baden Powell distinguishes two periods, viz. early and modern settlements. While the early settlements were based largely on previous assessments, and encouraged territorial autonomy, the period that immediately preceded the establishment of the settlement department in 1858 witnessed the use of 'rigorous criteria' and involved the services of settlement and survey officers who mapped the lands. A broad distinction of occupied and unoccupied lands was made which, for the purposes of administration, was described as follows: occupied land was cultivated land and unoccupied land was uncultivated waste. While seemingly encouraging an increase of land under cultivation and individual ownership, the process of surveying was an exercise to claim 'wasteland' and bring it under State Control. Lands, excluding the forest tracts that were reserved, were classified into the following finer categories: patta, assessed dry and wet waste, unassessed waste and puramboke (revenue and forest). Assessed dry and wet wastelands were lands that were kept uncultivated until an official allotment was made by the Revenue Department. This category of land included a range of habitats such as Marshes, seasonal wetlands, steep and rocky slopes, abandoned pasture lands, and lands under shifting cultivation. (Care Earth – Adaptive Management Plan for Pallikaranai Marsh, 2010)

7.3 Biodiversity of the Pallikaranai Marsh

The uniquely heterogeneous hydrology and ecology of the Pallikaranai Marsh makes the Marsh one of the most diverse natural habitats of the country. Biodiversity of Pallikaranai Marsh is typified by the presence of species representing various faunal groups, of which birds, fishes and reptiles are the most prominent. It is the natural habitat to some of the most endangered reptiles such as the Russell's viper and birds such as the Glossy Ibis, Pheasant tailed Jacana etc. The Marsh has also had the distinction of new records of reptiles and plants being described, on a rather regular basis since 2002.

Pallikaranai Marsh supports 349 species of flora and fauna. The Marsh is home to 133 species of birds, 10 species of mammals, 21 species of reptiles, 10 species of amphibians, 50 species of fishes, 9 species of molluscans (snails and clams), 5 species of crustaceans, and 7 species of butterflies. About 114 species of plants are found in the wetland including 29 species of grass (Care Earth, 2002; 2005 Daniels, 2002). (Lists appended).

Figure 7.3 Biodiversity of Pallikaranai Marsh



These plant species include some exotic floating vegetation such as, water hyacinth and water lettuce, which are less extensive now and highly localized. The region has a bird bio-diversity, about 4 times that of Vedanthangal Bird Sanctuary. Birds such as darters, herons, egrets, open-billed storks, spoonbills, white ibis, little grebe, Indian moorhen, black-winged stilt, glossy ibis, grey headed lapwing, stilts, purple moorhen, warbler, coot and dabchick have been spotted in large numbers in the marshland. Another rare species spotted in the region is one of the most endangered reptiles, the Russell's viper (*Vipera russelli*) largely eliminated from the city of Chennai (Care Earth, 2002). The report of the White-spotted garden skink (*Lygosoma albopunctata*) from the Velachery area of the marsh was reported for the first time in Tamil Nadu (Daniels, 2002). Fishes such as Dwarf Gourami and Chromides that are widely bred and traded worldwide for aquaria naturally occur in Pallikaranai. Other estuarine fauna present at the marsh includes the windowpane oyster, mud crab, mullet, half beak and green chromide. Many species of sub-fossilized shells and living plants and animals of marine and estuarine origin were observed in and around the southern limits of the Marsh, the section in front of the Thangavelu Engineering College and where the Okkiyanmadavu canal joins the marsh (Care Earth, 2005).

7.4 Habitat types

Habitat types found in Pallikaranai Marsh include:

i. **Open water** pockets that attract diving waterbirds such as darter, cormorants, grebes and some ducks which dive for bottom-dwelling animals or aquatic vegetation.

ii. **Islands** and mounds are used as breeding sites for a number of species that nest on the ground. Grasses have been planted on these to provide suitable habitat for ducks like teals and pintails. The raised mounds have been created at Pallikaranai to ensure better survival rates during the long inundation periods. Grasses have been planted on these mounds to provide suitable habitat for ducks like teals and pintails.

iii. **Shallow waters and mud flats** are rich feeding areas for a range of migratory waders who probe the water and flats for tiny animals. Larger waterbirds with long legs and bills such as the egret, pelican, heron, flamingo etc. can be found in the shallows probing, spearing, sieving and scooping for food.

iv. **Emergent sedges, reeds and grassy bank areas** attract many wading birds. Vegetation of this type provides cover for waterbirds. Ducks, moorhens and coots also use open water for feeding in emergent vegetation and grassy bank areas. Ibis, herons and swamp hens are also attracted to fringing sedges as feeding areas.

v. **Flooded live and dead timber** is used for nesting, perching and roosting. Cormorants use these structures for drying their wet wings.

Figure 7.4 Map showing habitat types in and around Pallikaranai Marsh (2001)

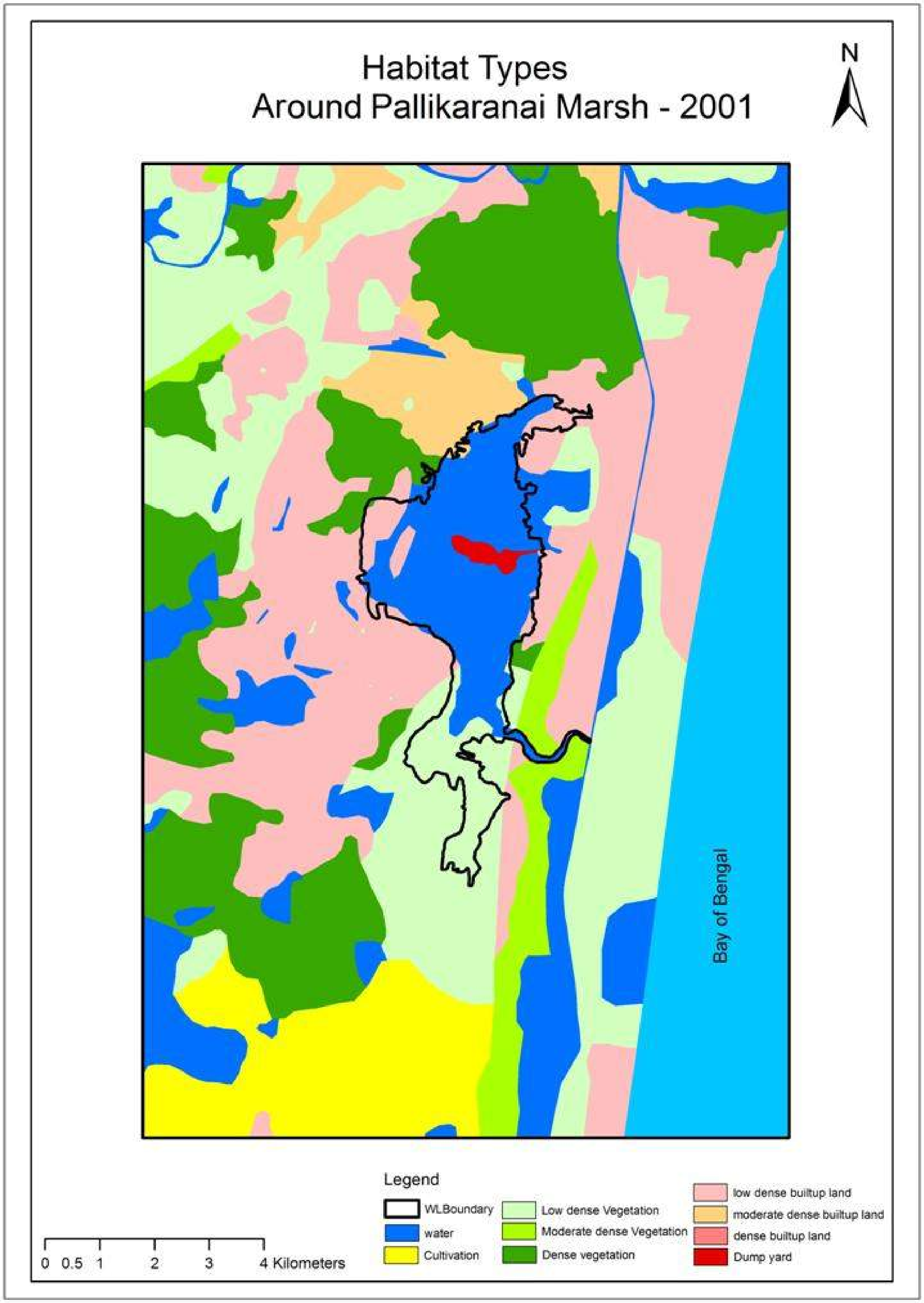
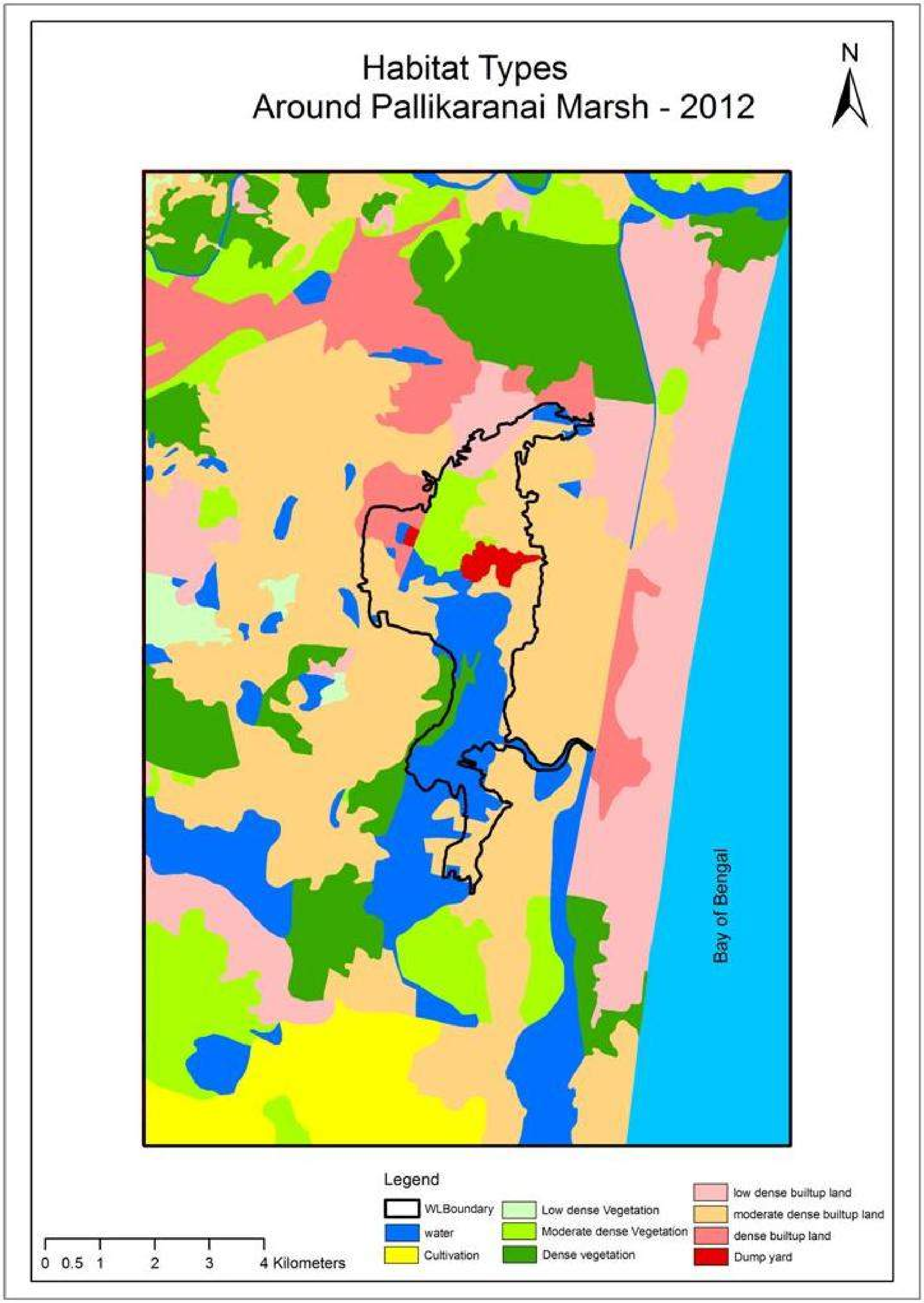


Figure 7.5 Map showing habitat types in and around Pallikaranai Marsh (2012)



Bacopa monnieri

Commelina benghalensis

Cressa cretica

Datura innoxia

Eichhornia crassipes

Euphorbia corrigioloides

Euphorbia serpens

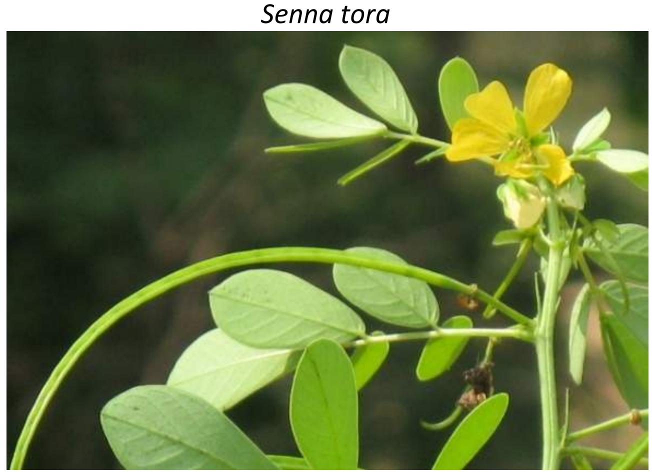
Alternanthera sessilis

Glinus lotoides

Ipomoea aquatica

Hygrophila sculli

Senna tora



Typha angustifolia

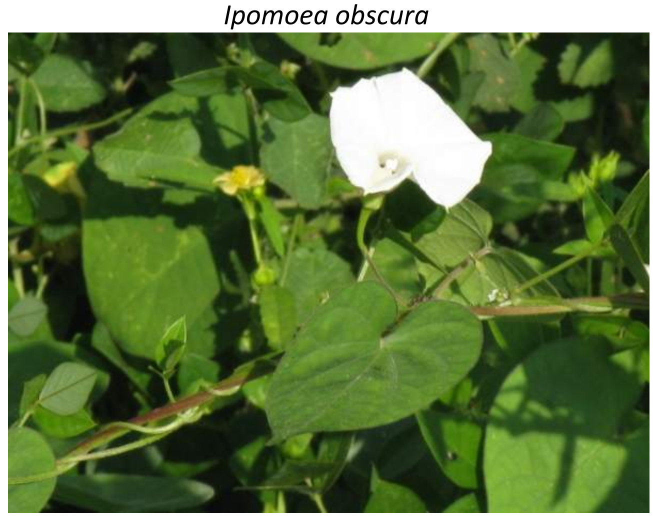
Solanum trilobatum

Macroptilium lathyroides

Turnera subulata

Mollugo disticha

Ipomoea obscura




Cattle Egret


Indian Pond Heron


Greater Flamingo


Spot-billed Duck


Pied Bushchat


Scaly-breasted Munia


White-breasted Waterhen with its chick


Pheasant-tailed Jacana


White-throated Kingfisher


Small Blue Kingfisher


Pied Kingfisher


Black-shouldered Kite


Great Egret and Spot-billed Pelican


Ibises


Black-winged Stilt


Barn Swallow


Asian Openbill


Blue-tailed Bee-eater

Black-line Rasbora

Common Carplet

Coolie Barb

Flying Barb

Spot-fin Barb

Orange Chromide


Back Swimmer - Nymph


Pondskater - Nymph


Mosquito - Larva


Water beetle - Adult


Giant water Bug - Adult


Water Boatman - Adult


Dragon fly - adult


Bloodworm - Larva

Dragonfly- Larvae

Mayfly - Larva

Shrimp

Freshwater Crab

Freshwater Mussel

Giant Apple Snail

8. Land use – Land cover change around the Pallikaranai Marsh

If the year 1965 is considered as a reference point, the last 50 years has led to a 90 percent habitat loss of the Pallikaranai Marsh (a large portion of the marsh falls within the survey numbers 657 and 658). Within this loss, three broad patterns can be discerned; the first where large tracts of the marsh especially those along the residential areas / erstwhile villages of Thoraipakkam, Pallikaranai and Perungudi have been reclaimed into terrestrial habitats and converted into residential colonies. The second loss is characterized by habitat fragmentation wherein roads, infrastructure, municipal landfills, sewage treatment facilities, etc have fragmented the marsh into smaller portions and grossly impacted the natural drainage pattern. The third is a direct consequence of the first two, as also the unscientific manner of addressing flood control, wherein large tracts of the marsh have been invaded by invasive species of plants notably *Prosopis juliflora* and Water Hyacinth. The following series of figures and tables provide further details on these aspects:

Figure 8.1 Land use and land cover change around the marshland 1965 (Corona) to 2006 (Quickbird - bandcombination 421)

Table 8.1: Analysis of changes in the area and perimeter of the Pallikaranai marsh since 2003[@]

Segment of the marsh	Year	Area (ha)	Perimeter (km)	Edge development
Municipal Landfill	2003	50.25*	5.785	**2.30**
	2005	57.54	6.046	**2.24**
Area impacted by garbage/sewage	2003	58.75*		
	2005	132.25		
Northern segment#	2003	227.00	12.11	**2.26**
	2005	150.56	7.6	**1.74**
Southern segment	2003	284.00	9.327	**1.56**
	2005	279.65	11.8	**1.99**
Total	2003	620.00	c. 13.0 –	
	2005	**620.00**	**c. 13.0 –**	

Edge development is calculated as the deviation of boundary/perimeter of the segment/polygon from the circumference of a circle that has the same area/extent. It is calculated as p/2 (3.14A); where p is the perimeter of the segment/ polygon in metres, A the area of the segment/polygon in square metres (1 ha = 10,000 sq. m); 3.14 = p. *50.25 + 58.75 = 109 ha recommended as the 'critical zone'. # excludes garbage dump and the impacted area. [@]The 2003 map was based on details provided by IRS ID PAN + LISS III (March 2001), GPS Field Survey by NIOT (February 2003) and Survey of India toposheet of 1972.

Table 8.2: Change matrix of land use/cover in and around Pallikaranai Marsh (ha) highlighting subcategories, Oct. 2001- Oct. 2008

Land use/ cover	R	IND	LiT	IU	WD	PL	WL	OW	C	2001 (ha)
R	**3444,2**	23,4	47,3	1,5	-	9,1	-	-	2,4	3527,9
IND	-	**95,9**	-	-	-	-	-	-	-	95,9
LiT	28,9	167,5	**4,6**	71,3	-	-	11,3	0,4	-	284,0
IU	-	-	-	**97,6**	-	-	-	-	-	97,6
WD	-	-	-	-	**64,5**	-	-	-	-	64,5
BL	526,1	7,5	57,9	8,3	-	**576,1**	36,1	10,3	1,9	1224,2
WL	288,2	23,3	267,3	7,3	1,0	31,1	**412,6**	12,2	2,4	1045,3
OW	37,5	5,6	5,3	22,0	12,4	17,6	217,7	**447,7**	0,8	766,5
C	443,7	19,0	75,5	19,1	-	215,3	0,0	20,4	**67,7**	860,7
2008 (ha)	**4768,6**	**342,1**	**457,6**	**227,4**	**77,9**	**849,0**	**677,6**	**491,0**	**75,3**	**7966,5**

Data labels: R, Residential land; LiT, Land in Transition(Landfill/Construction sites); IU, Infrastructure and Utilities; WD, Waste Disposal; PL, Pasture Land; WL, Wetland; OW, Open Water (including Tanks, Buckingham canal and Okkyiam Maduvu); C, Cultivations; IND, Industries (IT, Industry/ Commercial)

Table 8.3: Change matrix of land use/cover in Pallikaranai Marshland Oct. 2008-2015 highlighting sub categories

Land use/ cover	R	IND	LiT	IU	WD	BL	WL	WB	C	2008 (ha)
R	**4768,6**	-	-	-	-	-	-	-	-	4768,6
IND	-	**342,1**	-	-	-	-	-	-	-	342,1
LiT	109,6	313,6	**11,2**	23,3	-	-	-	-	-	457,6
IU	-	-	-	**227,4**	-	-	-	-		227,4
WD	-	-	-	1,5	**76,4**	-	-	-	-	77,9
BL	718,2	8,6	-	-	0,7	**121,6**	-	-	-	849,0
WL	66,9	250,9	-	-	17,4	16,5	**325,9**	-	-	677,6
WB	4,3	-	-	14,8	22,0	-	59,6	**390,3**	-	491,0
C	75,3	-	-	-	-	-	-	-	-	75,3
2015 (ha)	**5742,9**	**915,2**	**11,2**	**267,0**	**116,4**	**138,1**	**385,6**	**390,3**	**-**	**7966,4**

A time series analysis of land use –land cover change in the landscape of which Pallikaranai Marsh is a part of is provided in the following maps.

Figure 8.2 Map showing Human settlements around Pallikaranai Marsh

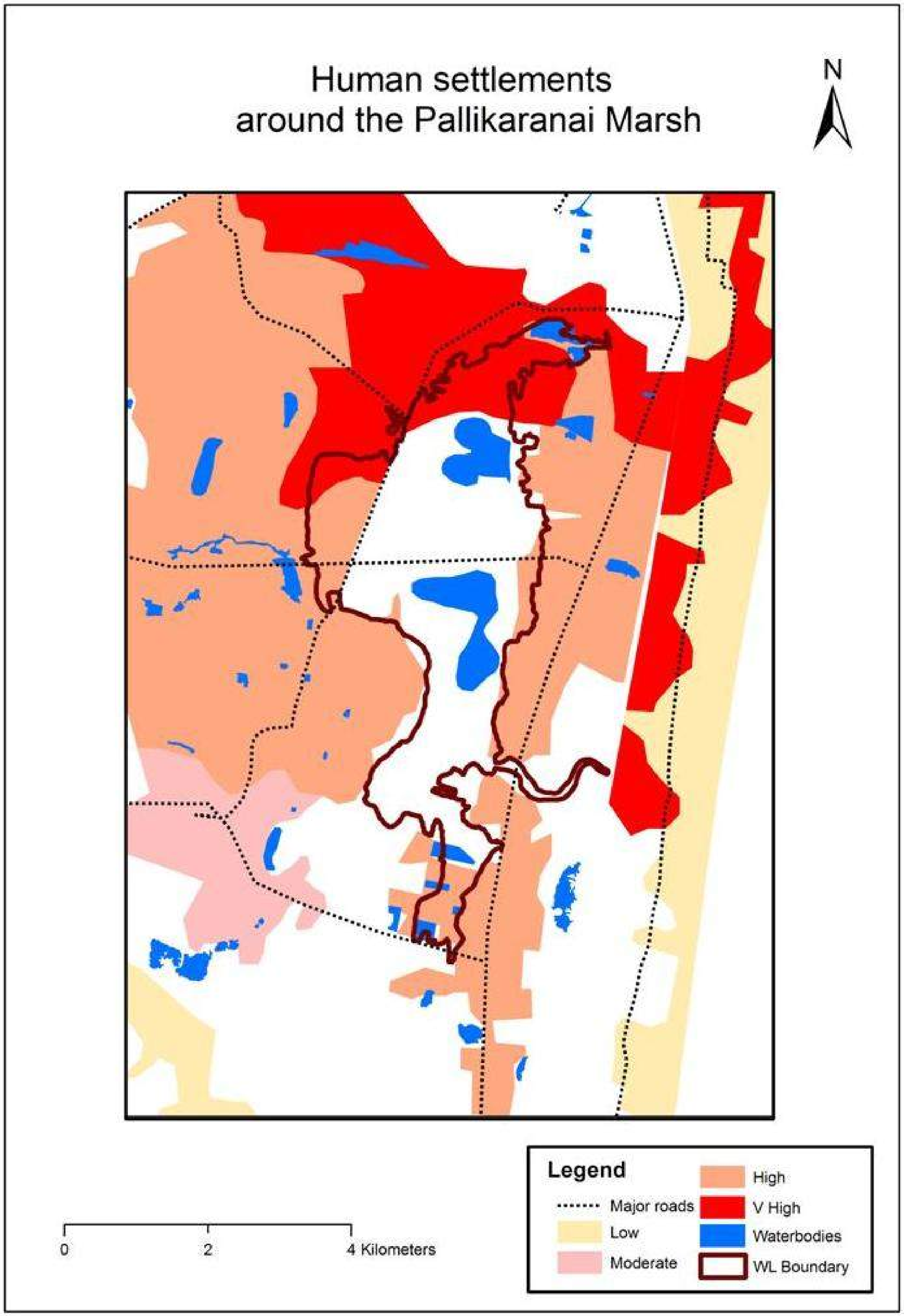


Figure 8.3 Map showing Pallikaranai Land Cover change (2001-2015)

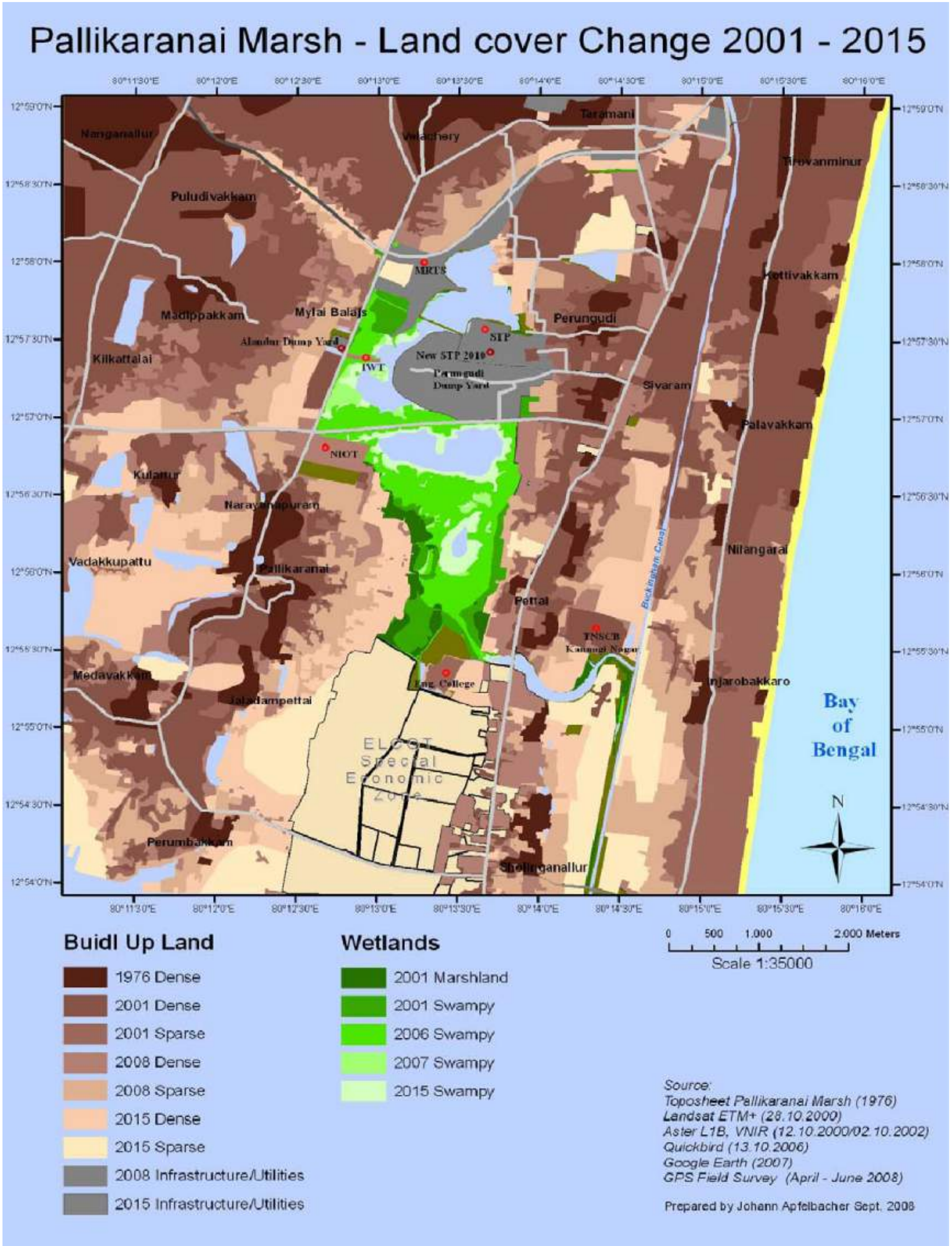


Figure 8.4 Map showing 2008-2015 LUCC Process

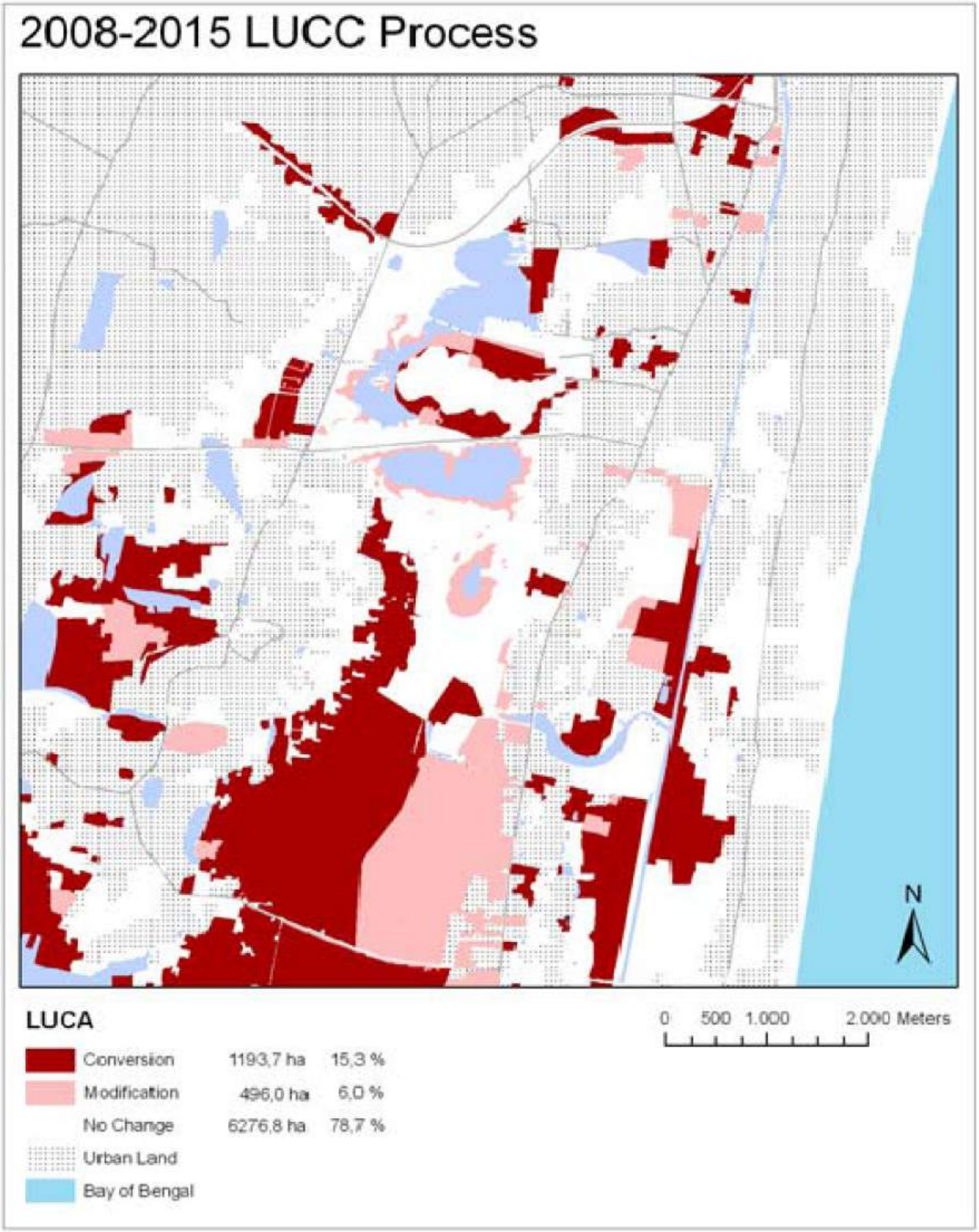
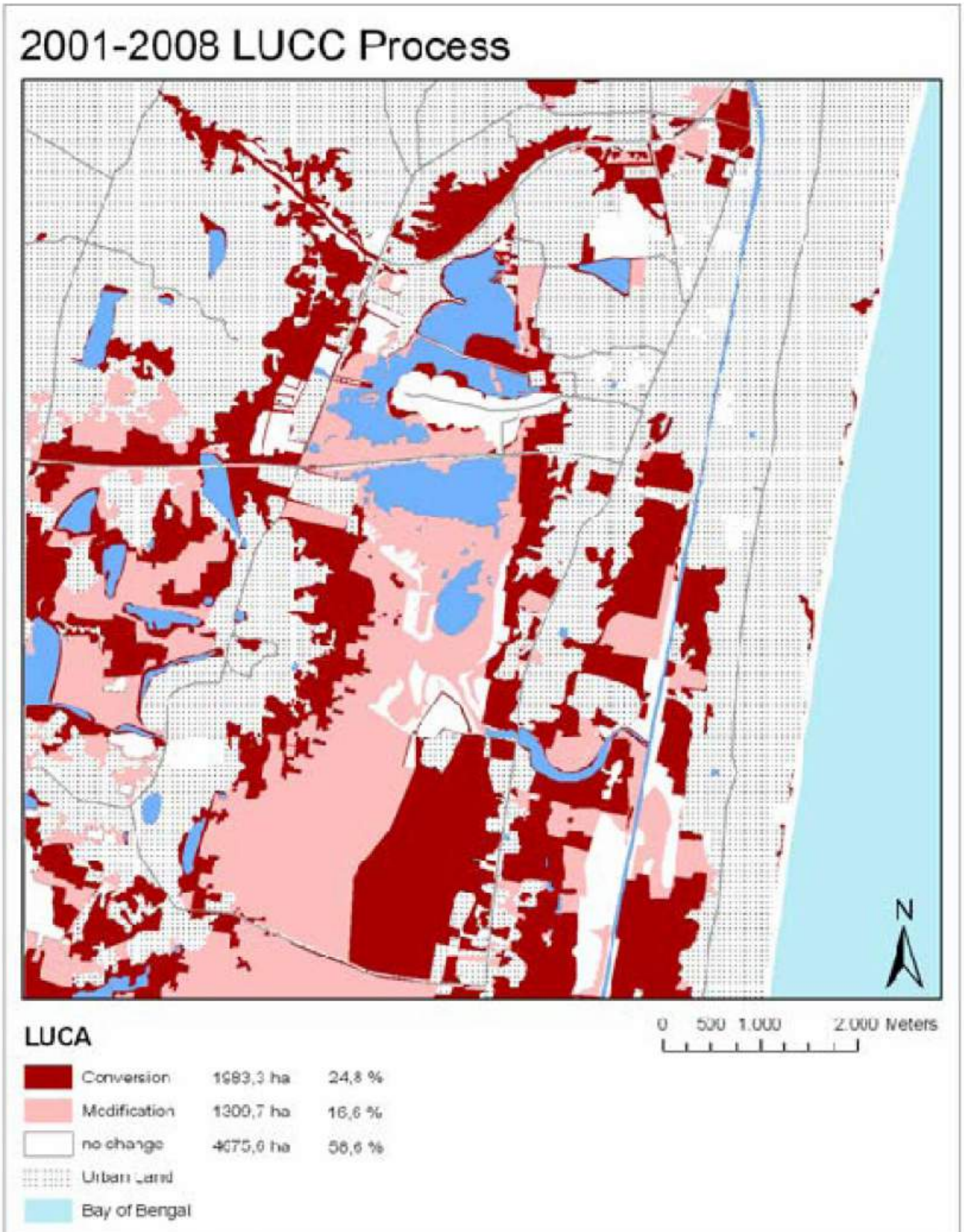


Figure 8.5 Map showing 2001-2008 LUCC Process



The following broad patterns of land use land cover change can be discerned for the landscape:

1. The landscape had during the period 2001-2008 undergone a significant transformation in terms of being either modified or converted into residential and industrial zones.

2. Following the declaration of a large part of the marsh as a protected area, the landscape has changed its pattern of conversion in that while the protected area alone remains insulated and unchanged; the rest of the area has been converted rather rapidly into human occupied zones (2008-2015).

3. The overall wetland area both within the designated marsh area and the adjoining habitations has reduced considerably. But of serious concern is the reduction in the area under open water within the marsh.

4. Density of habitation is at the maximum on the northern and north-western portions of the marsh, which are also the zones that are impacted intensively during flooding. Habitation density continues to be low to moderate on the eastern periphery due to the presence of the coast and the related regulations.

5. It is also evident that the marsh is under severe human pressure on all directions, except for the south which has the presence of an associated wetland thereby offering a semblance of buffer zone attributes.

9. Comprehensive Management Plan

The Comprehensive Management Plan (hereinafter referred to as CMP) consists of the following components:

1. Definition of the Vision and Mission of Pallikaranai Marsh
2. Definition of the strategic objectives of Pallikaranai Marsh
3. Technical components defining the strategy and recommended action; financial outlay
4. Components for monitoring and dissemination.

9.1 Vision

Protection, restoration and conservation of wetlands for the cause of biodiversity conservation and human well being

9.2 Mission

To develop and manage the Pallikaranai Marsh as a biodiversity refugium while enabling the wetland to effectively discharge its ecosystem services, notably flood mitigation and water holding, and also providing nature appreciation opportunities to people who visit the landscape.

9.3 Strategic Objectives

A strategic objective is a broadly defined objective that an institution or an organisation, such as the Tamilnadu Forest Department, must achieve in order to fulfil the defined vision and mission. The following are the strategic objectives of the Comprehensive Management Plan for Pallikaranai Marsh.

1. To undertake an ecological, social and interface assessment of the Pallikaranai Marsh and its environs.
2. To effectively utilise the results of the assessment in defining the strategic interventions of the action plan.

3. To formulate the strategies and actions for the identified technical components; and
4. To develop Pallikaranai Marsh as a public space for constructively engaging with the stakeholders.

9.4 Defining the strategy and strategic interventions

The strategy and strategic components of the Plan have been evolved and defined based on two overlapping forms of study viz. field research of the wetland and its surroundings over 3, 5 and 10 km radius, desk study of maps, satellite imageries (open source and procured) as well as technical papers and reports. In addition, inputs obtained from senior officials of the Tamilnadu Forest Department and other line departments of the State, naturalists and the public at large have also been considered. The theoretical framework has been developed by reviewing past and ongoing world-wide efforts in restoring wetlands.

The most critical aspect of the current plan is its shift from being a 'Management Plan for a Reserve Forest to a Comprehensive Management Plan for a Wetland for a five year period'. A three pronged strategy has been defined for the management of the Pallikaranai Marsh, which focuses first on consolidation and protection, followed by restoration and conservation. The term Consolidation and Protection is operationally defined as the process and means by which the ecological and legal boundaries of the marsh are identified, defined and protected using existing legal and regulatory provisions. Restoration indicates specific actions needed to be undertaken to recover in full or in part the degraded or manipulated or impacted state of the marsh. Conservation strategy is focussed on the processes and methods needed to be undertaken on a regular and dynamic and sustained basis to consolidate the protection and restoration efforts. Each of the strategies has been detailed in terms of strategic interventions (normally referred to as recommendations).

9.5 The approach to Wetland Conservation

Wetland conservation can be broadly defined as response category to recover ecosystems that have been degraded or destroyed. A primary goal of a wetland conservation project is to restore and enhance wetland benefits by re-establishing natural ecological processes. In the case of Pallikaranai Marsh, the primary focus is on the hydrological aspects of the wetland; notably not allowing the wetland to degrade to a water deficit, exceedingly dry entity.

Natural processes and existing conditions should be considered for planning and executing the restoration programme; to the extent that is possible, ecological engineering principles should be applied in preference to methods requiring hard structures or extensive excavation. For instance, the well entrenched methods used by the TN Forest Department such as trenching, creation of bunds, earthern mounds are preferable over concrete structures or creation of wells or dug out ponds inside the wetland area. Further, any excavation that is proposed within the sanctuary could be based on the hydrological assessments detailed in the current report. Or in certain instances, restoration of small pockets or individual patches as percolation ponds would contribute significantly to improving the quality of the wetland. The minimum acceptable scale for wetland restoration planning is always at the level of the catchment. Individual, relatively small restoration projects targeting a single wetland can be valuable provided they are planned within the context of the catchment.

Further, wetland restoration planning should not ignore the value of adjoining habitats, especially if agrarian or of other human centric use. Wetland restoration planning should consider water allocation principles in the landscape and the role that restoration can play in maintaining ecological functions of wetlands. To detail, one of the most common errors in planning that is made in wetland restoration programmes is to evolve public space designs around the sanctuary, that are water intensive such as laying of lawns or spaces that require periodic water cleansing. Yet another unforeseen corollary is an increase in extraction of water in the adjoining, non-protected habitats through digging wells or drilling borewells by local population. This needs to be reconciled through engagement with local self government institutions. The primary focus of the water allocation within and in the immediate environs should remain to the biodiversity, notably birds and fishes and their associated life forms.

While a special programme with well defined priorities, statement of goals, objectives and performance standards for restoring the wetland is being established through the current initiative, it is important that all efforts be undertaken to limit the possibility of undesirable side effects. For instance, careful planning could ensure that the restoration effort does not lead to problems such as an increase in the number of vermin such as mosquitoes, unwarranted water logging and flooding, etc.

The CMP should be an open process that involves local community stakeholders as well as stakeholders who will be affected by a project even though they may be geographically distant from the project, for example, stakeholders living well downstream. All stakeholders, including local communities, should be fully involved in a wetland restoration project from its earliest stage of consideration through its implementation to its long-term stewardship. Restoration requires long-term stewardship, including ongoing management and monitoring. Development of incentive measures, such as supporting local self help groups through revolving funds etc, can make a valuable contribution to the sustainability of the restoration project.

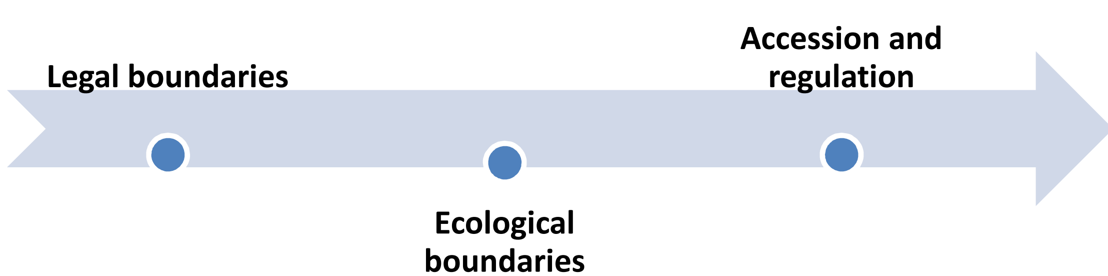
The principles of Adaptive Management should be applied to such restoration projects. Adaptive management is a technique that involves incorporating new information into all stages of a wetland project. Using adaptive management means one can continuously evaluate the project in light of new information, generating ideas and making decisions about how to further refine the project. This process also can be thought of as a "feedback loop" in which information about what is happening with the project currently helps one to determine how to go forward with the next step of project.

This entails that as the programme of restoration develops, modifications may be necessary to accommodate unforeseen developments and take advantage of newly acquired knowledge or resources.

Finally, restoration interventions should be coupled with measures to raise awareness and influence the behaviour and practices that led to the degradation of the ecosystem, in order to ensure that the causes, as well as the effects, of degradation are addressed. These actions provide a further mechanism for landowners, resource users and surrounding communities to be drawn into restoration projects, and for applying the Guidelines for establishing and strengthening local communities' participation in the management of wetlands.

9.6 Consolidation and Protection

The strategy of consolidation and protection is focussed not only on the area that has currently been protected (317 ha), but also includes the additional area of marsh being included in the ambit of protection through allotments or inclusion from other line departments and the Chennai Corporation and the Revenue Department such as the 170.40.5 ha and 71.58.0 ha. The total area that is currently under protection as a Reserve Forest is 558.98. 5 ha. The plan also recognises that further addition to the RF area is possible to a maximum of 620 ha. The strategy also includes, more importantly, aspects such as the identification of ecological boundaries, as well as additional areas that need to be brought under regulation /protection for ensuring the integrity of the Pallikaranai Marsh.



The following series of maps depict the legal and ecological boundaries of the Pallikaranai Marsh.

Figure 9.1 Map showing legal boundaries of Pallikaranai Marsh

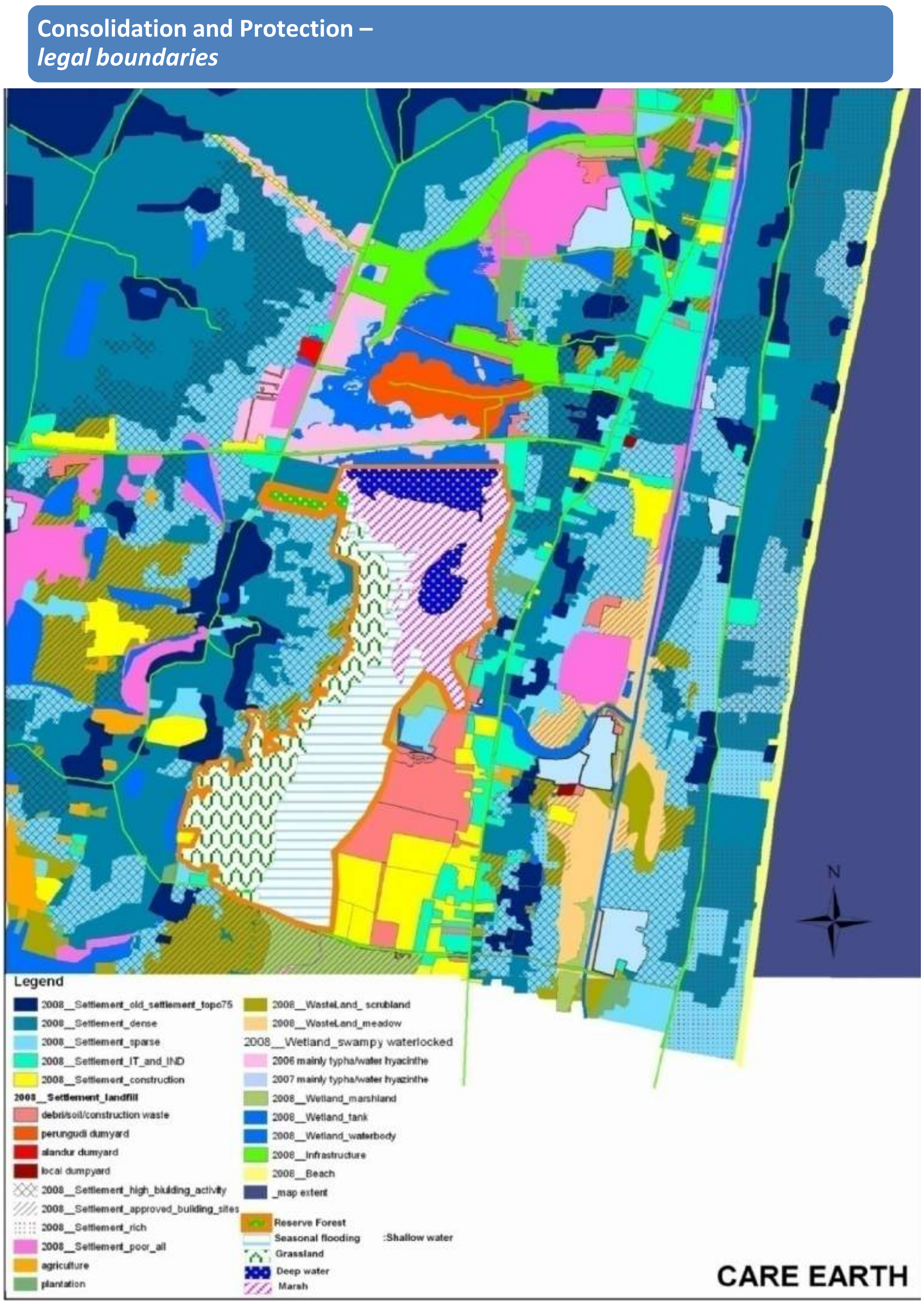


Figure 9.2 Consolidation and Protection: *ecological boundaries*

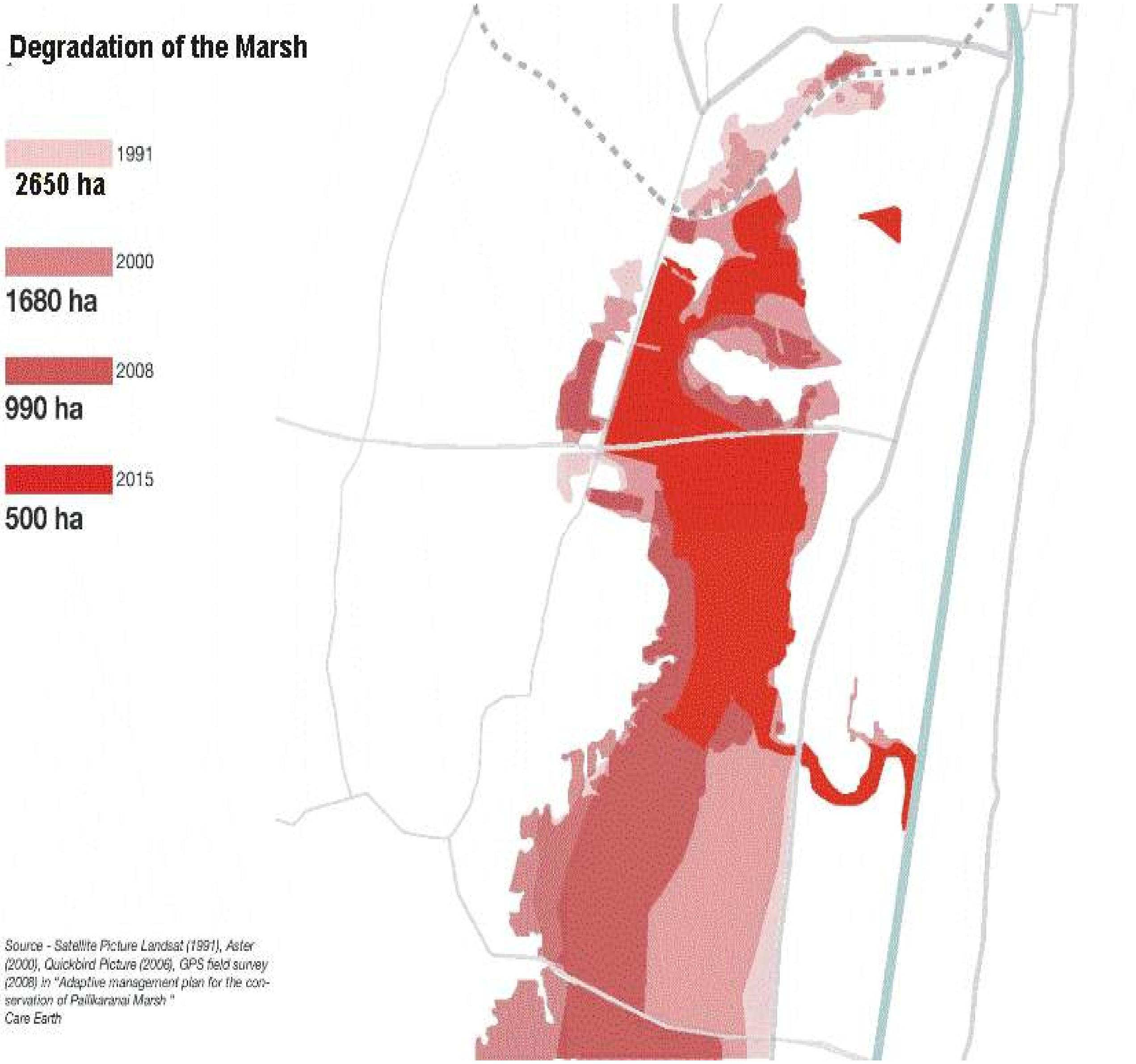
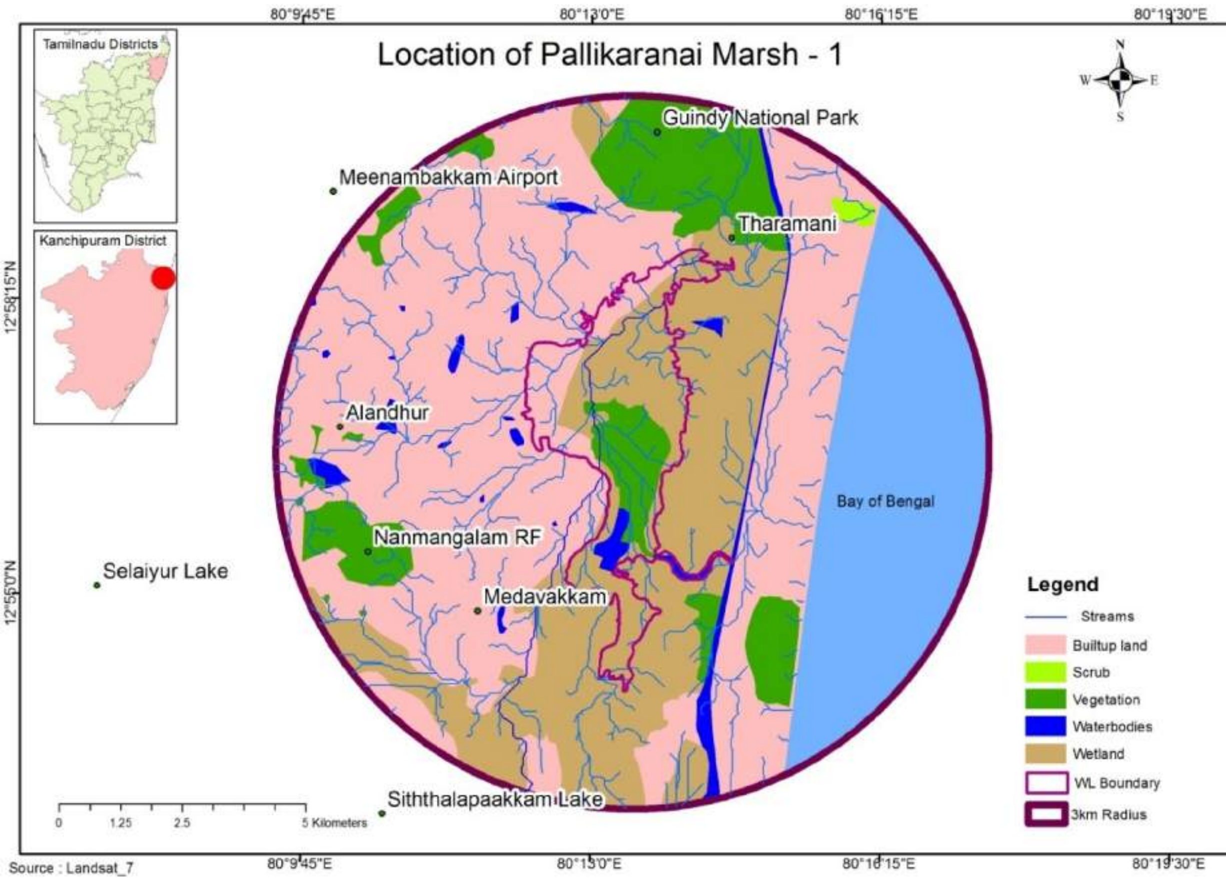
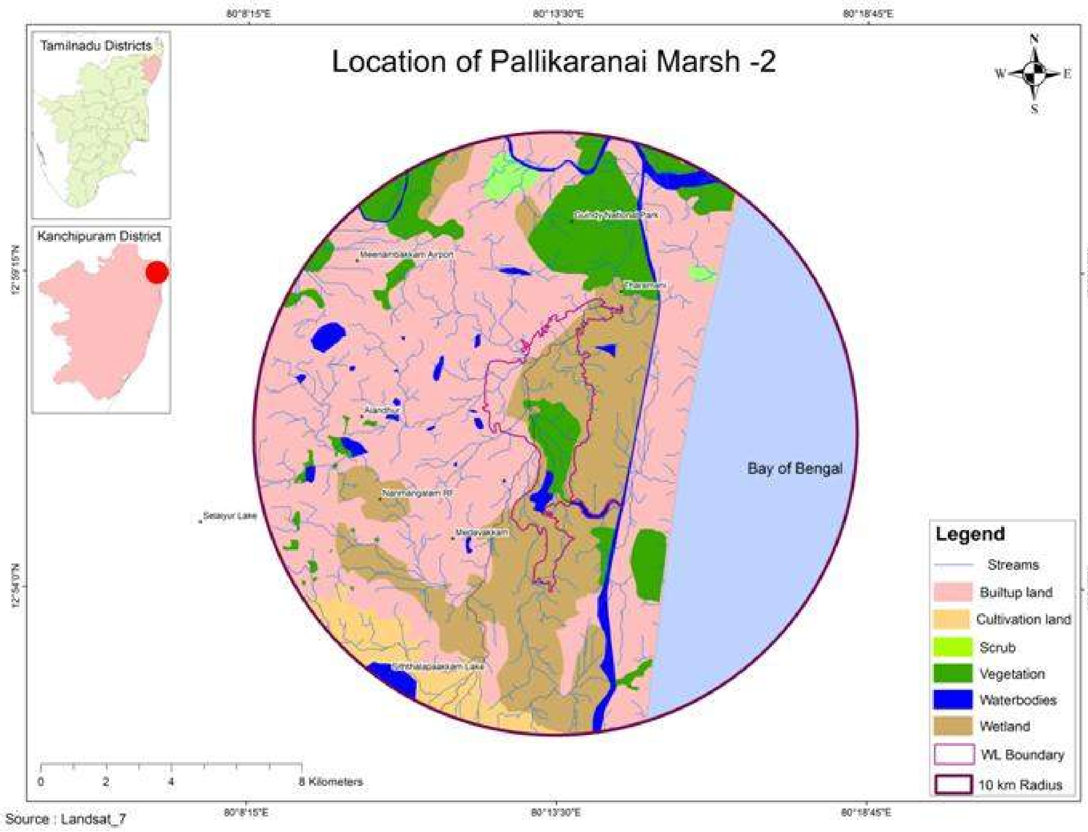
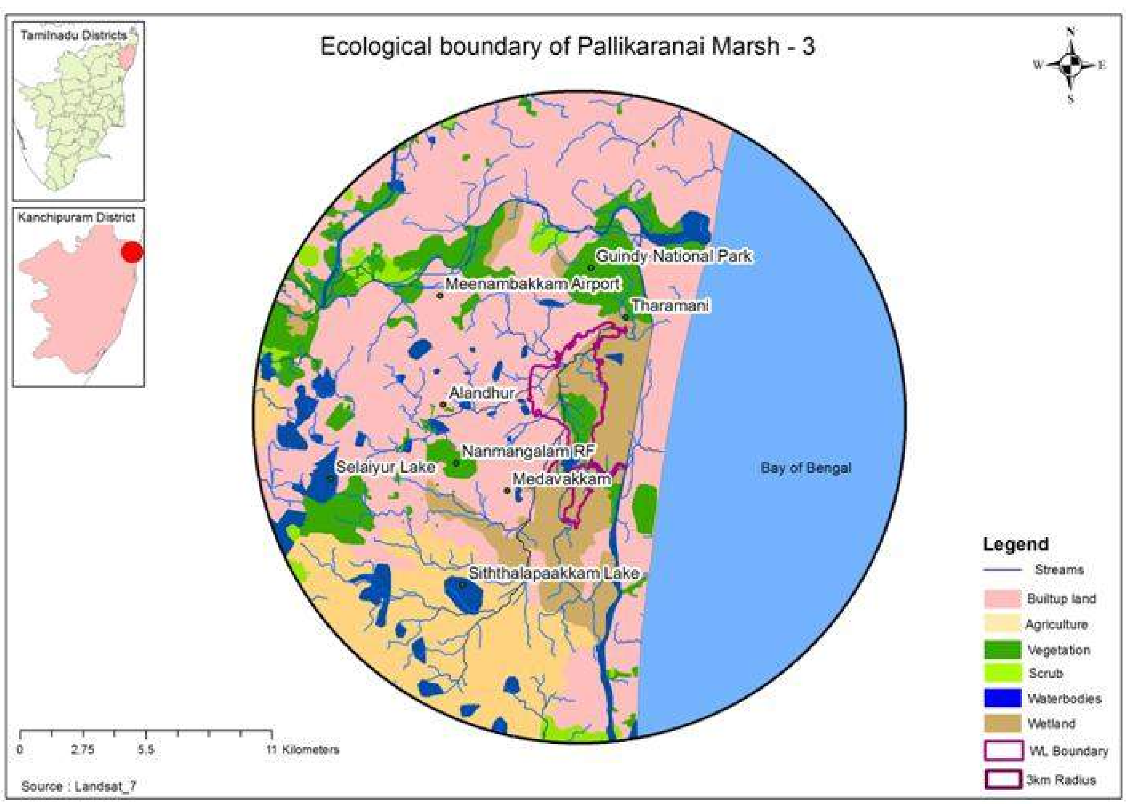


Figure 9.3 Maps (1-3) locating Pallikaranai Marsh over 3 km, 5 km and 10 km radius highlighting the ecological boundaries




Location of Pallikaranai Marsh -2
Tamilnadu Districts
Kanchipuram District
80°8'15"E
80°13'30"E
80°18'45"E
12°59'15"N
12°54'0"N
N
W
E
S
Bay of Bengal
Legend
Streams
Builtup land
Cultivation land
Scrub
Vegetation
Waterbodies
Wetland
WL Boundary
10 km Radius
0
2
4
8 Kilometers
Source : Landsat_7


Ecological boundary of Pallikaranai Marsh - 3
Tamilnadu Districts
Kanchipuram District
N
W
E
S
Guindy National Park
Meenambakkam Airport
Tharamani
Alandhur
Nanmangalam RF
Selaiyur Lake
Medavakkam
Siththalapaakkam Lake
Bay of Bengal
Legend
Streams
Builtup land
Agriculture
Vegetation
Scrub
Waterbodies
Wetland
WL Boundary
3km Radius
0
2.75
5.5
11 Kilometers
Source : Landsat_7

It is evident from the above series of diagrams that the wetland area of about 2650 ha in 1990s has shrunk rather rapidly to less than 500 ha in 2012-13, not only due to the actual decrease in wetland area but also due to the decimation and absolute degradation of adjoining wetlands within the landscape and the loss of hydrological processes as a consequence. It is also evident that the presence of two major protected zones, viz. the Guindy National Park and the Nanmangalam RF in close proximity to the marsh has provided invisible, yet significant buffer services to the marsh. Further, ongoing research has indicated that about 700-800 tankers extract water within 3 km of the Pallikaranai marsh either by directly pumping water from the wetlands or through borewells. This needs to be regulated for it is not only unsustainable, but also because rules and regulations are not being adhered to.

9.7 Ecological extensions and their relevance to boundaries of Pallikaranai Marsh

It is rather well established that restoration and conservation efforts are maximized in the event of a landscape approach although questions as to what constitutes a landscape in an urban scenario remains indistinct. The plurality of land use and land cover, organized as a mosaic of interlocked habitats often renders an area characteristics that obscure the original ecological character.

For instance, the area around Pallikaranai Marsh, which was originally a low lying floodplain (of which a large part was either at sea level or below sea level), is today a composite of high rise residential complexes, industrial and institutional zones, public infrastructure and remnant natural habitats. This obscures the fact that the area is one that has historically been the natural water holding zone for the city of Chennai. An analysis of the pre monsoon and post monsoon water holding of the area for the monsoon deficit year of 2013 demonstrates this rather categorically (see Fig 9.4 and 9.5). The oft repeated statement by local people who have historically been part of these villages, that they practiced agriculture (paddy and horticultural crops) using only water that inundated the area bears testimony to this.

Figure 9.4 Map showing existing waterbodies around Pallikaranai Marsh- May 2013 (Pre-monsoon)

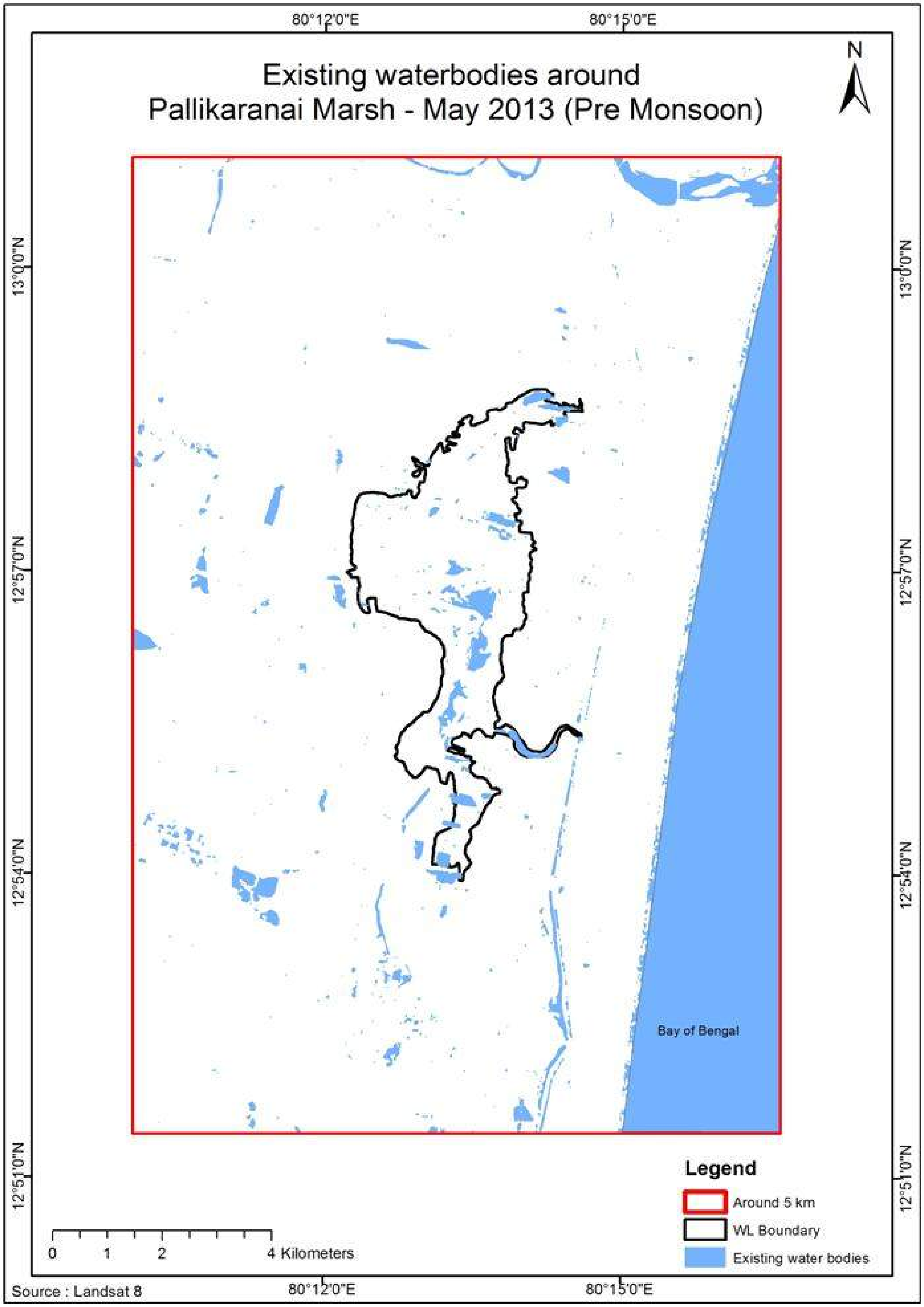
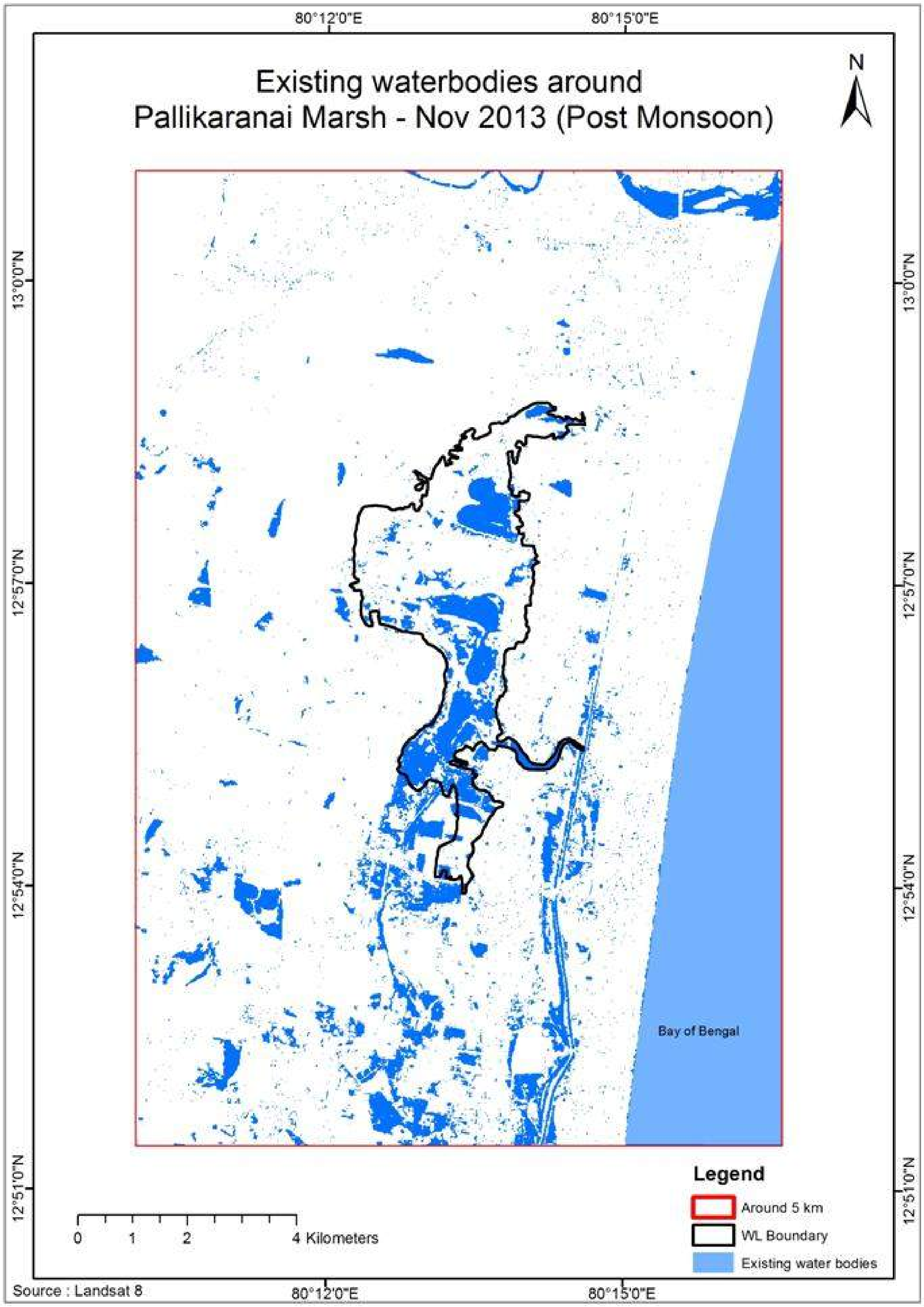


Figure 9.5 Map showing existing waterbodies around Pallikaranai Marsh- November 2013 (Post-monsoon)



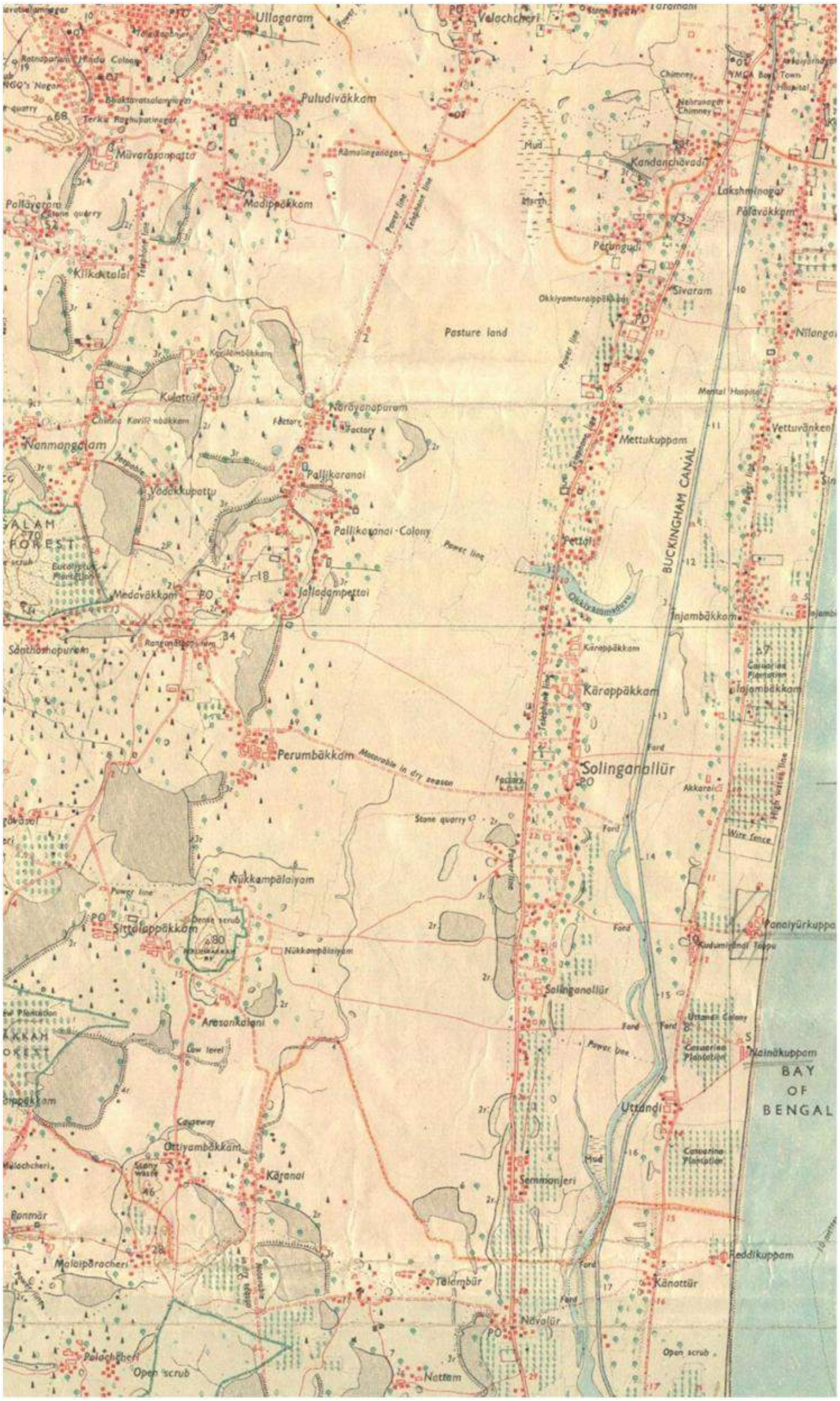
As regards the parameters of defining what constitutes a landscape, the well established notion of using watersheds as units of demarcation is valid in the current context as well, and the details are provided in the section on protecting the watersheds. The most critical data that emerges out of this analysis is the fact that the landscape under question is 231 sq. km, in which the remnant Pallikaranai Marsh is centrally located. The wetlands (which is a wetland complex with well established drainage patterns) around the Marsh as well as the remnant forests such as the Nanmangalam RF are thus ecological extensions of the marsh. This entails that the watershed, christened the South Chennai Flood Plain, is redefined as the management unit, and all natural habitats that are currently present either in full or as remnants be accorded protection. While this does not suggest a 'hand over' of all such natural habitats to one department, what it highlights is the need to undertake stringent protection and scientifically valid restoration efforts in the landscape. The focus hence is on the protecting the hydrology of the South Chennai Wetland Complex.

9.8 Hydrology of Pallikaranai Marsh and south Chennai

A rather perplexing issue confounding studies of the Pallikaranai Marsh has been its hydrology. While the geological profile of the marsh confirmed the fact that it was indeed a part of a floodplain, the absence of historical maps prior to 1900s and inaccessibiity rendered by dense human habitation to undertake field assessments has left the question of connectivity to rivers unanswered. This also led to a condition where the definition of the boundaries of the landscape was becoming untenable. More recently though, a toposheet of 1904 (Fig. 9.6) has been accessed which reveals certain interesting features.

As postulated, the construction of the Buckingham Canal was a key feature in connecting the easterly wetland of Okkiyam Thoraipakkam (which is currently the location of Kannagi Nagar) to the Pallikaranai Marsh. Secondly, the southern canal which originated in Ottiyambakam wetland and drained north through Perumbakkam has been compromised. Besides the historical topographic map an analysis for the derivation of flow pathways demonstrates that the natural flow paths are aligned to the north, which was re oriented in some point of history.

Figure 9.6 Pallikaranai Marsh in 1904 Toposheet



Against this background, it was decided to develop watershed maps for the region known as South Chennai. The following series of maps highlight the watersheds of the region as well as the extent of each of the watersheds.

It is evident from the following series of maps that the Pallikaranai Marsh and its wetland complexes are part of one watershed that is spread over an area of 231 km (designated as ws2).

The East coast is part of a small, yet distinct watershed. Buffering the two watersheds is a yet another watershed of an extent of 10 ha. which is what rendered historically connectivity to the Adyar River.

The Chembarambakkam lake and its wetlands are part of the most extensive of watersheds spanning about 400 ha.

The most critical feature of the maps is the validation of the initial assessment that the Pallikaranai Marsh is rendered with a hydrological flow that is rather unique. While the adjoining wetlands discharge water into the marsh either as an overflow or through the drainage network (which probabaly was of relevance to irrigation historically), the presence of a stream (of order 3) that cuts across the marsh from the south-western parts of the landscape (including the Perumbakkam wetland), to the north eastern part of the landscape is of critical significance for the south west – north east flow of freshwater into the system. This may in turn be the aquifer that is invisible.

The stream which runs through the marsh originates from a network of smaller streams that originate from St Thomas Mount, Pallavaram hills and the lower reaches of the Tambaram hills. About 16 wetlands were part of this system.

The saline water intrusion was through the coastal watershed, wherein once again the flow was south to north, with only the excess water draining into the marsh.

The conservation of the marsh is hence critically linked to the protection of the watershed which hosts the Adyar River, as well the entire watershed it is part of.

Figure 9.7 Watersheds connected to Pallikaranai Marsh

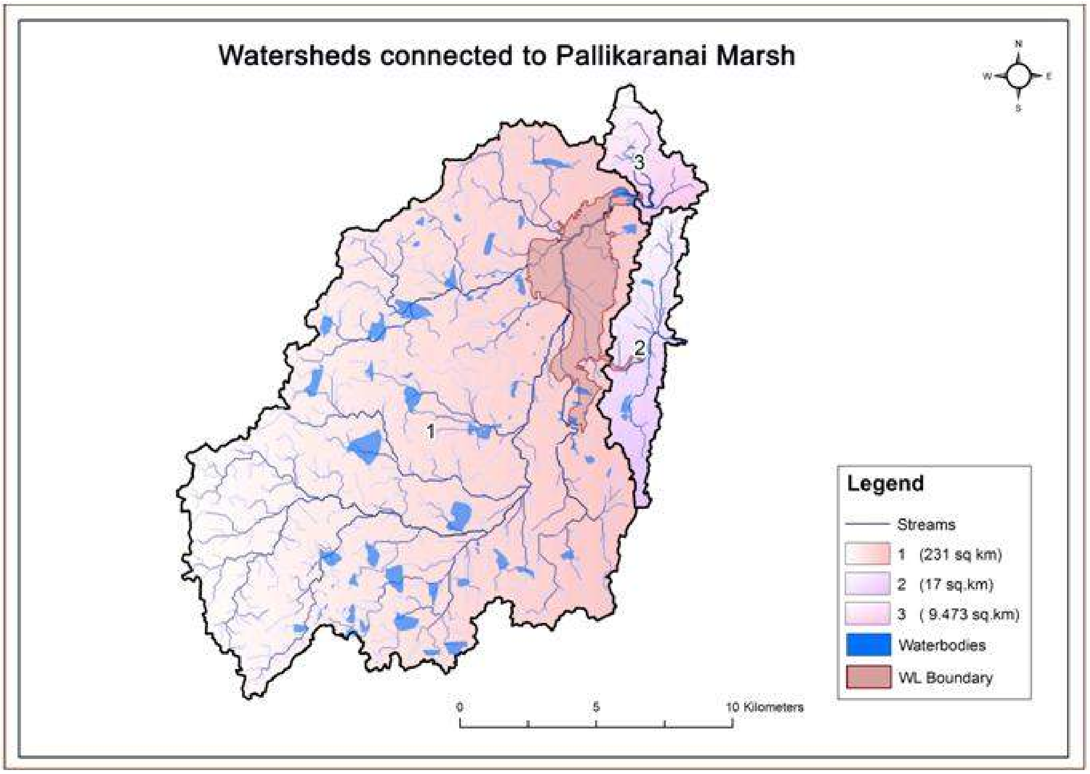


Figure 9.8 Major Watersheds around the Pallikaranai Marsh

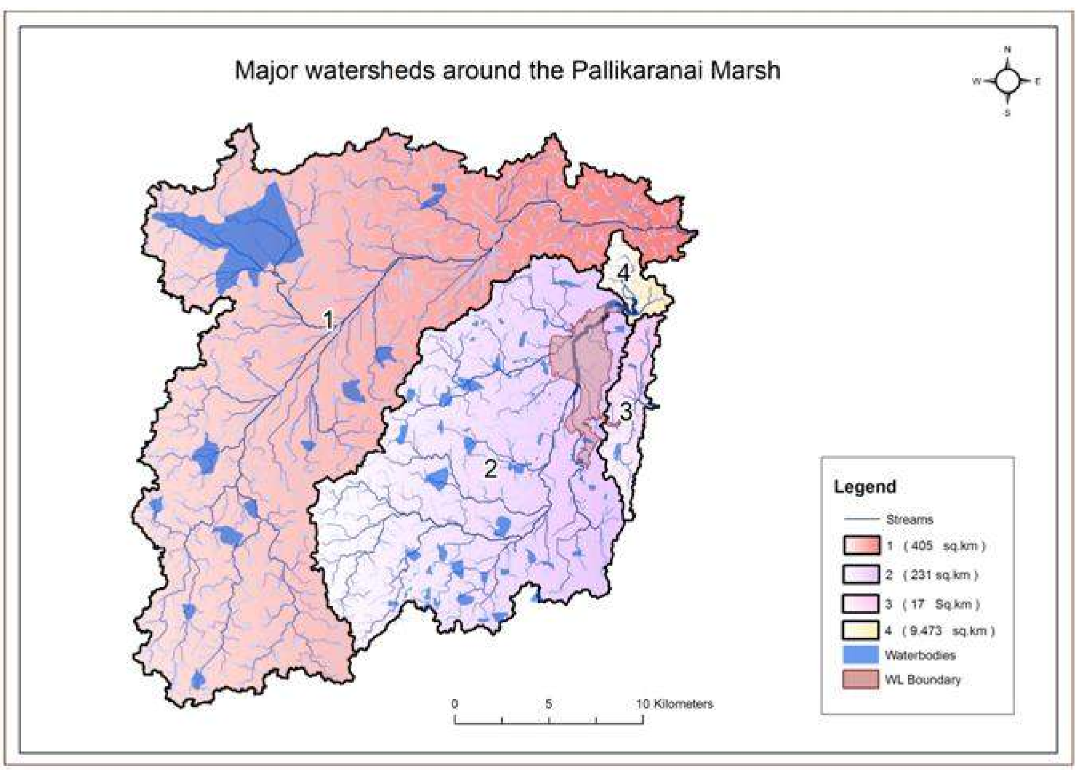
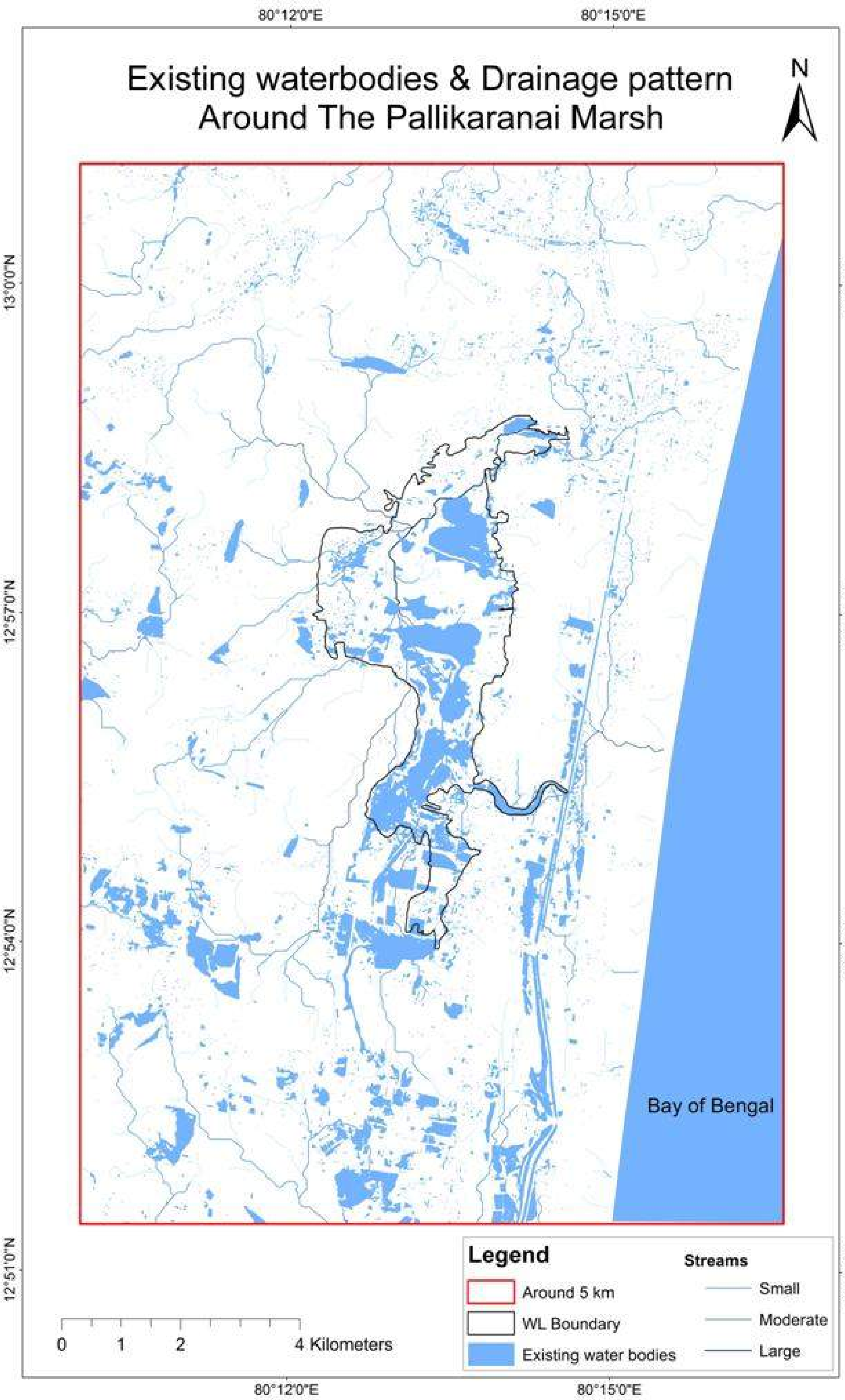


Figure 9.9 Existing waterbodies and drainage pattern around Pallikaranai Marsh



10. Restoration: domains, goals and targets

10.1 Guidelines and operational principles defining the restoration initiative

Restoration can be defined as "the act of restoring to a former state or position ... or to an unimpaired or perfect condition". Restoration is usually carried out for one of the following reasons: (a) to restore highly degraded but localized sites, (b) to improve production capability in degraded but localized production lands, (c) to enhance conservation values in protected/productive landscapes. According to the biological viewpoint restoration can be applied to ecosystems, habitats, communities, species, water or soil quality or some other characteristic of the degraded area.

Habitat restoration is a term that is frequently used to cover the general topic of restoring ecosystems for the specific purpose of providing habitat- either for an individual or a group of species found in an area. Habitat restoration lays more emphasis on the area where organism lives rather than ecological functions.

Habitat can be defined as the dwelling place of an organism or community containing the particular combination of resources and environmental conditions that are required by individuals of a given species or group of species to carry out life processes. Habitat is not equivalent to 'habitat type' which refers to the type of vegetation association in an area.

10.2 Restoration Goals

A **restoration goal** is a description of the desired outcome of restoration. The restoration goals identified should be **specific**, **measurable**, **agreed upon**, **realistic** and **time bound**, developed in consultation with the stakeholders. Following considerations should be taken into account for restoration.

1. Identification of target species

As habitat is a species-specific concept its restoration involves identification of a particular target species. The needs of the target species determine the desired composition and structure of the site and accordingly place importance on the components to be restored. The target species for restoration can include, (a) Threatened species, (b) Focal species, (c) Functional response groups, (d) Keystone species (e) Umbrella species and (f) Flagship species. In cases where data regarding particular species is lacking, landscapes can be modelled to identify groups of species associated with a particular habitat that are in active decline. All the above approaches have their advantages and disadvantages and no single approach can effectively conserve all species in an area. ***For the ecosystem functioning, certain processes like water and nutrient cycling, energy flow, soil formation, pollination etc. are desirable and Functional groups are groups of species that perform a role in ecosystem functioning, helping create a self-sustaining system. For e.g. pollinators, seed dispersers, nitrogen fixers, primary producers etc. The greater the number of functional groups greater would be the likelihood to cope with disturbance***. ***The target for the Pallikaranai Marsh is the functional groups.***

2. Habitat elements

Desired qualities of a restored habitat include:

- ✓ Should be adequate to meet target species' requirements over time
- ✓ Should be ecologically 'functional' and self-sustaining
- ✓ Should be resilient to disturbance in the shorter term
- ✓ Should be adaptive to change (e.g. climate change) over the longer term.

The restoration agenda for the Pallikaranai Marsh is based on the performance of the above four factors.

3. Habitat adequacy

A compilation of key habitat features and resources required by target species to successfully complete a life cycle and maintain a viable population, should be made. For example, minimum patch size, specialized food resources, special niches for feeding and shelter, tolerance to disturbance, etc. Habitat composition and structure is influenced by physical elements like soil fertility, topography, geology and hydrology which can further affect the target species.

4. Minimum Habitat requirement

As habitat availability is the most important determinant of population persistence, restoration requires assessing how much habitat is needed for persistence. The factors that need to be considered for this include, (i) individual area requirements; (ii) reproductive rate; (iii) increasing per capita emigration rate and dispersal mortality rate with decreasing habitat amount (Skellam's process); (iv) increasing effects of demographic and environmental stochasticity with decreasing habitat amount; and (v) decreasing colonization and immigration rates with decreasing habitat amount. ***The Pallikaranai Marsh has about 550 ha. dedicated for the restoration programme in blocks, strips or patches.***

5. Habitat heterogeneity is the variety of habitats across a landscape and this variety is important for the persistence of many species. For e.g. breeding site may be located in a different habitat type to food resources. **Habitat connectivity and patch size** is another factor that needs to be taken under consideration as the scale at which habitat is present is important. Habitat fragmentation can occur due to vegetation clearance, changes in land use or natural disturbance. Larger sites hold better habitat potential to support bigger population of species. Apart from the size, connectivity is also important, represented by the absence of barriers enabling movement of species for food, shelter and breeding. Hence, restoration should involve large interconnected patches assessed and prioritized based on the needs of the target species. The habitat heterogeneity is determined at the landscape level and a model to define the level of habitat modification in a landscape has been developed by McIntyre and Hobbs (2000):

- intact - >90% of habitat intact or with low levels of modification
- variegated - 60 to 90% habitat intact and/or low to high levels of modification of remaining habitat
- fragmented - 10 to 60% habitat intact and low to high levels of modification
- relictual - <10% habitat intact and most remaining habitat highly modified

In the intact and variegated landscapes the habitats are well connected for most species and they require only maintenance and improvement of integrity and resilience. In fragmented and relictual landscape, as with Pallikaranai Marsh, habitats are severely modified and fragmented, and restoration in these cases involves checking degradation and restoring the function of degraded patches like improving habitat connectivity and quality. ***Restoration of relictual habitats focuses on improving condition of remaining habitats and constructing a buffer area around them.***

6. Habitat Resilience

Resilience is defined as the capacity of an ecosystem to absorb disturbance without shifting to an alternative state and losing function and services, encompassing two separate processes: resistance- the magnitude of disturbance that causes a change in structure and recovery- the speed of return to the original structure. Recovery mainly depends on regeneration mechanism and migration of new individuals to the disturbed site, hence suitable habitat connectivity is important for movement of new colonists into the area. Degraded habitats are less resilient and more susceptible to disturbances. The degree to which habitat change influences community resilience depends on community structure and connectivity.

For the restoration of Pallikaranai Marsh, four sub themes of restoration have been identified and these are as follows: ecological, environmental, interventional and hydrological. Each of these sub themes, developed as strategies have detailed strategic interventions or recommendations which are discussed in the following sections of the report:

The schematic diagram presented herewith represents the over-lap that exists between the four domains, while also providing a glimpse of the scale of importance and restoration prioritization that each of the domains commands.

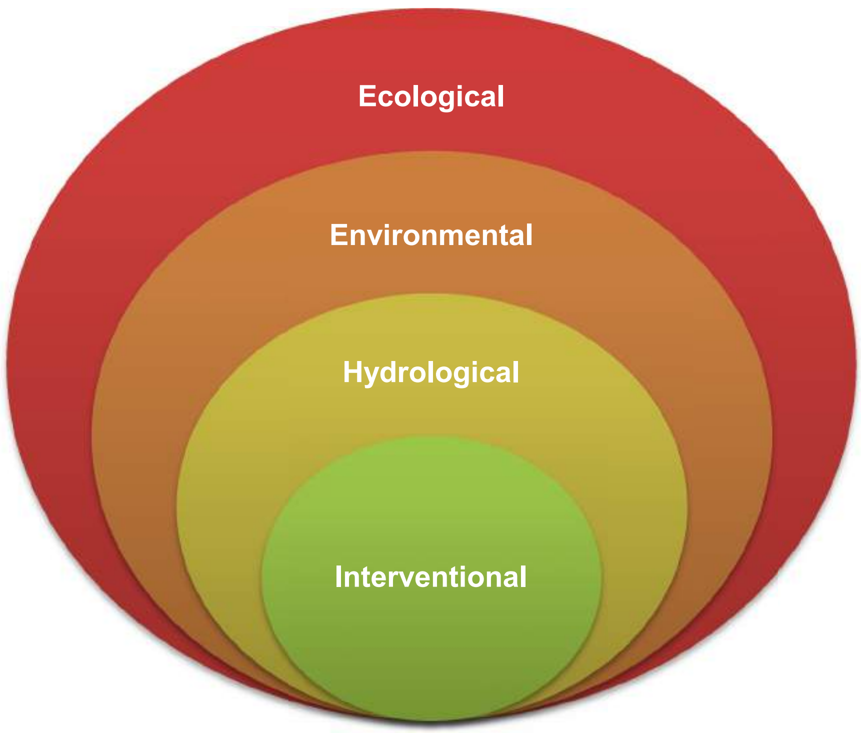


Figure 10.1 Restoration domains for the Pallikaranai Marsh

10.3 Ecological Restoration: Habitat Assessment and Intervention

The focus of ecological restoration for Pallikaranai Marsh is the wetland habitat. Hence the following analyses were found essential to evolve the strategic interventions that would facilitate the restoration of the Pallikaranai Marsh.

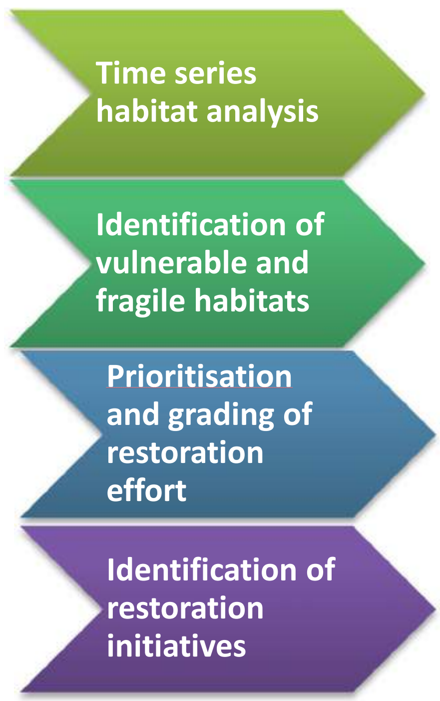
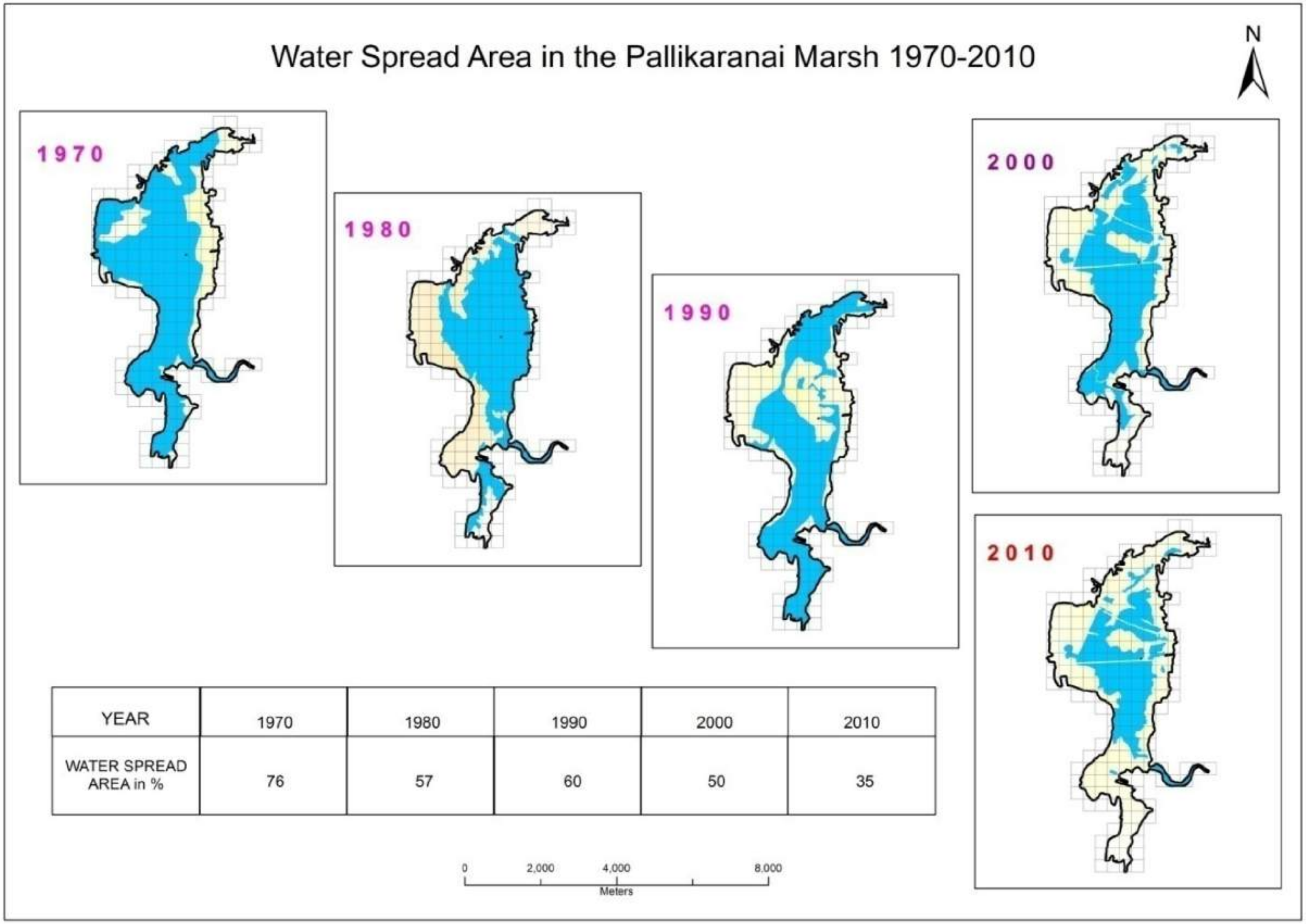


Figure 10.2 Water Spread Area in Pallikaranai Marsh 1970-2010



YEAR	1970	1980	1990	2000	2010
WATER SPREAD AREA in %	76	57	60	50	35

A. Strategic Intervention 1: improve wetland area to maximise hydrological efficiency

Fig. 10.2 which depicts the time series analysis the Pallikaranai Marsh demonstrates a 50 percent reduction in open and deep water area (which would still be < 6 m). It also depicts that the contiguity of water spread in the area is impacted by the presence of human infrastructure both within the marsh as well as on the periphery, rendering it a character of spread out deep water pockets.

In other words, apart from reclamation of large parcels of the marsh on the northern, western and eastern peripheries of the marsh to enable the development of residential and industrial complexes, the intervention within the designated marsh area in terms of roads, establishment of institutions and the presence of the Perungudi MSW dump have contributed not only to the overall reduction in the area and spread of the marsh, but have also altered the hydrology of the marsh.

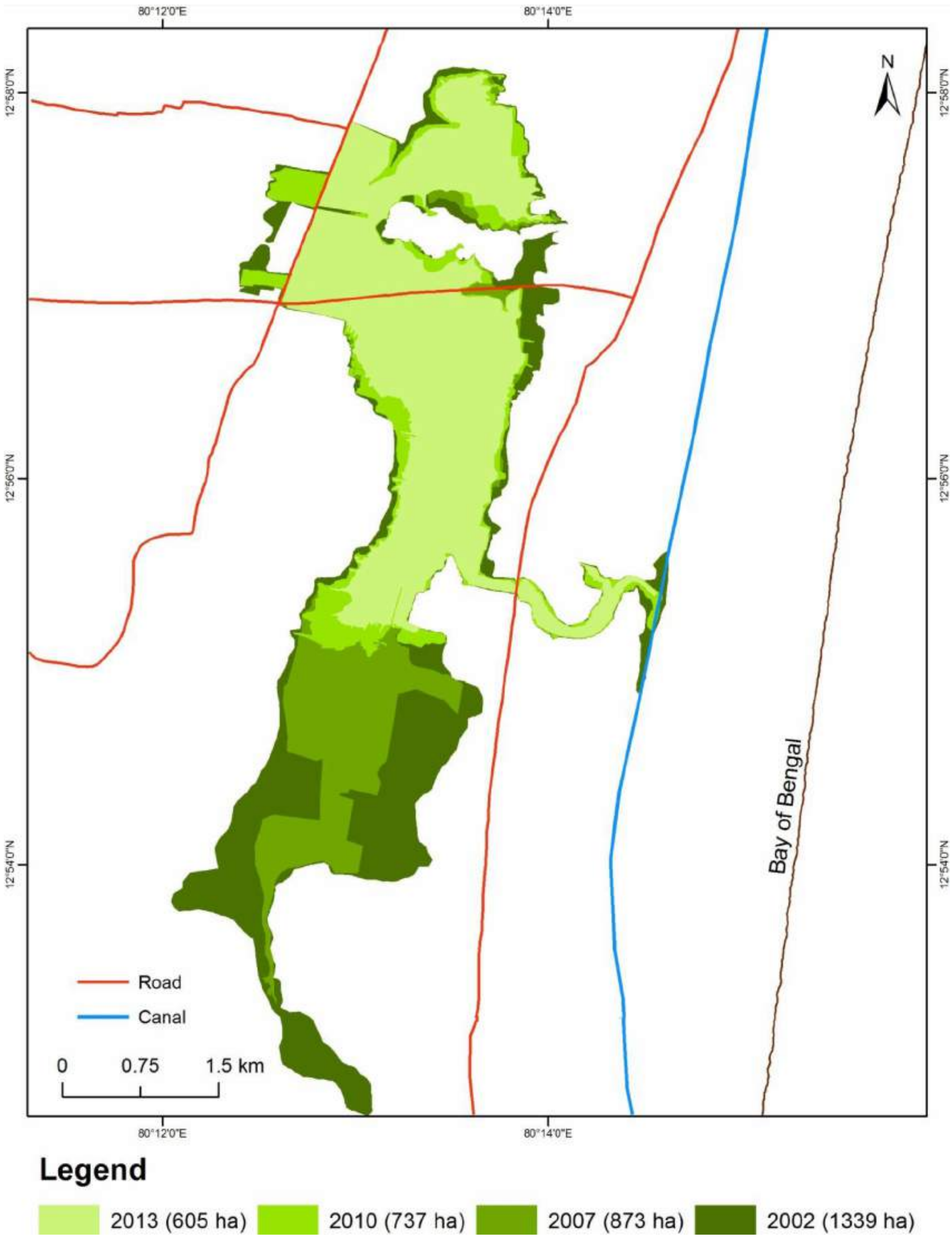
Changes on the southern aspect of the marsh are distinctly different in that four factors have contributed to the flip of the marsh into grassland over run by Invasive Alien Species.

The first of these pertains to the establishment of the educational institutions and small scale industries within the marsh, which for purposes of access manipulated the Okkiyam Madavu to establish roads. While the argument that these entities are located on ‘patta lands’ is valid from a legal stand point, the fact is that human considerations led to the regularization of the roads that were established have grossly interfered with the hydrology of the marsh leading to a decrease in water spread and water holding. This also facilitated the proliferation of Invasive Alien Species.

Second is the location of the ELCOT city on the southern aspects of the marsh, which still holds remnant pockets of the marsh which have been colonized by a large number of Spot Billed Pelicans.

The third is a disconnect that has been forced upon the landscape by the presence of the ELCOT city and the road, which has severed the natural drainage and buffer provided by the Perumbakkam wetland.

Figure 10.3 Pallikaranai wetland extension



In view of the above, the following interventions area proposed:

1. All areas identified as wetland / marsh areas to be protected by annexing the same to the existing Pallikaranai Marshland RF.

2. Areas outside the ambit of being part of RF, notably the 30 wetlands identified as being components of the South Chennai Wetland Complex need to be brought under the purview of the Conservation Authority for Pallikaranai Marsh.

3. In view of the fact that the Chennai River Restoration Trust (CRRT) currently has an extended mandate of focusing on water bodies and water courses of Chennai, it needs to be brought into the CAP or collaborate as a partner while developing its programmes.

4. Efforts need to be taken to ensure that ELCOT as well as the private industries holdings, allow the small pockets of remnant wetlands within the campus to continue status quo, and also take an active part in the protection of the Pallikaranai Marsh.

5. Industries on the periphery of the Marsh, notably IT giants like the Cognizant Technology Solutions, Tata Consultancy Services, eBay and others should be encouraged to evolve and implement campus restoration plans.

6. Guidelines for the real estate developers in the landscape needs to be distinct, highlighting the dos and don'ts. For instance, low water utilization gardens as opposed to large lawns could be made a norm.

7. Existing buildings, notably national institutions such as the National Institute of Ocean Technology and Centre for Wind Energy Technology, by the virtue of being located within the marsh have evolved to become refuges and breeding habitats for some of the large wetland birds. On the basis of the 'benefit sharing mechanism' with the landscape, as well as valuing the ecosystem services that the institutions could provide, the institutions should abandon their plans of expanding or improving the existing infrastructure.

B. Strategic Intervention 2: Restoring Wetland Attributes for supporting Biodiversity

Wetlands are of one of the most productive ecosystems, and thereby support a diverse range of organisms. Of the many organisms that wetlands harbour, birds are the most significant, and often serve as indicators of the wetland's health. The purpose of focussing on protecting, restoring and conserving habitat diversity of wetlands is three fold:

- the first is to facilitate an increase in the overall species diversity of the wetland, across life forms
- the second, to ensure that the ecological processes are set in place and functional and
- The third, to support the nesting, breeding and feeding habits and preferences of birds and other faunal groups.

Bird communities need to be understood more holistically. Ecologically, birds are classified as land birds and water birds. Land birds are of three broad types: those that feed and nest above ground (example sunbirds), birds that feed on ground but nest above ground (example pigeons) and birds that feed and nest on ground (example larks). Then there are land birds like swallows, finches, drongos and wagtails that are often found in wetlands. Water birds are generally categorised as swimming (ducks, pelicans), diving (cormorants, grebes) shorebirds (wading birds), storks and herons and lilly-trotters (jacanas). Each bird has a different food and micro-habitat choice. It is only when these differences are appreciated, wetland bird sanctuaries can be managed efficiently such that the overall species richness of the bird community in focus is not compromised. Waterbirds have specific adaptations which enable them to exploit particular niches within a wetland and limit direct competition with others. For example, certain waterbirds feed on shallow flooded areas and mudflats, while others graze upon submerged and floating plants or dive to catch aquatic invertebrates in deeper water. It is hence important to create conducive features within the wetland to support the diversity.

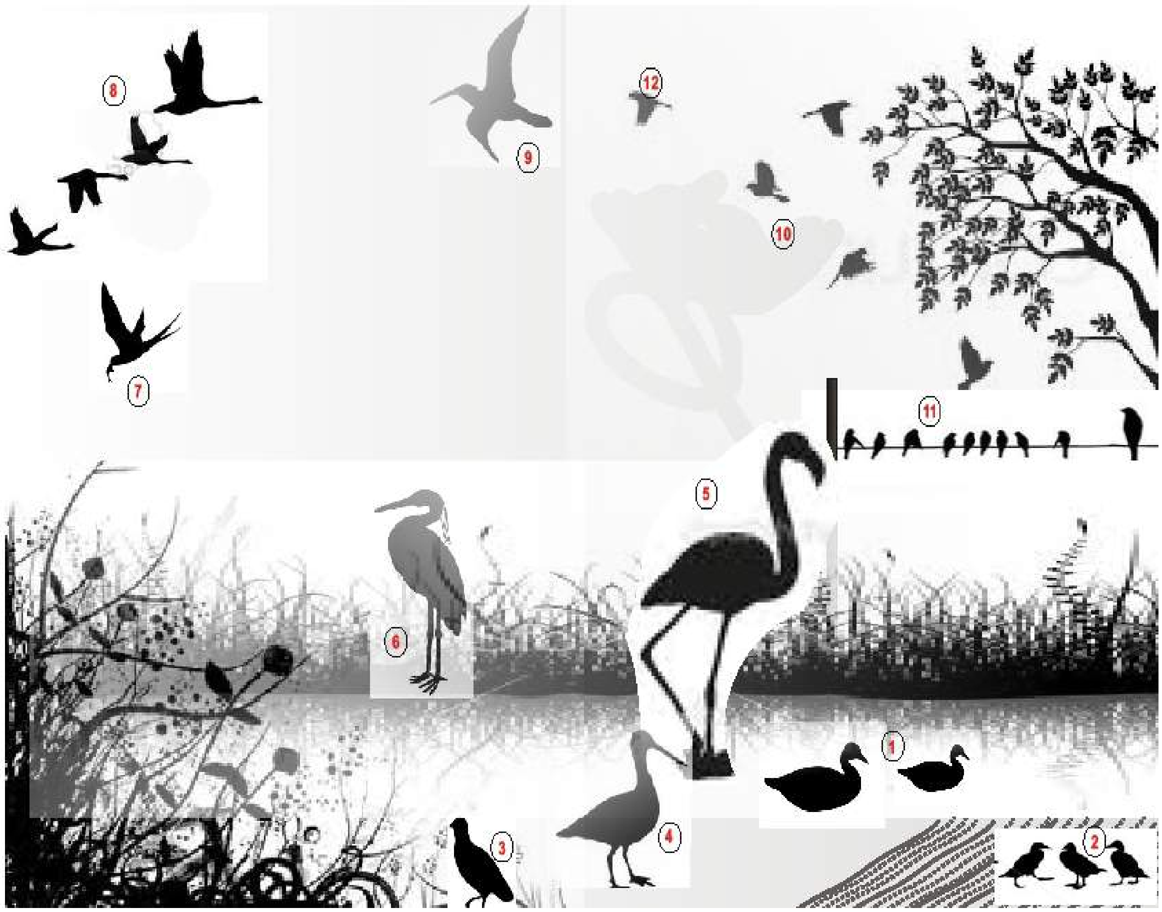
Following is a list of different habitat types utilised by waterbird species and that need to be preserved within the Pallikaranai Marsh:

- **Islands** used as breeding sites for a number of species that nest on the ground. Waders and terns also commonly use these areas as roosts for 'loafing'.

- **Mudflats** and shallow water that are rich feeding areas for a range of migratory waders such as the Stint, Curlew Sandpiper, etc. who probe the water and flats for tiny animals. Larger waterbirds with long legs and bills such as the egret, pelican, spoonbill, avocet, stilt, heron, curlew and the oystercatcher can be found in the shallows probing, spearing, sieving and scooping for food.

- **Emergent sedges, rushes and grassy bank** areas attract many wading birds. Vegetation of this type provides cover for waterbirds and nesting sites. Crakes, rails and various song birds are attracted to the rushes in freshwater swamps near estuaries. Ducks, moorhens and coots use open water for loafing and feed in emergent vegetation and grassy bank areas. Ibis, herons and swamp-hens are also attracted to fringing vegetation as feeding areas.

- **Deep open water** attracts diving waterbirds such as swans, coots, cormorants, grebes and some ducks which dive for bottom-dwelling animals or aquatic vegetation. Other waterbirds such as terns feed on fish close to the surface.



Typical Community of Wetland Birds

1. Swimming birds like ducks feed on insect s, crabs, fish and plants
2. Swimming birds need rocks or mudflats to rest
3. Land birds like Quails and Francolins use grass along the banks
4. Wading birds need shallow water and mudflats
5. Flamingo is a filter feeder – it feeds on small invertebrates and seeds
6. Storks and Herons, feed in shallow water or along edges. They eat small aquatic animals
7. Flying birds like swallows feed on insects
8. Some birds may just been seen flying over the wetland
9. Waders like Snipes tend to hide, best seen while flying
10. Land birds like Weavers, Finches and Buntings use wetlands
11. Starlings, Mynas, Drongos perch around wetlands
12. Bee-eaters are insect eaters that use wetlands.

C. Strategic Intervention 3: identify and restore wetland areas under Invasive Alien Species of Plants

Invasive Alien Species

Wetlands are extremely vulnerable to invasions. Even though ≤6% of the earth's land mass is wetland, 24% of the world's most invasive plants are wetland species. Invasive plants in wetlands include grasses, graminoids, forbs, shrubs, and trees. Furthermore, many wetland invaders form monotypes, which alter habitat structure, lower biodiversity, change nutrient cycling and productivity, and modify food webs. Wetlands act as natural sinks, which accumulate sediments, water, and nutrients, all of which facilitate invasions by creating canopy gaps or accelerating the growth of opportunistic plant species. Other disturbances to wetlands, such as propagule influx, salt influx, and hydroperiod alteration also create opportunities for wetland opportunists. Invasive plants establish where soils are bare and where disturbances create bare soil, all of which are associated with wetlands. The species that take advantage of each opportunity depend on dispersal mode and constraints like salt, native competitors. In the case of wetland invasion the seeds are often dispersed via water or whole plants and plant fragments can be dispersed via flotation. They have abundant aerenchyma that protects belowground plant tissues from flooding and anoxic soils as well as allow efficient use of carbon in above-and belowground growth and also exhibit rapid nutrient uptake, allowing rapid growth.

Invasive Species Management

Choice of control method is based on a number of considerations like the size of the infestation, the amount of vegetation that should be retained, and resources available to the group (both labour and money). Broadly, control methods fall into three categories:

1. Mechanical- Mechanical methods are those that stop the invasive plant from growing and spreading without the use of chemical herbicides. They include hand pulling, cutting, pulling with tools, mowing, etc.
2. Mechanical with application of systemic herbicide
3. Herbicide alone

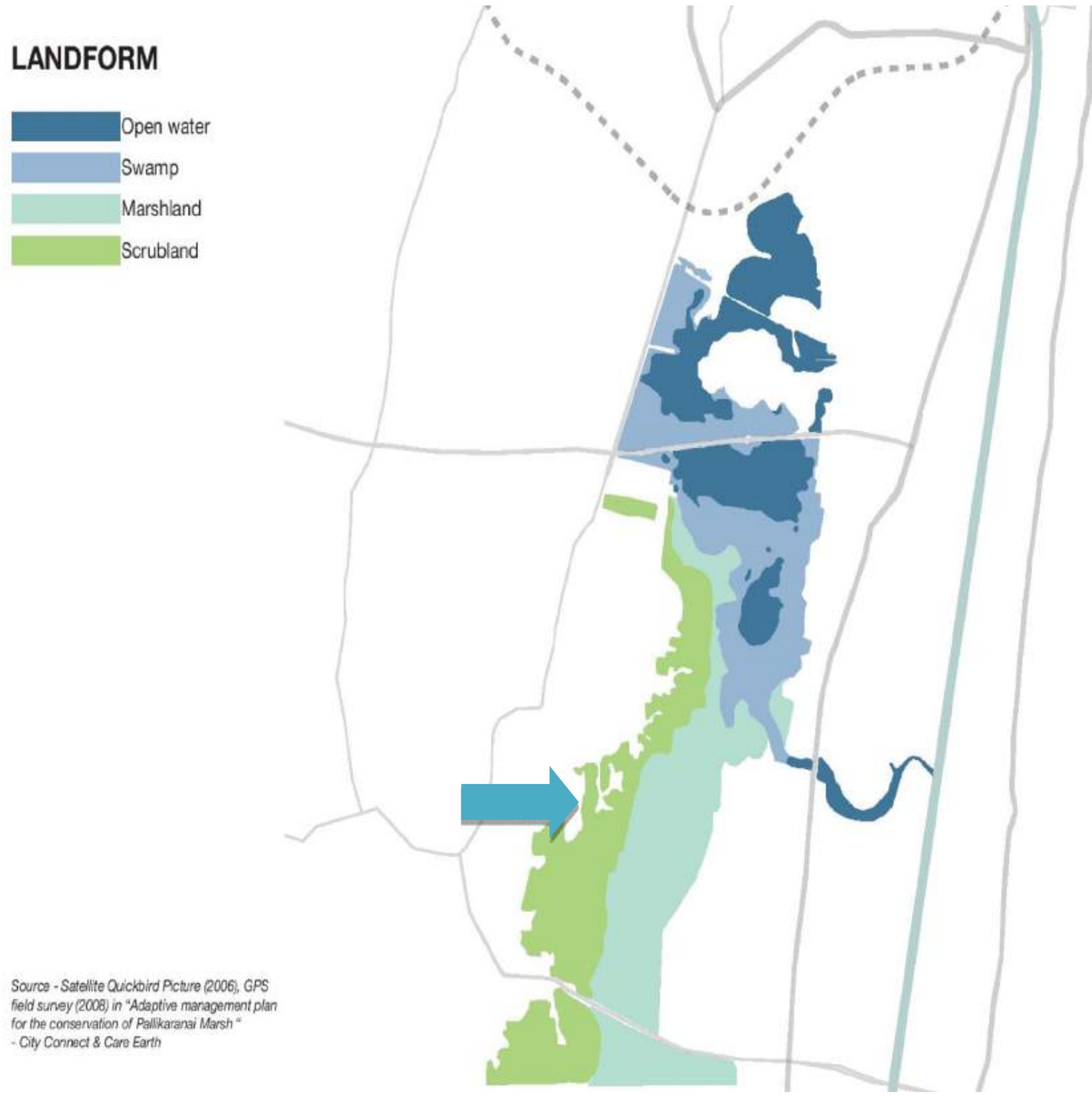


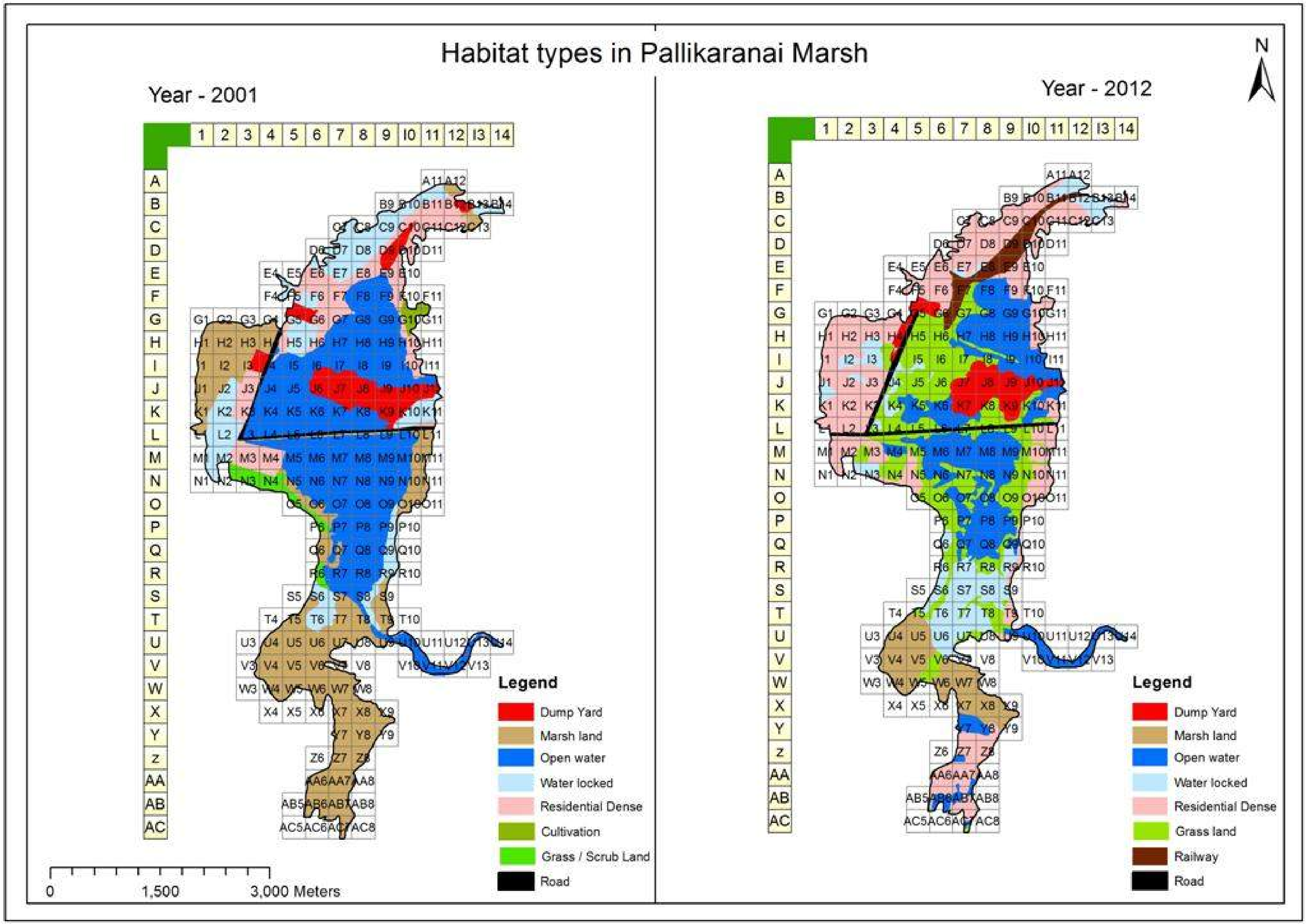
Figure 10.4 Landform classification in Pallikaranai

All the invasive woody vegetation including *Prosopis* should be removed from within the wetland to prevent excessive water loss due to evapo-transpiration.

While there cannot be a dispute on the need to protect and restore the diversity of habitats within the Pallikaranai Marsh, it is also critical to ensure that the open spread of water is maintained for ensuring that the integrity of the marsh as a wetland is protected. This does not entail deepening as in the case of lakes or tanks, but requires a well defined plan for managing the aquatic vegetation, notably *Typha*. While taking into consideration that the dense patches of *Typha* are conducive feeder-breeding habitats for the many organisms that are naturally found in the marsh, it is essential that areas within the marsh are earmarked for physical removal of *Typha*, more on the lines of pruning.

Wetlands play a critical role in regulating the movement of water within watersheds. Wetlands store precipitation and surface water and then slowly release the water into associated surface water resources, ground water, and the atmosphere. Wetland types differ in this capacity based on a number of physical and biological characteristics, including: landscape position, soil saturation, the fibre content/degree of decomposition of the organic soils, **vegetation density and type of vegetation**. During the growing season, plants actively take up water and release it to the atmosphere through evapotranspiration. This process reduces the amount of water in wetland soil. Larger plants and plants with more surface area will transpire more. Hence it is important to remove excessively transpiring plants to conserve water in the wetland. The following figure depicts the habitat types within the marsh over two time frames, marked into grids, which could be used to identify the habitat types within the marsh, and the change therein over a decade.

Figure 10.5 Habitat types in Pallikaranai Marsh



D. Strategic Intervention 4: to address the issue of Aquatic Invasive Alien Species

This intervention pertains to the protection and maintenance of the aquatic biodiversity and the key features and interventions are as under:

1. Fifty species of fish are known in the marshland. However, the presence of nearly 10 species has not been authenticated in the past 10 years. These are therefore treated as ‘unconfirmed’. As some of these have been reported from Adyar river system and Cooum river system in the historical past, they may have also occurred in Pallikarnai.
2. Around 1/3rd species are air-breathing and those capable of surviving under low levels of DO. This has been the case historically. However, in the event of further degradation of water quality in the marshland, the relative abundance and dominance of these fish are likely to increase. Air-breathing fish can be a source of food to birds when the water recedes and turns foul collecting in smaller pools locally. As many of these species are catfishes or like the climbing perch that are armoured or equipped with poison-bearing spines, smaller fish-eating birds may not be able to handle and swallow them.
3. Seven species are Invasive Alien (IAS) – of these the Giant African Catfish and the Armored Catfish are a matter of serious concern. The Giant African Catfish grows very large and can be directly in conflict with larger native fish like snakeheads. It may also feed on smaller fish and other aquatic fauna competing with larger fish-eating birds. The Armored Catfish (popularly sold as sucker in the aquaria) is dangerous as its bony skin can choke fish-eating birds.
4. The marshland is open to further invasions by alien fish species. One species that is likely to invade is the Pacu (a large relative of the dreaded Piranha). This fish widely sold in Chennai as ‘Kerala Vavvaal’ or ‘Kerala Pomphret’ is now reported from many of the large drinking water reservoirs of Chennai.
5. All three species of Tilapia introduced into the country for fisheries are now thriving in Pallikaranai Marsh. Earlier these were harvested by humans locally. In

the absence of human harvest, these species are likely to become more abundant.

6. Small-sized fish that are important in the aquatic food web are diverse; especially cyprinid fish (*Puntius, Rasbora, Esomus*, etc). These are also abundant. However, they are highly sensitive to DO levels and do not survive in muddy and eutrophied waters.
7. Diadromous fish (fish that migrate between sea and freshwater) like eels (*Anguilla*), mullet and half-beak are found in the marshland. This is an indication of the connectedness of the marshland waters to the Bay of Bengal and associated marine backwater systems.
8. Fish that thrive in shallow water like panchax, mosquito fish and others are common in the marshland. Proper utilization of these species coupled with habitat management will help in the control of mosquitoes locally.
9. The vastness and muddy nature of the marshland makes it difficult to monitor fish diversity and populations. However, monitoring the relative abundance of the IAS and the air-breathing fish will be useful in tracking the water quality of the marshland.
10. Monitoring the diadromous fish and smaller cyprinid fish will be useful in understanding the salinity and DO levels of the marshland.
11. To maintain the diversity of fish in the marshland, habitat management is important. This is possible by monitoring the depth and DO levels of the water and by making an effort to maintain connectivity with the sea and also locally within the various segments of the marshland. Shallow water micro-habitats are often vulnerable deepening, dumping and invading plants. Managing shallow water micro-habitats is a greater challenge in seasonal wetlands than the deep water reservoirs. This concern has to be seriously addressed.

Table 10.1 Fishes of Pallikaranai Marsh

S. No	Common English Name	Scientific Name	Status
1.	Long-fin Eel	*Anguilla bengalensis*	Frequent
2.	Short-fin Eel	*Anguilla bicolour*	Rare
3.	Anchovy	*Stolephorus* sp	Rare
4.	Glass Barb	*Esomus danricus*	Common
5.	Carplet	*Amblypharyngodon microlepis*	Common
6.	Baril	*Barilius bendelisis*	Unconfirmed
7.	Black-line Rasbora	*Rasbora daniconius*	Common
8.	Razor belly	*Salmostoma clupeoides*	Common (local)
9.	Silver Razor Belly	*Salmostoma acinaces*	Rare
10.	One-spot Barb	*Puntius filamentosus*	Common
11.	Spot-fin Barb	*Puntius sophore*	Common
12.	Ticto Barb	*Puntius ticto*	Common
13.	Peninsular Olive Barb	*Barbodes sarana subnasutus*	Common (local)
14.	Swamp Barb	*Puntius chola*	Rare
15.	Long-snouted Barb	*Puntius dorsalis*	Rare
16.	Scarlet-banded Barb	*Puntius amphibious*	Unconfirmed
17.	Fringe-lipped Peninsular Carp	*Labeo fimbriatus*	Unconfirmed
18.	Loach	*Lepidocephalus thermalis*	Common
19.	Long-whiskered Catfish	*Mystus gulio*	Common (local)
20.	Striped Dwarf catfish	*Mystus vittatus*	Common
21.	Stinging Catfish	*Heteropneustes fossilis*	Frequent
22.	Indian Potassi	*Pseudeutropius atherinoides*	Rare
23.	Gangetic Mystus	*Mystus cavasius*	Unconfirmed
24.	Giant River Catfish	*Aorichthys seenghala*	Unconfirmed
25.	Magur	*Clarias batrachus*	Unconfirmed
26.	**Giant African Catfish**	***Clarias gareipinnus***	**Alien Invasive**
27.	**Armored Catfish**	***Pterygoplichthys*** sp	**Alien Invasive**
28.	Panchax	*Aplocheilus parvus*	Frequent

29.	Half Beak	*Hyporahamphus limbatus*	Rare
30.	Rice Fish	*Oryzias melastigma*	Rare
31.	**Mosquito fish**	***Gambusia affinis***	**Alien Invasive**
32.	Spotted Snake Head	*Channa punctatus*	Common
33.	Striped Snake Head	*Channa striatus*	Frequent
34.	Giant Snake Head	*Channa marulius*	Unconfirmed
35.	Asiatic Snake Head	*Channa orientalis*	Unconfirmed
36.	Orange Chromide	*Etroplus maculates*	Common
37.	Green Chromide	*Etroplus suratensis*	Frequent
38.	**Common Tilapia**	***Oreochromis mossambicus***	**Alien Invasive**
39.	**Nile Tilapia**	***Oreochromis nilotica***	**Alien Invasive**
40.	**Golden Tilapia**	***Oreochromis aureus***	**Alien Invasive**
41.	Glass Fish	*Ambassis commersonii*	Common (local)
42.	Tank Goby	*Glossogobius giurus*	Common
43.	Climbing Perch	*Anabas testudineus*	Common
44.	Dwarf Gourami	*Colisa lalia*	Common
45.	**Three-spot Gourami**	***Trichogaster trichopterus***	**Alien Invasive**
46.	Spike-tail Paradise Fish	*Macropodus cupanus*	Common
47.	Striped Spiny Eel	*Macrognathus pancalus*	Frequent
48.	Tire-track Spiny Eel	*Mastacembelus armatus*	Rare
49.	One-stripe Spiny eel	*Macrognathus aral*	Unconfirmed
50.	Mullet	*Liza parsia*	Common (local)

E. Strategic Intervention 5: restoration of the groundwater system of the landscape

Groundwater is the water held in permeable rocks, such as limestone, and unconsolidated sediments, such as sand and gravel. The level of the groundwater, below which the rocks or sediments are saturated, is called the water table. Water also occurs above the water table, in the unsaturated zone e.g. as soil water, but this water is not normally abstracted for human use and is usually not referred to as groundwater. Consequently, water in wetland soils is referred to as groundwater if the soil is almost permanently saturated.

All rocks, sediments and soils can hold and transmit water, but the rate of movement of water is slow (often only metres per year - m yr^{-1}) compared to flow in rivers (normally metres per second - m s^{-1}). This leads to slower responses of groundwater to recharge or abstraction.

Water movement in rocks and sediments can vary over many orders of magnitude and three broad types can be distinguished:

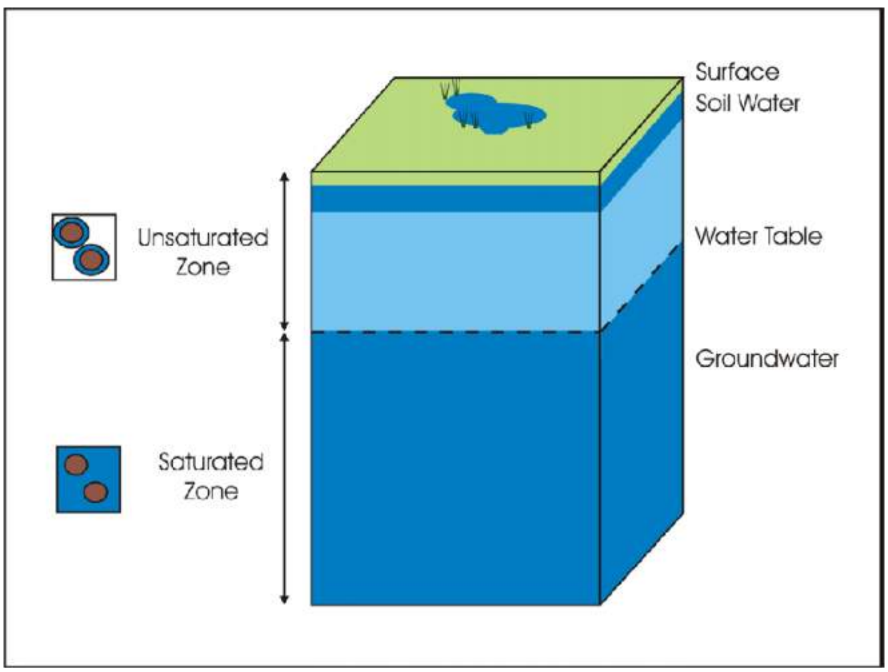
i) those that have large pore spaces (voids) or fissures (cracks) - these are called aquifers and include chalk, limestone, sandstone and gravel;

ii) those that contain small amounts of water and allow water to pass through them slowly - these are called aquitards and include coarse mudstones;

iii) Those that contain very little water and stop the movement of groundwater - these are called aquicludes and include clay and unfractured granite.

However, where high permeability aquifers (e.g., chalk or limestone) do not occur, water is sometimes abstracted commercially from low permeability rocks (e.g., fractured granites in Africa), and these may thus also be referred to as aquifers. Surface springs issuing from aquifers are the visible water sources for many rivers and other kinds of wetlands. The base of a wetland, such as a river bed, may be in contact with an aquifer and hidden from view.

The precise nature of interactions between groundwater and wetlands will depend on local geological conditions. Just because an aquifer is shown on a geological map, it does not mean that any wetlands which overlie it will necessarily be fed by groundwater or will be able to recharge the aquifer. The extent of interaction depends on the permeability of any rocks or sediments that lie between the wetland and the aquifer. Where impermeable rocks (an aquiclude) overlie an aquifer, water cannot move vertically upwards or downwards, and the aquifer is said to be "confined". In such cases, the wetland and the aquifer are hydrologically separate and exchange of water will not occur. Where rocks or sediments of low permeability (an aquitard) overlie the aquifer, interaction may occur, but the rates of movement will be slow and the amounts of water involved will be small. Where there are no overlying low permeability rocks (no aquitard or aquiclude present) the aquifer is said to be "unconfined"; here the wetland and aquifer are in direct contact and the degree of interaction can be high.



Assessing the potential for groundwater-wetland connectivity

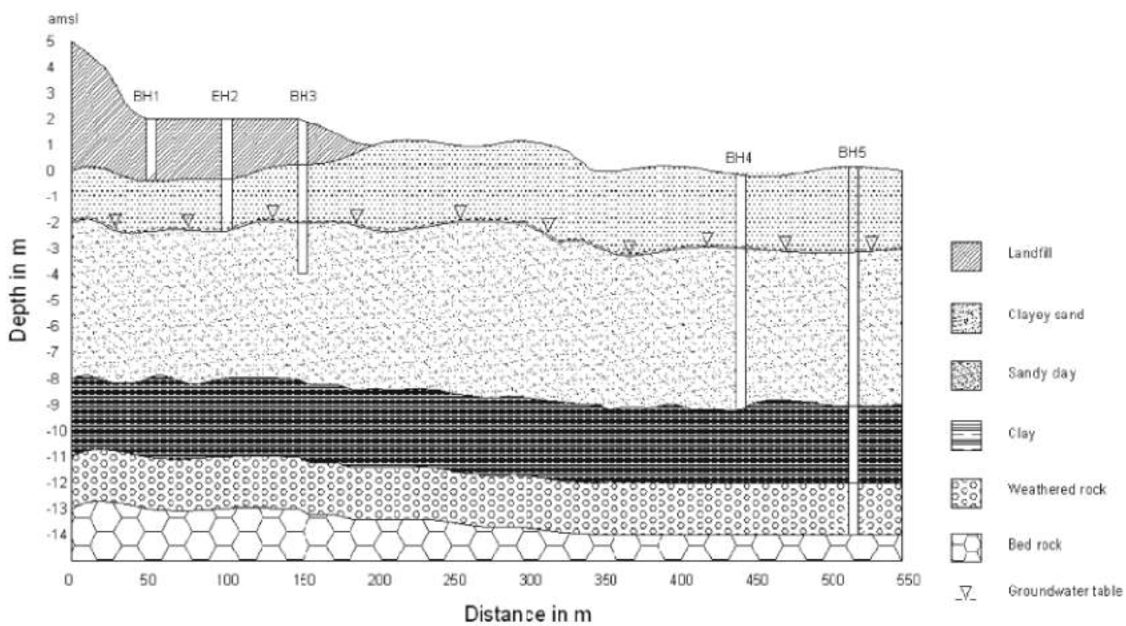
Many wetlands are hydrologically and ecologically linked to adjacent groundwater bodies, but the degree of interaction can vary greatly. Some wetlands may be completely dependent on groundwater discharge under all climatic conditions, whilst others may have very limited dependence such as only under very dry conditions and some may have no connection with groundwater at all. Some aquifers are dependent almost entirely on recharge from wetlands.

It is essential that those agencies concerned with protection and maintenance of the ecological character of wetlands should be able to influence and provide inputs to groundwater management plans and strategies. It is also necessary, however, to identify what level of technical input into water resources management is needed from wetland managers. There may be cases where the wetland-groundwater interaction is very limited or absent altogether, and abstraction of groundwater from local aquifers may have very little, if any, impact on wetlands. On the other hand, there are cases when abstraction of groundwater from a deep aquifer at a considerable distance from the wetland can have unforeseen but very significant impacts on the hydrology and hence the ecological character of a wetland. A joint team of the line departments should undertake screening studies at a river basin or regional aquifer scale, to assess the potential for interaction between wetlands and groundwater. The degree of connectivity will largely be determined by a combination of geology, regional hydrology, and topography. This screening study undertaken by a team of specialists with geological, hydrological and ecological expertise, should allow wetland and water resources administrators to identify areas where there is high potential for wetlands to be dependent to some degree on groundwater, and hence where more detailed studies or field assessments might be necessary in order to ensure that the groundwater needs of wetlands in these areas are accounted for in any groundwater management plan.

Typically, this kind of screening study lends itself to a GIS-based approach, possibly with the complementary use of remote sensing tools, to provide an indication of the potential risk to wetlands of regional groundwater abstraction or other forms of exploitation such as artificial recharge with wastewater. Much of the analysis can be desk-based, although at best, at that level of resolution, it can only provide “red flags” as to the location of high-risk areas where extensive groundwater exploitation should not be considered without additional studies to ascertain the potential impact on wetlands in the region.

Understanding hydrological links between wetlands and groundwater

A prerequisite to assessing the implications for a wetland of any external hydrological impacts is to understand the ways in which water enters and leaves the wetland (termed water transfer mechanisms) and to quantify the associated rates of water movement. Most departments are very familiar with geographical (horizontal or plan-form) analysis of wetlands, using maps of open water bodies and vegetation zonation. However, understanding interactions with groundwater requires a geological view in a third dimension*, i.e.* looking at vertical sections through the soils and rocks that lie beneath the wetland. The following figure depicts the geological profile of Pallikaranai Marsh at the intersection of the Thoraipakkam radial road.



The first step in understanding wetland hydrology involves identifying which water transfer mechanisms are present in a wetland and which of these are the most important. Whether movement of groundwater to or from a wetland is an important mechanism depends not only on the presence of an aquifer, but also on the nature of the soils and rocks between the aquifer and the wetland. If the wetland is in direct contact with the aquifer, exchange of water is very likely. However, if there is a low permeability layer (an aquitard or aquiclude) between the wetland and the underlying aquifer, there may be little or no exchange of groundwater.

The groundwater aquifer recharge

The groundwater aquifer recharge rate depends on several factors; for example the nature of the rock/the bedrock, the relief/topography as well the rainfall, and on the anthropogenic factors on the other side like the landuse of the recharging area and the pumping (discharge) amount (Gnanansundar et al., 2000). The Pallikaranai Marsh adjoins the south Chennai aquifer that runs parallel to the Old Mahabalipuram Road. The aquifer originates from the south of Thiruvanmiyur and extends up to Kovalam Creek in the south (Azeez et al., 2007). A groundwater flow modeling study for the adjoining Thiruvanmiyur aquifer was done in 2000 by Gnanansudar et al. The study shows that there could be lowering in the groundwater level due to industrialization and the high groundwater pumping. The Aquifer spreads about an area of ca. 160. The recharge from the rainfall was estimated to be 290mm per year representing 28% of the average annual precipitation (depending on the soil type). The study also revealed that the aquifer recharge may be reduced, due to the reducing of the recharging area (Gnanasundar et al., 2000).

A study done by Care Earth and the Albert Ludwig University in 2008, shows the decrease in the holding capacity (recharge area) of the Pallikaranai Marshland due to the constructions on the Marshland (Apfelbacher et al, 2008). This reduction in water holding capacity could also mean a reduction in rain-water catchment area, which, in turn, could be a reason in the decreasing of groundwater recharging capacity of the Marshland. Metrowater reports that a major portion of rainwater that falls on the earth surface is lost due to the runs-off from steams to rivers and to sea and that due to urbanization it is increasingly difficult to find open spaces which could enhance the recharge of groundwater. Therefore, it is interesting to know the importance of the groundwater loss that occurs due to the shrinkage of marsh. If the Pallikaranai area is considered as a complete water catchment area and the constructions as the non-permeable or only partly-permeable groundwater recharging areas, the loss in the groundwater recharge capacity that could have occurred in the past years can be calculated. This calculation can only be taken in account if the following parameters are considered:

Geology/Lithology

Pallikaranai´s soil is a marshy land. The geological profile reveals that the top zero to two meters are clayey-sand, followed by a sandy clay (2-8m), a greenish clayey layer with calcareous orange streaks (8-11m), the weathered charnokite (11-13m) and on the bottom the charnokite, as bedrock (Parameswari et al., 2013). For a more precise calculation, every rock layer groundwater capacity recharge should be considered separately. The properties of every layer should be known. In this study only the upper soil properties are taken in account.

The Groundwater Recharging amount

The sandy-clay layer has a high water-holding capacity and a relatively low permeability. This affects the whole stratigraphic sequence, and reduces the water´s percolation ability into the aquifer. The study of Gnasasudar et al (2000) indicates that the clay soil has a capacity of aquifer recharging capacity of 17%. Since the underground in the Marshland is a mix layer of sand and clay, it was decided to take a higher recharging capacity (sand has a higher capacity of recharge) and the average of the Marshland´s recharging capacity is estimated to be 17%. In the urban area 5% of the rainfall percolates on the ground writes Janakarajan et al. (2007). Once again, for a more precise calculation, further geotechnical analyses should be done in order to get the real permeability of the soil (or recharging capacity). Like for example the real discharge amount, a study about the real soil´s features as well as the effective evapotranspiration amount.

The Rainfall amount

The average rainfall has been taken for the city of Chennai for the past 10 years from the Keaweather rainfall station. The rainfall is a stationary value, and could differ within very short distance, especially in the case of high altitude differences. Two possible scenarios have been constructed for the Pallikaranai Marsh by Seifelislam (2013).

The 2001 case:

- The catchment area in 2001 has been calculated by Apfelbacher et al. (2008):
- 1632ha= 16,320,000 sq m
- Volume of rain over the area in 2001 (from KeaWeather Station) gives the waterfall volume: 1.67m*16,320,000=27,205,440 cum
- 17% of the waterfall volume goes as a recharging for the aquifer= 4,624,924.8 cum

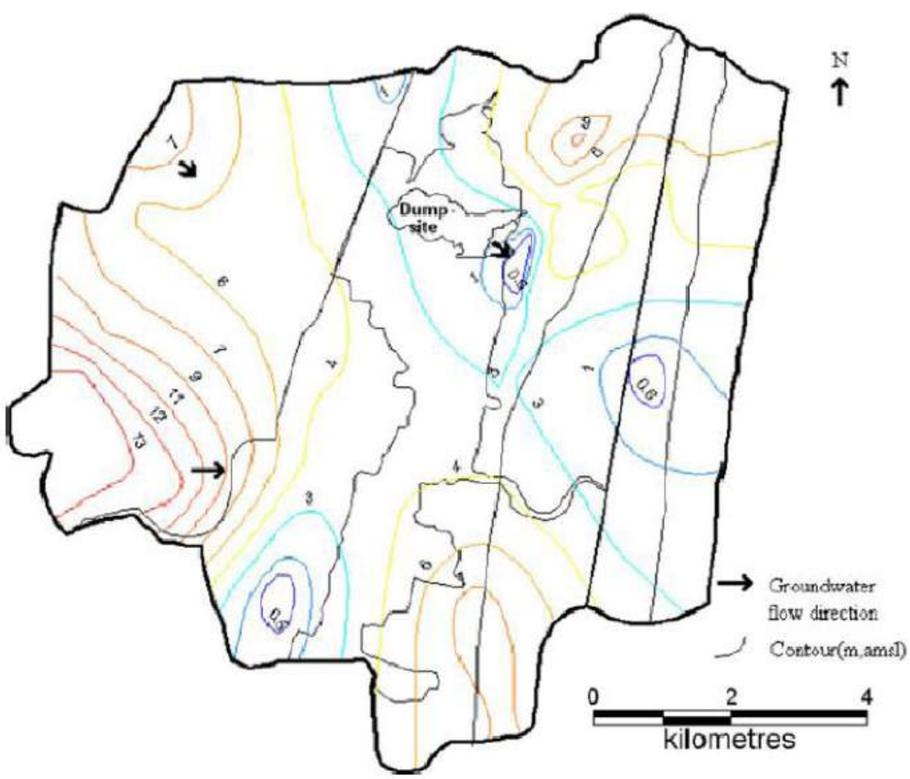
The 2002 case:

- The catchment area in 2002: 13,390,000 sq m
- Volume of rainfall volume over the area in 2002:
- 1.4m*13390000 =18,772,780 cu m
- As a result a water recharging amount in the wetland of 3,191,372.6 cu m
- The Urban area is the loss of wetland area between two years (wetland´s catchment area 2002-wetland´s catchment area 2003): 2,930,000 sq m
- Water rain volume from urban area : 2,930,000*1.4m=4,107,860 cu m
- The percolation amount from the urban area is 5%: 4107860*0.05=205,393 cu m
- The effective groundwater recharge is: water volume from wetland+ water volume from urban area= 3,396,766 cu m

Table 10.2 Effective recharge in cu meters over the period 2001 to 2013

	Percipitation	Catchment area	Percolation Form PML	Urban area	Percolation Urban area	Effective recharge amount
2001	1.092	16,320,000	4,624,924	0	0	4,624,925
2002	1.667	13,390,000	3,191,372	2,930,000	205,393	3,396,766
2003	1.402	12,458,000	1,562,345	932,000	34,377	1,596,722
2004	0.7377	11,526,000	2,345,425	932,000	55,780	2,401,206
2005	1.197	10,594,000	4,621,314	932,000	119,576	4,740,890
2006	2.566	9,662,000	2,173,080	932,000	61,652	2,234,732
2007	1.323	8,730,000	1,944,171	932,000	61,046	2,005,217
2008	1.31	8,276,667	2,247,032	453,333	36,199	2,283,231
2009	1.597	7,823,333	1,570,424	453,333	26,765	1,597,189
2010	1.1808	7,370,000	2,022,932	453,333	36,598	2,059,530
2011	1.6146	6,930,000	2,162,991	440,000	40,392	2,203,384
2012	1.836	6,490,000	1,126,689	440,000	22,466	1,149,156
2013	1.0212	6,050,000	1,012,249	440,000	21,652	1,033,902

Figure 10.6 Groundwater Aquifer in and around Pallikaranai Marsh



F. Strategic Intervention 6: Enabling the Ecosystem Services of the Pallikaranai Marsh – Mitigating Flooding

Overall climatological characteristics of the monsoon regime in Southwest

The Climate of Tamilnadu is triggered by the Monsoon regime. The main seasons are listed in following items:

- Summer Monsoon (June – September)
- Winter Monsoon (December – February)
- Early Monsoon (March – May)
- Late Monsoon (October – November)

During the early Monsoon Chennai gets no precipitation and the summer Monsoon is also slightly distinctive then in other parts of the Indian Subcontinent. The Eastern Ghats and the Coast are more affected in the late Monsoon due to cyclones from the Bay of Bengal. The months with the highest precipitation are from October until December. The Coast especially is highly impacted by precipitation due to orographic convergence.

The following paragraph illustrates the different steps of the analysis.

Fig 10.7 shows the monthly precipitation over the district of Kancheepuram (Chennai and vicinity) for the years 1995 until 2006. The deviation of the precipitation shows the characteristic rainfall events for this part of India with the highest rain sums in the last quarter of the year.

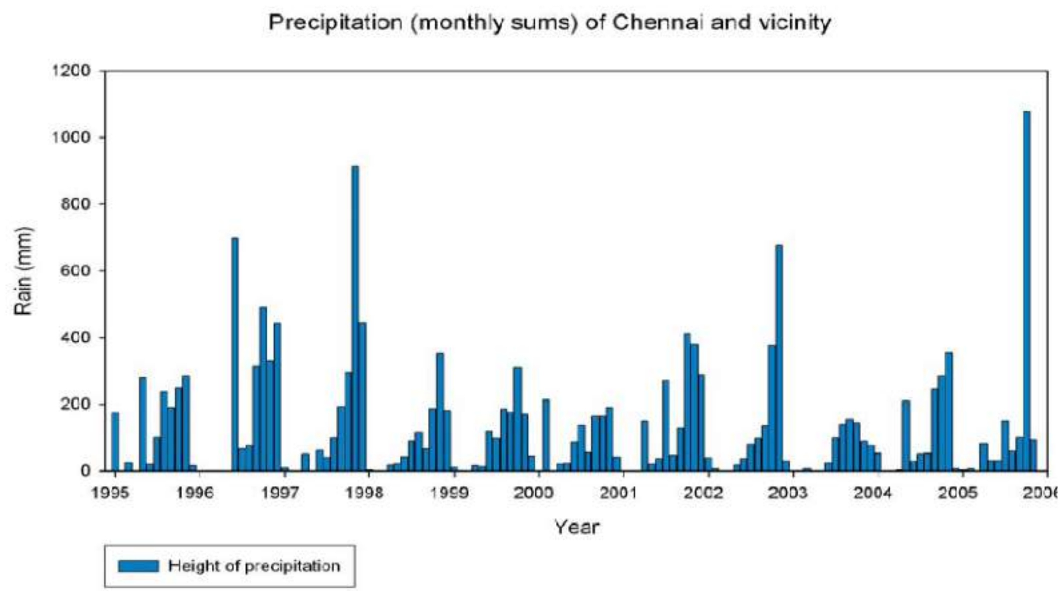


Figure 10.7 Precipitation of Chennai and vicinity on a monthly basis. The dry periods are always in the beginning of the year. The rain falls mainly in the late Monsoon period between October until December. Only the year of 1996 is an exception to the normal late Monsoon characteristic for the Bay of Bengal and Chennai.

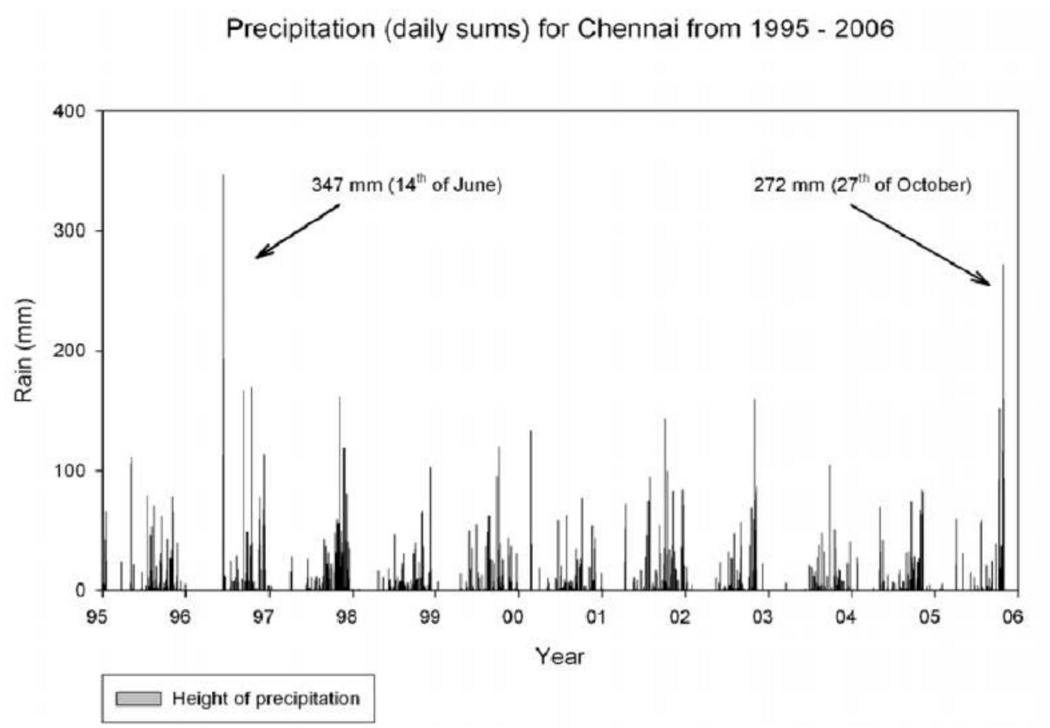


Figure 10.8 Precipitation of Chennai and vicinity on a daily basis. The most extreme rain events occurred on the 14th of June 1996 and on 27th of October 2005 and are indicated with arrows.

Based on data dating back to 1813, already analysed by Walsh et al. (1999), which was prolonged into the modern period, a trend analysis was carried out. The time series reveal the long-term, the medium-term trend and short-term variations. Obviously there exist decadal medium-term fluctuations, which can be regarded as dry or wet periods. Above these, there had been single extreme dry and wet years, which exceeded these overall fluctuations from time to time dramatically. To ease the visual interpretation and to quantify these findings, different statistical parameters were used.

The trend analyses for the whole period doesn't show any long-term downwards or upwards trend. The overall structure of the precipitation can be regarded as stationary. But as pointed out, there are significant changes on the medium-term, decadal scale. The modern medium-term period can be characterized by a decadal decrease in precipitation since 1975, starting from a relatively high level. The trend of this period is significant, but this modern fluctuation does not exceed the "normal" variation. So far the annual precipitation is characterised by a mean amount of rainfall of 1270 mm. The standard deviation, which includes about two third of all years is at 1640 mm. Years of an annual rainfall of more than 1640 mm can be called years of "high precipitation or wet years". Years of extreme precipitation appear statistically two to three times in 100 years and show a precipitation higher than nearly 2000 mm.

In reality eight extreme events are documented since 1813. The course of the precipitation in Chennai, changed after Walsh et al. (1999). The reason for the increase of floods is not based on a long or medium-term trend reflecting increasing precipitation amounts at the eastern coast of India. The reasons of a higher risk of floods are strong single rainfall events in connection with anthropogenic reasons.

The derivation of the transfer function – the relation between rainfall and the dimension of the water body

One crucial step was the derivation of a transfer function, which quantifies the relation between the rainfall and the extent of the main water body.

Figure 10.9 Dependencies between water body and precipitation for Chennai Marshland

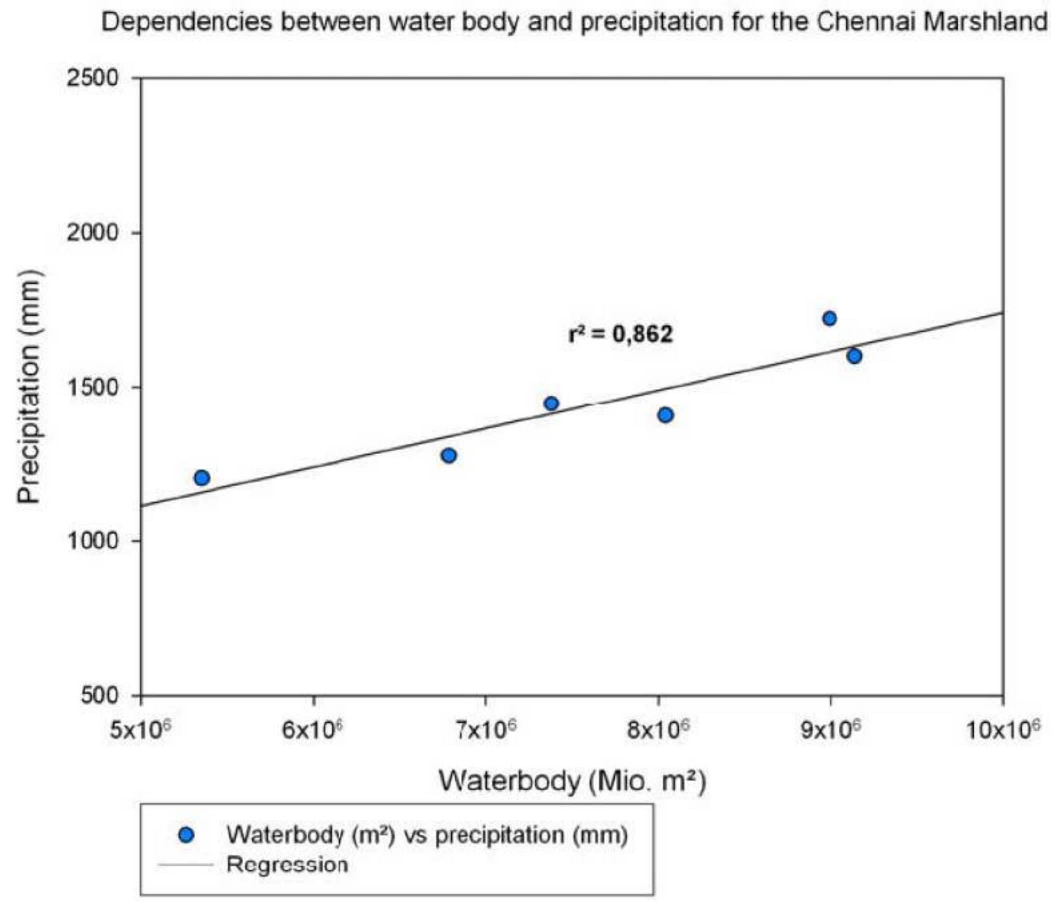


Fig 10.9 shows a significant increase of the water body with a higher annual rainfall. The expansion of the water bodies was correlated with the annual rainfall and indicates high dependencies. The mean expansion of about 6 million m² corresponds with the annual rainfall mean of 1271 mm/a. The biggest expansion derived from the satellite picture of about 9.1 million m² resulted in a rainfall of about 1600 mm/a, which indicates a wet year according to the 1 δ deviation of the rainfall data set. If the rainfall reaches an amount of an extreme wet year according to 2 δ deviation (more than 2003 mm/a), the expansion of the water body can reach up to 15 million m² in the Marshland under natural conditions. Due to changes in the Marshland its retention capacity is rapidly decreased and will lead to extreme floods in Chennai with precipitation sums which are already under the 95 % confidence interval like in the year 2005.

G. Strategic Intervention 7: restoration and repair of structural impediments to the hydrology of the wetland

One of the most critical issues pertaining to the restoration and the conservation of the marsh is the need to facilitate the seasonal hydrology of the system. The following interventions are recommended based on the elevation and watershed and drainage maps of the landscape as well as existing practices and norms.

It is evident that much of the landscape is either at sea level or below sea level in terms of the altitude; reiterating the fact that this is a coastal landscape.

The low lying nature of the landscape is not conducive for human habitation and hence large scale structural manipulation has been undertaken to either increase the ground level through reclamation or manipulate the flow of water through ad hoc construction of channels and water courses.

In addition, the presence of the MSW dump as well as other human infrastructure, as well the lack of focus in maintaining the channels for facilitating exchange of water, as opposed to flushing has rendered the landscape an artificial quality of structural impediments to the flow of water.

Further, coping strategies of institutions in building or raising bunds to ensure that flooding does not impact their campuses has grossly interfered with the hydrology of the system.

In view of the above the following recommendations are suggested:

1. All drainage systems in and out of the Pallikaranai Marsh to be brought under the joint purview of the Public Works Department and the TN Forest Department

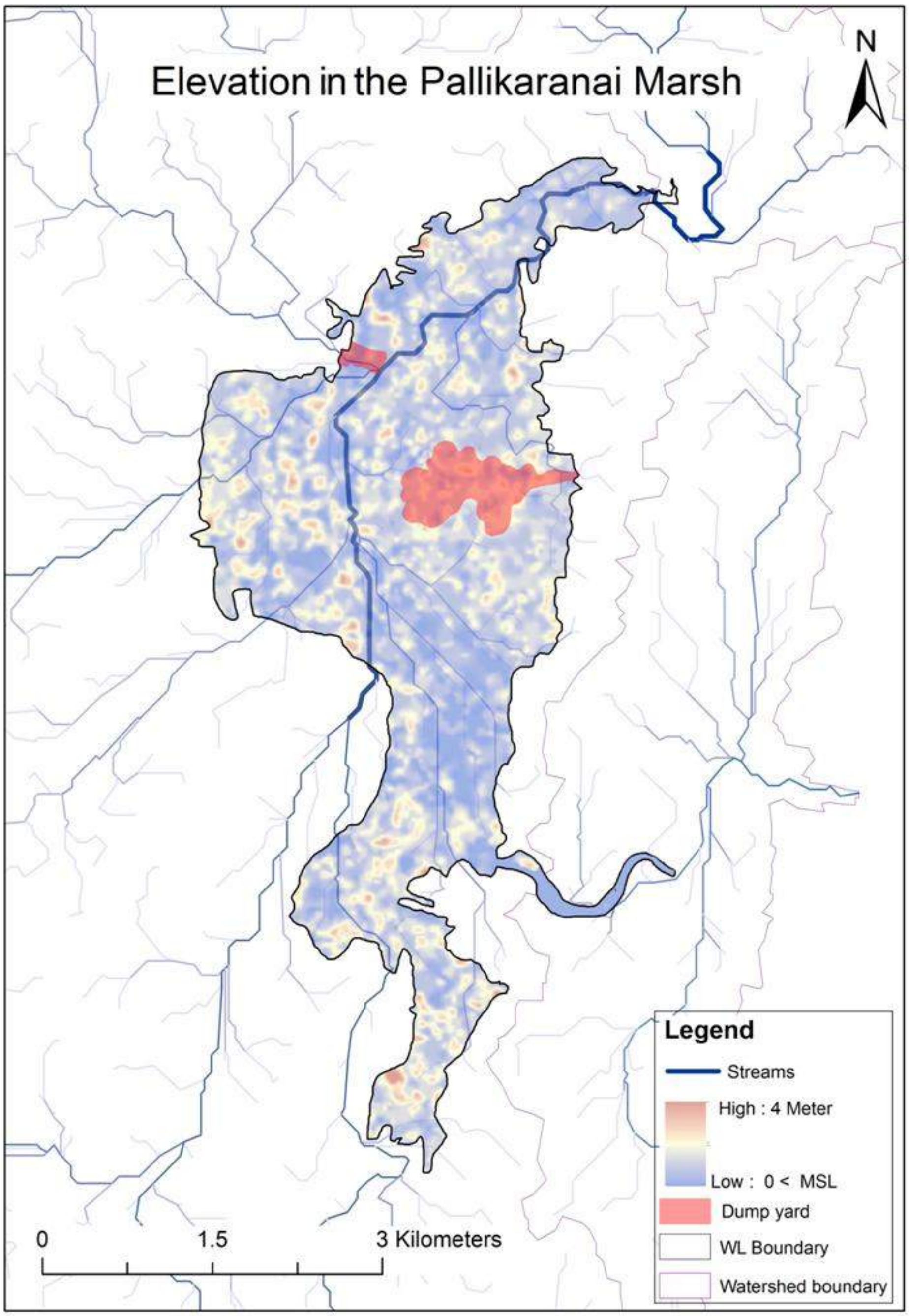
2. Culverts on the Thoraipakkam-Keelkattalai Road be maintained on a regular basis as opposed to the post monsoon intervention

3. Flow channels in Elcot city to be maintained as a joint venture between Elcot and TN Forest Department.

4. Management of the mouth of Okkiyam Madavu be handled jointly by the TNFD and PWD, since the most critical aspect of brackish/saline water flushing into the marsh is impacted by the existing practice of managing the sand bar formation.

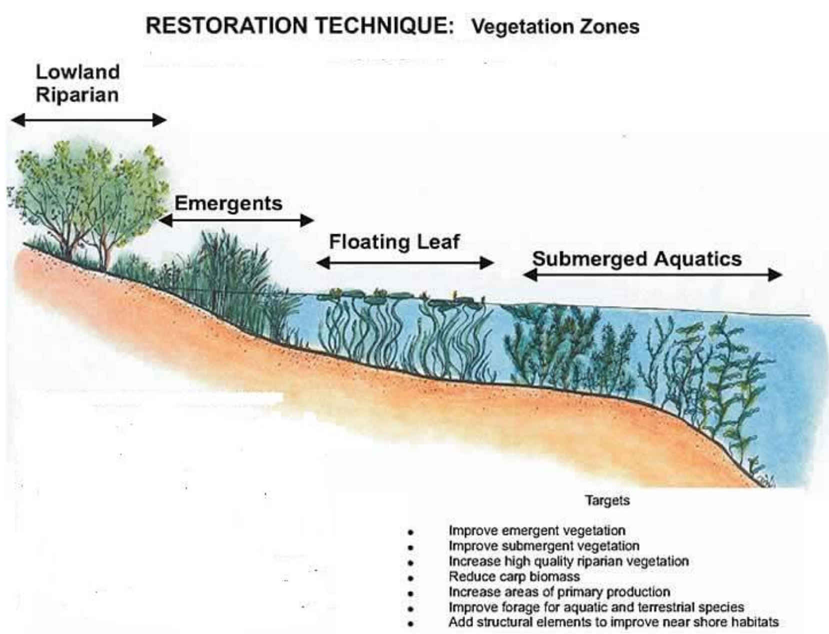
5. No further structural intervention in any form within the designated marsh area.

Figure 10.10 Elevation of Pallikaranai Marsh



In addition to the above listed actions, the following interventions can help in restoring the marsh as a critical waterbird habitat.

- ✓ Stacking water-washed rocks underwater to provide habitat for small animals and fish that are prey for birds.
- ✓ Leaving some logs and rocks protruding from the water for waterbirds to roost on.
- ✓ Placing branches and large logs around the edge of the wetland at varying heights, to provide roosting and nesting sites.
- ✓ Providing for a range of water depths. Link shallow mudflats to an island rather than the shore to provide secure habitat for waders.
- ✓ Using natural edges with slopes rather than steep banks. The provision of vegetated banks and some bare areas will provide birds with access in and out of the wetland and will allow them to see predators.



- ✓ Eradicating aquatic weeds as they can spread rapidly in and around wetlands and have the potential to degrade waterbird habitat and reduce food resources.
- ✓ Fencing can be used to limit access to livestock, and thus reduce bank erosion and disturbance to fringing vegetation. This will also allow natural regeneration in disturbed areas.
- ✓ Maintaining mature trees around the wetland to provide habitat for birds and small animals. A number of water birds utilise tree hollows or forks for nests.

10.4 Environmental Restoration

A. Strategic Intervention 1: identification of major pollutants in water, sediment and air and their sources

Chandramohan et al. (2008) reported that the Chennai Metropolitan Water Supply and Sewerage Board have been letting out 32 million litres of untreated and partially treated sewage water every year directly into the Marshland. Even if this report is categorised as contentious and ignored, the ongoing disposal of sludge by the CMSWB within the wetland area does deplete the quality of the marsh.

The second source of pollution within the marsh is the Perungudi MSW dump, which is currently spread over an expanse of 78 ha. Over the last 12 years, a number of studies have been conducted to analyse the impact of the STP facility as well as the Perungudi dump over the marsh and its constituents and the findings are summarised below:

The existing dump site at Perungudi is located approximately 1.2 km south of the city center. The landfill lies between 2 km to 3 km west of the Buckingham canal and approximately 3.5km to 4.5km away from the Bay of Bengal coast line. The site occupies an extensive area of marsh land and mud flats adjacent to, and west of the Perungudi sewage treatment works operated by Metro water. Metro water's current land holding extends to approximately 364 ha of which approximately 25 ha has been over tipped with municipal solid waste by Chennai corporation since 1987.The whole of the area is low lying, being closed to sea level and is poorly drained being occupied by extensive areas of marsh land and mud slats which are permanently wet and seasonally inundated.

The weigh bridge at the site entrance adjacent to the STW offices, vehicles proceeds directly to the current tipping area where they are directed to unload their wastes. Site roads are developed on compacted waste and during periods of wet weather they are prone to a loss of bearing capacity as a result of water logging or flooding. Waste was dumped directly into the water and become submerged during periods of elevated water levels.

No engineering measures are undertaken to isolate the deposited waste from surface water and ground water and to prevent the free flow of water into and out of land fill site. No daily or intermediate cover of any description is placed over the spread waste to inhibit the ingress of surface water. The presence clinical waste .and potentially some hazardous wastes, compounds the environmental health risks of such site management practices (Mallikarjunaiah, 1984).

The entire area of Chennai is covered by Pleistocene/recent alluvium and is underlain by the crystalline complex of charnokite, granite gneiss types of rock at depths ranging from 10m to 20m below ground level .A similar sequence of soil strata was recorded in almost all locations beneath the municipal solid waste (Dhanasekar, 1990). A black soft clay of 2m to 2.5m thickness exist immediately beneath the solid waste. The black soft clay layer turns into grey firm silty clay at a depth of 2m to 2.5m. The thickness of the second layer is around 1.5m to 2m.This silty clay layer is underlined by affirm to stiff greenish yellow silty, sandy clay of 3m thickness. This layer is followed by medium dense to dense yellowish green, weakly cemented clay sands (Dhanasekhar, 1980).

Surface water is stored in marshlands of dumping yard for long periods because of its low elevation above sea level, higher elevations along the eastern margin of the depression, long drainage path and extremely low hydraulic gradients. The pH value of 4.0 indicates the acidic nature of the soil. At some locations the soil is alkaline in nature. The reduction in pH value may be explained as follows. The soil particles present in the soil material may undergo displacement or replacement reactions in a much faster manner in the beginning and after the salts get settled in the pores and then cause a decrease in pH value. The organic matter present in the solid waste may occupy the pores present in the soil and the decomposition with time might vary, so decrease in pH may be observed .The variation in pH is mainly due to inflow water characteristics of solid wastes and the constituents present in the soil. The chloride content is more concentrated between 1.5m to 2.5m depth. Variation in the chloride content may be due to changes in the salt content. The organic matter present in the solid waste may also increase the chloride content of soil because the solid waste contains more vegetables and food waste(Sivapullaiah and Sridhran, 1985).The sulphate content is more concentrated between 2m to 3m depth..The variation in sulphate content of the soil may be due to chemical alteration, bacteria attack or both, which changes the solid waste properties significantly and due to the decomposition in landfills the solid waste temperature increases. When temperatures are high, the detention times are long and sulphate concentrations are appreciable. The estimated values of chemical analysis tests reveal that there is a drastic variation in the chlorides, sulphates and pH Value. Chloride contents are increased in locations which were located very close to the dumping yard. The sulphate content was increased at all locations, whereas the pH is decreased to less than 5.5 at first 3 locations. This indicates the increase in the pollution levels of soil within a period of two years.

It is apparent that the Pallikaranai marsh is largely affected by organic waste disposal and contamination as is indicated by the high levels of Chloride and Sulphate. An updated report prepared by the Tamil Nadu Pollution Control Board on the water quality of the Pallikaranai Marsh based on samples collected in August 1995 suggests that concentration of some of the hazardous chemicals and certain physical features such as total solids, have since gone up. For instance the 1995 study revealed that the total solids in water varied from 1410-5120 mg/l (10 samples). Care Earth, 2002 recorded the solid waste in water between 405- 9220 mg/l. Similarly the electrical conductivity reported in 1995 was between 1480 and 7100 uS/cm as against what Care Earth recorded in their study as 630-14400 uS/cm. An unpublished report by Care Earth reported various levels of dissolved solid waste, pH and TDS in PML from 2002- 2011. The samples were collected from Perungudi garbage, near NIOT wall and opposite Maxworth Nagar.

Table 10.3 pH and TDS levels in Pallikaranai Marsh (Unpublished data, Care Earth-2002)

S.No	**S2**	**S4**	**S8**	**S9**
pH	7.92	7.85	8.10	8.15
TDS	2620	2410	9220	405

Table 10.4 pH and TDS levels in Pallikaranai Marsh (Unpublished data, Care Earth- 2011)

S.No	S1A	S2A	S3A	S5A	S6A	S7A	S1B	S2B	S3B	S5B	S6B	S7B
pH	7.65	7.07	7.79	7.67	7.74	7.81	7.42	7.38	7.57	7.73	7.42	7.63
TDS	5448	916	1386	1584	1470	654	5482	1250	1558	1584	1852	710

A study from the University of Madras reveals that the concentration of the TDS in the PML area is generally higher than the desirable limit of 500mg/L for safe drinking, and that more than 50% of the samples show a higher concentration amount than the permissible amount of 2000mg/L for agricultural use (Vijayakumar, 2011). The pH analysis revealed that surface and groundwater are both alkaline (pH above 7), and the groundwater samples taken next to the dumpsite were acidic (pH less than 7). Other studies (above) showed a potential surface and groundwater pollution as well. The results of studies done at the Anna University are illustrated in following table

Table 10.5: The TDS and pH analyzes of the PM

Jayanthi et. al. 2012		**Parameswari et al.2012**		
Premonsoon-2008-2009	Postmonsoon -2008-2009	Premonsoon-2010	Post monsoon-2010	
pH	7	7	7	8
TDS	4,114	2,972	2,374±1,321	1329±667

Chennai generates about 5200 metric tonnes (MT) of garbage every day[1]. This garbage, also known as "municipal waste" comprises of the organic waste, plastic, packaging waste, paper, metal, glass, construction debris and other components like ash, sand and grit. The Municipal Corporation of Chennai is responsible for waste collection and disposal on a daily basis. In March 2000, the Corporation privatised waste collection in certain parts of the city which included 3 zones in South Chennai. These include Kodambakkam, Teynampet and Adayar which in total generate about 1694MT of waste daily[2]. The waste from these wards is disposed into the Perungudi

[1] Corporation of Chennai http://www.chennaicorporation.gov.in/departments/solid-waste-management/index.htm
[2] RTI Data from Corporation of Chennai, Solid Waste Management Dept.

dumping ground inside the ecologically sensitive Pallikaranai Marsh. However, the Corporation admits to dumping upto 2400MT daily[3], the excess could belong to recently annexed areas. In the absence of any monitoring, municipal waste dumps in India are known to receive hazardous from households, industrial and medical waste, Perungudi is no exception.

The study of Parameswari et al. (2012) also affirms that the water level in the Marshy area is two meters above the groundwater level, which creates a hydraulic gradient recharging the groundwater with the marshy water (Parameswari, 2012). Due to this topographic situation, the produced leachate from the Perungudi dumpsite flow is generally towards the Marshland, which is a lower lying area (Parameswari, 2012). Indian Institute of Technology-M has been conducting a series of experiments on issues pertaining to environmental pollution in the Pallikaranai Marsh for the last three years. The following table summarises heavy metal presence in the leachate within the marsh.

S.No.	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
1	2.38	8.0	70.72	137	1.7	328	473	80
2	2.74	8.0	125.0	102	1.7	322	606	104
3	2.89	15.0	5.90	42	8.3	277	319	BDL
4	3.45	26.0	60.23	8	1.7	591	466	220
5	0.17	16.0	200.0	108	1.7	392	396	221
6	1.07	17.0	61.35	96	6.7	255	268	35
7	6.86	14.0	79.52	23	1.7	285	299	27
Typical* values	-	1 to100	50 to1000	20 to 1000	-	100 to 1000	100 to 1000	500 to 30000

* Jones-Lee and Lee, 1993. All values are in µg/L & average of 5 determinations

From the table it is evident that the Marsh harbours high or alarmingly high concentrations of the heavy metals known to be carcinogenic in nature *viz.* Cadmium, Mercury and Lead. The dry season and post monsoon scenario of the distribution of the

[3] Corporation of Chennai http://www.chennaicorporation.gov.in/departments/solid-waste-management/index.htm

pollutants within the marsh is depicted in a series of maps that highlight the fact that the contamination while remaining contained near or at the Perungudi MSW dump during the dry season, spread out across the marsh post monsoon thereby impacting all the residential areas in the vicinity.

But the most serious data pertains to the presence of Hexavalent Chromium in very high levels, indicating that there is an outflow of effluent from industries known to generate Hexavalent Chromium as a by product such as steel, batteries etc into the marsh. The point source in exact terms for this could not be established as on date, but potential remedial measures are being experimentally tested. One such possibility is the installation of *In situ* Permeable Reactive barrier wall, whose design is depicted below.

Figure 10.11 Design of *In situ* Permeable Reactive barrier wall

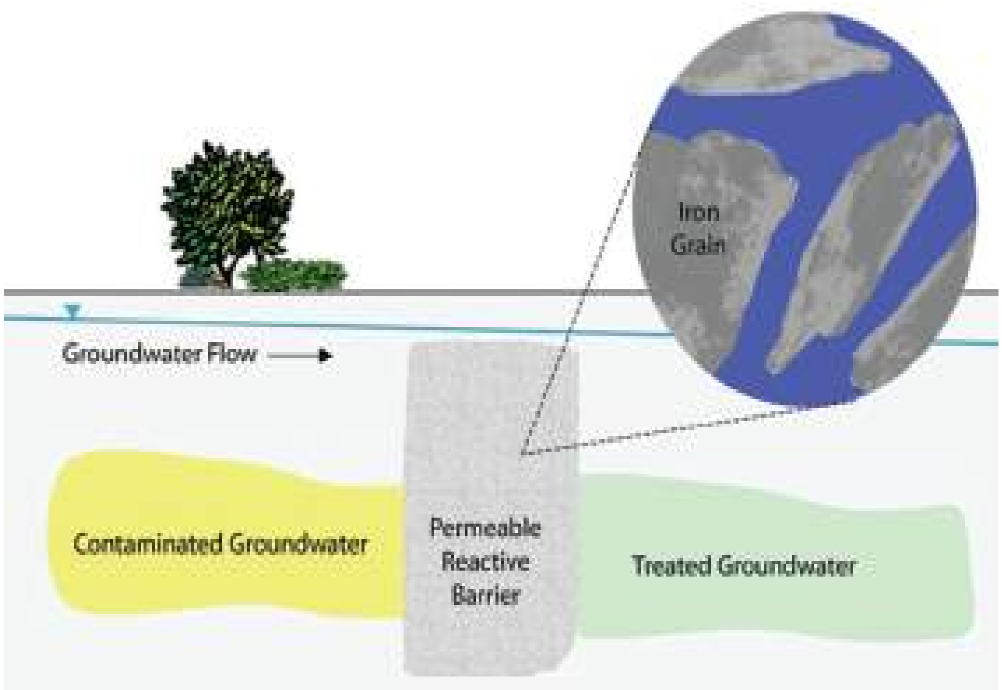
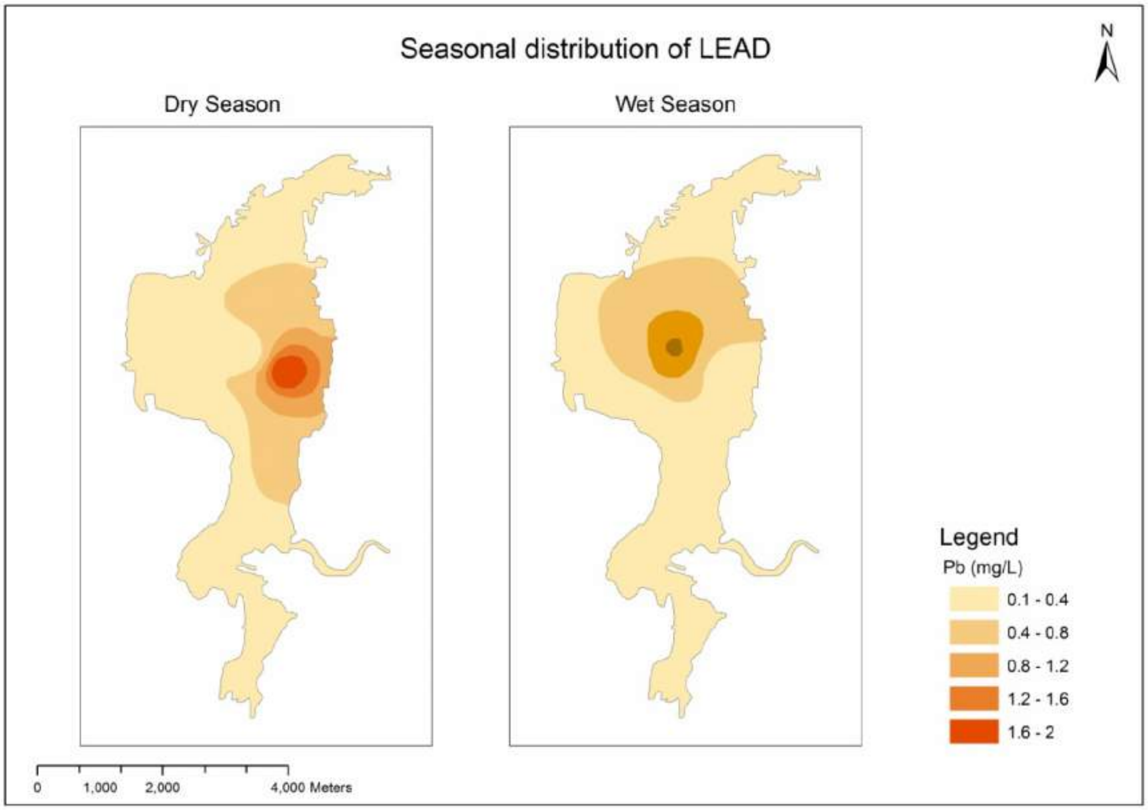


Figure 10.12 seasonal distributions of Lead and Cadmium in the Marsh



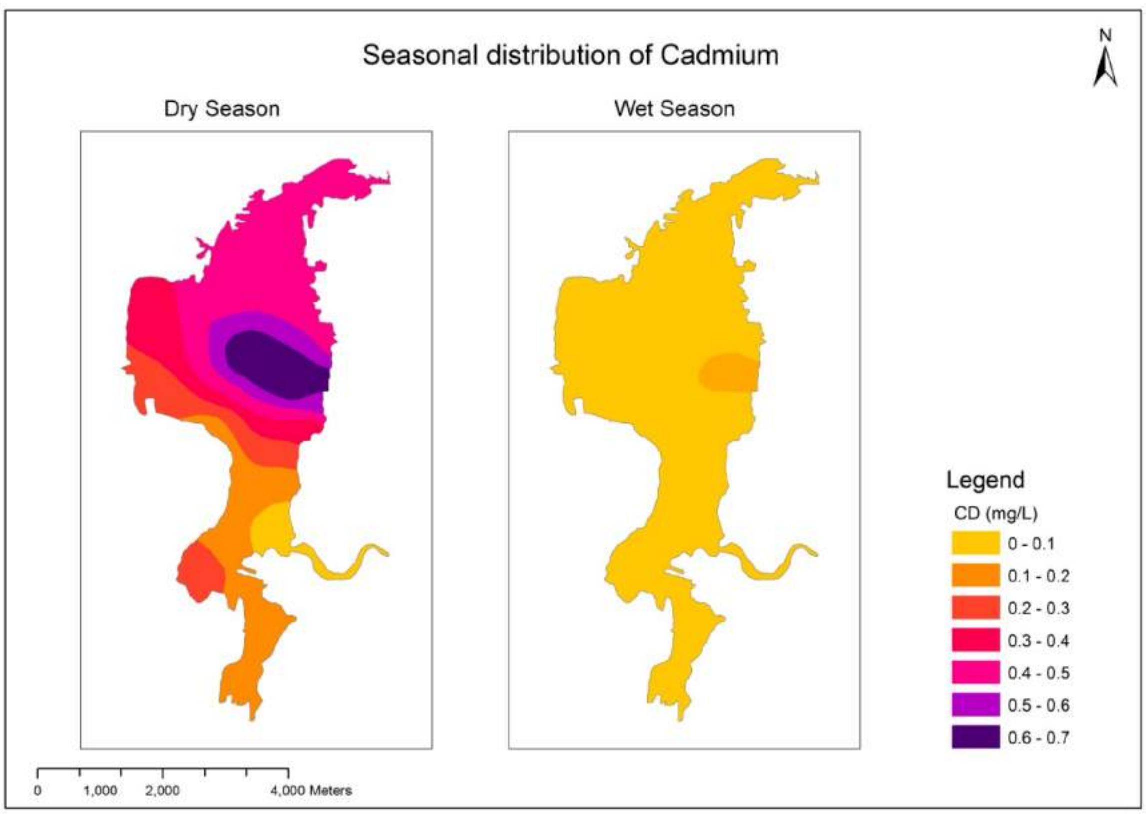


Figure 10.13 Seasonal distribution of DO in the Marsh

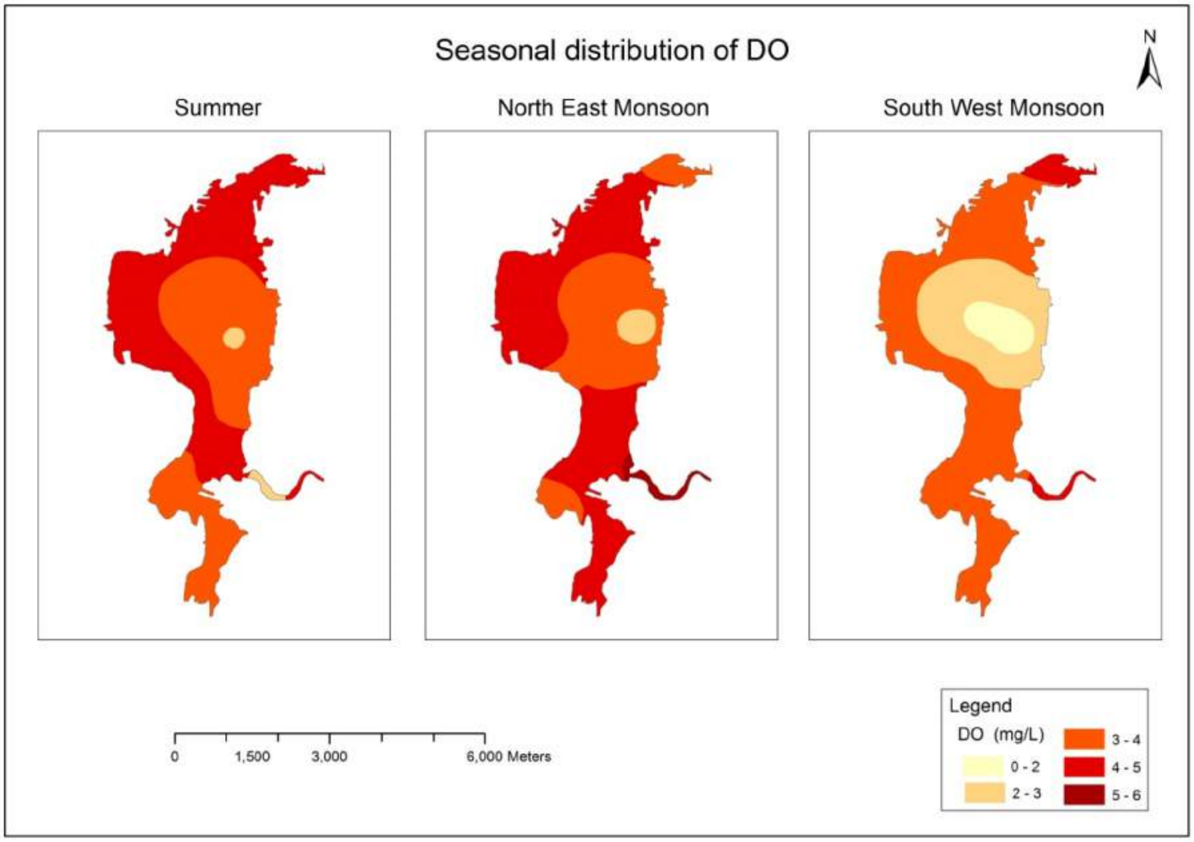
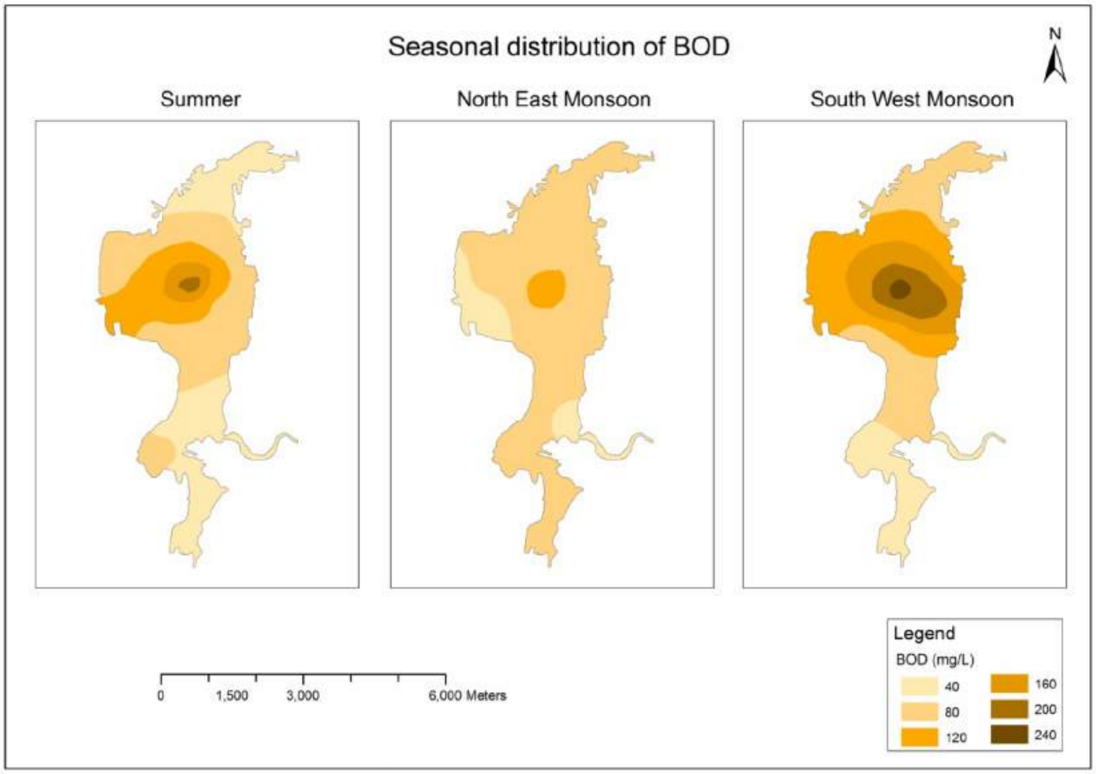
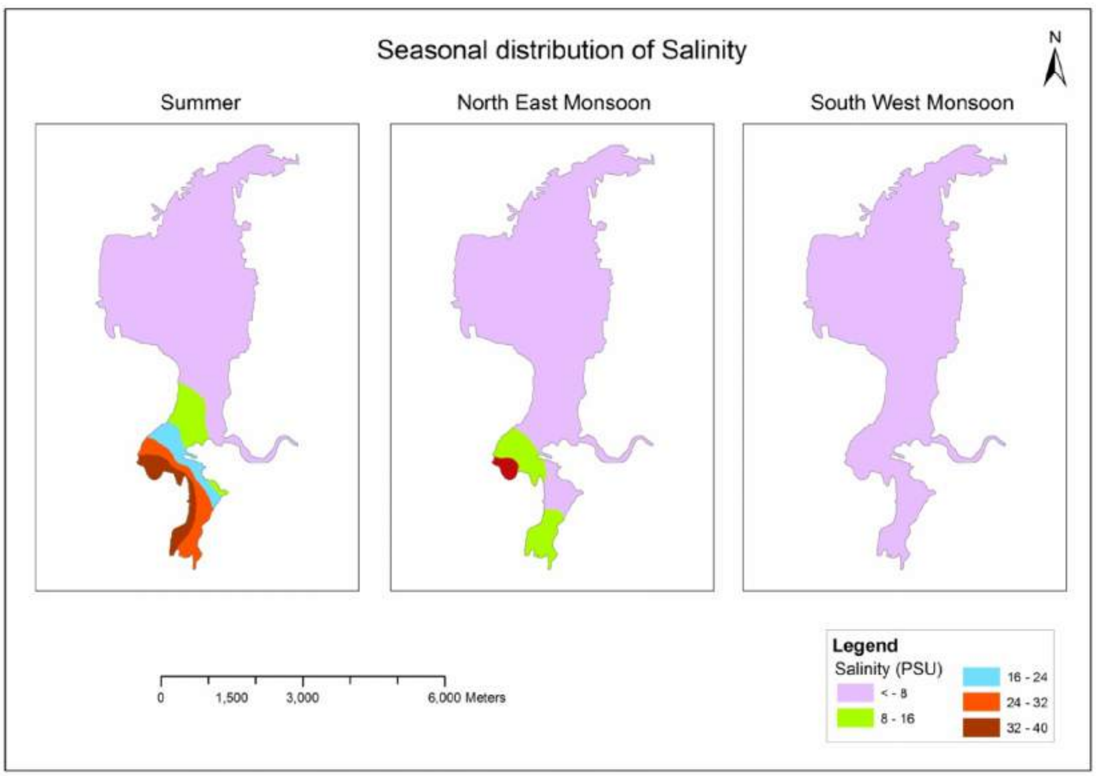


Figure 10.14 seasonal distributions of BOD and Salinity in the Marsh





B. Strategic Intervention 2: implementation of remedial measures Phyto-remediation

Open Dumping - Health Risks

Environmental and health impacts of the waste dumping/burning in Perungudi have been extensively documented. Groundwater in several pockets around the marshlands is now contaminated. The rich organic content of the municipal waste degrades over time to release highly acidic and toxic leachate. Dark pools of foul smelling streams are common in the area around the garbage dump. Mass kills of frogs, fish and sometimes water birds has also been reported in the area[4].

An air sample taken during a routine fire at the dump in December 2005 revealed the presence of 27 toxic chemicals including 3 carcinogens (CEM 2005)[5]. These chemicals are known to impact every major system and organs of the human body. Another study published in January 2007 by a team of Indian and Japanese scientists found considerably higher amounts of banned chemicals like *dichlorodiphenyltrichloroethane* (DDT) and *hexachlorocyclohexane* (HCH). The study concluded, HCH levels increased considerably in Chennai mothers' milk when compared to the data collected a decade before. Apart from food, we suspect the ambient atmosphere and water supply as the possible sources of HCHs and DDTs to Chennai people[6]. Similarly a detailed ground water study conducted by IIT Madras between 2005 and 2007 shows that the lead in all locations ranged from 0.121 milligram per litre (mg/l) to 0.23mg/l.

The maximum permissible limit is 0.05 mg/l. Copper and nitrate concentrations were also above the permissible level of 0.05mg/l and 45 mg/l respectively. The same study also analysed solid waste samples taken at different depth at the dump sites. They revealed the presence of 408 milligram per kg (mg/kg) of lead and 335 mg/kg chromium as against the permissible level of 100 mg/kg and 41 mg/kg respectively.[7]

[4] Inland Wetlands of India – Tamil Nadu, 2000 2002; Care Earth; http://www.careearth.org/summary.html
[5] Community Environmental Monitoring, 2005. Choking in Garbage I - http://www.sipcotcuddalore.com/choking_in_garbage.html
[6] High levels of organochlorines in mothers' milk from Chennai (Madras) city, India - Subramamanian, Ohtake et al, 2007.
[7] The Hindu, November 2008. Groundwater around Perungudi turning worse http://www.hindu.com/2008/11/19/stories/2008111960200300.htm

Legal frame work

The continued disposal of solid waste in Perungudi is also in violation of several environmental laws. *The Municipal Solid Waste (Management and Handling) Rules, 2000* that govern the management and disposal of MSW in India prohibits disposal of waste into wetlands and mandates source separation of organics among other things. The Chennai Corporation has been one of the few cities in the country that has failed to implement the MSW Rules. Apart from this, there are official guidelines prescribed by the Central Pollution Control Board (CPCB) for evaluation of landfills. These guidelines draw out detailed assessment report checklists for closure of waste dumps or landfills without liners[8].

Remediation Options

Given the evidence of the negative environmental impact caused by the dump at Perungudi it is quite clear that business as usual cannot continue if the integrity of the marshland is to be conserved. Planned closure followed by a through remediation is the most logical plan of action. However, a full assessment should be done to identify the key problems associated with the open dumpsite in question. While several studies have been undertaken on the air emissions and contamination of the groundwater and soil, few have done a comprehensive assessment of the site.

Perungudi was part of a case study conducted by Anna University, Asian Institute of Technology and University of Kalmar (Kurien et al., Anna University 2008)[9] in which two dumpsites were examined. The study created an environmental risk ranking system which proved to be an effective method for dumpsite assessment. A risk index was used to assess open dumpsites of both the Perungudi and Kodungaiyur dumpsites in Chennai. The risk index varied from very high to very low hazard potential. Perungudi and Kodungaiyur received scores in the range of 569 and 579, indicating moderate hazard potential with recommended action of immediate rehabilitation of the dumpsite into a sustainable landfill. These scores were calculated by evaluating the dumpsites from a list of criteria, all with different scores relating to the assumed environmental risk

[8] CPCB, August 2008. Guidelines and Check-list for evaluation of MSW Landfills proposals with Information on Existing Landfills.
[9] Kurien.J, Nagendran, Thanasekaran, 2008. Dumpsite Rehabilitation Manual, Center for Environmental Studies, 2008.

factor associated with it. A few examples of the different scoring criteria used are: area of the dumpsite, total quantity of waste at site, annual rainfall at site, public acceptance, moisture of waste, total dissolved solids of leachate etc. Each example had an associated sensitivity index and weightage that was factored into the overall score (Thanasekaran et al., 2008)[10]. Once the scores are calculated and the problem assessed, mitigation techniques could be better prepared. However, the study does not consider the ecological sensitivity of the site as a parameter. The waste dump is adjacent to a reserve forest and in the migratory path of many birds and this should raise the risk index to high to very high for which the recommended action is closure, no more land filling and remediation.

Perungudi is also situated in a very poor setting for waste disposal. The dumpsite is situated on low-lying, marshy, flood prone ground with poor drainage. Some areas of the dumpsites are consistently wet because the drainage it so poor (Esakku et al 2003)[11]. Having an open dumpsite this close to a water source is highly unfavorable due to the large risk of both ground and surface water contamination. Understanding both the composition and location of the dumpsite in question is a useful tool when determining where and how the rehabilitation phase can begin. In the next section, these two dumpsites are used to illustrate the usefulness of dumpsite mining. In order to streamline the assessment process, the following method suggested by the United States Environment Protection Agency's (USEPA), Superfund Accelerated Cleanup Model (SACM) could be explored. The SACM was designed specifically for municipal landfills where waste is usually present in large volumes and is a heterogeneous mixture of municipal waste frequently co-disposed with industrial and/or hazardous waste. Because treatment usually is impracticable, EPA generally considers containment to be the appropriate response.[12] The goal of the Remedial Investigation and Feasibility Studies (RI/FS) is to provide information necessary to: - adequately characterize the site; define site dynamics; define risks and develop the response action.

[10] Thanasekaran, K., Visvanathan, C., Joseph, K., Nagendran, R., Hogland, W, 2008 (p 27). "Dumpsite Rehabilitation Manual".
[11] Esakku, S., Joseph, K., Palanivelu, K., and Selvam, A. (2003) "Studies on Landfill Mining at Solid Waste Dumpsites in India" Proceeding Sardina 2003, Ninth International Waste Management and Landfill Symposium.
[12] USEPA, 1993. Presumptive Remedy for CERCLA Municipal Landfill Sites.

Similar methodologies for assessment have also been developed by European nations. The most appropriate assessment approach would be the one that is as comprehensive as possible and would look into social and political aspects in addition to the conventional aspects mentioned above. This site investigation activity checklist (UNEP 2005)[13] can be used as a guideline for carrying out Remedial Investigation and Feasibility Studies (RI/FS) at Perungudi.

- ✓ Review of important data such as the geology of the site, depth of groundwater, volume and types of wastes disposed, reports, studies, historical records concerning the dumpsite (operations, unusual events such as fires, dumping of hazardous wastes, etc);
- ✓ Review of available maps (map of the dumpsite and its surroundings, topographical, geological, hydrogeological, etc);
- ✓ Detailed interview with those directly involved with the operation of the dumpsite, waste pickers, and residents near site;
- ✓ Inventory of existing settlements, structures, surface water bodies, water wells, etc.;
- ✓ Determine points of leachate seepage and ponding within and beyond the disposal facility;
- ✓ Identify existing land uses around the area;
- ✓ Conduct topographic survey of the dumpsite, extending some distance from its boundaries;
- ✓ Conduct geotechnical investigation to determine stability of slopes;
- ✓ Identify sources of soil or other cover material for the site;
- ✓ Determine, if practical, the depths of the dumped wastes;
- ✓ Determine gas leakage within and on the areas surrounding the dumpsite;
- ✓ Conduct leachate and gas sampling (if practical); and
- ✓ Conduct water quality sampling of surface waters, water wells, groundwater (if practical).

[13] UNEP, 2005. Training Module on Closing an Open Dumpsite and Shifting from Open Dumping to Controlled Dumping and to Sanitary Land Filling.

Remediation Process and Evaluation of Options

After conducting the RI/FS, the collated information should be analyzed in order to draw out practical solutions. The regulatory requirements, which in this case are the MSW 2000 Rules and the Wetland Rules 2011, as well as the technical, financial, environmental and social considerations, will generally dictate closure and post-closure plans. The United Nations Environment Program (UNEP 2005) has outlined the following evaluation process for selection of remediation options:

Minimum Regulatory Requirements

Laws governing waste disposal facilities like the MSW Rules 2000 include provisions for closure and post-closure maintenance. CPCB has also issued guidelines (see section III). These stipulations need to be adhered to before designing or selecting remediation options.

Technical Feasibility

This pertains to technically “doable” activities based on the existing conditions at the dumpsite. The key is to use those that are reliable and cost effective.

Financial Viability

Financial limitations of local government units often determine which activities may or may not be included in a closure and post-closure programme.

Environmental Sustainability

Closure and post-closure activities should not add to the damage that the open dumpsite is already exerting on the surrounding environment. These activities are intended to provide environmental controls to mitigate the adverse effects caused by the dumpsite as well as enhance its appearance for potential redevelopment later.

Social Considerations

If an open dumpsite is close to a developed area, there is generally more pressure for the site owners and/or operators to implement more acceptable or stringent closure and post-closure measures. Owners and operators of waste disposal facilities, especially financially-constrained local government units, should determine what is most appropriate based on several other factors as described above rather than solely on initial costs.

Other Considerations

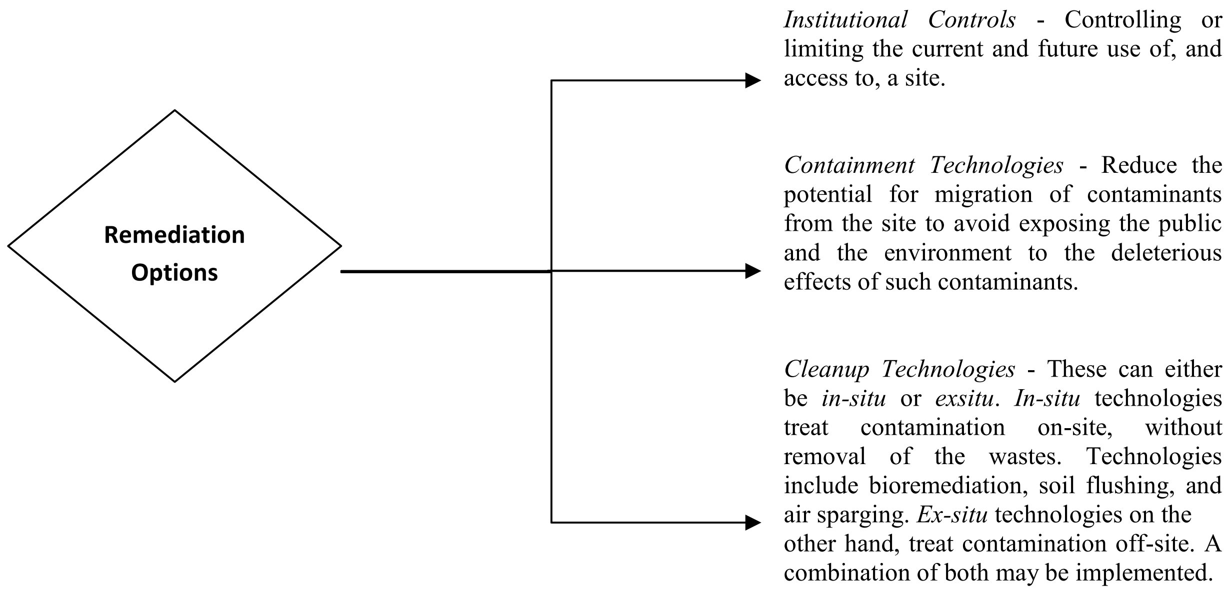
Remediation is also a socio-political issue hence a robust public consultation component has to be included in the process. Public participation has also been stipulated by the Supreme Court in the matter of India Research Foundation for Science vs Union of India & Others (WP 657/1995) on a case regarding hazardous waste disposal in India. In its final order the court noted that "*the right to information and community participation for protection of environment and human health is also a right which flows from Article 21. The Government and authorities have, thus to motivate the public participation. These well-enshrined principles have been kept in view by us while examining and determining various aspect and facets of the problems in issue and the permissible remedies.*"

Decommissioning, Phase out and Remediation

It is crucial to ascertain that the nodal waste management agency has a clear plan to phase out of its dependence on Perungudi for waste disposal. Without this all remediation efforts face the threat of failure. In most landfills, not only are a number of critical compounds present, but also specific situations (mechanical instability, high leachate level, areas with reduced permeability or too low moisture content etc.) have to be addressed (Ritzkowski et al., 2006)[14]. The objectives or reasons for remediation should also be defined by various stakeholders. Remediation goals or objectives are very much related to the intended after use of the site which is being jointly drafted through a consultative process led by the Tamil Nadu Forests Department.

[14] Ritzkowski, M., Heyer, K.-U., Stegmann, R., 2006. Fundamental Processes and Implications During in situ Aeration of old Landfills. Waste Management 26, 356-372

Figure 10.15: Evaluation of Remediation Options, UNEP 2005



Institutional Control: Waste Diversion through Decentralised Management in Kodambakkam, Teynampet, Adayar and other areas that send their waste to Perungudi. This includes a combination of interventions such as source separation of waste streams, door-to-door collection by workers, separate treatment of organics through appropriate organics treatment technologies, recovery and marketing of recyclables and disposal of residuals. This process, if initiated, could eventually eliminate the city's dependence on landfills and hence is considered the best approach to prevent new landfills to replace old ones.

Containment and Clean Up: The evidence of soil, groundwater and ambient air pollution is well established hence the immediate priority should ideally be containment of pollutants before moving on to the remediation phase. However, containment can be a difficult proposition in uncontrolled dumps like Perungudi. Hence, the best option would be application one or a combination of the following clean up technologies:

Landfill Mining: The concept of landfill mining is defined as "*a process for extracting materials or other solid natural resources from waste materials that previously have been disposed of by burying them in the ground*" (Krook et al. 2012)[15]. The basic

[15] Krook, J., Svensson, N., Eklund, M., 2012. Landfill mining: A critical Review of Two Decades of Research. Waste Management 32, 513-520.

approach to dumpsite mining involves the excavation and separation of materials into different classifications based on their ability to be recycled. Dumpsite mining should involve the sorting of waste into compostables, recyclable, asphalt, C&D waste, metals, general residuals and hazardous waste (Thanasekaran, et al, 40)[16].

There are two approaches to landfill mining, *in situ* and *ex situu*, which should be adopted in response to the fundamental characteristics of the site determined during the assessment phase and extrinsic parameters like availability of technologies and societal and economic conditions (Jones, et al 2012)[17].

- *In Situ* – this refers to resource recovery activities like methane extraction, leachate collection and treatment, partial recovery of materials etc., without excavation of the site.
- *Ex Situ* – this refers to resource recovery by partially or fully excavating the waste material for further treatment through appropriate technologies.

For Perungudi, the ex situ approach is recommended as the site is on an ecologically sensitive area which requires the most stringent decontamination process possible. Once the sorting process has begun, reuse of materials can begin by means of processing waste that is recyclable or compostable. An example of a successful sample material recovery process conducted at Perungudi and Kodungaiyur has been depicted in the case study referred to above (Thanasekaran, et al, 40).

In this study, soil samples were taken from various sections of the two dumpsites to assess their soil fraction. Twelve auger and eighteen excavation samples were examined to yield soil fractions in the range of 33% to 41% for the Perungudi dumpsite. Since a large quantity of the residuals will be fines or soil; it can be used as natural cover during refilling prior to final closure of the site.

[16] Thanasekaran, K., Visvanathan, C., Joseph, K., Nagendran, R., Hogland, W. “Dumpsite Rehabilitation Manual” 2008.
[17] Jones, P.T., et al., Enhanced Landfill Mining in view of multiple resource recovery: A critical review, Journal of Cleaner Production (2012).

Natural Cap/Catch: This approach has so far been used to a limited extent to remediate scientific landfills and not open dumps. It falls in the realm of the Bioremediation science that uses the properties of natural organic material and wetland ecosystems to isolate contaminated waste (natural cap) and prevent contaminated leachate from spreading (natural catch). Wetland ecosystems offer more sustainable potential to contain and decompose hazardous substances. Natural attenuation can occur in wetlands via various physical, chemical and biological processes. They include biodegradation by plant uptake, anaerobic degradation by micro-organisms and adsorption to organic matter (Natural Cap Conference, 2011).[18] This approach is best suited for the Perungudi but in combination with some artificial containment methods.

Closure Plan

A proper closure plan should precede a remediation plan and before a disposal facility stops receiving wastes. It is important that a final closure plan is prepared, approved, and available for implementation. The main components of the plan include, but are not limited, to the following:

Stabilization of Critical Slopes: The absence of proper operational procedures in most of the open dumpsites often results in dangerously high heaps of garbage. Thus, it may be necessary to level the heaps of garbage in order to reduce the hazards posed by unstable slopes. The final surface of the fill should be graded to about 2 - 4%, while the side slopes should have a vertical to horizontal ratio less than 1:3 (UNEP, 2005).

Leachate Collection and Treatment: Leachate pipes may be installed to collect the leachate for subsequent treatment if feasible. However, this will depend on several factors such as depth of the waste, topography of the area, underlying soil, and age of the deposited waste. Information on some aspects is available but for a final decision on this, the following general procedures may be applied in addressing leachate problems due to the absence of leachate collection and/or treatment facilities:

- A site survey and investigation should first be conducted and the following items determined:

[18] Natural Cap Conference, Amsterdam 2011. Green Rehabilitation Opportunities for Hazardous Waste Sites.

- Sources of leachate seepage at and around the surface of the disposal site. This should be determined before application of the final soil cover to determine the points of potential leachate seepage or ponding;
- General topography of the area, and
- Inventory of existing water wells in the area.

■ For leachate seepages on the surface, these may be intercepted by constructing canals/ditches to collect the leachate. The collected leachate is then channeled towards a leachate retention basin/pond located down gradient of the site.

In the context of uncontrolled dumps like Perungudi, leachate capture might pose a challenge. These measures do not ensure that ground or surface water contamination near the site will not occur. They are only simple and inexpensive remedial measures that are intended to reduce, as much as practical, the potential contamination that may occur. The collected leachate is usually treated using biological or chemical methods (or a combination of both). The latter is less preferred since it is more costly.

Fire Control: If waste is burning in the dumpsite, or burning has been practiced for a long time, it is essential that the fire be thoroughly extinguished first before initiating other activities. For shallow fires (low depth), the waste in the affected area should be spread out to allow for complete combustion and after which, water may be applied to cool it down. Sand may also be applied instead of, or with water. If the depth affected by burning is relatively deep, it may be necessary to isolate the burning area by excavating trenches around it. The waste should then be spread or regularly agitated to allow for complete combustion. The ashes subsequently produced should then be smothered with sand or soil.

Waste Picker Resettlement Action Plan: There are roughly 400 waste pickers in the Perungudi site.[19] The closure of the site will have an impact on their livelihood. The plan will have to envisage a resettlement plan for the waste pickers either through jobs generated in the closure project or by inclusion in the formal waste management system(s).

[19] Based on site interviews and settlement mapping conducted by Chennai Metro Construction and Unorganised Workers Union.

Post Closure Monitoring

A long-term monitoring plan will be required as part of the remediation design and implementation. Depending on the technology adopted for closure, such plans generally span over 20 to 25 years during which a variety of monitoring exercises would have to be carried out on a regular basis to determine the health of the ecology surrounding the dump. Such a plan will also help identify and isolate persistent toxic hot spots in the dump which might require specific treatment.

If a direct capping and gas capture approach is taken then the CPCB prescribes periodic inspection and maintenance activities with respect to the landfill cover, surface water drainage system, leachate management facilities, gas management facilities etc., need to be undertaken.

If separation and decontamination through bio-mining with natural cap and capture is being undertaken then monitoring of ambient environmental quality, studies on health of the flora and fauna should be carried out at regular intervals. Specific monitoring procedures will have to be developed with the help of scientists.

Costs

In the absence of baseline data and a final decision on the choice of technology or remediation approach, it is difficult to assess the cost of the project. However, estimates for landfill mining are available based on a pilot project carried out in Gorai dumping ground in Mumbai with similar climatic conditions as Chennai. The pilot project to mine and stabilize a 1 hectare x 9 meters high area of municipal waste cost Rs.1.5 crores. However, a quick economic feasibility study into each method is required to determine the actual cost for Perungudi.

The closure and remediation of an uncontrolled open dump like Perungudi poses significant challenges. Currently very little technical expertise is available to address these challenges. The options prescribed here may not be able to adequately decontaminate the site to the full extent but they will certainly be helpful in mitigating certain long term impacts that can be caused by a ‘do nothing scenario’. Considering the various aspects the *in situ* landfill mining approach followed by Bioremediation for decontamination is the best option compared to capping and methane extraction.

Economics will also play a crucial role in determining the nature of remediation and final closure but the existence of external benefits of landfill mining - reduced global footprint, land reclamation, avoided land use for primary mining, sustainable material and energy production - justify supporting this mechanism (Van Passel, et al. 2012)[20].

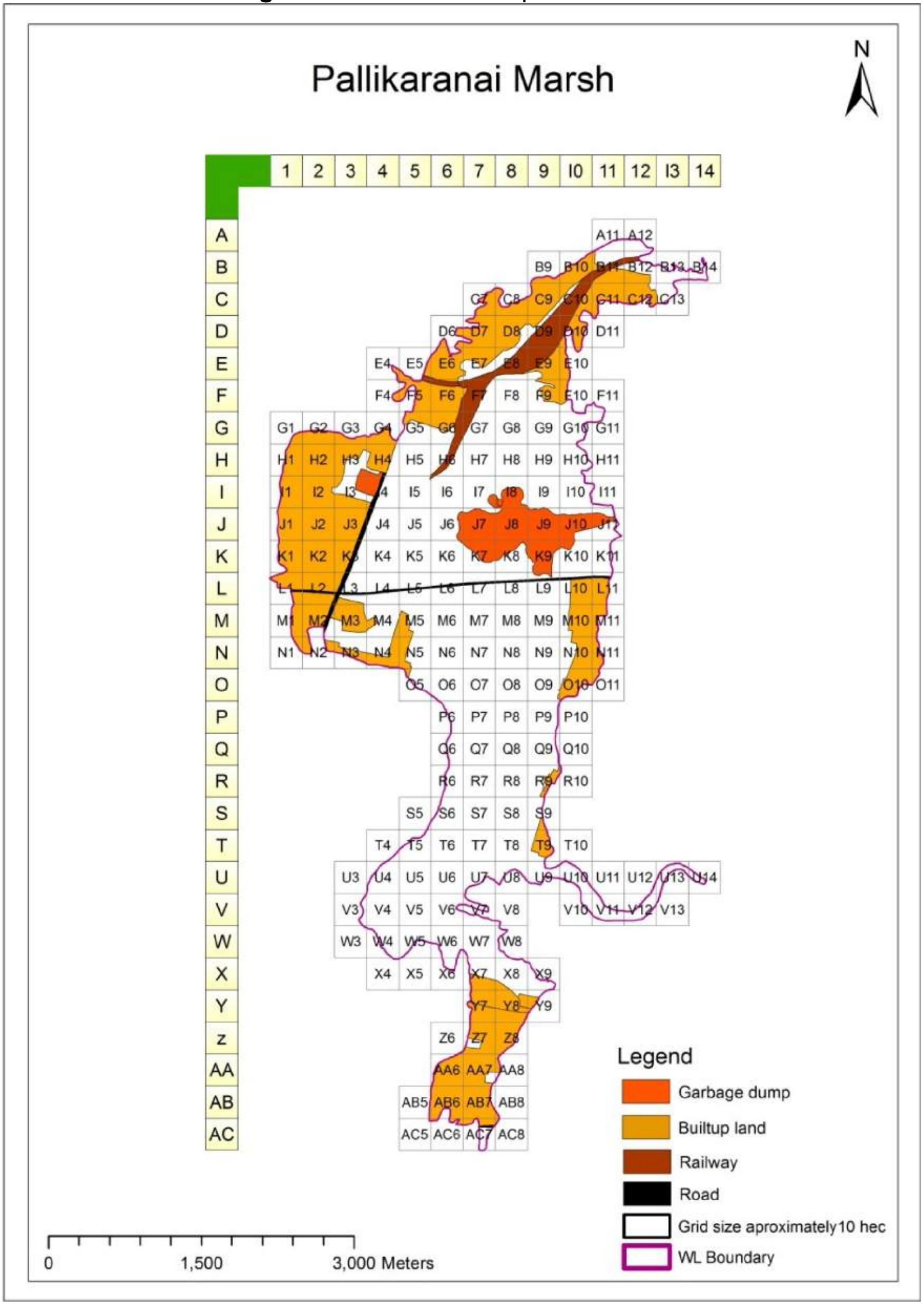
The significance of public participation is also essential and should be incorporated into the process wherever practically possible. An alternate system of waste management that does not rely on disposal but rather on recovery of resources at source should be initiated in all the zones that rely on Perungudi. This process could eventually eliminate the city's dependence on landfills and hence is considered the best approach to prevent new landfills to replace old ones. This scenario has been envisioned in the *European Commissions' Roadmap for a Resource Efficient Europe* (2011)[21] where waste is managed as a resource, recycling and reuse of waste have become economically attractive options, energy recovery is limited to non-recyclable materials and landfilling – as we know it – is eliminated (Jones, Geysan et al., 2012)[22].

10.5 GIS based interventional model

Restoration initiatives are easily defined at a very generic scale; and very often the recommendations while being profound and well meaning have very little relevance to the administrators and managers. It is in this context, a GIS based interventional model has been developed for Pallikaranai Marsh at a resolution of 10 ha. grids (Fig 10.16). This model has delineated the entire marsh, irrespective of its legal status or administrative jurisidiction into equal sized 10 ha. grids, which have been numbered using numerals as well as alphabets. Each of the grids therefore has a distinct identity. Interventions proposed as parts of the restoration strategy for the Pallikaranai Marsh have therefore been identified at a 10 ha scale and listed in the following table.

[20] Van Passel, S., Dubois; M., Eyckmans, J., de Gheldere, S., Ang, F., Jones, P.T., Van Acker, K. The Economics of Enhanced Landfill Mining: costs and benefits from a private and public perspective, Journal of Cleaner Production, 2012.
[21] European Commission, 2011. Roadmap to a Resource Efficient Europe. COM (2011) 571.
[22] Jones P.T., Geysen et al, 2012. Enhanced Landfill Mining in View of Multiple Resource Recovery: A Critical Review.

Figure 10.16 Gridded map of the Marsh



Strategy	Intervention	Location/Grid
Managing wetland fauna		
Birds	Deep water for sw63 imming and diving birds	K4-6; L4-6; M5-7; N5-7; P7;Q7; R7; S7; T7; U7
	Shallow water for wading birds & filter-feeding birds	L7-9; M7-9; N7-9; U5-6; V5-6
	Mudflats and sediment beds for wading & probe-feeding birds	L7-9; M7-9; N7-9; U5-6; V5-6
	Elevated earth banks/islets/rocks & grass-topped platforms for resting	K4-6; L4-6; M5-7; N5-7; P7;Q7; R7; S7; T7; U7; W7-9; X8-9
	Wet grass meadows for snipes, lapwings and storks	H5; I4-6; J4-6; U4-5; V4-5; W4-5
	Reeds for cover & nesting	M4-6; N4-6; N9; O6; O9; P9; Q9; R9; S9; T9
	Floating plants	L3; M4; N3-4
	Trees for roosting & nesting	J6; K6-7; X6-7
Fish	Open deep water	K4-6; L4-6; M5-7; N5-7; P7;Q7; R7; S7; T7; U7
	Open shallow water	L7-9; M7-9; N7-9; U5-6; V5-6
	Creeks	M4; N3-4; V7; X5
	Marine-freshwater eco-tone	U9-10; V10-12
	Connectivity & surface flows	F8; G7; H6; L3-10; U4-10
Other aquatic animals	Amphibians – breeding	H5-6; I5-6; J5-6
	Amphibians – prevention of road kills	H4; I4; J3; K3; L3-10
	Reptiles (water snakes, turtles) – breeding	T5; U4-5; V4-5
	Reptiles – prevention of road kills (turtles)	H4; I4; J3; K3; L3-10
	Invertebrates – aquatic and water-dependant	B10-12; C7-13; D6-10; E6-10; F4-7; F9&10; G1-7; H1-4; I1-3; 17; J1-3; J6; K1-3; K7; L1-3; L10-11; M1-3; M5; M10-11; N1-5; N10-11; O10-11;R9; S9; X7; Y7-9; Z8-9;AA6-8; AB6—7; AC6-7

Strategy	Intervention	Location/Grid
Managing wetland flora		
Floating plants	Encourage	L3; M4; N3-4
	Control	F8; G7; H6; L3-10; U4-10; V10-12
Submerged plants	Encourage submerged herbaceous plants	K4-6; L4-6; M5-7; N5-7; P7;Q7; R7; S7; T7; U7
Emergent plants	Encourage	M4-6; N4-6; N9; O6; O9; P9; Q9; R9; S9; T9
	Control	K4-6; L4-6; M5-7; N5-7; P7;Q7; R7; S7; T7; U7
Invading terrestrial plants	Encourage	J6; K6-7; X6-7
	Control	H5; I4-6; J4-6; U4-5; V4-5; W4-5
Trees	Encourage/plant	F8; G7; H4; I4; J4; J6; K6-7; X6-7
Managing hydrology		
Surface runoff & inflow	Regulate over-the-road flow	H4; I4; J3; K3; L1-10
	Manage topography	F8; G7; H6; L3-10; U4-10
Saline-freshwater balance	Manage topography	U9-10; V10-12
Widespread desiccation	Improve in situ connectivity	K4-6; L3-10; M5-7; N5-7; P7;Q7; R7; S7; T7; U7
Managing pollution		
Solid waste disposal	Monitor and control disposal	I6-11; J6-11; K6-11; M4; N3-4; U9-10; V7; V10-12; X5
Sewage disposal	Monitor and control disposal	I6-11; J6-11; K6-11; M4; N3-4; U9-10; V7; V10-12; X5
Managing edges		
Perimeter distortion	Protecting small creeks	F10-11; G10-11; H10; I10; K11; O5; P6; P9; Q6; Q9; R6; S6; T5; U4; U7-9; V3; W4-5; W8; X6; X9
Water depth management	Avoiding ‘harbour effect’ (abrupt land-water edge)	B10-12; C7-13; D6-10; E6-10; F4-7; F9&10; G1-7; H1-4; I1-3; J1-3; K1-3; L1-3; L10-11; M1-3; M5; M10-11; N1-5; N10-11; O10-11;R9; S9; X7; Y7-9; Z8-9;AA6-8; AB6—7; AC6-7

Strategy	Intervention	Location/Grid
Public participation	Awareness building	B10-12; C7-13; D6-10; E6-10; F4-7; F9&10; G1-7; H1-4; I1-3; J1-3; K1-3; L1-3; L10-11; M1-3; M5; M10-11; N1-5; N10-11; O10-11;R9; S9; X7; Y7-9; Z8-9;AA6-8; AB6—7; AC6-7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11. Conservation: prioritisation, thematic areas and desired goals

Refugia (singular **Refugium**) are geographical locations where natural environmental conditions have remained relatively constant or stable during times of great environmental change. Refugia also protect populations of geographically isolated organisms which may then re-colonize a region when the wider environment returns to levels within the organism's tolerance levels. This theory is commonly referred to as **The Refugia Theory**.

Haffer first proposed the idea of refugia in 1969 to explain the high diversity of Amazonian bird species. Haffer proposed that the Amazon Basin paleoclimate experienced several warm, dry periods during episodes of continental glacier advance in the Pleistocene. These glacially driven periods led to the conversion of forest to savanna, which resulted in the isolation of small fragments of forest separated by expanses of open plains. Birds within these forest patches were geographically isolated from each other, leading to allopatric speciation. When the forests returned to their previous range in conjunction with achanging climate, these newly evolved species of birds radiated with the forest. Where the forest ranges overlapped the bird species that evolved in the refugia were no longer in competition because they exploited different resource niches. The exploitation of different niches allowed for multiple species to occupy the same geographic area, leading to the present state of high bird diversity (Leonard, 2013).

Although Hafer's idea of refugia has gained widespread acceptance as an ecological concept, the idea faces significant opposition. Much of the opposition lies not with the idea itself, but with how it applies to a particular geographical research unit. Colinvaux in particular, disagreed with the hypothesis that the Amazonian forest was fragmented during the Pleistocene. He believes that the Amazon basin forests remained intact during the last glacial cycles and therefore there must be an alternate explanation for the high species diversity found in the Amazon.

Although initially tied to glaciers and focused on a discussion of tropical diversity, the term refugia now applies to any isolated region where species may be able to survive during times of ecological change. It is important that the term 'isolation' be understood in its context, notably when there is a significant presence of human population (Vencatesan, 2002).

11.1 Ecological significance of Pallikaranai Marshland

Pallikarnai Marshland is a part of the vast Bay of Bengal Large Marine Ecosystem. It is one of the few natural aquatic habitats that qualify as wetlands in India. The seasonal dynamics in water volume, spread and chemistry, both historical and current, have together rendered the Pallikaranai Marshland a biodiversity-rich south Indian wetland.

While complete information on the biological communities that inhabit the wetland is lacking, what is best known is that there are around 130 species of birds and more than 50 species of fish are present the Pallikarnai Marshland. In the absence of aquatic mammals and reptiles such as otters and crocodiles, fish and fish-eating birds are the flagship species that characterize wetland ecosystems. It is this consideration that has attributed a greater conservation value to just two Classes of the Vertebrate fauna of the marshland. Further, as birds are more conspicuous attracting greater public attention, the ecological health of the Pallikaranai Marshland is monitored using the associated community of birds as the yardstick.

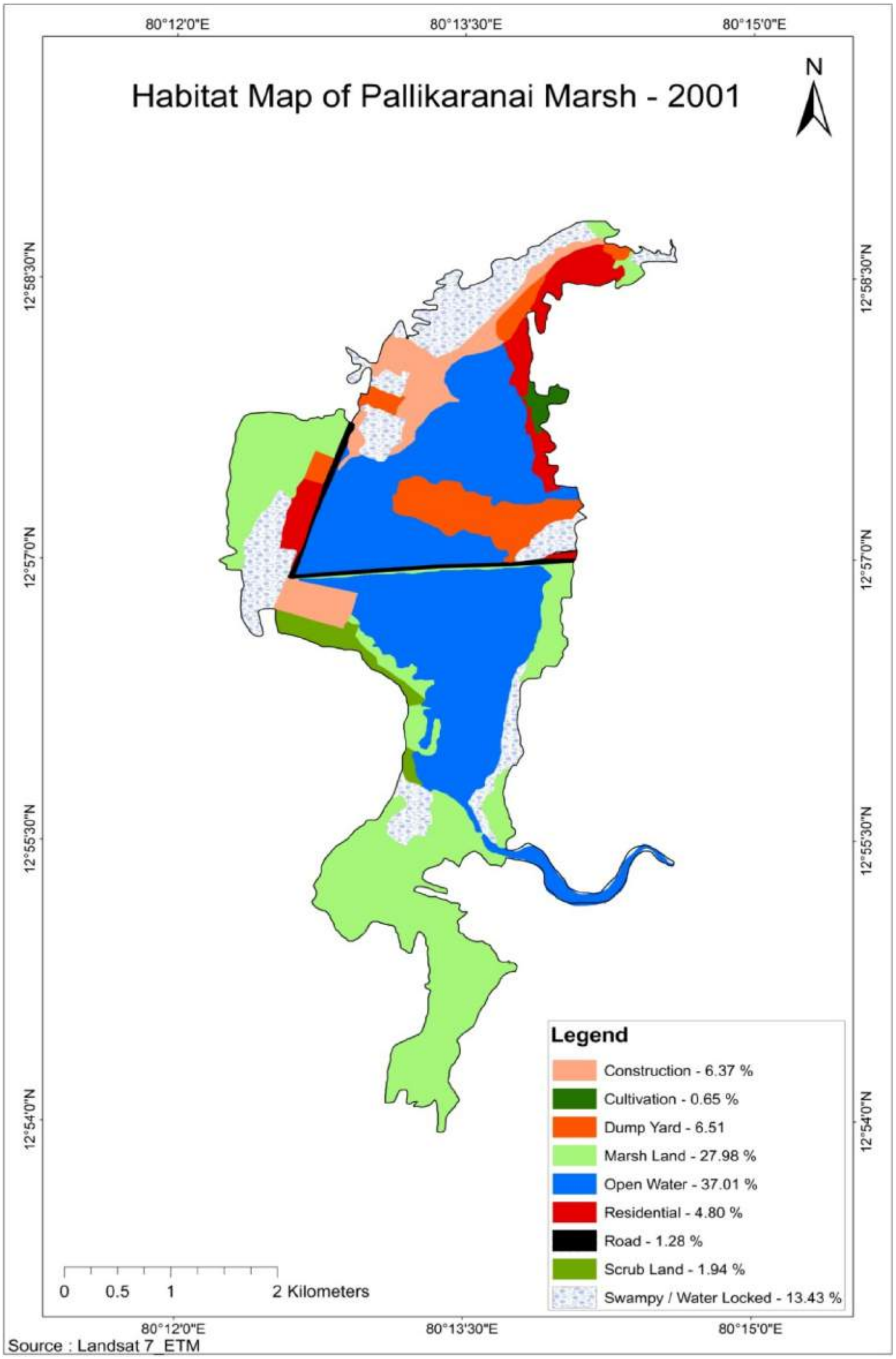
11.1.1 Pallikaranai Marsh Wetland as part of the migration path

In general, billions of birds travel between continents twice a year in only a few weeks. The geographic location of a wetland may determine how and when birds will use it or use the adjacent habitat. Some wetlands are on the migration path of waterfowl and other migratory birds and provide stopover locations for migratory birds. In the event of the wetland being part of an agrarian landscape, the birds might feed in agricultural fields during the day and return to the shelter of wetlands during the night. Pallikaranai Marsh also serves, as a feeding ground to a number of visitors. Migrants like the sandpipers and teals are not uncommon here. Blackwinged Stilts may usually be found in a small number at the northern edge of the water, facing the village; pelicans arrive singly, in pairs, or in large numbers. Occasionally coots and terns may also visit the tank.

Migrating waterfowl use a wide range of altitudes, from as low as 300 feet to as high as 10,500 feet. Some birds have been recorded at extremely high altitudes. Individual birds show amazing consistency to their migratory pathways and their nesting locations from year to year. Birds that migrate from the same geographic region often follow broadly well-defined routes known as migratory flyways. The Central Asian flyway spans about 30 countries from the Arctic to the Indian Ocean. But these flyways are just generalizations and bird populations have been known not to strictly follow it.

Food obtained at stopovers provides energy for the migratory flight and nutritional reserves that may be essential for successful reproduction upon arrival at the breeding grounds. "Traditional" stopovers are medially aligned in the migration route, used in successive years, and occupied for extended periods each year. "Nontraditional" stopovers are selected opportunistically at the end of each day's flight, may not be used every year, and are used only for short periods. Stopovers also have been defined for shorebirds based on an individual's length of stay. Shorebird "staging" areas are defined as those areas where birds spend extended periods of time and during which considerable fat gains occur. "Resting" areas are used for shorter periods and birds accumulate less fat. The stopover concept also has been applied at different spatial scales and different levels of biological organization. The term has been used to describe relatively large geographic areas that are important to shorebird populations on a hemispheric scale. These large wetland areas provide abundant food for thousands of shorebirds, although the spatial location of food patches within the areas may vary annually. At a small spatial scale, stopovers have been defined as the area used by an individual bird during a refuelling. At this scale, the spatial distribution of food patches affects the energy expenditure required in searching for food and the rate at which individuals replenish their energy reserves.

Figure 11.1 Habitat map of Pallikaranai Marsh- 2001



11.1.2 Fish Community and the Fish-eating Birds

As typical of wetlands characterized by shallow stagnant water, the fish fauna of Pallikarnai Marshland is dominated by species that are capable of withstanding lower dissolved oxygen levels during summer and other non-rainy months. Air-breathing fish and surface-feeding fish are both diverse and abundant throughout the year. Some like the snakeheads (*Channa* spp) are entirely predaceous. To add to the diverse native fish fauna, there are some species of alien fish too. Of these, the higher relative abundance of invasive alien species such as the mosquito fish (*Gambusia affinis*) and tilapia (*Oreochromis mossambicus*) is evident. While there is little information on the relative abundance of the various other species of fish in the Pallikarnai Marshland, what is inferred from the available data on the community of fish found in the wetland is that the species represent various feeding guilds and together sustain a very complex underwater food web.

It is also inferred that fish availability is rather substantial. This inference is based on the large numbers of fish-eating birds such as cormorants, pelicans, storks, herons, egrets and terns that swarm the marshland. Further, specialized fish-eating raptors such as the Osprey are also known to visit the marshland during winter.

Fish-eating birds forage more intensively, often in large flocks, than other carnivorous birds that feed on terrestrial vertebrates. Although there are no specific studies to substantiate the following suggestion, based on the body size of the different species and their abundance, it may be said that the average annual biomass of fish-eating birds in the marshland may be higher than that of the other wetland birds that belong to the community. It is also noteworthy that the most abundant fish-eating birds are predominantly native (breeding locally in the watershed-landscape and subject to seasonal movements) while the other wading and swimming birds with comparable abundance are mostly migratory (a few exceptions being the Black-winged Stilt, Spot-billed Duck, Cattle Egret and the Purple Swamphen). Of the latter, in terms of abundance, the Black-winged Stilts locally out-number the others (Table 11.2).

In brief, what is of significance is that the Pallikarnai Marshland is rich in fish thereby providing adequate supply of food to a large number of fish-eating birds. Considering the body size of birds such as the Spot-billed Pelican and Painted Stork, and the large flocks that build up in the marshland, it may be inferred that the daily harvest of fish by the birds might be a few hundred kilograms.

Annual fish availability is guaranteed by two important ecological factors: first, the meta-population dynamics. Due to the perennial nature of the water in parts of the marshland, there is a resident community of fish throughout the year. In addition to the resident community, rains and the flood water that enter the marshland deliver thousands of fish including a diverse array of species. The exact limits of the meta-population are not known. However, available information suggests that the runoff water carries with it fish from perennial sources such as the Velachery Lake and the ponds and lakes within the Guindy National Park and IIT Madras and also from many smaller lakes distributed sparsely in the western parts of the landscape. Apart from these sources the runoff and flooding also connect the isolated parts of the marshland thereby transporting fish across the entire marshland. Majority of these fish breeds as the season progresses into summer and, the volume of water declines creating smaller lake-like conditions and swamps. Fish densities locally increase. Such a meta-population process is generally common in low-lying coastal wetland complexes. Interestingly in the Pallikarnai Marshland, fish meta-population dynamics also concern certain estuarine species such as mullets (*Mugil* sp) and *Etroplus suratensis*. The Okkiyammadavu that drains the marshland into the Buckingham Canal during the monsoons is an important conduit for the entry and exit of saltwater fish into the marshland during summer months. It may also be responsible for the existence of diadromous eels (*Anguilla* sp) in the marshland.

Second important factor is the ecological support system provided by the complex underwater food web (ecological complexity). The ecological complexity of the marshland is due to its variation in depth, sedimentation, vegetation, water chemistry and oxidation (heterogeneity). The heterogeneous nature of the habitat is critical to the existence of the complex underwater food web. Such a food web is created and sustained primarily by fish and various other aquatic organisms such as invertebrates, submerged plants, algae and plankton. The existence of a complex underwater food web in the marshland was directly inferred in the recent past when humans freely entered the habitat to collect fish and harvest other aquatic invertebrates (for supply as feed to aquaria and other fish-breeding centers). Complex aquatic food webs (including human predators) have their foundations underwater and are therefore often overlooked in conservation planning.

Most species of fish-eating wetland birds hunt in flocks or as loosely organized groups. It is common to observe pelicans, cormorants and terns flocking together to feed on fish in a specific location in the marshland. Similarly, several species of egrets and herons also cooperate while fishing. Mixed flocks hunting for fish can be a great source of amusement to the amateur bird watcher and nature-lover. It has immense educational and tourism values too. Mixed foraging flocks of wetland birds offer a lot of scope for interesting field scientific study on cooperative hunting in birds.

11.1.3 Freshwater-saltwater Balance and the Vegetation Succession

Although tropical in bio-climate, the influence of the Bay of Bengal Large Marine Ecosystem has been significant on the marshland. Dramatic changes in its hydrology and biodiversity witnessed annually may be attributed to the maritime influence and the vagaries of the northeast monsoon. The fact that it is so close to the sea and not fully estuarine is however a unique aspect.

Parts of the marshland are well below the mean sea level and thus qualify as low-lying basins. Naturally, therefore the marshland should have therefore been an estuarine habitat or at least the water predominantly brackish. In fact, analysis of the organic material in excavated soils in the southern parts of the marshland in 2002 revealed the presence of maritime animals such as mud crab, window-pane oysters and other bivalves. The remains of these animals were in sub-fossilized condition suggesting that the sediments were formed during a long period of maritime influence.

The mixing of freshwater and seawater is brought about by the huge volume of surface runoff that the marshland receives year after year during the monsoons. Considering its original spread of around 5000 ha and an average depth of 1m during the peak monsoons (when flooding is also widespread) the water-holding capacity of the marshland may be estimated as 50 million cubic meters (5000x100mx100mx1m). This is a conservative estimate given the vastness of the watershed-landscape. This is primarily rainwater and hence freshwater.

Right mix of freshwater and seawater is important in maintaining the ecological integrity of the marshland. It is well-known that in the natural process of ecological succession marshes tend to give way to grasslands and scrub, eventually attracting the colonization of woody shrubs and trees. The heavy inflow of freshwater every year and the influence of tidal water that is brackish (if not saline) have limited the vegetation to herbaceous plants including salt-tolerant sedges (Cyperaceae) and grasses. Surface runoff from almost all sides, the tidal influence from the south and southwest and the dense growth of emergent aquatic plants have balanced siltation creating extensive mudflats and wide sediment banks that border the shallow water. The dynamics of siltation may at present be affected by the disposal of solid and liquid wastes into the marshland. This is a matter of concern that calls for careful scientific research.

11.1.4 Benthic Fauna and Mud-probing Birds

Natural organic fertilization of silt due to in situ death and decomposition and oxidation due to the prolonged summers and bright sunshine of Chennai may have primarily contributed to the benthic food availability. It is the copious supply of benthic food that attracts the abundance and diversity of shore and wading birds, including trans-boundary migrants, and the Greater Flamingo.

Population and diversity of waders and shorebirds in the marshland start building up after the northeast monsoon and peak during December-March seasons when the water recedes and becomes shallower. Some shorebirds birds that visit the marshland in winter migrate from the north as far away as Siberia and the Arctic Circle. The diversity of migratory shorebirds has increased considerably during the past 10 years with rare visitors like the Great Knot that was reported during the winter of 2013.

The maritime ecology of the marshland may also be responsible for the diversity of certain species of migratory waders. These wetland birds are generally commoner in estuarine habitats in south India. Whereas reports of species like the godwit, knot, ruff & reeve, Grey-headed Lapwing and other migratory birds in the inland wetlands of south India are sporadic and sparse, in the Pallikaranai Marshland, the abundance and frequency of sighting of these species have been on the rise year after year.

11.1.5 Ducks and Grebes

Apart from the fish-eating birds, waders and shorebirds, there are the ducks and other swimming birds like the grebe. These birds are of interest as they occupy a rather distinct sub-habitat. Open waters and the associated submerged vegetation are primarily responsible for the diversity and abundance of these birds (Table 11.2). Swimming birds are generally omnivorous opportunistically feeding on small invertebrates and fish, but chiefly dependent on aquatic plants. These birds are also very important dispersers of aquatic plants as they fly far and wide within a season and across seasons.

What is of interest about the ducks in particular is that around 10 years ago, the ducks that were found in the marshland were largely migratory winter visitors from the northern hemisphere. Resident ducks have since slowly colonized with species like the Spot-billed Duck becoming both common and abundant (Table 11.2). There is also evidence that the Spot-billed Duck breeds in the marshland.

Lesser Whistling Duck that breeds locally around Chennai is a common bird in south Indian wetlands. However, its population in the marshland is not very high. In the past couple of years, the Fulvous Whistling Duck (a new-comer) is becoming commoner and there are sporadic records of the Comb Duck – both species are native to the sub-continent and are not winter migrants as are the other true ducks (genus *Anas*).

11.2 Perumbakkam Wetland

This satellite wetland habitat on the southern end of the marshland has assumed great conservation significance due to its unique ecology. It is unique in being a freshwater habitat with an abundance of submerged and emergent herbaceous plants, especially water lilies. The habitat is suited to swimming and diving birds and the longer legged wading birds like storks, egrets and herons. It is generally easier to find flocks of Painted and Open-billed Storks, Black-headed Ibises and occasionally Spoonbill and the endangered Darter. The Fulvous Whistling Duck is also seen more frequently here. The fish-eating raptor, Osprey is also seen during winter. This habitat is however not suited to waders and shorebirds, especially the many species of wintering sandpipers, plovers and allied mud-probing birds.

11.3 Ecological Resilience

It is reiterated that fish and birds are not the only organisms that contribute to the conservation value of the Pallikarnai Marshland. However, as mentioned earlier they are organisms that occupy niches that are higher up in the ecological pyramid that monitoring their dynamics will offer vital information for the long-term conservation of the marshland.

Conservation value of the marshland is contributed equally by its delicately balanced hydrology and resultant biodiversity. The natural geo-chemical cycles of the marshland, although considerably disturbed by highly transformative human interference such as waste disposal and heavy footprint habitation and the associated infrastructure development, continue to sustain the unique hydrology and biodiversity.

Heterogeneous landscapes are known to support greater biodiversity than landscapes that are monotonous. The watershed-landscape that cradles the Pallikarnai Marshland is a mosaic of freshwater, brackish water, estuarine conditions, beaches, sea, wooded plains and hillocks. The marshland has shown considerable amount of resilience. Despite being reduced to a mere 10% of its original extent, the marshland has not lost its conservation value. Historically, the Adyar estuarine system was known for its bird species richness and abundance. There have also been considerable investments made from time to time in the restoration of the Adyar estuarine habitats. In comparison, the Pallikarnai Marshland has had very little restoration investment. There has however been a steady increase in the diversity of birds and their populations from year to year in the past 10 years. While the only obvious sign of resilience has been the overall increase in birds, the abundance of fish-eating birds has dramatically increased is an indication that the underwater biodiversity is also resilient.

Given the inference that the ecological web that sustains the Pallikarnai Marshland is relatively intact, it is important that future interventions – direct or indirect, do not upset the existing balance. Major interventions that might affect the ecology of the marshland are that which concern the hydrology. Historically, the marshland received copious volumes of freshwater due to seasonal surface runoff. The runoff was cleaner and well-oxidized as the surface over which it flowed was more open, covered with grass and low vegetation and less polluted with organic and inorganic wastes. Current patterns of surface runoff are very different and continue to change. Important changes are in the course of the flow; much of the runoff water has been diverted through narrow channels and closed storm-water drains offering less scope for free oxidation as the water flows. There is also considerable mixing of organic waste in the water as the channels are generally used to dispose wastes during the dry months.

Minimum hydrological flows are necessary to maintain the quality of water in any aquatic habitat. The direction of flow, the speed and volume of flow, and the particle load have a bearing on the pattern of sedimentation. Based on the assumption that the minimum hydrological flows will be interfered with by the rapidly changing land use around the marshland it is foreseen that the pattern of sedimentation, mudflat and shore formation will be very dynamic (and unpredictable) that habitat management for shore and wading birds will be a major future challenge. This emerges as a very significant issue as the diversity of birds that use the marshland is largely due to wading and shorebirds.

11.4 Shifting Vegetation Mosaics and the Problem of Invasive Plants

The dynamics of sedimentation will also affect water-land ratio leading to shifts in the vegetation mosaics. The pattern of sedimentation and land formation will also create newer habitat niches (micro-habitats) for invasive terrestrial plants like *Prosopis juliflora*. The rapid invasion of the Adyar estuarine complex by *Prosopis juliflora* and the subsequent heavy costs involved in ridding parts of the habitat of the alien species are the results of major changes in hydrology and sedimentation.

In Pallikarnai Marshland, the invasion of *Prosopis juliflora* has been rather rapid along the northeast boundary and this may be attributed to the substrate created by the solid waste disposal from the Perungudi side. The highly invasive plant has very efficient seed dispersal mechanism. Seeds are carried by surface runoff, along with other solid wastes and to a smaller extent by animals. Whereas there is some merit in having mature stands of *Prosopis juliflora* in wetlands, as they provide roosting and nesting habitats to fish-eating birds, proliferation of the invasive alien plant in many south Indian wetlands has eventually led to major changes in hydrology resulting in the premature drying up of the habitat and the consequent shifting of important breeding/roosting colonies of the birds.

Other species of plants that have the potential of interfering with the hydrology and the land-water ratio of the marshland are the cattail (*Typha* angustifolia), water lettuce (*Pistia stratiotes*), duckweed (*Lemna* sp & *Spirodella* sp) and water hyacinth (*Eichhornia crassipes*). All these plants have the ability to choke wetlands and adversely affect the oxidation process. However, with the exception of the water hyacinth which is an alien invasive plant with origins in Africa, the others are pan-tropical, the dispersal of which is primarily aided by natural processes such as wind (Cattail) and migrating birds (duckweed and water lettuce). Managing these plants therefore needs appropriate strategies that may not be easy in wetlands where there is a high density of nomadic and migratory birds.

It is however important that these plants are managed wisely and not totally eliminated. Floating mats of plants play an important role in offering nesting and feeding micro-habitats to birds like jacanas and moorhens. Herons and egrets also use these platforms. In deeper water, the floating mats are important in providing shade that fish use for resting and sometimes spawning (best example Loktak Lake in Manipur). Vegetation mats are unique micro-habitats where other herbs, grasses, sedges and ferns grow creating more substrates for a number of small animals.

Vegetation Influences on Bird Distribution and Abundance: a Case Study

During December 2011 and January 2012, a brief study was conducted to assess the distribution and abundance of birds in selected sub-habitats of the marshland. Point counts in the early morning for duration of 15 minutes per location were used to estimate abundance of birds in 4 locations. Two locations were in the northern segment of the marshland and 2 were in the south. All 4 locations were on either side of the Thoraipakkam Link Road. The 4 locations sampled had varying proportions of vegetation, open water, sediment banks and mudflats. Location 1 was however predominantly covered with short grass and sedges with occasional pools of water and no mudflat or sediment bank. Each location was sampled 9 times during the study period.

Seventy-two species of birds were recorded from a total count of 31,548 birds. Of these, 97.41% of the counts (30,733) were of just 17 species (Table 11.1). These 17 species were treated as 'common' for purposes of understanding patterns of distribution and abundance and how vegetation affects the abundance of a common species in a specific location. Whereas Garganey (14,799), Black-winged Stilt (6979) and Northern Pintail (3338) emerged as the three most common birds during the study, the number of counts of these birds varied considerably from one location to the other suggesting that habitat heterogeneity created by vegetation does affect the distribution and abundance of even the common birds in the marshland (Table 11.1).

Table 11.1: The 17 species of common birds observed along the Thoraipakkam Link Road and the local variation in the species counts in winter of 2011-12

Species	Count/location				Total count
	1	2	3	4	
Garganey	2	3662	515	10620	14799
Black-winged Stilt	0	2794	992	3193	6979
Northern Pintail	1	2399	656	282	3338
Cattle Egret	264	174	409	42	889
House Crow	125	332	124	78	659
Large Egret	21	113	2	476	612
Spot-billed Pelican	64	158	128	100	450
Glossy Ibis	240	63	53	32	388
Median Egret	77	273	1	4	355

Pond Heron	245	56	27	12	340
Purple Swamphen	98	82	65	22	267
Spot-billed Duck	46	62	115	21	244
Grey Plover	0	21	125	98	244
Common Myna	63	73	88	8	232
Little Cormorant	135	57	18	13	223
Barn Swallow	11	25	50	130	216
Indian Cormorant	38	107	37	13	195

The results presented in Table underline the need to maintain habitat heterogeneity in the marshland. Although the results are based on a brief study, they have brought to light the fact that even the distribution and local abundance of common birds are affected by the availability of the preferred sub-habitat type. Location 1, for instance is in the northern segment bordering the Velachery road. The sub-habitat in this location is predominantly grass, sedges, cattail and water hyacinth with small pools of open water. Birds like the Pond Heron, Little Cormorant, Glossy Ibis and Cattle Egret tend to prefer this location (Table 11.1).

Besides the various species of typically aquatic birds there are other species of birds commonly associated with wetlands. These include insect-eating birds such as swallows, swifts, wagtails, pipits and several species of warblers and weaverbirds. The wintering swallows are quite common and abundant in the marshland (Table 1). Their abundance may be attributed to the greater availability of small soft-bodied insects and appropriate roosting and nesting habitats, especially the tall reeds. It is also noteworthy that the Pallikarnai Marshland is one of the few wetlands in south India where the Clamorous Reed Warbler (*Acrocephalus stentoreus*) breeds.

11.5 Birds of Pallikaranai Marsh

The following table is a consolidation of assessments carried out by Care Earth Trust over the last fourteen years through regular, weekly visits and observations. The table also highlights the conservation status of the birds, both globally and within the sanctuary and their habitat requirement. The table also provides information on food requirement of individual species of birds.

Table 11.2 Annotated Checklist of Birds

S. No.	Common Name	Family/Scientific Name	Habit & Habitat (feeding, resting & nesting)	Food requirement
	Grebes	**Podicipedidae**		
1.	Little Grebe	*Tachybaptus ruficollis*	Swimming, diving. Open water, floating vegetation	Fish, frogs, small aquatic invertebrates
	Pelicans	**Pelecanidae**		
2.	Spot-billed Pelican	*Pelecanus philippensis*	Swimming, basking. Open water, stumps/rocks, trees	Mainly fish
	Cormorants	**Phalacrocoracidae**		
3.	Little Cormorant	*Phalacrocorax niger*	Swimming, diving, basking. Open water, stumps/rocks, trees	Mainly fish
4.	Great Cormorant	*Phalacrocorax carbo*	Swimming, diving, basking. Open water, stumps/rocks, trees	Mainly fish
5. .	Indian Cormorant	*Phalacrocorax fuscicollis*	Swimming, diving, basking. Open water, stumps/rocks, trees	Mainly fish
	Darters	**Anhingidae**		
6.	Darter	*Anhinga melanogaster*	Swimming, diving, basking. Open water, stumps/rocks, trees	Mainly fish

S. No.	Common Name	Family/Scientific Name	Habit & Habitat (feeding, resting & nesting)	Food requirement
	Herons, Egrets & Bitterns	**Ardeidae**		
7.	Little Egret	*Egretta garzetta*	Shore-bird, wades in shallow water. Stumps, rocks, water-logged grass & trees.	Fish, frogs and aquatic invertebrates
8.	Grey Heron	*Ardea cinerea*	Shore-bird, wades in shallow water. Stumps, rocks, water-logged grass & trees.	Fish, frogs and aquatic invertebrates. Small rodents.
9.	Purple Heron	*Ardea purpurea*	Shore-bird, wades in shallow water in proximity of reeds and tall aquatic vegetation. Trees, Pandanus thickets.	Fish, frogs and aquatic invertebrates. Small rodents.
10.	Large Egret	*Casmerodius albus*	Shore-bird, wades in shallow water. Stumps, rocks, water-logged grass & trees.	Fish, frogs and aquatic invertebrates
11.	Median Egret	*Mesophoyx intermedia*	Shore-bird, wades in shallow water. Stumps, rocks, water-logged grass & trees.	Fish, frogs and aquatic invertebrates
12.	Cattle Egret	*Bubulcus ibis*	Ground-bird. Meadows, water-logged grass. Thickets and trees.	Insects.
13.	Indian Pond-Heron	*Ardeola grayii*	Shore-bird. Shallow water, water-logged grass & trees.	Fish, frogs & aquatic invertebrates.
14.	Black-crowned Night-Heron	*Nycticorax nycticorax*	Crepuscular shore-bird. Shallow water, reeds & trees.	Fish, frogs & aquatic invertebrates. Occasionally eggs and chicks of other birds.
15.	Cinnamon Bittern	*Ixobrychus cinnamomeus*	Shy shore-bird. Tall reeds and grass in shallow water.	Fish, frogs & aquatic invertebrates.

S. No.	Common Name	Family/Scientific Name	Habit & Habitat (feeding, resting & nesting)	Food requirement
16.	Black Bittern	*Ixobrychus flavicollis*	Shy shore-bird. Tall reeds and grass in shallow water.	Fish, frogs & aquatic invertebrates.
17.	Yellow Bittern	*Ixobrychus sinensis*	Shy shore-bird. Tall reeds and grass in shallow water.	Fish, frogs & aquatic invertebrates.
	Storks	**Ciconiidae**		
18.	Painted Stork	*Mycteria leucocephala*	Shore-bird, wading in shallow water. Open water, water-logged grass. Trees.	Mainly fish. Reptiles, frogs & aquatic invertebrates.
19.	Woolly-necked Stork	*Ciconia episcopus*	Shore-bird, wading in shallow water. Open water, water-logged grass. Non-breeding migrant.	Mainly fish. Reptiles, frogs & aquatic invertebrates.
20.	White Stork	*Ciconia ciconia*	Shore-bird, wading in shallow water. Open water, water-logged grass. Non-breeding winter migrant.	Mainly fish. Reptiles, frogs & aquatic invertebrates.
21.	Asian Openbill-Stork	*Anastomus oscitans*	Shore-bird, wading in shallow water. Open water, water-logged grass. Trees.	Mainly snails. Frogs, crabs and other aquatic invertebrates.
	Ibises & Spoonbills	**Threskiornithidae**		
22.	Oriental White Ibis	*Threskiornis melanocephalus*	Shore-bird, wading in shallow water. Open water, water-logged grass. Trees.	Fish, frogs & aquatic invertebrates.
23.	Glossy Ibis	*Plegadis falcinellus*	Shore-bird, wading in shallow water. Open water, water-logged grass & floating vegetation. Trees.	Frogs, tadpoles & aquatic invertebrates.

S. No.	Common Name	Family/Scientific Name	Habit & Habitat (feeding, resting & nesting)	Food requirement
24.	Eurasian Spoonbill	*Platalea leucorodia*	Shore-bird, wading in shallow water. Open water, water-logged grass. Trees.	Fish, frogs & aquatic invertebrates.
	Flamingoes	**Phoenicopteridae**		
25.	Greater Flamingo	*Phoenicopterus roseus*	Flocking bird, wading in shallow water. Open water, silt & mud. Mudflats. Non-breeding winter migrant.	Aquatic invertebrates.
	Geese & Ducks	**Anatidae**		
26.	Spot-billed Duck	*Anas poecilorhyncha*	Non-diving duck. Swimming & up-ending. Shallow, open water. Floating vegetation & reeds. Rocks & mud-banks.	Mainly aquatic vegetation and seeds. Aquatic invertebrates occasional.
27.	Northern Pintail	*Anas acuta*	Non-diving duck. Swimming & up-ending. Shallow, open water. Floating vegetation & reeds. Rocks and mud-banks. Non-breeding winter migrant.	Submerged aquatic plants. Rice. Seeds. Aquatic invertebrates.
28.	Common Teal	*Anas crecca*	Non-diving duck. Swimming & up-ending. Shallow, open water. Floating vegetation & reeds. Rocks & mud-banks. Non-breeding winter migrant.	Submerged aquatic plants. Rice. Seeds. Aquatic invertebrates.

S. No.	Common Name	Family/Scientific Name	Habit & Habitat (feeding, resting & nesting)	Food requirement
29.	Garganey	*Anas querquedula*	Non-diving duck. Swimming & up-ending. Shallow, open water. Floating vegetation & reeds. Rocks and mud-banks. Non-breeding winter migrant.	Submerged aquatic plants. Rice. Seeds. Aquatic invertebrates.
30.	Northern Shoveller	*Anas clypeata*	Non-diving duck. Swimming & up-ending. Shallow, open water. Floating vegetation & reeds. Rocks and mud-banks. Non-breeding winter migrant.	Submerged aquatic plants. Rice. Seeds. Aquatic invertebrates.
31.	Ruddy Shelduck	*Tadorna ferruginea*	Non-diving duck. Shallow, open water. Floating vegetation & reeds. Rocks and mud-banks. Non-breeding winter migrant.	Submerged aquatic plants. Rice. Seeds. Aquatic invertebrates.
32.	Comb Duck	*Sarkidiornis melanotos*	Non-diving duck. Shallow, open water. Floating vegetation & reeds. Rocks and mud-banks. Non-breeding migrant.	Submerged aquatic plants. Rice. Seeds. Aquatic invertebrates.
33.	Fulvous Whistling Duck	*Dendrocygna bicolor*	Non-diving duck. Shallow, open water. Floating vegetation & reeds. Rocks and mud-banks. Non-breeding migrant.	Submerged aquatic plants. Rice. Seeds. Aquatic invertebrates.

S. No.	Common Name	Family/Scientific Name	Habit & Habitat (feeding, resting & nesting)	Food requirement
34.	Lesser Whistling Duck	*Dendrocygna javanica*	Non-diving duck. Shallow, open water. Floating vegetation & reeds. Rocks and mud-banks. Trees.	Submerged aquatic plants. Rice. Seeds. Aquatic invertebrates.
	Hawks, Eagles, Buzzards, Vultures, Kites, Harriers	**Accipitridae**		
35.	Osprey	*Pandion haliaetus*	Fishing predator. Open water. Trees. Non-breeding winter migrant.	Fish.
36.	Black-shouldered Kite	*Elanus caeruleus*	Hunting predator. Open grasslands. Trees.	Insects. Lizards. Small rodents.
37.	Black Kite	*Milvus migrans*	Scavenging predator. Open grasslands. Trees.	Dead animals. Insects. Rodents. Chicken. Chicks of other birds.
38.	Brahminy Kite	*Haliastur indus*	Hunting predator. Open water. Trees.	Fish. Small rodents. Chicken. Chicks of other birds.
39.	Shikra	*Accipiter badius*	Hunting predator. Groves & trees.	Birds, rodents, lizards, frogs & insects.
40.	Marsh Harrier	*Circus aeruginosus*	Hunting predator. Open water, reeds and floating vegetation. Non-breeding winter migrant.	Wetland birds. Fish, frogs, mice & large insects.
41.	Pallid Harrier	*Circus macrourus*	Hunting predator. Open grasslands & scrub. Non-breeding winter migrant.	Terrestrial vertebrates. Large insects.

S. No.	Common Name	Family/Scientific Name	Habit & Habitat (feeding, resting & nesting)	Food requirement
42.	Booted Eagle	*Hieraaetus pennatus*	Hunting predator. Open grasslands & scrub. Non-breeding winter migrant.	Terrestrial vertebrates. Large insects.
	Falcons	**Falconidae**		
43.	Common Kestrel	*Falco tinnunculus*	Hunting predator. Grasslands. Non-breeding winter migrant.	Lizards, small rodents, frogs, insects and occasionally chicks of ground-nesting birds.
	Pheasants, Partridges, Quails	**Phasianidae**		
44.	Grey Francolin	*Francolinus pondicerianus*	Ground dweller. Open grasslands, fallow lands.	Fruits, seeds & insects.
	Rails, Crakes, Moorhens, Coots	**Rallidae**		
45.	White-breasted Waterhen	*Amaurornis phoenicurus*	Shore-bird. Marsh with grass and reeds. Floating vegetation.	Aquatic plants, seeds. Insects and other aquatic invertebrates.
46.	Slaty-breasted Rail	*Gallirallus striatus*	Shore-bird. Marsh with grass and reeds. Floating vegetation.	Aquatic plants, seeds. Insects and other aquatic invertebrates.
47.	Watercock	*Gallicrex cinerea*	Shore-bird. Marsh with grass and reeds. Floating vegetation.	Aquatic plants, seeds. Insects and other aquatic invertebrates.
48.	Purple Moorhen	*Porphyrio porphyrio*	Shore-bird. Marsh with grass and reeds. Floating vegetation.	Aquatic plants, seeds. Insects and other aquatic invertebrates.
49.	Common Moorhen	*Gallinula chloropus*	Shore-bird. Marsh with grass and reeds. Floating vegetation.	Aquatic plants, seeds. Insects and other aquatic invertebrates.

S. No.	Common Name	Family/Scientific Name	Habit & Habitat (feeding, resting & nesting)	Food requirement
50.	Common Coot	*Fulica atra*	Swimming bird. Open water. Marsh with grass and reeds. Floating vegetation.	Aquatic plants, seeds. Insects and other aquatic invertebrates.
	Jacanas	**Jacanidae**		
51.	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	Leaf-walking birds. Floating vegetation. Water lilies, lotus.	Aquatic plants, seeds. Insects and other aquatic invertebrates.
	Coursers & Pratincoles	**Glareolidae**		
52.	Oriental Pratincole	*Glareola maldivarum*	Shorebird. Open water, mudflats. Non-breeding migrant.	Insects.
	Lapwings	**Charadriidae**		
53.	Red-wattled Lapwing	*Vanellus indicus*	Shore-bird. Wet mudflats, sand banks and grass. Rocks. Ground nesting.	Insects and soil invertebrates.
54.	Yellow-wattled Lapwing	*Vanellus malabaricus*	Shore-bird. Dry sandy shores & short-grass/meadows. Ground nesting.	Insects and soil invertebrates.
55.	Grey-headed Lapwing	*Vanellus cinereus*	Wading shore-bird. Wet mudflats, sand banks and grass. Rocks. Non-breeding winter migrant.	Insects and soil invertebrates.
56.	Little Ringed Plover	*Charadrius dubius*	Shore-bird. Dry sandy shores & short grass meadows.	Insects and soil invertebrates.

S. No.	Common Name	Family/Scientific Name	Habit & Habitat (feeding, resting & nesting)	Food requirement
57.	Grey Plover	*Pluvialis squatarola*	Wading shore-bird. Wet mudflats & short-grass/meadows. Non-breeding winter migrant.	Aquatic insects and other mud invertebrates.
	Sandpipers, Stints, Snipes, Godwits & Curlews	**Scolopacidae**		
58.	Eurasian Curlew	*Numenius arquata*	Wading shore-bird. Wet mudflats & short-grass/meadows. Non-breeding winter migrant.	Aquatic insects and other mud invertebrates.
59.	Black-tailed Godwit	*Limosa limosa*	Wading shore-bird. Wet mudflats & short-grass/meadows. Non-breeding winter migrant.	Aquatic insects and other mud invertebrates.
60.	Common Snipe	*Gallinago gallinago*	Wading shore-bird. Wet grass, water-logged reed-beds. Non-breeding winter migrant.	Worms, larvae and other soil invertebrates.
61.	Spotted Redshank	*Tringa erythropus*	Wading shore-birds. Wet mud-flats. Shallow puddles. Non-breeding winter migrant.	Worms, larvae and other soil invertebrates.
62.	Marsh Sandpiper	*Tringa stagnatilis*	Wading shore-birds. Wet mud-flats. Shallow puddles. Non-breeding winter migrant.	Worms, larvae and other soil invertebrates.
63.	Wood Sandpiper	*Tringa glareola*	Wading shore-birds. Wet mud-flats. Shallow puddles. Non-breeding winter migrant.	Worms, larvae and other soil invertebrates.
64.	Green Sandpiper	*Tringa ochropus*	Wading shore-birds. Wet mud-flats. Shallow puddles. Non-breeding winter migrant.	Worms, larvae and other soil invertebrates.

S. No.	Common Name	Family/Scientific Name	Habit & Habitat (feeding, resting & nesting)	Food requirement
65.	Common Sandpiper	*Tringa hypoleucos*	Wading shore-birds. Wet mud-flats. Shallow puddles. Non-breeding winter migrant.	Worms, larvae and other soil invertebrates.
66.	Little Stint	*Calidris minuta*	Wading shore-birds. Wet mud-flats. Shallow puddles. Non-breeding winter migrant.	Worms, larvae and other soil invertebrates.
67.	Great Knot	*Calidris tenuirostris*	Wading shore-birds. Wet mud-flats. Shallow puddles. Non-breeding winter migrant.	Worms, larvae and other soil invertebrates.
68.	Ruff	*Philomachus pugnax*	Wading shore-birds. Wet mud-flats. Shallow puddles. Non-breeding winter migrant.	Worms, larvae and other soil invertebrates.
	Stilt & Avocet	**Recurvirostridae**		
69.	Black-winged Stilt	*Himantopus himantopus*	Wading shore-bird. Shallow open water. Mud-flats. Floating vegetation.	Soil invertebrates. Seeds.
70.	Pied Avocet	*Recurvirostra avosetta*	Wading shore-birds. Shallow open water. Wet mud-flats. Shallow puddles. Non-breeding winter migrant.	Aquatic and mud invertebrates.
	Painted Snipe	**Rostratulidae**		
71.	Greater Painted Snipe	*Rostratula benghalensis*	Shy wading birds. Shallow water. Dense reeds.	Aquatic insects and soil invertebrates.
	Thick-knees	**Burhinidae**		
72.	Eurasian Thick-knee	*Burhinus oedicnemus*	Crepuscular ground bird. Dry scrub and rocky open spaces.	Insects and other invertebrates.

S. No.	Common Name	Family/Scientific Name	Habit & Habitat (feeding, resting & nesting)	Food requirement
	Gulls & Terns	**Laridae**		
73.	Gull-billed Tern	*Sterna nilotica*	Hunting aquatic birds. Open water. Non-breeding winter migrant.	Fish.
74.	Lesser Crested Tern	*Sterna bengalensis*	Hunting aquatic birds. Open water. Non-breeding winter migrant.	Fish.
75.	Little Tern	*Sterna albifrons*	Hunting aquatic birds. Open water. Non-breeding winter migrant.	Fish.
76.	Black-bellied Tern	*Sterna acuticauda*	Hunting aquatic birds. Open water. Non-breeding migrant.	Fish.
77.	Whiskered Tern	*Chlidonias hybridus*	Hunting aquatic birds. Open water. Non-breeding migrant.	Fish.
78.	White-winged Tern	*Chlidonias leucopterus*	Hunting aquatic birds. Open water. Non-breeding winter migrant.	Fish.
	Pigeons & Doves	**Columbidae**		
79.	Blue Rock Pigeon	*Columba livia*	Ground-feeding birds. Dry sand beds, short-grass/meadows. Built spaces.	Grains and seeds.
80.	Spotted Dove	*Streptopelia chinensis*	Ground-feeding birds. Dry sand beds, short-grass/meadows. Trees.	Grains and seeds.
	Parakeets	**Psittacidae**		
81.	Rose-ringed Parakeet	*Psittacula krameri*	Arboreal birds. Trees.	Fruits. Seeds & nectar.

S. No.	Common Name	Family/Scientific Name	Habit & Habitat (feeding, resting & nesting)	Food requirement
	Cuckoos, Malkohas & Coucals	**Cuculidae**		
82.	Pied Crested Cuckoo	*Clamator jacobinus*	Arboreal birds. Trees. Thickets. Parasitic breeders. Presence of host birds – Babblers.	Fruits, insects.
83.	Common Hawk Cuckoo	*Hierococcyx varius*	Arboreal birds. Trees. Thickets. Parasitic breeders. Presence of host birds – Babblers.	Fruits, insects.
84.	Asian Koel	*Eudynamys scolopacea*	Arboreal birds. Trees. Thickets. Parasitic breeders. Presence of host birds – Crows.	Fruits, insects.
	Barn Owls	**Tytonidae**		
85.	Barn Owl	*Tyto alba*	Nocturnal predator. Built spaces.	Rodents. Small birds.
	Owls	**Strigidae**		
86.	Spotted Owlet	*Athene brama*	Nocturnal predator. Built spaces. Dead tree. Tall trees.	Insects, frogs and small lizards.
	Swifts	**Apodidae**		
87.	Asian Palm-Swift	*Cypsiurus balasiensis*	Aerial insect-eating birds. Palms – Palmyra.	Flying insects and midges.
88.	House Swift	*Apus affinis*	Aerial insect-eating birds. Built spaces.	Flying insects and midges.
	Kingfishers	**Alcedinidae**		
89.	Small Blue Kingfisher	*Alcedo atthis*	Small hunting birds. Shallow water with stumps and perches. Mud-banks for nesting.	Fish and aquatic insects.

S. No.	Common Name	Family/Scientific Name	Habit & Habitat (feeding, resting & nesting)	Food requirement
90.	Black-capped Kingfisher	*Halcyon pileata*	Hunting birds. Shallow water with stumps and perches. Non-breeding migrant.	Fish, frogs, lizards, small snakes and insects.
91.	White-breasted Kingfisher	*Halcyon smyrnensis*	Hunting birds. Grass meadows. Shallow water with stumps and perches. Dead trees and mud-banks for nesting.	Fish, frogs, lizards, small snakes and insects.
92.	Lesser Pied Kingfisher	*Ceryle rudis*	Fishing birds. Open water. Perches. Earth banks for nesting.	Fish.
	Bee-eaters	**Meropidae**		
93.	Small Bee-eater	*Merops orientalis*	Arboreal insect-eating birds. Trees. Low perches. Earth-banks for nesting.	Flying insects.
94.	Blue-tailed Bee-eater	*Merops philippinus*	Arboreal insect-eating birds. Trees. Low perches. Earth-banks for nesting.	Flying insects.
	Rollers	**Coraciidae**		
95.	Indian Roller	*Coracias benghalensis*	Arboreal hole-nesting birds that feed on ground. Trees. Perches. Old trees and palms for nesting.	Insects. Small vertebrates.
	Hoopoes	**Upupidae**		
96.	Common Hoopoe	*Upupa epops*	Ground-feeding hole-nesting bird. Trees. Built spaces.	Soil insects.

S. No.	Common Name	Family/Scientific Name	Habit & Habitat (feeding, resting & nesting)	Food requirement
	Woodpeckers	**Picidae**		
97.	Golden-backed Woodpecker	*Dinopium benghalense*	Arboreal hole-nesting birds. Trees. Dead trunks and branches.	Insects. Fruits and nectar.
	Pittas	**Pittidae**		
98.	Indian Pitta	*Pitta brachyura*	Non-breeding ground bird. Winter migrant. Trees. Thickets.	Soil invertebrates.
	Larks	**Alaudidae**		
99.	Ashy-crowned Sparrow-Lark	*Eremopterix grisea*	Small ground-dwelling birds. Grass meadows. Low perches.	Grass seeds and soil insects.
100.	Syke's Lark	*Galerida deva*	Small ground-dwelling birds. Grass meadows. Low perches.	Grass seeds and soil insects.
101.	Eurasian Skylark	*Alauda gulgula*	Small ground-dwelling birds. Grass meadows. Low perches.	Grass seeds and soil insects.
102.	Rufous-winged Bush lark	*Mirafra assamica*	Small ground-dwelling birds. Grass meadows. Low perches.	Grass seeds and soil insects.
	Swallows & Martins	**Hirundinidae**		
103.	Common Swallow	*Hirundo rustica*	Non-breeding aerial feeding bird. Winter migrant. Bare trees, overhead lines, fences.	Flying insects.
104.	Wire-tailed Swallow	*Hirundo smithii*	Aerial feeding birds. Overhead wires and fences. migrant.	Flying insects.

S. No.	Common Name	Family/Scientific Name	Habit & Habitat (feeding, resting & nesting)	Food requirement
	Wagtails & Pipits	**Motacillidae**		
105.	Large Pied Wagtail	*Motacilla maderaspatensis*	Ground-feeding birds. Meadows and moist soil. Rocks, walls and culverts for nesting.	Insects.
106.	Yellow Wagtail	*Motacilla flava*	Ground-feeding non-breeding winter migrants. Wet grass and shallow pools.	Insects.
107.	Richard's Pipit	*Anthus richardi*	Ground-feeding non-breeding winter migrants. Short-grass meadows.	Insects. Grass seeds.
108.	Paddyfield Pipit	*Anthus rufulus*	Ground-feeding birds. Short-grass meadows.	Insects. Grass seeds.
	Bulbuls	**Pycnonotidae**		
109.	Red-vented Bulbul	*Pycnonotus cafer*	Arboreal birds. Thickets, trees.	Insects. Small fruits.
110.	Red-whiskered Bulbul	*Pycnonotus jocosus*	Arboreal birds. Thickets, trees.	Insects. Small fruits.
111.	White-browed Bulbul	*Pycnonotus luteolus*	Arboreal birds. Thickets, trees.	Insects. Small fruits.
	Thrushes, Robins,	**Turdinae**		
112.	Orange-headed Thrush	*Zoothera citrina*	Ground-feeding arboreal birds. Trees, thickets. Non-breeding migrants.	Insects & soil invertebrates.

S. No.	Common Name	Family/Scientific Name	Habit & Habitat (feeding, resting & nesting)	Food requirement
	Robins and Bushchat	**Muscicapidae**		
113.	Oriental Magpie-Robin	*Copsychus saularis*	Ground-feeding arboreal birds. Trees, thicket. Meadows and scrub. Built spaces.	Insects.
114.	Pied Bush chat	*Saxicola caprata*	Ground-feeding arboreal birds. Trees, thicket. Meadows and scrub. Built spaces.	Insects.
	Babblers	**Timaliinae**		
115.	White-headed Babbler	*Turdoides affinis*	Ground-feeding arboreal birds. Trees, thickets. Scrub.	Insects. Small fruits. Nectar. Small lizards.
	Prinias, Warblers	**Sylviinae**		
116.	Plain Prinia	*Prinia inornata*	Bush-dwelling birds. Scrub. Thickets. Tall grass.	Insects.
117.	Ashy Prinia	*Prinia socialis*	Bush-dwelling birds. Scrub. Thickets. Tall grass.	Insects.
118.	Blyth's Reed-Warbler	*Acrocephalus dumetorum*	Bush-dwelling birds. Scrub. Thickets. Tall grass. Non-breeding winter migrant.	Insects.
119.	Clamorous Warbler	*Acrocephalus stentoreus*	Reed-dwelling wetland birds. Tall grass.	Insects.
120.	Common Tailorbird	*Orthotomus sutorius*	Canopy and bush-dwelling birds. Scrub. Thickets. Tall grass. Trees.	Insects.

S. No.	Common Name	Family/Scientific Name	Habit & Habitat (feeding, resting & nesting)	Food requirement
	Cisticolas	**Cisticolinae**		
121.	Zitting Cisticola	*Cisticola juncidis*	Ground-feeding birds. Tall grass, reeds and floating vegetation.	Insects.
	Sunbirds	**Nectariniidae**		
122.	Purple-rumped Sunbird	*Nectarinia zeylonica*	Arboreal birds. Trees, thickets.	Nectar. Insects.
123.	Loten's Sunbird	*Nectarinia lotenia*	Arboreal birds. Trees, thickets.	Nectar. Insects.
	Munias (Estrildid Finches)	**Estrildinae**		
124.	Black-headed Munia	*Lonchura malacca*	Arboreal ground-feeding birds. Thickets. Scrub. Grass and reeds.	Seeds and grains.
	Sparrows	**Passerinae**		
125.	House Sparrow	*Passer domesticus*	Arboreal ground-feeding birds. Built spaces. Trees. Grass meadows. Fallows.	Grains. Insects.
	Weavers	**Ploceinae**		
126.	Streaked Weaver	*Ploceus manyar*	Arboreal ground-feeding birds. Reeds. Marshes.	Grains. Insects.
	Starlings & Mynas	**Sturnidae**		
127.	Brahminy Starling	*Sturnus pagodarum*	Arboreal ground-feeding birds. Trees. Meadows.	Insects. Small fruits. Nectar.
128.	Common Myna	*Acridotheres tristis*	Arboreal ground-feeding birds. Trees. Built spaces. Meadows.	Insects. Small lizards. Fruits. Nectar.

S. No.	Common Name	Family/Scientific Name	Habit & Habitat (feeding, resting & nesting)	Food requirement
129.	Rosy Starling	*Sturnus roseus*	Arboreal birds. Non-breeding winter migrants. Trees. Crops.	Seeds. Nectar.
	Orioles	**Oriolidae**		
130.	Eurasian Golden Oriole	*Oriolus oriolus*	Arboreal non-breeding winter migrant. Trees.	Insects. Nectar.
	Drongos	**Dicruridae**		
131.	Black Drongo	*Dicrurus macrocercus*	Arboreal birds. Trees. Stumps. Fallows.	Insects. Nectar.
	Wood-swallows	**Artamidae**		
132.	Ashy Wood-swallow	*Artamus fuscus*	Arboreal aerial feeding birds. Trees. Palmyra palms.	Insects.
	Crows, Jays, Treepie	**Corvidae**		
133.	Indian Treepie	*Dendrocitta vagabunda*	Arboreal birds. Trees.	Fruits. Insects. Eggs and chicks of birds.
134.	House Crow	*Corvus splendens*	Arboreal birds. Trees. Built spaces.	Human wastes. Insects. Fruits. Eggs and chicks of birds. Other small vertebrates. Carcass.
135.	Jungle Crow	*Corvus macrorhynchos*	Arboreal birds. Trees. Built spaces.	Human wastes. Insects. Fruits. Eggs and chicks of birds. Other small vertebrates. Carcass.

11.6 Humans as Wetland Engineers

Biological communities are a natural mix of native species that are specialized habitat users and opportunists. Among opportunists, some tend to be invasive. Due to the longer history of human involvement in the management of freshwater wetlands than other aquatic habitats, the incidence and proliferation of opportunists and invasive species is also higher. The problem of invasive animals, especially fish, are generally more felt in wetlands than rivers, estuaries and other major natural aquatic habitats in India. Humans have also carried with them many species of aquatic plants used as food/fodder, those that are ornamental (example water hyacinth) and also those considered sacred (water lilies and lotus) aiding the widespread colonization of wetlands by a handful of common plants.

Human-aided homogenization of wetlands is seen throughout India and many other parts of South Asia. Wetland birds are in general more mobile than terrestrial birds and this inherent habit and the human-aided homogenization of wetlands have together contributed to the vast home ranges of many species of resident wetland birds. It is important to be aware of this fact, so that frantic reactions to unforeseen declines in diversity and abundance of birds in Pallikarnai Marshland are avoided. The changes may be temporary. However, when there is a consistent decline in the diversity or abundance of common birds is noticed, there is reason to be alarmed.

The general trend in diversity and abundance of birds in the Pallikarnai Marshland since 2002 has been one that is positive. This may be due to the changes in the hydrology, land-water ratio and the resultant vegetation mosaic. Considering the dynamic nature of the surrounding landscape, it is important to monitor not just the diversity and abundance of birds, but also the dynamics of micro-habitats within the protected area and the shifting mosaics of major habitats in the entire watershed-landscape that sustains the marshland.

Topographic changes brought about by construction activities in the landscape have shrunk the water-spread of the marshland. Parts of the marshland that were historically dry during summer (as inferred from the Survey of India topographic maps prepared before 1970) are now wet and locally water-logged or under deeper water. Deep water that does not flow is vulnerable to eutrophication. Further, the high-rise buildings that surround the marshland create a new light-shade regime and interfere with the wind movement leading to changes in the water temperature and oxidation. This is a long-term concern and may be responsible for major changes in the water quality, fish and the entire food web.

Tree-cover within the watershed-landscape needs to be carefully assessed and monitored. One general and consistent observation is that fish-eating birds (especially the large-bodied) have increased in abundance in the last 10 years. Fish-eating birds (with the exception of seabirds, gulls and terns) normally roost and breed in trees. Human-aided increase in tree biomass in and in and around wetlands has proven to attract fish-eating birds like pelicans, storks, ibises, herons, egrets and cormorants. The already existing tree cover especially that in Nanmangalam RF, IIT Madras and Guindy National Park, the NIOT Campus complemented by that within the many newly established residential and commercial complexes and the roadside planting of trees will in the long-term increase the tree biomass within the watershed-landscape. Such a change, while in favour of fish-eating birds may have an adverse impact on the many species of trans-boundary migratory ducks and shorebirds.

11.7 Restoration Planning with Birds as the Flagship

One of the best known functions of wetlands is to provide a habitat for birds. Wetlands are important bird habitats, and birds use them for breeding, nesting, and rearing young. **The highest number of waterbirds is often found in wetlands which also have the greatest diversity of plant species and vegetation types, or where there is permanent water.** Birds also use wetlands as a source of drinking water and for feeding, resting, shelter, and social interactions. Some waterfowl, such as Grebes, have adapted to wetlands to such an extent that their survival as individual species depends on the availability of certain types of wetlands within their geographic range. Other species, such as the Northern Pintail use wetlands only during some parts of their lives. Wetlands provide a variety of habitats and food sources for birds to live and reproduce. Many waterbirds move regularly to newly flooded habitats to feed and/or breed before a wetland dries down. Some semi-permanent, permanent and coastal wetlands can provide refuge for species when wetlands in other regions are dry for long periods. **Many species depend on particular wetlands, for refuelling and resting, during their long migrations between wetlands.**

The relationship between the wetland and waterfowl populations depends on the following attributes:

1. Number of wetlands in the area
2. Wetlands' size and water depth
3. Whether the wetlands hold open water in the desired seasons
4. Climate
5. Species of bird and the bird's adaptations to wetlands

A diverse community of wetland birds is a good sign. However, community that is dominated by a set of birds belonging to a specialized guild (example fish-eating) will place undue burden on the habitat and the food web. Of the various conservation challenges posed by wetlands, preventing homogenization of micro-habitats and the biological community assumes greater significance.

Well-informed conservation planning is the key to the long-term sustenance of the Pallikarnai Marshland. A natural marsh located in an urban landscape that is highly dynamic will pose a number of foreseen and unforeseen management challenges. The following are some of the key ecological attributes that need to be paid due attention while restoration plans for the wetland are developed and adopted:

- Fragile hydrology governed by the delicate balance in the annual freshwater and saltwater inflows

- Water-land ratio, sedimentation pattern and the shifting mosaics of vegetation, mudflats and shoreline and the impact of the rapidly changing light-shade and wind regime within the watershed-landscape

- Changes in the distribution of terrestrial vegetation within the watershed-landscape and in the tree biomass in and around the marshland
- Shifts in the community organization of wetland birds; the ratio of fish-eating birds and non-fish-eating wetland birds is the key to monitoring the health of the Pallikarnai Marshland

- The underwater food web keeping in view the fish and fish-eating birds as the flagship

- Finally, the ecological resilience of the marshland and the fact that restoration plans and interventions should only boost the natural recovery of the ecological system and not interfere with it.

- Availability of food and shelter for the birds and other life forms is a conservation priority

- Wetlands provide food for birds in the form of plants, vertebrates, and invertebrates. Some feeders forage for food in the wetland soils, some find food in the water column, and some feed on the vertebrates and invertebrates that inhabit submerged and emergent plants. The number of algae and invertebrates in wetlands depends on quality of water, its temperature and amount of sunlight reaching the wetlands.

- Waterbirds depend on free-standing water to feed – by swimming, wading or diving – or to establish nesting sites. These include waterfowl (ducks, geese, and swans), grebes, pelicans, cormorants, ibis, egrets, herons and shorebirds (or waders). Waterbirds use a range of wetland habitats to source a variety of food. This helps meet the specific dietary needs for different waterbird species, with many being either fish-eaters, herbivorous, or invertebrate feeders. Fish-eating birds include some of the larger waterbirds such as pelicans, cormorants, herons and egrets.

- Wetlands with deep, open water attract diving ducks. These birds feed on aquatic plants and animals, particularly freshwater shellfish and mussels. Grazing waterfowl are often found roosting on grassy banks of a wetland or feeding on wetland plants. Reeds and sedges provide cover for shoreline foragers like swamp-hens. Mudflats and shallow water are rich feeding areas for invertebrate feeders such as spoonbills, ibis, stilts and sandpipers.

- The strategy and recommended action for this component is focussed on improving the productivity of the wetland, especially fish. Wetlands in southern India are seasonal. They come to life after the monsoons and dry up in part or full, during the summer months. Seasonal wetland dynamics are synchronized with the breeding of resident and locally migrating birds (example the large wetland birds). The wet-dry dynamics of the habitat are also synchronized with the inter-continental migrants such as many species of ducks, teals, geese, terns and waders. Of these, majority of the birds that breed in the sanctuary are fish-eating.

- Field studies have indicated the overall lack of fish in the waters except for the presence of the Giant African Catfish, a voracious feeder. Since the species is an air-breather, it is capable of surviving even in waters where the BOD is high. The species is known as one of the most aggressive of Invasive Alien Species (IAS) and thus a major competitor with the fish-eating large breeding wetland birds.

- Fish diversity and abundance in the wetland have to be carefully managed so that the breeding birds find adequate food within the sanctuary. For this, it is important that during the dry season, the catfish is harvested and eliminated. Procedures to initiate selective fishing need during summer needs to be initiated; a feasible option would be to dovetail the same into the Eco development activities of the sanctuary.

Wetland vegetation provides shelter from predators and from the weather**.** The presence or absence of shelter may influence whether birds will inhabit a wetland or a nearby upland area. Wetlands form an important buffer or barrier to land-based predators and reduce the risk of predation to nesting or young birds. Many bird species that are highly adapted to feeding in a wetland environment also have adaptations that lower their risk of becoming prey. One such example is the bittern, which has excellent protective coloration.

Management of Eutrophication

Management techniques used for managing eutrophication and improving the water quality in reservoirs include:

i. **Artificial mixing and oxygenation**- Artificial mixing procedures results in oxidation of either a deoxygeneted hypolimnion or the entire waterbody and/or inhibition of phytoplankton growth. Destratification is accomplished by injection of compressed air from a diffuser into water at a reservoir bottom.

ii. **Sediment removal and sediment aeration**- Sediments accumulate phosphorus over long periods of time resulting constant exchange with the adjacent water. As a consequence of the large phosphorus storage in the sediments, eutrophic conditions may continue for several years after phosphorus supply to the reservoir is considerably reduced. Sediment removal consists of the removing the upper layers of sediment that contain high phosphorus levels, however the cost is high.

iii. **Biomanipulation** (fish management)- The principle of the method is food chain manipulation by maintaining low feeding pressure on zooplankton by fish, so that large species of zooplankton predominate that can keep phytoplankton under control. This can be accomplished by maintaining a low number of zooplankton feeding fish by development of fish populations that can control zooplankton and phytoplankton.

iv. **Hydraulic regulation-** This can be achieved by regulating the runoff and discharge from the tank.

v. **Light reduction-** Trees can be planted to enhance shading of the tank and reduce algal bloom.

vi. Macrophyte control and ecoremediation.

Effects of wetland loss and degradation on Birds

For most wetland-dependent birds, habitat loss in breeding areas translates directly into population losses. As a result some birds may move to other less suitable habitats where reproduction tends to be lower and mortality tends to be higher, thereby reducing their contribution to a sustainable population through the years. Degradation of wetlands can occur in various forms of which those pertinent to the Palliakaranai Marsh are summarised as under:

- Amounts and periodicity of water flow being altered.
- The quality of water flowing into and through a wetland is being modified
- The flows of sediments into the wetland are unknown and uncurtailed.
- Water-table fluctuations are intense.
- Wetland vegetation is altered by harvesting or by introducing exotic species, making it of little or no value to wetland-dependent birds
- Chemicals and sediments moving from adjacent agricultural areas into wetlands.

Water Management Implementation Guidelines

- ✓ A long-term strategy or plan should be established to manage water demand so as to achieve water allocations for ecosystems. Water allocations may be achieved in a variety of ways, including flow releases from reservoirs or restrictions to abstraction. In some cases, pumping from groundwater may also be used to augment stream flow. Groundwater extractions to supplement stream flows to wetlands should only be supported where such extraction does not significantly impact on other water-dependent ecosystems and their values.
- ✓ In many cases, where a wetland ecosystem is already impacted, or is threatened by excessive water use or impacts on the water regime, measures to provide water for the wetland ecosystem will have to be phased in gradually over a period of time, in order to avoid serious negative impacts on the local economy.
- ✓ Imposition of water restrictions in order to reduce current levels of demand.
- ✓ Instituting water conservation and demand management programmes in the catchment in order to reduce overall abstraction and ensure that more water is available for the wetland ecosystem.
- ✓ Structural options such as building a dam to store water and make dedicated releases for a wetland ecosystem or inter-basin transfer of water.
- ✓ Rehabilitation of degraded catchment areas, prevention of soil erosion, and removal of alien vegetation which reduces runoff.
- ✓ Allocation of water as closely as possible to the natural regime (of both wetter and drier periods), using natural cues from reference catchments or to meet specific use requirements.
- ✓ Resources should be redirected to supporting change, for example, in agricultural practices, such as using irrigation systems requiring less use of water (for example, drip rather than sprinkler irrigation).
- ✓ Water resource management at the scale of a catchment should not only address managing the wet parts of the system (rivers, lakes and other wetlands) but also needs to incorporate management of terrestrial ecosystems, since inappropriate activities in these systems can impact on water management. Ideally, activities which reduce runoff or cause changes in hydrology, such as commercial forestry, should be considered as water uses and managed as such to ensure truly integrated catchment management.
- ✓ Proper design of storage reservoirs can minimize evaporation losses, whilst the covering, where possible, of open water supply canals and the impervious lining of canals can also reduce water losses due to evaporation, seepage and evapotranspiration.
- ✓ Increase public and stakeholder awareness through the promotion of water conservation and demand management.
- ✓ In cases where water quality has become degraded, it is sometimes possible to divert streamflow or abstract groundwater for treatment and then return the treated water to its original water body.
- ✓ Disseminate real-time information about releases/flow patterns to stakeholders.
- ✓ Adapt management strategies in the light of monitoring and evaluation.

11.8 Pallikaranai Marsh as a Public Space

A 'public space' is a social space that is generally open and accessible to people. Roads (including the pavement), public squares, parks and beaches are typically considered public space. This definition has in recent years been expanded to include nature reserves, protected zones or natural habitats and heritage sites so that the principles of sustainable living or development could become part of everyday living. It is also a fact that to foster a tradition and culture of pro-nature, children and other stakeholders be allowed to experience and appreciate various services provided by nature in the domains of aesthetic, cultural, economic, social and ecological.

Discussions with the senior officials of the District MU at Chennai have revealed that Pallikaranai Marsh would be an ideal site for a public space. Two watch towers have been recently constructed by the Forest Department to make bird watching easier. Visitors are able to walk around the lake on elevated bunds observing colourful butterflies and flight of birds. An interpretation Centre has been constructed to create awareness amongst general public and school children. Binoculars and spotting scopes for the visitors are available with the forest guard for bird watching. Characteristics of a Great Public Space include:

1. Promotes human contact and social activities.
2. Is safe, welcoming, and accommodating for all users.
3. Has design and architectural features that are visually interesting.
4. Promotes community involvement.
5. Reflects the local culture or history.
6. Relates well to bordering uses.
7. Is well maintained.
8. Has a unique or special character, like being a bird sanctuary.

Recommended Strategy and Action

Based on the available conditions, potential upgradation and ecological considerations the following facilities are proposed for Pallikaranai Marsh.

1. Eco tourism

There is much confused and liberal usage of the term ‘ecotourism’, any nature-based activity or destination is labelled as ecotourism. In reality, Ecotourism Is not just about ‘green’ destinations, it is much more about ‘green’ behaviour in reaching and exploring such destinations. The International Ecotourism Society (1991), the world’s largest and oldest ecotourism organisation established in 1990, defines ecotourism as:

‘Responsible travel to natural areas that conserves the environment and improves the welfare of local people’. The IUCN-World Conservation Union (1996) definition of ecotourism, albeit less succinct, makes specific reference to the appreciation of cultural, as well as natural, heritage and to low visitor impact. The definition is as follows: *Environmentally responsible travel to natural areas, in order to enjoy and appreciate nature (and accompanying cultural features, both past and present) that promotes conservation, have a low visitor impact and provide for beneficially active socio-economic involvement of local peoples.* The key components of ecotourism are considered to be as follows (Wood, 2002):

- Contributes to conservation of biodiversity.
- Sustains the well being of local people.
- Includes an interpretation/learning experience.
- Involves responsible action on the part of tourists and the tourism industry.
- Is delivered primarily to small groups by small-scale businesses.
- Requires lowest possible consumption of non-renewable resources.

- Stresses local participation, ownership and business opportunities, particularly for rural people.

Unlike many other forms of sustainable tourism, ecotourism must be rigorously planned and managed to successfully deliver its key ecological and social objectives. This requires:

- Specialised marketing to attract travellers primarily interested in visiting natural areas.
- Management skills, particularly related to handling visitors in protected areas.
- Guiding and interpretation services, preferably provided and managed by local inhabitants, which focus on natural history and sustainable development issues.
- Government policies that earmark fees from tourism to generate funds for both conservation of wild lands and sustainable development of local communities and indigenous people.
- Focused attention on local peoples, who must be given the right of prior informed consent, full participation and, if they so decide, the opportunity and training to engage in this sustainable development option.

A project titled Ribbon Walk has been proposed for Pallikaranai Marsh on the Thoraipakkam – Keelkattalai Radial Road, whose design elements and cost estimates are provided as separate section in the CMP.

11.9 Establishment of a Wetland Centre with a Wetland Monitoring Centre

Ever since the issue of conserving and protecting the Pallikaranai Marsh came into reckoning in the year 2002, a number of researchers and naturalists have been drawn to take up research studies on the marsh. About 52 research studies have been undertaken so far covering various aspects.

The marsh has also attracted the attention of naturalists and popular media with as many as 120 stories / media coverage on various issues pertaining to the marsh.

Since 2007, wherein the southern portion of the marsh was protected and concrete steps were initiated to conserve through dedicated management plans, signs of revival have been witnessed. In view of the fact that the Pallikaranai Marsh serves as a refugium for birds, and a standing example of protecting a wetland situated in the midst of a metropolis, as also a viable example of effective public – government partnership for conservation (the Conservation Authority of Pallikaranai Marsh), it is proposed to develop and construct a dedicated **Wetland Centre (WC) at Pallikaranai Marsh. Key features of the Wetland Centre would include: education and awareness, training and capacity building, research and monitoring.**

Some of the elements in the centre would include:

Learning Gardens

A series of learning gardens can be created to support the educational objectives Native plants enhance circulation pathways. Thematic gardens (such as a medicinal garden) will extend the interest of visitors. The character of the gardens will be naturalistic, containing mostly native plants. Information panels will display information on how to create similar gardens elsewhere.

Environmental Education Centre

In this component, the following features could be considered:

• Native plants garden

• Butterfly garden

• Sound garden

• Sculpture or mural garden

• Rock garden

• Medicinal plant garden

Examples of activities that could be conducted for learner groups and interested public could be

- growing edible plants,
- Creating a native plant garden
- Producing a native plant cookbook
- Studying the food web
- Building an ecological pyramid
- Studying plant genetics
- Developing herbal medicines

Open Interpretation Centre with facilities for day camping

The Open Interpretation Centre and the day camp area should ideally accommodate about 50 children and their teachers or 30 adults at a time. It is a multipurpose area used for learning, appreciation of nature, awareness building, common lectures or school projects. The components that should ideally be part of the OIC are as follows:

• Auditorium / lecture room (indoor presentations, projection room, and virtual field trip)

• Demonstrations / exhibits space with panels for display of birds, bird calls, other forms of life etc. Permanent and seasonal displays and Rotating galleries could also be considered.

• Observation deck (as an elevated bridge with a viewing deck) and three watch towers (including refurbishing the existing towers) fully equipped with one spotting scope/tower and three binoculars / tower.

• Multipurpose space (for meetings, community workshops, etc.)

• Library / resource area

• Information desk area

• Gift or souvenir shop

• Snack bar / vending / outdoor eating

• Washing room, or wet lab (sinks and non-carpeted floors)

• Office for the staff

• Restrooms and Solid waste and sewage management centre

- Check out point for trays, binoculars, charts, cameras
- Guard station (full time staff monitoring, controlling trail lighting, infrared night goggles)
- First aid station
- Construction of a compound wall on the front road side portion of the sanctuary with a gate
- Chain-link fencing along the bounding

Trails

The system of trails encourages visitors to explore the site. The trails offer an unusual variety of spaces that encourage visitors to exercise in the fresh air and, at the same time, to learn about the inequitable environmental qualities of the site. The sensory path adds interest to the system of trails. Plants and flowers (with different textures, fragrances, and colours), rocks, and ground surfaces border the path. It is especially stimulating for people with disabilities.

Some of the elements could be

- Boardwalk along the creek
- Meadow trail
- Animal Track Prints Pathway
- Sensory Path
- Rope walk
- Ephemeral art projects
- Team building activities
- Building birdhouses and bird baths
- Creating sculptures from waste material

Wetland Monitoring Centre

The Wetland Monitoring Centre within the WC will be the hub for undertaking research and monitoring the marsh. Wetland monitoring systems should build upon the information provided in wetland inventory and assessment activities. Specific monitoring should be based on a hypothesis derived from the assessment data and be contained within a suitable management structure. Predicted impacts on biodiversity should be monitored, as should the effectiveness of mitigation measures proposed in the environmental impact assessment. Proper environmental management should ensure that anticipated impacts are maintained within predicted levels, that unanticipated impacts are managed before they become a problem, and that the expected benefits are achieved as the project proceeds. The results of monitoring provide information for periodic review and alteration of environmental management plans, and for optimising environmental protection through good practice at all stages of the project. The proposed features of the centre include:

Weather Station

Monitoring the weather, downloading the information in a database, and interpreting the findings interweave many student skills. Schools in and around Kanchipuram and Chennai will have daily access to the station to conduct weather studies. Some of the activities of the feature could be

1. Documentation of seasonal changes
2. Monitoring daily max-min temperatures
3. Study of rainfall / drought impact on wetlands
4. Charting wind direction and speed
5. Downloading and interpreting data on computer

Wetlands Study Station

The Wetlands Study Stations offer three settings for experiential learning on wetlands behaviour, water quality, and the indivisible link between wetlands and habitat conservation. Some of the activities could include: Hydrological studies of water bodies, water quality test, soil test, stream invertebrate study, bird census and ornithological studies, erosion control study etc. The Wetland Study Station could be part of the Open Interpretation Centre and also be supported by air-boats or paddle boats.

Research Interface

To evolve as a pioneering centre for research on wetlands, the following themes and topics are being suggested to be taken up by the TNFD as research studies. It is also realised that this requires the appointment of in house researchers especially in biology and ecology.

1. **Integration of wetlands within the landscape matrix.** Often, studies of habitats have focused only on the individual habitat type. Further, information regarding differential use of wetland types by wetland-dependent species is lacking. Little attempt has been made to determine how the combination of various wetland or habitat types affects their respective uses by wildlife.
2. **Regional and national monitoring of populations**. Breeding locations of most waterfowl have to be identified as part of the regular inventory. Inventories should be supported to determine waterbird status in critical wetlands, especially for little-studied species.
3. **Fragmentation effects** Research is required to investigate how changing sizes and patterns of distinct wetlands affect their use by a variety of wetland birds.

Some of the longitudinal studies and the methodological framework could be:

The hierarchical approach to wetland inventory

Level 1 – desk study to describe the broad geologic, climatic and ecological features of each geographic region using existing datasets, increasingly available on the Internet

Level 2 – desk study to identify the wetland regions within each geographic region using the information already collated on geology, climate, hydrology, and vegetation

Level 3 – fieldwork and analysis to identify the physical, physico-chemical and biological features of wetland complexes within each wetland region; and

Level 4 – detailed fieldwork and analysis to describe the physical, physicochemical and biological features of each wetland habitat within each wetland complex. This includes information on plant and animal assemblages and species, land and water use and wetland management.

Types of Assessments

Rapid assessment of wetlands is an approach which, depending on the purpose of the assessment, involves where the methods are adapted to permit the adequate collection, analysis and presentation of the assessment information when this information is urgently needed. It may also involve the rapid collection of 'baseline' wetland inventory information. Rapid assessment methods can be particularly useful in the assessment of the impacts of natural disasters such as storm surges, tsunamis and hurricanes. The guidance recognizes that the purposes for rapid assessment of wetlands include:

a) collecting general biodiversity data in order to inventory and prioritize wetland species, communities and ecosystems; obtaining baseline biodiversity information for a given area;
b) gathering information on the status of a focus or target species (such as threatened species); collecting data pertaining to the conservation of a specific species;
c) gaining information on the effects of human or natural disturbance (changes) on a given area or species;
d) gathering information that is indicative of the general ecosystem health or condition of a specific wetland ecosystem; and
e) Determining the potential for sustainable use of biological resources in a particular wetland ecosystem.

Indicator assessment The development and use of indicators is designed to assess temporal patterns in the status and trends of ecosystems, habitats and species, the pressures and threats they face, and the responses made to address these pressures and threats. Such indicators are not designed to provide a complete and comprehensive assessment of all aspects of wetland ecosystems and their dynamics: rather they are intended to give a series of related pictures of these patterns, in order to guide further design and the focusing of decision-making for addressing unwanted change. Such indicators are also generally components of hypothesis-driven wetland monitoring programmes. Indicators are:

- The overall conservation status of wetlands
- The status of the ecological character of sites
- Trends in water quality
- The frequency of threats
- Wetland sites with successfully implemented conservation or wise use management plans
- Overall population trends of wetland taxa
- Changes in threat status of wetland taxa

Environmental Impact Assessment is a process of evaluating the likely environmental impacts of a proposed project or development, taking into account interrelated socio-economic, cultural and human-health impacts, both beneficial and adverse.

Vulnerability and Risk Assessments help define baselines, tolerance limits and other elements to feed into Environmental Impact Assessment, as well as potential measures for reducing the risk of wetland degradation. Vulnerability assessment determines the extent to which a wetland is susceptible to, or unable to cope with, adverse effects of climate change and variability and other pressures, such as changes in land use and cover, water regime, or over-harvesting and over-exploitation, and invasion by alien species.

These pressures can act individually, cumulatively or synergistically. Vulnerability is determined at specific spatial and temporal scales and is a dynamic property as it changes depending on the local conditions, e.g., a system can be vulnerable at a particular time but may not be at other times (e.g., vulnerability to fire increases during dry seasons). Steps involved are,

i. Identification of the problem- site-specific information on stressor and environment
ii. Identification of the adverse effects- field assessment: e.g., bioassays, monitoring, surveys, etc.
iii. Identification of the extent of the problem- e.g., chemical concentrations

iv. Identification of the risk- comparison of effects with the extent of exposure using a GIS framework
v. Risk management and reduction manage inputs / alter practices
vi. Monitoring- use of early warning and rapid assessment indicators / GIS based approach.

Wetland Valuation provides information on the value (importance) of wetlands and their services to different stakeholders, so as to ensure that balanced decision-making occurs about competing uses of wetlands. Such information has often not fully been taken into account in the past when making decisions about economic development. Valuation has been defined by the *Millennium Ecosystem Assessment* as “The process of expressing a value for a particular good or service . . . in terms of something that can be counted, often money, but also through methods and measures from other disciplines.

A structured framework for planning a wetland inventory

Step	Guidance
1. State the purpose and objective	State the reason(s) for undertaking the inventory and why the information is required, as the basis for choosing a spatial scale and minimum data set.
2. Review existing knowledge and information	Review the published and unpublished literature and determine the extent of knowledge and information available for wetlands in the region being considered.
3. Review existing inventory methods	Review available methods and seek expert technical advice to: a) choose the methods that can supply the required information; and b) ensure that suitable data management processes are established.
4. Determine the scale and resolution	Determine the scale and resolution required to achieve the purpose and objective defined in Step 1.
5. Establish a core or minimum data set	Identify the core, or minimum, data set sufficient to describe the location and size of the wetland(s) and any special features. This can be complemented by additional information on factors affecting the ecological character of the wetland(s) and other management issues, if required.
6. Establish a habitat classification	Choose a habitat classification that suits the purpose of the inventory, since there is no single classification that has been globally accepted.
7. Choose an appropriate method	Choose a method that is appropriate for a specific inventory based on an assessment of the advantages and disadvantages, and costs and benefits, of the alternatives.
8. Establish a data management system	Establish clear protocols for collecting, recording and storing data, including archiving in electronic or hardcopy formats. This should enable future users to determine the source of the data, and its accuracy and reliability. At this stage it is also necessary to identify suitable data analysis methods. All data analysis should be done by rigorous and tested methods and all information documented. The data management system should support, rather than constrain, the data analysis. A meta-database should be used to: a) record information about the inventory datasets; and b) outline details of data custodianship and access by other users.

9. Establish a time schedule and the level of resources that are required	Establish a time schedule for: a) planning the inventory; b) collecting, processing and interpreting the data collected; c) reporting the results; and d) regular review of the program. Establish the extent and reliability of the resources available for the inventory. If necessary make contingency plans to ensure that data is not lost due to insufficiency of resources.
10. Assess the feasibility & cost effectiveness	Assess whether or not the program, including reporting of the results, can be undertaken within under the current institutional, financial and staff situation. Determine whether the costs of data acquisition and analysis are within budget and that a budget is available for the program to be completed.
11. Establish a reporting procedure	Establish a procedure for interpreting and reporting all results in a timely and cost effective manner. The report should be succinct and concise, indicate whether or not the objective has been achieved, and contain recommendations for management action, including whether further data or information is required.
12. Establish a review and evaluation process	Establish a formal and open review process to ensure the effectiveness of all procedures, including reporting and, when required, supply information to adjust or even terminate the program.
13. Plan a pilot study	Test and adjust the method and specialist equipment being used, assess the training needs for staff involved, and confirm the means of collating, collecting, entering, analysing and interpreting the data. In particular, ensure that any remote sensing can be supported by appropriate "ground-truth" survey.

Core (minimum) data fields for [wetland inventory]

Revised core wetland inventory fields (Harmonized with Ramsar ecological character description sheet)
• Site name: Official name of site and catchment/other identifier(s) (e.g., reference number)
• Area, boundary and dimensions: • Site shape (cross-section and plan view), boundaries, area, area of water/wet area (seasonal max/min where relevant), length, width, depth (seasonal max/min where relevant)
• Location: Projection system, map coordinates, map centroid, elevation
• Geomorphic setting: Setting in the landscape/catchment/river basin - including altitude, upper/lower zone of catchment, distance to coast where relevant, etc.
• Biogeographical region:
• Climate: Overview of prevailing climate type, zone and major features (precipitation, temperature, wind)
• Soil: Geology, soils and substrates; and soil biology
• Water regime: Water source (surface and groundwater), inflow/outflow, evaporation, flooding frequency, seasonality and duration; magnitude of flow and/or tidal regime, links with groundwater
Water chemistry: Temperature; turbidity; pH; colour; salinity; dissolved gases; dissolved or suspended nutrients; dissolved organic carbon; conductivity
• Biota: Plant communities, vegetation zones and structure (including comments on particular rarity, etc); Animal communities (including comments on particular rarity, etc); Main species present (including comments on particular rare/endangered species, etc.); population size and proportion where known, seasonality of occurrence, and approximate position in distribution range (e.g., whether near centre or edge of range)
• Land use: Local, and in the river basin and/or coastal zone
• Pressures and trends: • Concerning any of the features listed above, and/or concerning ecosystem integrity
• Land tenure and administrative authority: • For the wetland, and for critical parts of the river basin and/or coastal zone

Training of professionals: Advanced training is required to understand the ecological processes in wetlands and to understand the significance of wetland complexes over a larger landscape. Geographic information systems can be used as vital tools for managers to learn the basics of ecosystem and landscape management. In addition the frontline staff, in house researchers and the managerial staff should be facilitated to visit other wetlands for hands-on experience and learning.

Additional Factors that need to be monitored

- **Water level control**. If measures to control flooding are conducted in an adhoc manner as in the case of Pallikaranai Marsh, flooding during the nesting season must be avoided, or else birds nesting on the ground or even over water may be flooded out.
- **Control of pesticide use**. Pesticides in wetlands have been known to be lethal. Organochlorine pesticides are known to reduce productivity in birds including waterfowl, terns, gulls, herons or indirectly by affecting the behaviour of adults. Pesticides may also cause pathological conditions in wildlife. Chemicals kill the birds that are natural insect controls as well as kill the insects themselves, reducing the control factor and hastening an outbreak of insects that multiply much faster than the controls.
- **Regulation of human disturbance**. As recreational activities increase, human disturbance also increase which can exert a tremendous influence on some wetland species which require undisturbed habitat for nesting. Uncontrolled livestock grazing also could trample nests and alter vegetation.
- **Public awareness concerning wetlands**. The public must develop an appreciation of wetlands for the many ecological, recreation, aesthetic and ecosystem service values that they provide. Teaching of wetland ecology should be included in school curriculum, and should be part of the outreach effort of every scientist and landscape manager. Training workshops for wetland biologists and managers should be expanded and should include the private

sector. Aquaculturists and rice farmers should be included in the educational process.

- **Ecological assistance.** Assistance in ecological planning for wetland restoration or alteration needs to be institutionalized. As part of the process, regulatory personnel in state governments should require a consult with professional wetland scientists before embarking on large-scale wetland projects such as construction of reservoirs, aquaculture facilities, or irrigation systems.

11.10 Wetland disease management

Disease is a natural component of population ecology and ecosystems and is one mechanism by which population numbers are regulated. However, anthropogenic activities can often create novel disease problems or increases in prevalence and frequency of existing disease tipping a 'balanced' system into one where losses are increased. A broad range of proactive and reactive strategies and practices are available to the wetland managers and other wetland stakeholders to achieve or maintain the health of the ecosystem including:

1. Targeting the environment and land use *e.g*. healthy habitat management including wise use; maintaining appropriate water quality and quantity; reducing risk from pollutants and toxicants; and manipulation of habitat to reduce disease agents or their invertebrate vectors.
2. Targeting host populations *e.g*. maintaining good nutritional status; reducing stressors; managing density of domestic animals and wildlife; reducing contact between domestic animals and wildlife (including zoning); and vaccination or veterinary treatment.
3. Targeting pathogens and parasites *e.g*. managing bio-security; hygiene, disinfection and sanitation; and interrupting transmission by exploiting weaknesses in a parasite's life cycle, such as targeting intermediate hosts and/or their preferred habitat.

Guidelines for disease management in wetlands

- ✓ The appropriate approach to disease management will depend on the characteristics of the problem and, when dealing with an infectious disease, on the correct identification of reservoirs, hosts and vectors of infection. Management measures may target the pathogen, host, vector, environmental factors or human activities. Ultimately, an integrated approach involving several complimentary measures is likely to be most successful in managing diseases in wetlands.

- ✓ Disinfection and sanitation procedures target pathogens and can be very effective at controlling spread of infection but must be used with caution in wetland situations to avoid negative impacts on biodiversity.

- ✓ Animal carcasses represent a significant potential source of infection and require rapid and appropriate collection and disposal. Disposal options are varied and again need to be used with caution in wetland situations to reduce risks of pollution of water courses or further spread of infection.

- ✓ Targeting vectors in integrated disease control strategies can be effective and usually take the form of environmental management, biological controls and/or chemical controls, or actions to reduce the contact between susceptible hosts and vectors. To reduce negative impacts on biodiversity caution must be used when using these measures within wetlands.

- ✓ Vaccination programmes, often supplemented by other disease control measures, can help control and even eliminate diseases affecting livestock. Vaccination of wildlife is feasible but it is often complex - other management strategies may be of greater value.

- ✓ Habitat modification in wetlands can eliminate or reduce the risk of disease, by reducing the prevalence of disease-causing agents, vectors and/or hosts and their contact with one another, through the manipulation of wetland hydrology, vegetation and topography and alterations in host distribution and density.

- ✓ Movement restrictions of animals and people, usually imposed by government authorities, can be an effective tool in preventing and controlling disease transmission through avoiding contact between infected and susceptible animals.

- ✓ Complete eradication of a disease requires a thorough understanding of its epidemiology, sufficient political and stakeholder support and thorough resourcing. 'Stamping out' (involving designation of infected zones, quarantine, slaughter of susceptible species, safe disposal of carcasses and cleaning and disinfection) is a management practice used for rapidly reducing the prevalence of a disease during an outbreak situation.

11.11 Establishing local communities' participation in the management and conservation of Pallikaranai Marsh

Involvement of local people and their institutions such as Self Help Groups, Panchayats and Gram Sabas in resource management falls within the general resource management approach known as participatory management. The general principles of participatory management, in the Indian context, are agreed to be the following

- ✓ Incentives, both monetized and non-monetised, for local people's involvement and prudent use of resources are essential and everyone must benefit in the long term

- ✓ Local people benefit from participatory management arrangements through the maintenance of sustainable livelihoods, including activities such as: sustainable farming, regulated reed harvesting, fishing and collection of forest products, salt extraction, recreational uses and ecotourism and water for domestic and irrigational purposes.

- ✓ Other benefits of participatory management for local and indigenous people include:
  - maintaining spiritual and cultural values associated with a wetland;
  - more equitable access to wetland resources;
  - increased local capacity and empowerment;
  - reduced conflicts among stakeholders; and
  - Maintaining ecosystem functions (e.g., flood control, improved water quality, etc.).

- ✓ Government agencies benefit from participatory management arrangements through improved ecosystem viability reduced management costs, assistance with monitoring and surveillance, fewer infringements; and enhanced social sustainability and quality of life for communities dependent on wetlands.

Cautionary principles of this component include:

a. Ensure that all stakeholders understand the role of the facilitators/ coordinators.
b. Regularly verify that all stakeholders agree upon the basic objectives of the initiative.
c. Raise awareness of wetland conservation and sustainability issues.
d. Involve local people in preparing and running awareness-raising activities.
e. Ensure the involvement of influential individuals in the community and all sectors of the population, and especially the women and youth of the community.
f. Develop local capacity including organizational and negotiating skills, keeping of records and financial accounts, and conflict management, and provide (as necessary) the meeting place, telephone access, basic equipment, and transportation.
g. Work with public-sector stakeholders to build capacity for developing and administering participatory management processes.

h. Ensure that local people learn participatory assessment and planning techniques so that they can be applied to other community concerns.
i. Develop a site monitoring and process testing programme using local resources to check progress.
j. Establish networks among communities involved in wetland management and encourage regular contact and sharing of experiences.
k. Support the application of traditional knowledge to wetland management including, where possible, the establishment of centers to conserve indigenous and traditional knowledge systems.

Guiding principle for participatory management

Based on the demographic and socio cultural profile of the landscape, the following guiding principles may be taken into consideration for evolving the participatory management programme for the conservation of Pallikaranai Marsh.

- That one or more communities in the landscape are closely related to the ecosystem and species culturally and/or because of survival and dependence for livelihood
- That the communities are the major players in decision-making and implementation regarding the management of the landscape, implying the community institutions such as the Gram Saba or the Panchayat have *de facto* and /or de jure capacity to enforce regulations such as closed seasons, prudent harvest etc.
- That the communities recognize and accord importance to other stakeholders, notably the State and engage in efforts that lead to the development of a collaborative system of management.
- That the community management plans, decisions and efforts lead to conservation of habitats, species and ecological services and related cultural values.

Creation of Local Interest Group

Creating an active Local Interest Group (LIG) through community mobilization efforts would be the most critical aspect of managing the sanctuary. When efforts are voluntary, conflicts are minimal. But when new initiatives are planned, there is always a corollary concern of being viewed as an employment initiative. To address this potential demand and also create livelihood opportunities without compromising on the overall goal of this technical component viz. conservation necessitates a well planned balancing act.

In this regard, establishment of a Local Interest Group which could through a well ***entrenched Eco tourism programme,*** provide livelihood opportunities as an incentive for engaging in protection and conservation would be welcome. These LIGs should primarily be constituted of local members, representatives of the resident welfare groups and the Tamil Nadu Forest Department. In tune with the norms followed elsewhere in the State and the Country, the LIG should be represented by all caste groups and marginalized sections such as women. Ideally, the LIGs could be carved out the 300 plus Below Poverty Line households of the landscape. **Hence, it would be necessary to collaborate and discuss these requirements with the resident welfare groups for efficient management of the marsh.**

A group so evolved could be supported with a revolving fund, but also encouraged to derive income by engaging itself in collection of nominal tourist fee and toll (to ensure sustainability). Support from the department could include provision of wages for watches and anti poaching guards. The locals should also be made aware of the dangers of the invasive catfish and other exotic fish.

Creation of a Nature Guides Corp should also be taken up the LIG. This group should be well trained by involving experts and Nongovernmental Organisations. These efforts should be strengthened by the publication of brochures and pamphlets on the sanctuary.

To address the issue of fostering a eco-sensitive approach**, the LIG could evolve a cycle trail in parts around the marsh. This includes maintenance of roads (ideally not black topped, but strong mud roads) and making available cycles on rent. Such an effort could be further strengthened by declaring the marsh a 'no-plastic zone.'**

The possibility of regulated extraction of *Typha* reed (Cat tail grass) and the conversion of the same into eco friendly products could also be explored.

Yet another pioneering effort could be the commemoration of local conservation efforts as a carnival during birding seasons.

11.12 Establishment of a Wetland Authority for the State of Tamilnadu

- In view of the fact that Tamilnadu is a critical land mass for water birds, especially the migratory birds that traverse across continents to seek refuge or breed, it is imperative that the historical wetlands as well as recent entrants be protected stringently for the cause of conservation.

- It is also a matter of concern that very often wetlands that are shallow or seasonal in nature do not receive the importance they deserve, since non-monetised and indirect ecosystem services are not readily visible during enumeration exercises.

- Management of land and water resources if often the joint responsibility of many of the line departments of the State, and in the absence of a commonly agreed upon agenda, or guidelines, inadvertent cross-working scenarios are set in place.

- Considering the historical human-interface in terms of creation, utilisation and management of wetlands, a collaborative approach with local human communities needs to be evolved and implemented to ensure the continued survival of the habitats, and a minimal human-animal conflict scenario. Likewise, mechanisms to enable real time and active participation of local stakeholders and the use of traditional knowledge systems are essential.

- In view of the statutory provisions of the National Wetland Rules of 2011, and the recognition of the importance of conserving wetlands, it is herein recommended that a State Wetland Authority be constituted that would function as an umbrella entity to ensure the protection, restoration and conservation of the critical wetlands of the State of Tamilnadu.

12. Pallikaranai Marsh as a Ramsar Site

Seven international conventions focus on biodiversity issues: the Convention on Biological Diversity (year of entry into force: 1993), the Convention on Conservation of Migratory Species, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (1975), the International Treaty on Plant Genetic Resources for Food and Agriculture (2004), the Ramsar Convention on Wetlands (1971), the World Heritage Convention (1972) and the International Plant Protection Convention (1952).

Each of the biodiversity-related conventions works to implement actions at the national, regional and international levels in order to reach shared goals of conservation and sustainable use. In meeting their objectives, the conventions have developed a number of complementary approaches (site, species, genetic resources and/or ecosystem-based) and operational tools (e.g., programmes of work, trade permits and certificates, multilateral system for access and benefit-sharing, regional agreements, site listings, funds, etc).

The Ramsar Convention

The Ramsar Convention on Wetlands of International Importance is an internationally binding agreement especially for the protection and conservation of water fowl habitats. It entered into force in Ramsar, Iran on 2.2.1971 and amended by the Protocols of 3.12.1982 and the Amendments of 28.5.1987. The Ramsar Convention can be broadly defined as an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. The Ramsar Convention is the only global environmental treaty that deals with a particular ecosystem. It comprises of 12 Articles. The number of contracting parties (countries) as of date is 168, wherein 2186 sites have been protected. The total surface area of designated sites in hectares is 208,674,247.

The Convention's mission is "the conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world".

The Convention uses a broad definition of the types of wetlands covered in its mission, including lakes and rivers, swamps and marshes, wet grasslands and peatlands, oases, estuaries, deltas and tidal flats, near-shore marine areas, mangroves and coral reefs, and human-made sites such as fish ponds, rice paddies, reservoirs, and salt pans

The Wise Use Concept

At the centre of Ramsar philosophy is the 'wise use' concept. The wise use of wetlands is defined as 'the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development. Wise use therefore has at its heart the conservation and sustainable use of wetlands and their resources, for the benefit of humankind.

The Ramsar definition of wetland

- "Wetlands are 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 metres" (Article 1.1).
- In addition Ramsar Sites "may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six metres at low tide lying within the wetlands" (Article 2.1).

The Ramsar definition of wetlands (Article 1.1) should be read/understood to include surface and subterranean wetlands, although the Convention text does not explicitly refer to these systems.

The Wetlands (Conservation and Management) Rules, 2010, which was promulgated by India largely as a response to the Ramsar Convention and its own commitment to the protection of wetlands and water bodies defines wetlands as follows:

‘wetland’ means an area or of marsh, fen, peatland or water; 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, and includes all inland waters such as lakes, reservoirs, tanks, backwaters, lagoon, creeks, estuaries and man-made wetlands and the zone of direct influence of wetlands that is to say the drainage area or catchment region of the wetlands as determined by the authority but does not include main river channels, paddy fields and coastal wetlands covered under the notification of the Government of India in the MoEF, S. O. number 114 (E) dated the 19th February, 1991 published in the Gazette of India, Extraordinary, Part II, Section 3, Sub-section (ii) of dated the 20th February, 1991. The designated Wetland Authority in India is as follows:

- Ministry of Environment and Forests headed by the Secretary
- Ministry of Environment and Forests : Joint Secretary – Designated National Focal Point
- Ministry of Environment and Forests: Director – Designated NFP for matters relating to STRP and Communication, Education and Public Awareness
- Designated NGO National Focal Point for CEPA: Wetlands International

Guiding Principles and Criteria

Designating Ramsar Sites: The Strategic Framework and guidelines for the future development of the List of Wetlands of International Importance Handbook 17 provides a detailed account of the processes and compliance conditions for designating wetlands under the Ramsar Convention. However, Contracting Parties should also be aware that in some instances they may require more detailed guidance at the supranational/ regional level in establishing the relative importance of sites for possible designations.

This may apply in the following situations:

i) where plant or animals species do not occur in large concentrations (such as migratory waterbirds in northern latitudes) within the country; or

ii) where collection of data is difficult (particularly in very large countries); or

iii) where there may be a high degree of spatial and temporal variability of rainfall – particularly in semi-arid or arid zones – resulting in dynamic use of complexes of temporary wetlands within and between years

Some critical points of caution include the following: Less visible interests such as fish, should not be overlooked. Fish are not only an integral part of aquatic ecosystems, but are a vital source of food and income for people throughout the world.

Boundary definition of sites. When designating sites, it is imperative to adopt a management-oriented approach to determining boundaries, recognizing that these should allow management of the site to be undertaken at the appropriate scale for maintaining the ecological character of the wetland. In the event of the candidate site under consideration viz. Pallikaranai Marsh, the unit of consideration viz. landscape would be the South Chennai Flood Plain that encompasses the Guindy National Park and the Nanmangalam Reserve Forest in addition to the Pallikaranai Marsh and the buffer wetlands.

Zonations of communities should be included as completely as possible in the site. Important are communities showing natural gradients (transitions), for instance from wet to dry, from salt to brackish, from brackish to fresh, from oligotrophic to eutrophic, from rivers to their associated banks, shingle bars and sediment systems, etc.

Natural succession of vegetation communities often proceeds rapidly in wetlands. To the greatest extent possible and where these exist, all phases of succession (for example, from open shallow water, to communities of emergent vegetation, to reed swamp, to marshland or peatland, to wet forest) should be included. Continuity of a wetland with a terrestrial habitat of high conservation value will enhance its own conservation value. These are all components that have been included as strategic interventions in the management plan for Pallikaranai Marsh.

The Criteria used for designating wetlands as Ramsar Site are organised as follows:

Group A of the criteria represent sites contaiing representative, rare or unique wetland types.

Criterion 1: A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.

Criterion 2: A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.

Criterion 3: A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.

Criterion 4: A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.

Group B of the criteria: Sites of international importance for conserving biodiversity

Specific criteria based on waterbirds

Criterion 5: A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.

Criterion 6: A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.

Specific criteria based on fish

Criterion 7: A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.

Criterion 8: A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.

Specific criteria based on other taxa

Criterion 9: A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species.

Other Points of Weightage

- **Hydrological importance***.* As indicated by Article 2 of the Convention, wetlands can be selected for their hydrological importance which, *inter alia*, may include the following attributes. They may:

  i) play a major role in the natural control, amelioration or prevention of flooding;

  ii) be important for seasonal water retention for wetlands or other areas of conservation importance downstream;

  iii) be important for the recharge of aquifers;

  iv) form part of karst or underground hydrological or spring systems that supply major surface wetlands;

  v) be major natural floodplain systems;

  vi) have a major hydrological influence in the context of at least regional climate regulation or stability (e.g., certain areas of cloudforest or rainforest, wetlands or wetland complexes in semi-arid, arid or desert areas, tundra or peatland systems acting as sinks for carbon, etc.);

The candidature of Pallikaranai Marsh

Occurrence of 5 species of near-threatened birds (Black-tailed Godwit, Darter, Black-headed Ibis, Spot-billed Pelican and Painted Stork) and 1 vulnerable species (Great Knot) and 1 endangered species (Black-bellied Tern) emphasise the global importance of this wetland. It is also noteworthy to mention that up to 1400 individuals of Grey headed Lapwing, an uncommon migrant species to southern India, have been recorded at Pallikarnai.

The global importance of this wetland is well understood in providing the wintering ground for the vulnerable migratory wader the Great Knot, and several uncommon species in India (eg., Fulvous Whistling Duck, Grey-headed Lapwing) and near-threatened species (Black-tailed Godwit), is indicated by the occurrence of globally endangered Black-bellied Tern. The largest known congregation of the Grey-headed Lapwing also occurs in this wetland.

Supporting over 40,000 birds at a time during the migratory season and over 5000 birds during the non- migratory season (summer months) this wetland can easily qualify as an important Ramsar Site. During summer months, the occurrence of large numbers (up to 1500) of the local migratory Fulvous Whistling Duck which is rare in southern India, Spot-billed Duck (maximum up to 3500 birds) and Lesser Whistling Duck (up to 1500 birds) are important features of this wetland to be considered as a wetland of global importance. The following Ramsar Site criteria are met by the Pallikarnai wetland

Table 1: Ramsar site criteria met by Pallikarnai (Birds)

S.No	Ramsar Criteria	Status at Pallikaranai
1	A wetland qualifies as a Ramsar site if it supports vulnerable, endangered or critically endangered species.	Yes (see table A)
2	A wetland qualifies as a Ramsar site if it regularly supports 20,000 or more waterbirds	Yes (see table B)

3	A wetland qualifies as a Ramsar site if it regularly supports 1% of the individual in a population of one species or sub species of waterbird	Yes (see table C)
4	A wetland should be considered internationally important if it supports species at a critical stage in their life cycle, or provides refuge during adverse conditions.	Yes

Table A: Threatened Bird Species

S.No	Common Name	Scientific Name	IUCN Status
1.	Black-bellied Tern	*Sterna acuticauda*	Endangered
2.	Great Knot	*Calidris tenuirostris*	Vulnerable
3.	Oriental Darter	*Anhinga melanogaster*	Near Threatened
4.	Painted Stork	*Mycteria leucocephala*	Near Threatened
5.	Oriental White Ibis	*Threskiornis melanocephalus*	Near Threatened
6.	Black-tailed Godwit	*Limosa limosa*	Near Threatened
7.	Spot-billed Pelican	*Pelecanus philippensis*	Near Threatened

Table B: Months with bird populations of more than 20,000

S.No	Month	Bird Population
1	January 2013	38433
2	February 2013	35491
3	March 2013	29023
4	December 2013	47448
5	January 2014	41671
6	February 2014	28861

Table C: Species with number of individuals more than 1% of their bio-geographical population

Species	1% threshold	Maximum no. of individuals recorded
Spot-billed Pelican	150	900
Spot-billed Duck	1000	3500
Grey-headed Lapwing	1000	1400
Black-winged Stilt	1400	8000

Table 2: Ramsar Site Criteria met by Pallikaranai (Others)

S.No	Ramsar Criterion	Yes/Not Known
1	A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region	Yes; a rare example of a coastal wetland that is partly of freshwater; it is found in the Coromandel Biogeographic Province of India where no such wetland exists
2	A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities	Yes; birds
3	A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region	Yes; birds, fish and amphibians
4	A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions	Yes; birds, fish and amphibians
5	A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity	Yes; fish including species of eels and other food-fish
6	A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend	Yes; species of mullets and other brackish water fish migrate from estuaries for spawning during certain seasons
7	A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species	Not known; there is very little information on aquatic invertebrates some of which might qualify in this
8	Play a major role in the natural control, amelioration or prevention of flooding	Yes
9	Be important for the recharge of aquifers	Yes
10	Be major natural floodplain systems	Yes

13. Assessment and Monitoring of Ecological Character

Ecological character is a technical term that defines the combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time. Within this context, ecosystem benefits are defined in accordance with the Millennium Ecosystem Assessment (MA) definition of ecosystem services as "the benefits that people receive from ecosystems (Ramsar Convention, 2014). For the purposes of implementation of Article 3.2 of the Ramsar Convention, change in ecological character is the human-induced adverse alteration of any ecosystem component, process, and/or ecosystem benefit/service. And once this is established as a condition or status of a wetland, the nomination of the site for Ramsar accreditation becomes part of a specific provision called the Montreux Record of the Ramsar Convention. In some sense, this is a negative accreditation.

The point of consideration in the current context is the following:

1. What is the past and present status and ecological character of Pallikaranai Marsh?
2. How have the changes around the marsh and within the marsh contributed to the current definition of its ecological character?
3. How do we characterize the ecosystem services of Pallikaranai Marsh?
4. Can the prioritization of the ecosystem services be attempted? If yes, to what consequence?
5. Does the current management plan contribute to or deflect the ecological character of the marsh?
6. What are the cautionary principles in ensuring the ecological character of the marsh?

13.1 History of the Montreux Record

Recommendation C.4.8 *Change in ecological character of Ramsar Sites*, adopted by the Conference of Parties (COP4) in Montreux, Switzerland, in 1990, instructed "the Convention Bureau, in consultation with the Contracting Party concerned, to maintain a record of Ramsar Sites where . . . changes in ecological character have occurred, are occurring or are likely to occur, and to distinguish between sites where preventive or remedial action has not as yet been identified, and those where the Contracting Party has indicated its intention to take preventive or remedial action or has already initiated such action."

Paragraph 21 of Resolution VIII.8 reaffirmed that, "in accordance with the *Guidelines for the operation of the Montreux Record* (Annex to Resolution VI.1), the Montreux Record is the principal tool of the Convention for highlighting those sites where an adverse change in ecological character has occurred, is occurring, or is likely to occur and which are therefore in need of priority conservation action", and acknowledged "that the voluntary inclusion of a particular site on the Montreux Record is a useful tool available to Contracting Parties in circumstances where:

a) demonstrating national commitment to resolve the adverse changes would assist in their resolution;
b) highlighting particularly serious cases would be beneficial at national and/or international level;
c) positive national and international conservation attention would benefit the site; and/or
d) Inclusion on the Record would provide guidance in the allocation of resources available under financial mechanisms."

More detailed Guidelines for the Record were established through paragraph 3 of the Annex to Resolution VI.1, adopted by COP6 in Brisbane, Australia, in 1996. Key aspects of the guidelines are as follows:

i) "The Montreux Record is the principal tool of the Convention for highlighting those sites where an adverse change in ecological character has occurred, is occurring, or is likely to occur, and which are therefore in need of priority conservation attention. It shall be maintained as part of the Ramsar Database and shall be subject to continuous review.

ii) The following procedure should be observed when considering the possible inclusion of a listed site in the Montreux Record:

• A Contracting Party may request inclusion of a site in the Montreux Record, because of potential or actual adverse change in its ecological character, in order to draw attention to the need for action or support. Alternatively, the [Secretariat], on receipt of information on actual or possible adverse change from partner organizations, other international or national NGOs, or other interested bodies, may draw the attention of the Contracting Party concerned to this information and enquire whether a Ramsar Site should be included in the Montreux Record. A site can only be included in the Record with the approval of the Contracting Party concerned.

• The [Secretariat] will pass the information received from partner organizations, other international or national NGOs, or other interested bodies, to the Contracting Party, together with a concise, voluntary questionnaire. The questionnaire is as follows:

Montreux Record - Questionnaire

(Annex to Resolution VI.1)

Section One: Information for assessing possible inclusion of a listed site in the Montreux Record

Essential items

- Name of site
- Ramsar Criteria for listing the site as internationally important
- Nature of the change in ecological character/potential for adverse change
- Reason(s) for adverse change, or potential adverse change, in ecological character

Additional items which may be included

- Date Information Sheet on Ramsar Wetlands submitted
- Date and source of Information Sheet updates (e.g., National Reports, national wetland inventory, specific survey)
- Benefits and values derived from the site
- Extent to which values and benefits derived from the site have decreased or changed
- Monitoring programme in place at the site, if any (technique(s), objectives, and nature of data and information gathered)
- Assessment procedures in place, if any (how is the information obtained from the monitoring programme used?)
- Ameliorative and restoration measures in place or planned (if any) so far
- List of attachments provided by the Contracting Party (if applicable)
- List of attachments provided by the Ramsar Bureau (if applicable)

Section Two: Information for assessing possible removal of a listed site from the Montreux Record

- Success of ameliorative, restoration or maintenance measures (describe if different from those covered in Section One of this questionnaire)
- Proposed monitoring and assessment procedures (describe if different from those in Section One of this questionnaire)
- Extent to which the ecological character, benefits and values of the site have been restored or maintained (provide details)
- Rationale for removing the site from the Montreux Record (refer to Guidelines for operation of the Montreux Record, together with Section One of this questionnaire)
- List of further attachments (if applicable)

In the context of ensuring that concerns by the Montreux Record are addressed, the following issues are to be considered in the assessment of the usefulness and feasibility of wetland restoration projects. The outcome and impact of the restoration initiative for Pallikaranai Marsh could be effectively tracked using the following tool.

1. Will there be environmental benefits (for example, improved water quantity and quality, reduced eutrophication, preservation of freshwater resources, biodiversity conservation, improved management of “wet resources”, flood control)?
2. What is the cost effectiveness of the proposed project? Investments and changes should in the longer term be sustainable, not yielding only temporary results.
3. What options, advantages or disadvantages will the restored area provide for local people and the region? These may include health conditions, essential food and water resources, increased possibilities for recreation and ecotourism, improved scenic values, educational opportunities, conservation of cultural heritage (historic or religious sites), etc.
4. What is the ecological potential of the project? What is the present status of the area in terms of habitats and biological values, and in particular will any current features of wetland conservation or biodiversity importance be lost or damaged? How is the area expected to develop with respect to hydrology, geomorphology, water quality, plant and animal communities, etc?
5. What is the status of the area in terms of present landuse. The situation will differ widely between developed countries, countries with economies in transition, and developing countries, and within such countries depending on local circumstances, with respect to the objectives of restoration and rehabilitation. In particular, marginal lands yielding few benefits in the present situation can often be improved.
6. What are the main socio-economic constraints? Is there a positive regional and local interest in realising the project?
7. What are the main technical constraints?

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Carriageway

The primary purpose of a carriageway is vehicular mobility. A carriageway provides dedicated space for motorised vehicles separate from slow-speed modes, such as walking and cycling, and stationary activities. Carriageways are replaced by shared space in the case of narrow, traffic-calmed streets where motor vehicles, pedestrians, and cyclists coexist. A carriageway also can include segregated space for public transport.

Median

Reduces conflict between opposite directions of traffic and acts as pedestrian refuge but has frequent enough breaks to discourage motor vehicle users from driving in the wrong direction.

Ribbon Sidewalk

2 m wide footpath for comfortable pedestrian mobility.

Speed table Crosswalk

A speed table is a traffic calming device designed as a long speed hump with a flat section in the middle. The raised table also allows for easy pedestrian crossing.

Boardwalk

A wooden walkway across sand or marshy ground.

Bus Bay

Bus bay means that portion of the highway beside a bus stop sign that is used by buses for the boarding and alighting of passengers. Good bus stops are easy to identify, provide safe and comfortable passenger waiting space, are conveniently located near street crossings, and do not obstruct pedestrian paths and cycle tracks.

The Ribbon Walk Project
at Pallikaranai Marsh

Schematic Proposal / April 2014

MOAD
The Madras Office for Architects and Designers

The Ribbon Walk Project
at Pallikaranai Marsh

The site for this project is a strip along southern edge of 200ft road that intersects Tambaram-Velachery Main road on the west and joins OMR on east

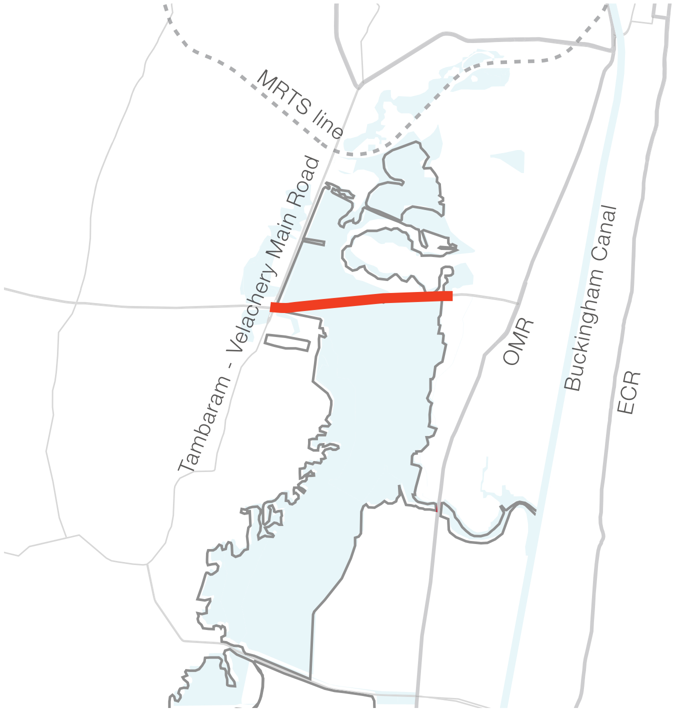
The Ribbon Walk Project is a 2km long pedestrian strip along this road on the pallikaranai marsh.

It's a narrow pedestrian realm designed as a ribbon side walk that aims to provide variety of experience that engages the user with the natural habitat. This is acheived by incorporating the following components.
Board walks – to provide direct access into the wet land,
Bird watching decks and towers for Nature enthusiasts
Play area for children.

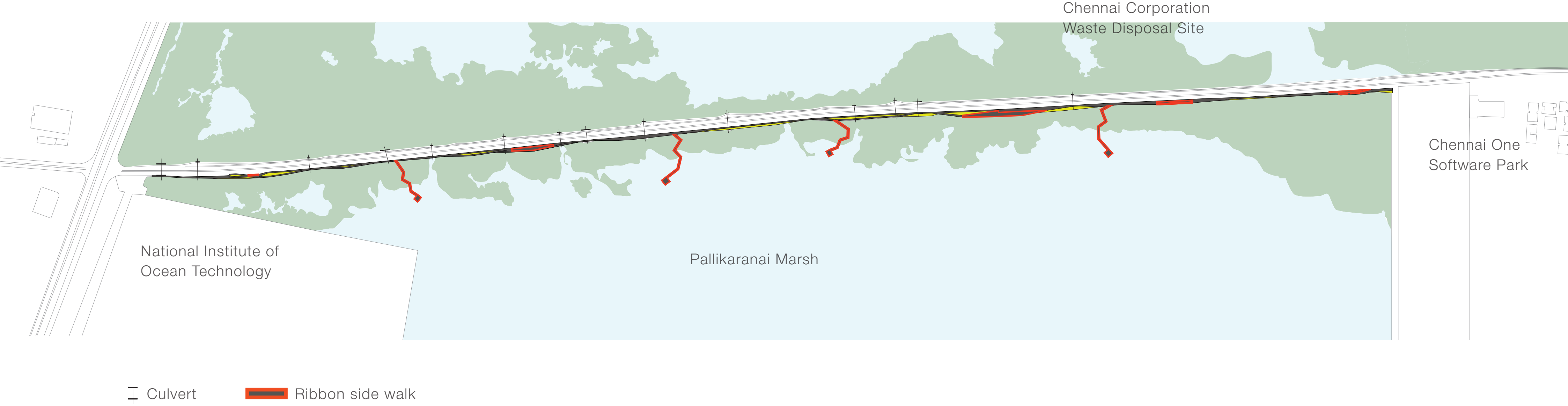
The project will also increase awareness of the environment through interpretation tunnels and urban furniture that integrates information through environment design.

The ribbon walk project will be designed for floods to protect habitats, offer access and support water related activities in a forward looking, ecologically diverse setting.

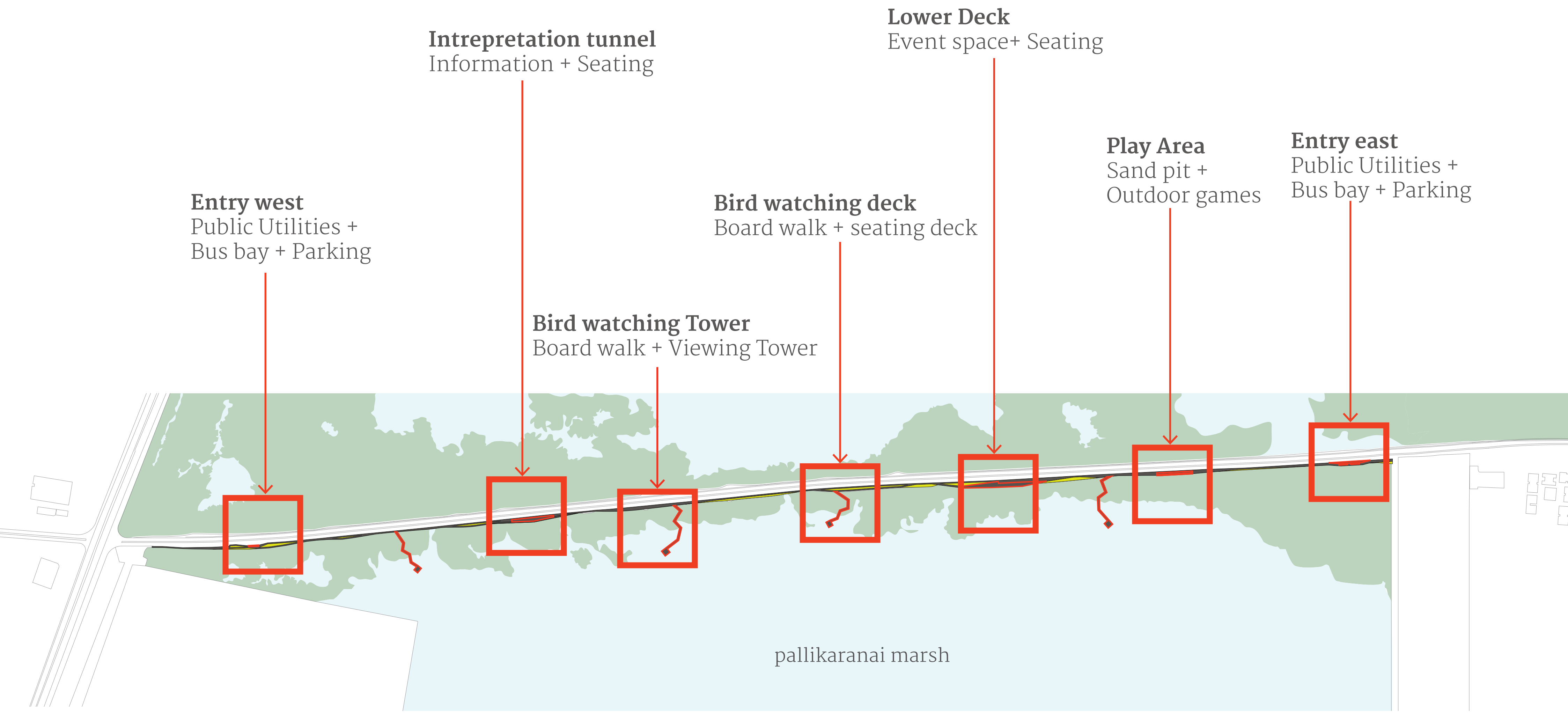
Context



Site Plan

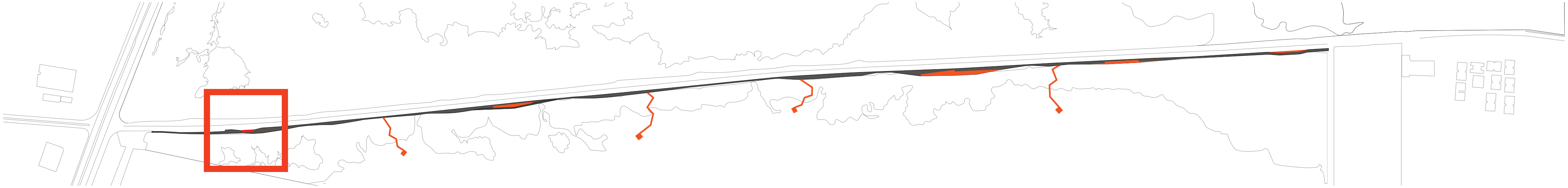


Components

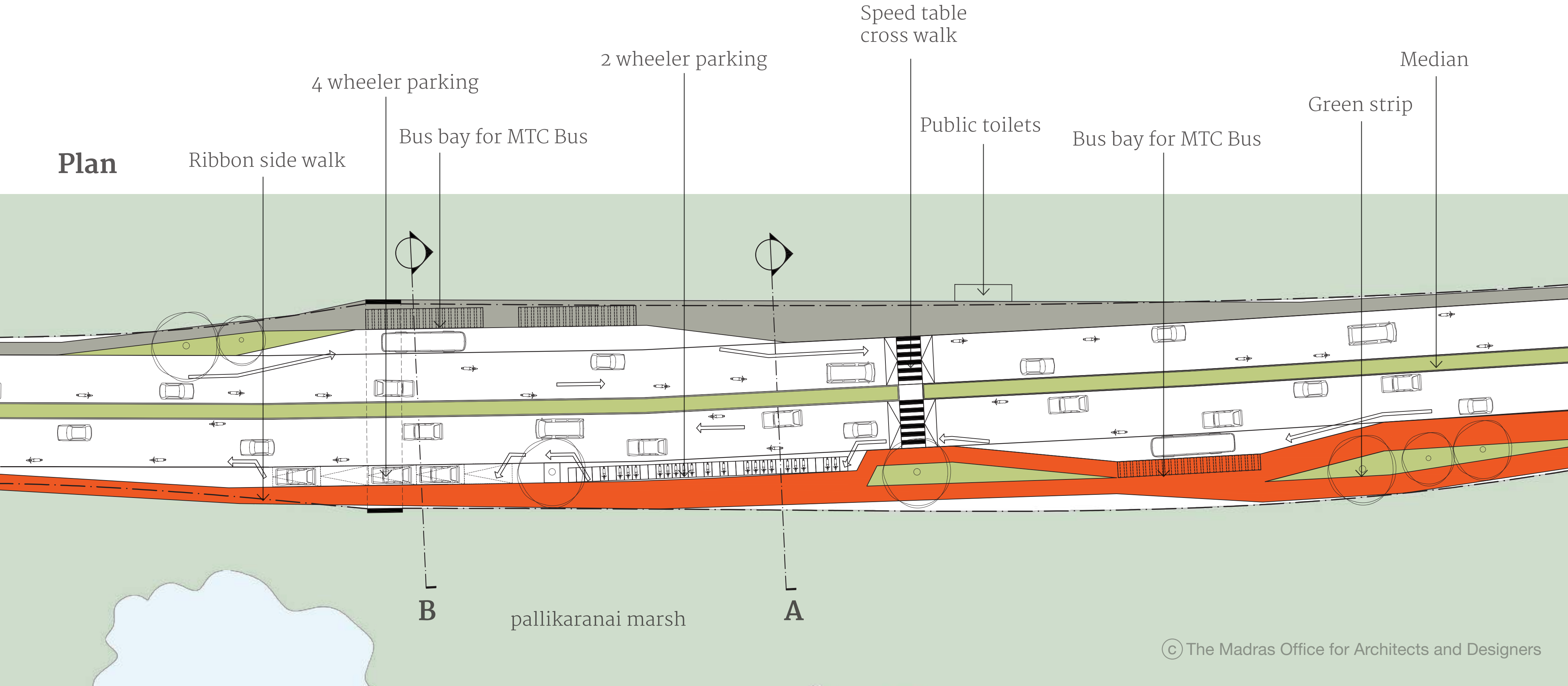


Lower Deck
Event space+ Seating
Intrepretation tunnel
Information + Seating
Play Area
Sand pit +
Outdoor games
Entry east
Public Utilities +
Bus bay + Parking
Bird watching deck
Board walk + seating deck
Entry west
Public Utilities +
Bus bay + Parking
Bird watching Tower
Board walk + Viewing Tower
pallikaranai marsh

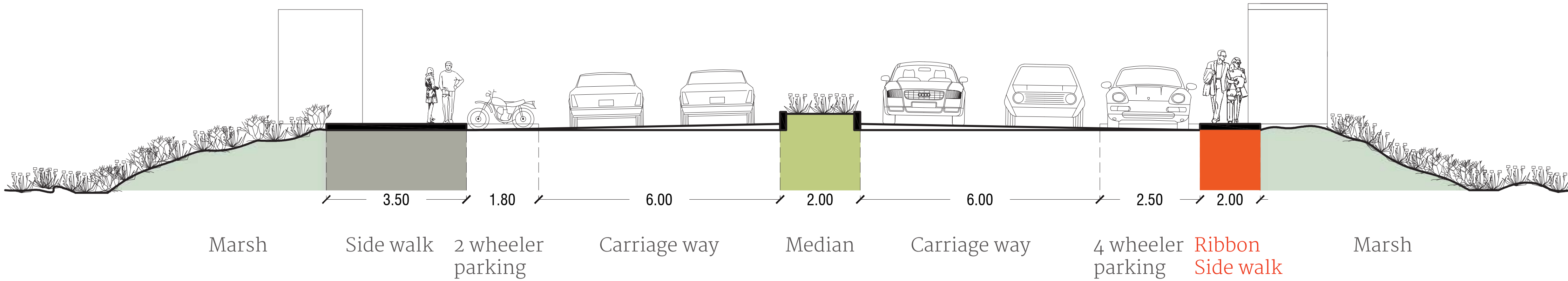
Entry west
Public Utilities



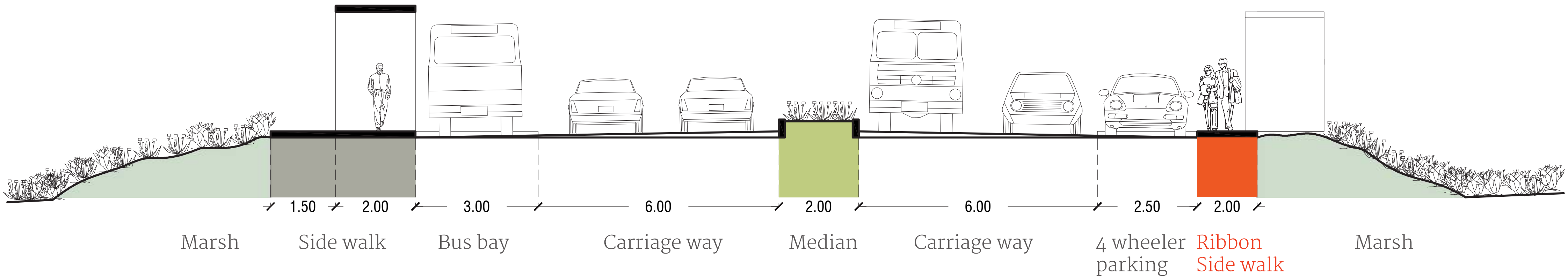
Plan



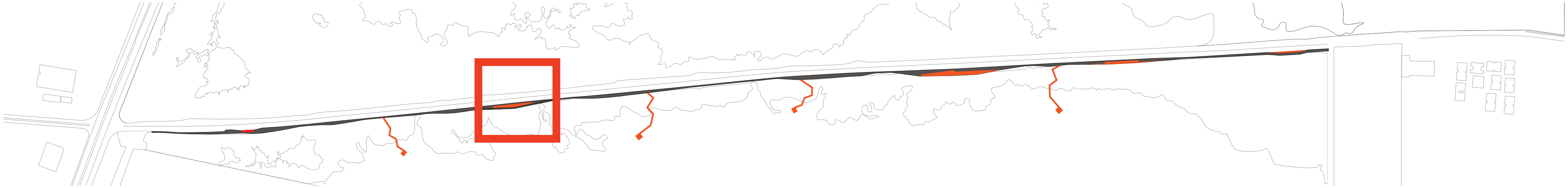
Section A



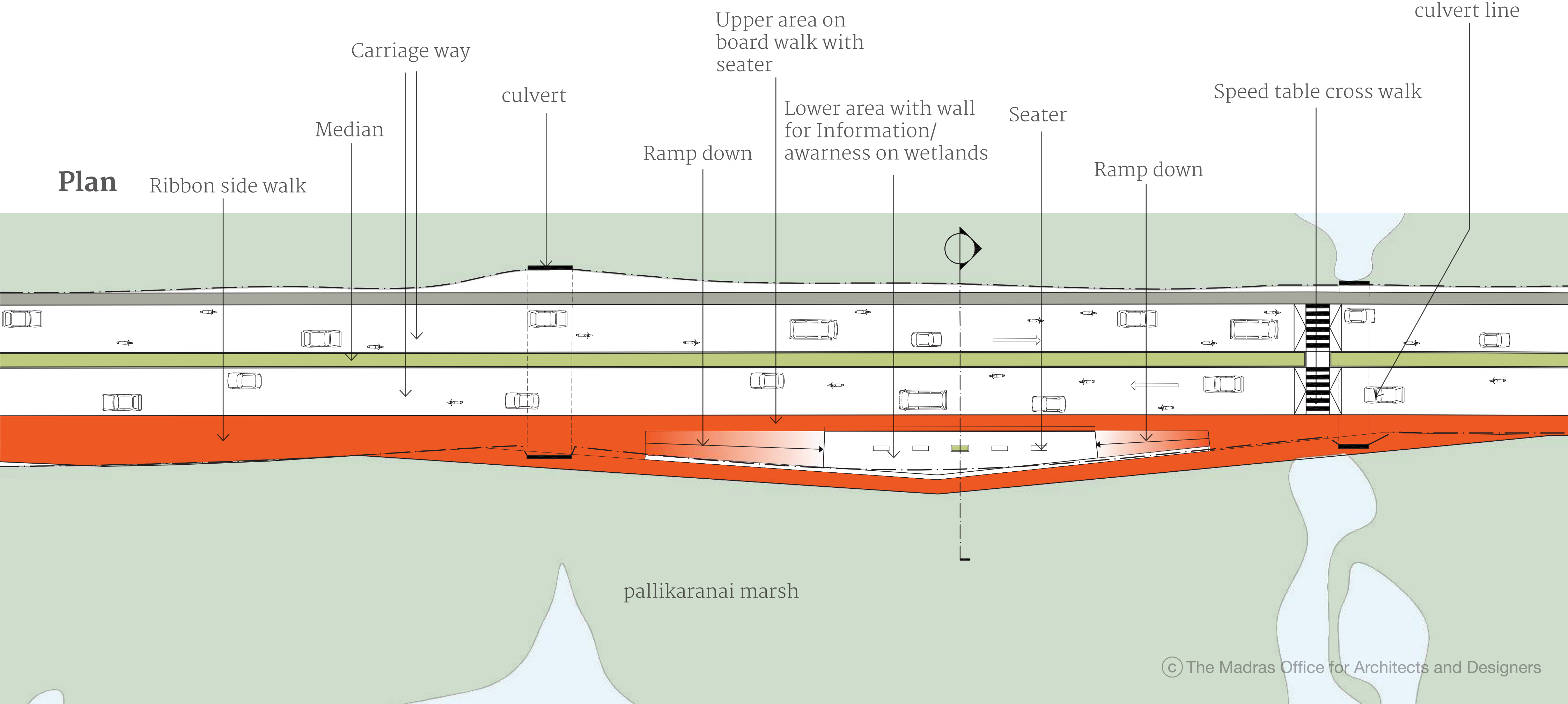
Section B



Intrepretation tunnel 1
Information + Seating



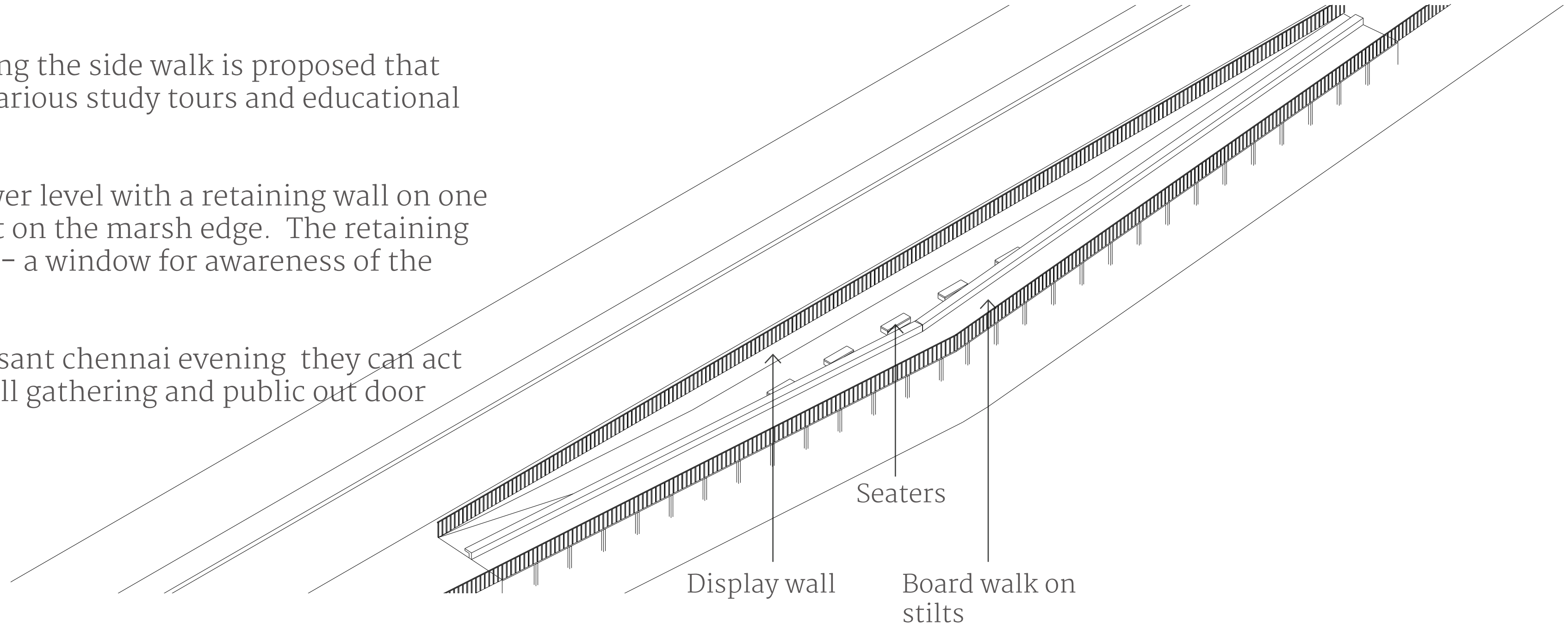
Plan



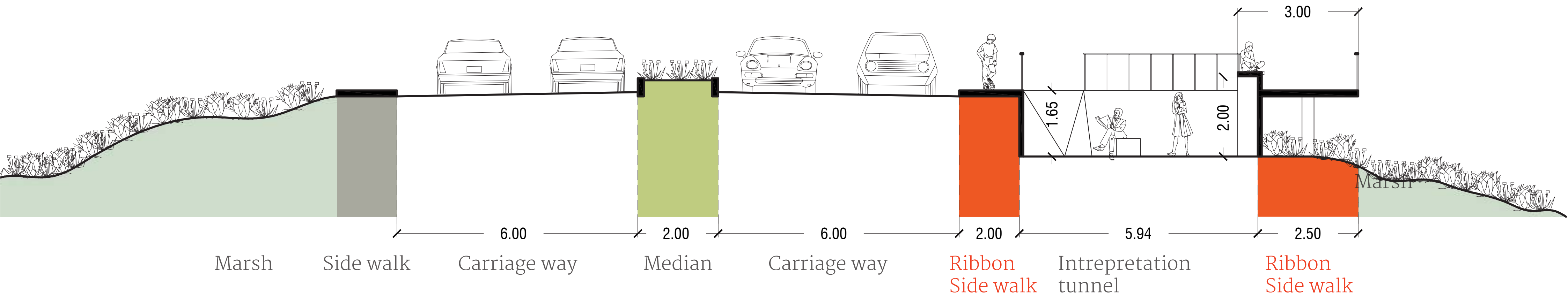
An intrepretation tunnel along the side walk is proposed that will be an anchor space for various study tours and educational activities.

The tunnel is located at a lower level with a retaining wall on one side and a board walk on stilt on the marsh edge. The retaining wall can be used as a display - a window for awareness of the environment

When not in use or on a pleasant chennai evening they can act as an enclosed space for small gathering and public out door

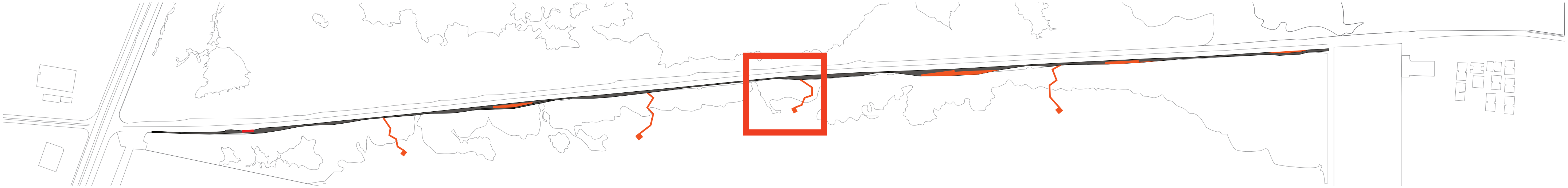


Section

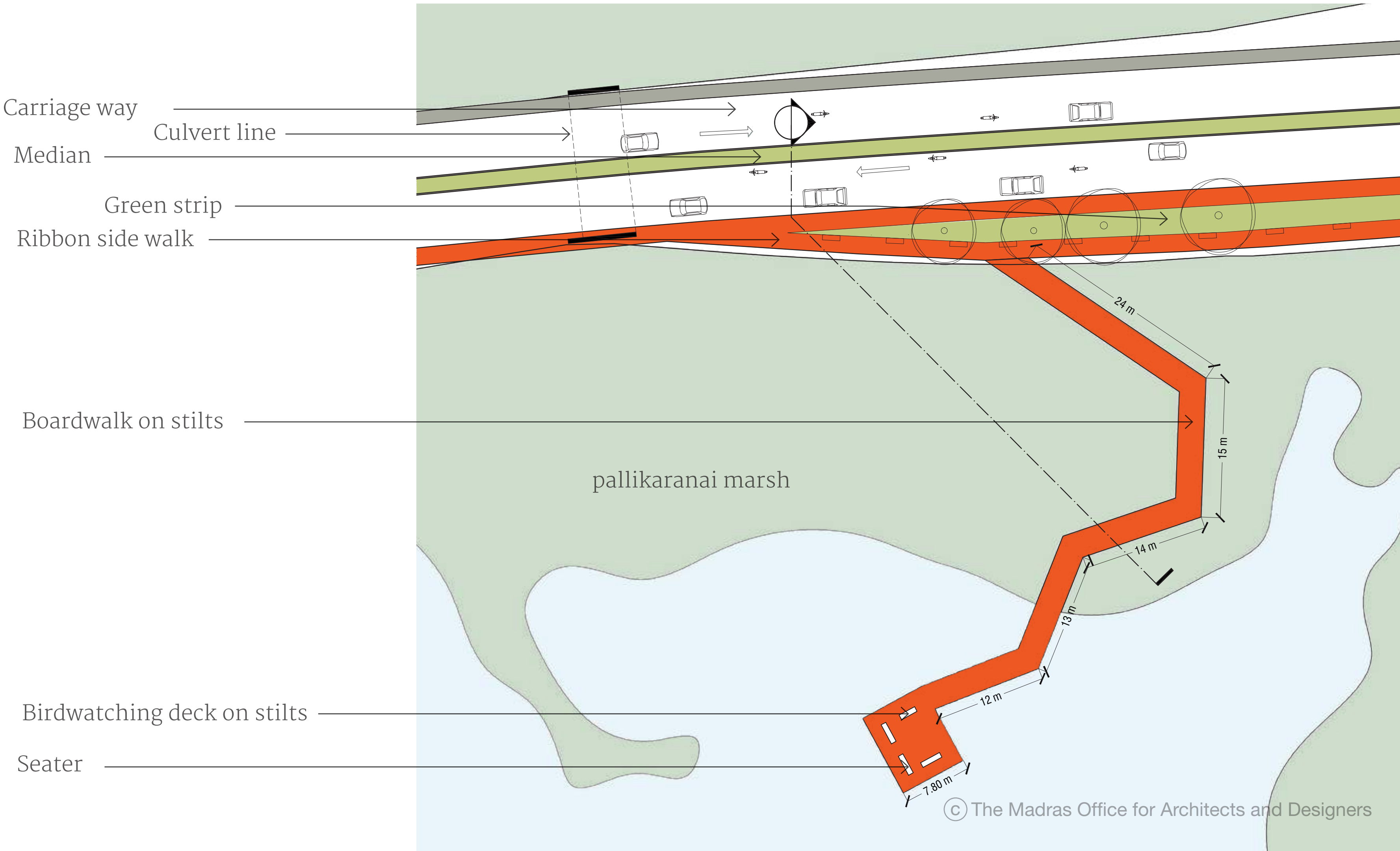


View
Intrepretation tunnel

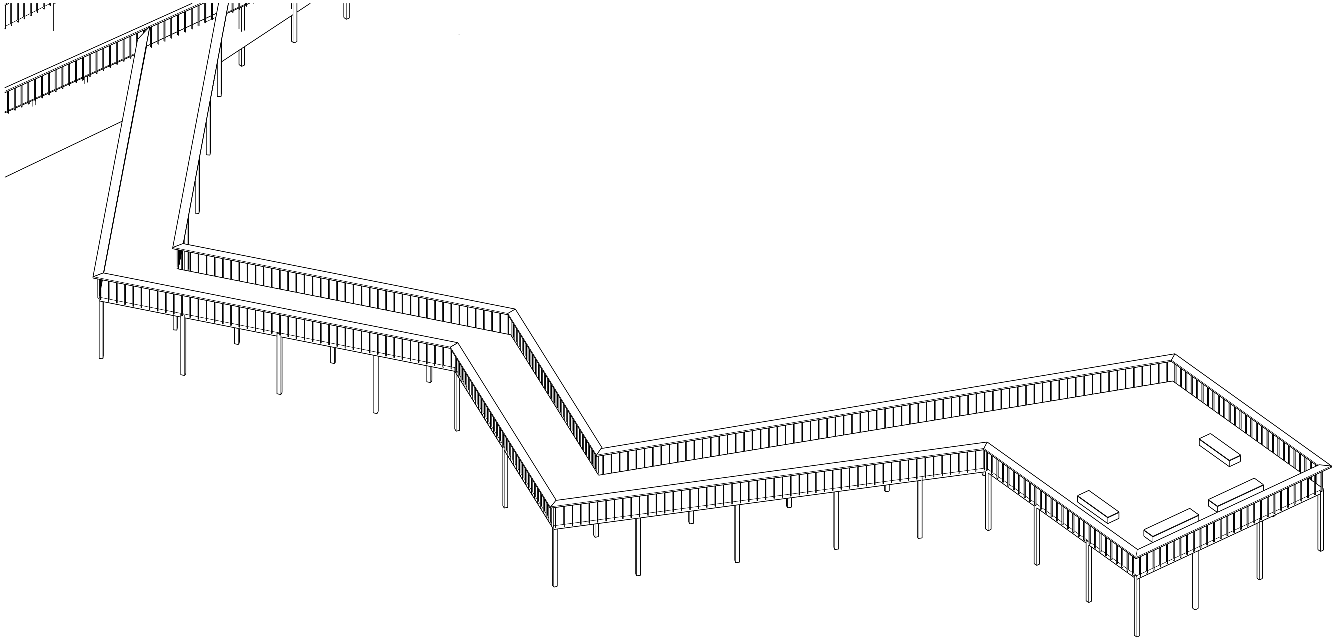
Bird watching deck
Board walk + seating



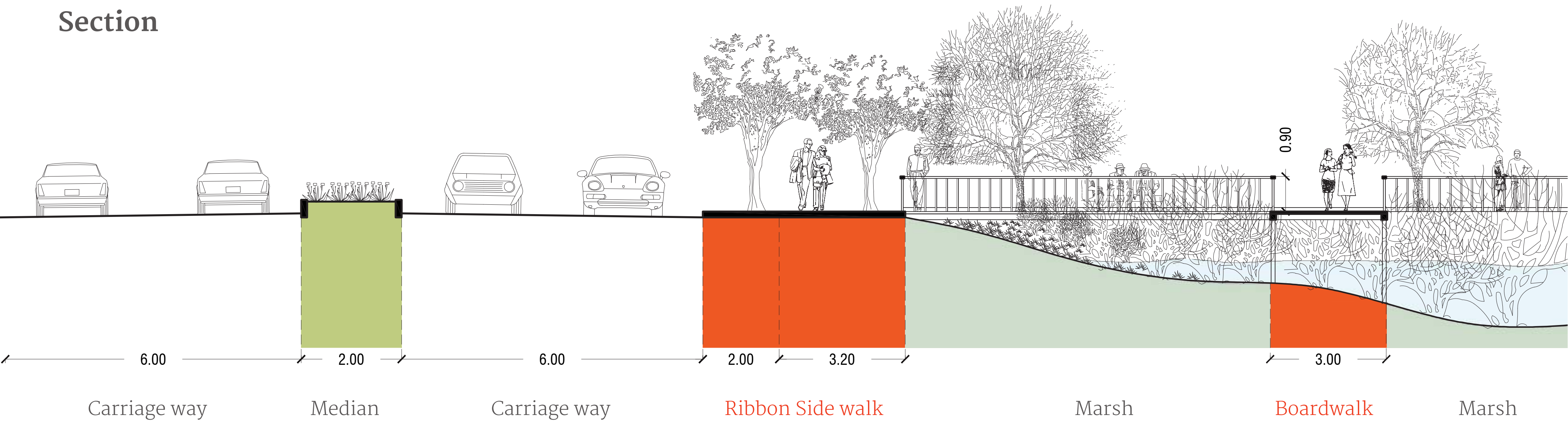
Plan



The ribbon walk arms into the marsh through boardwalk s on stilts at various strategic that end in a deck with seaters. This deck is meant as a place for bird watchers to share their knowledge, their sightings and their favorite spots.

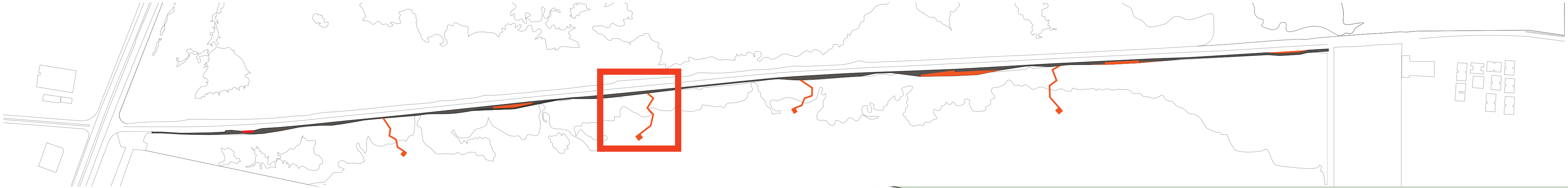


Section

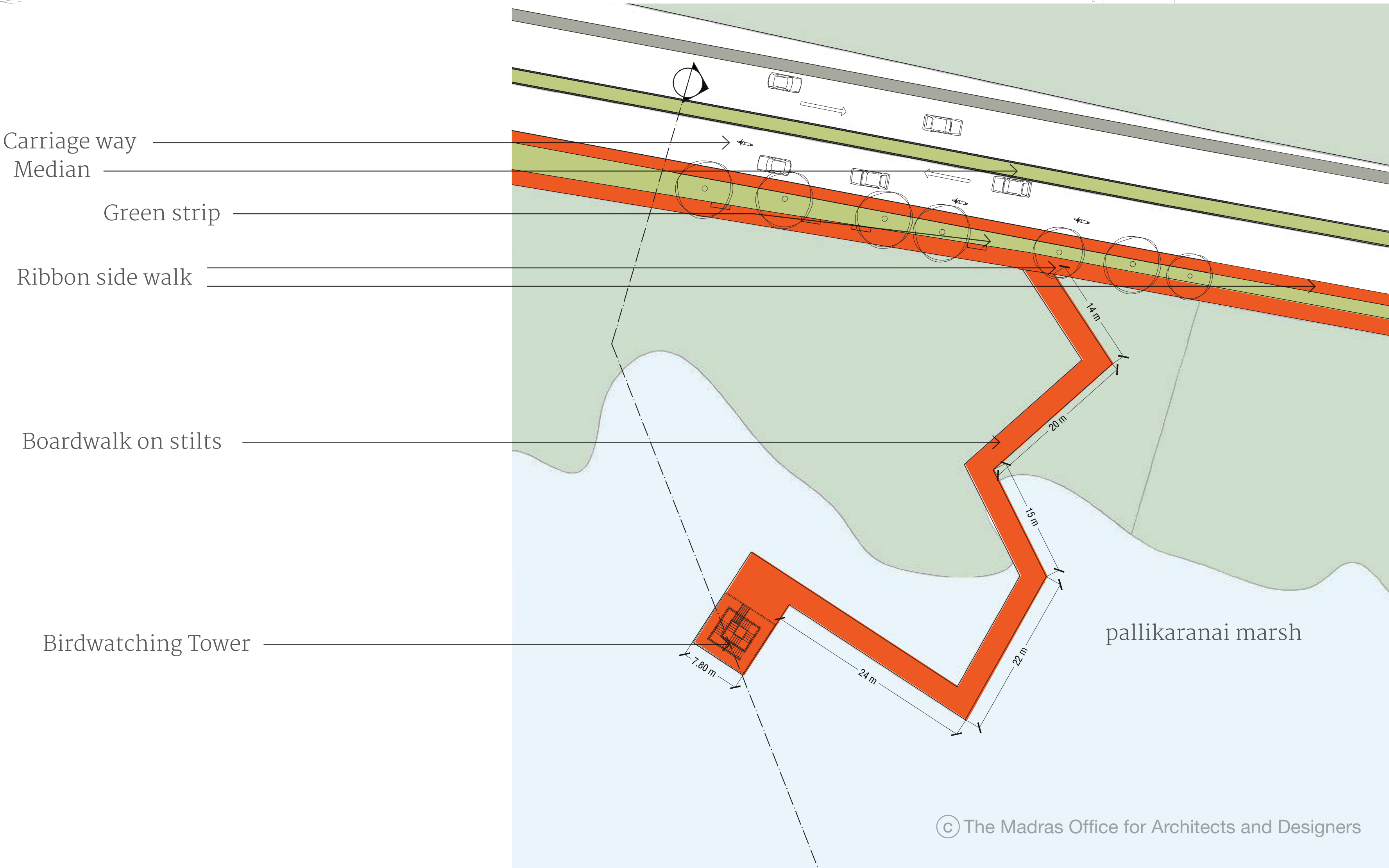


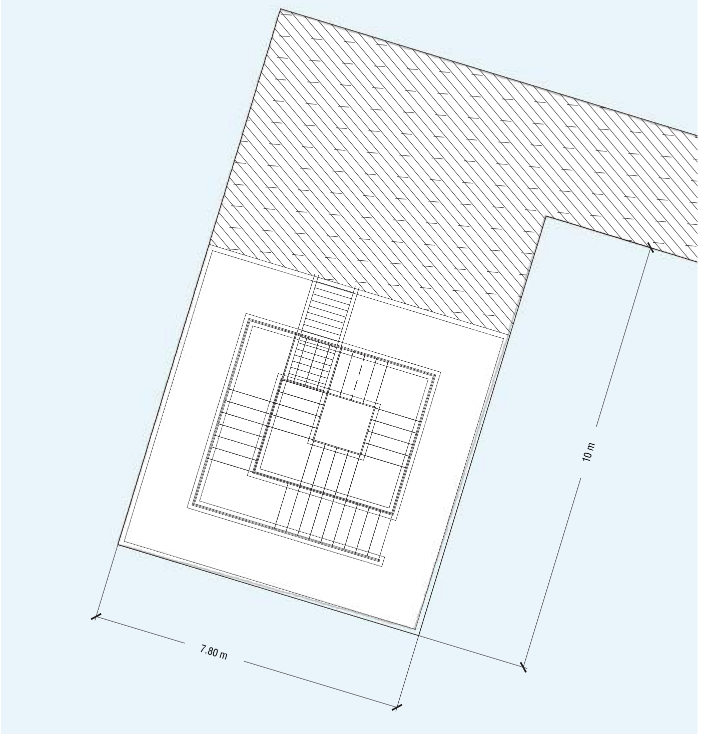
View
Bird watching deck

Bird watching Tower
Board walk + seating

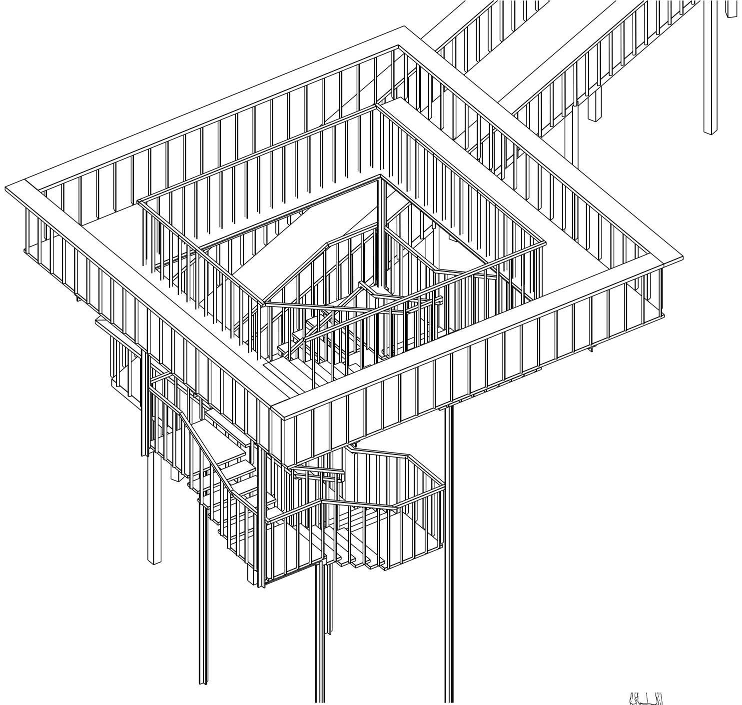


Plan



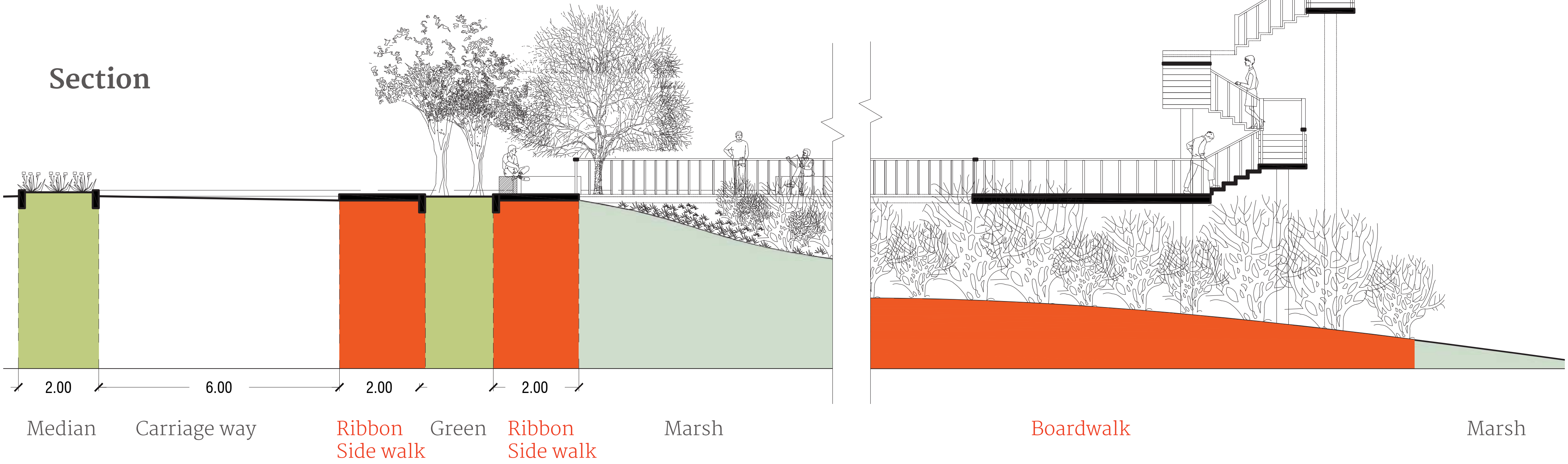


Plan



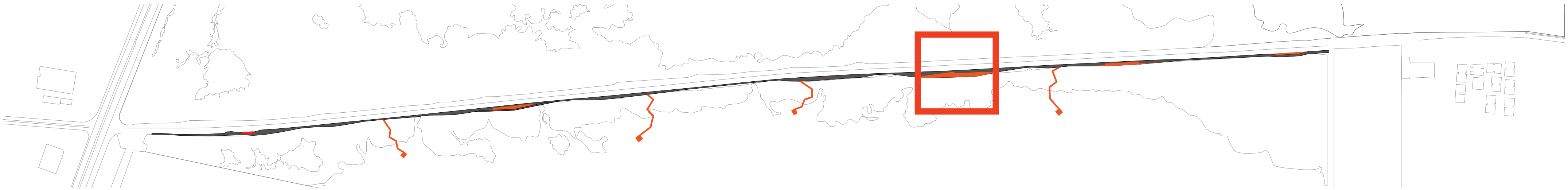
Axonometric View

Section

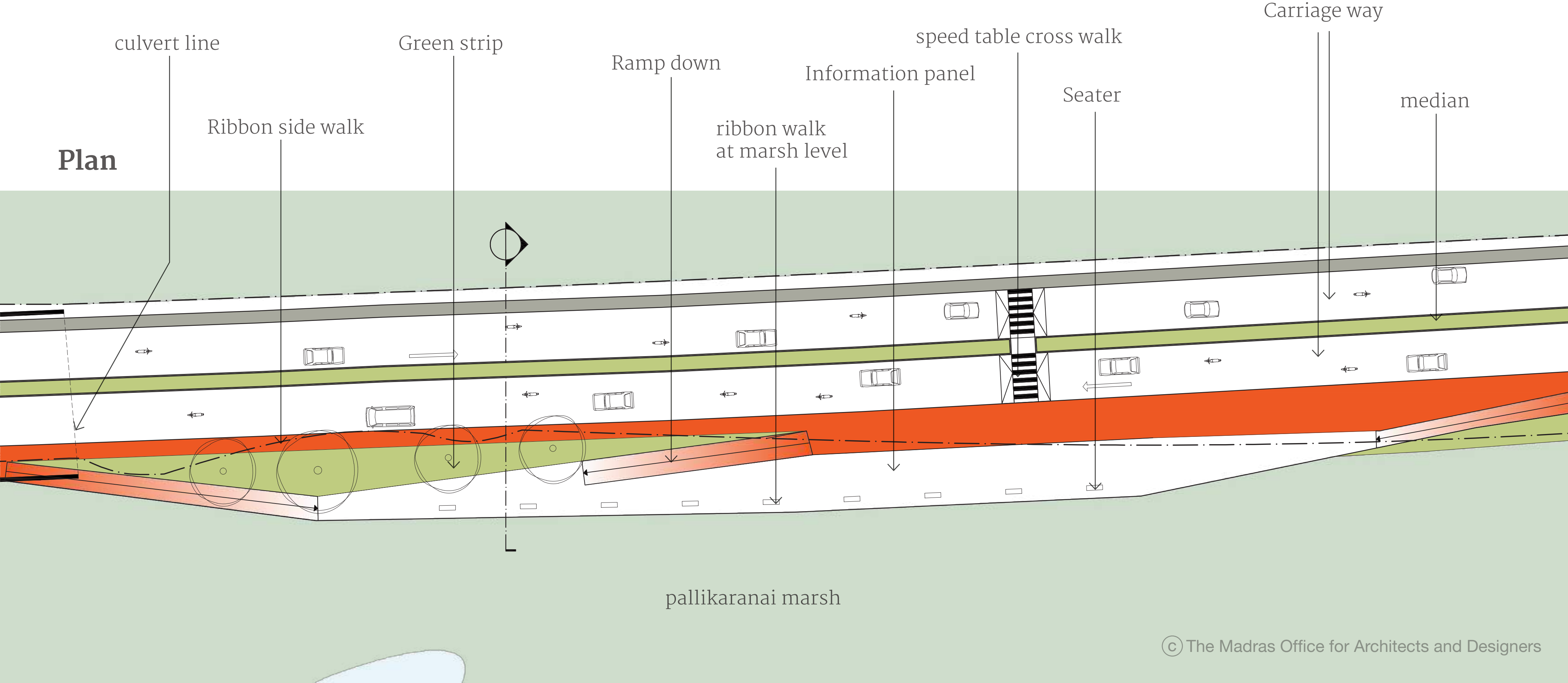


View
Bird watching Tower

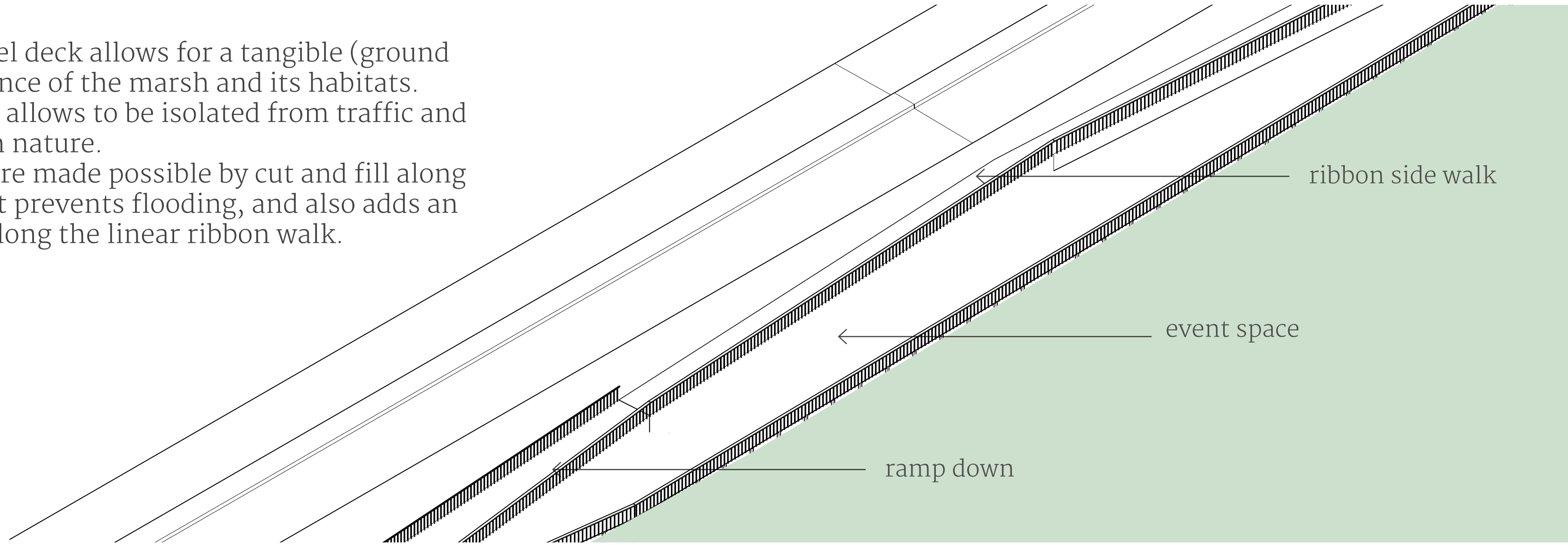
Lower Deck
Board walk + Seating



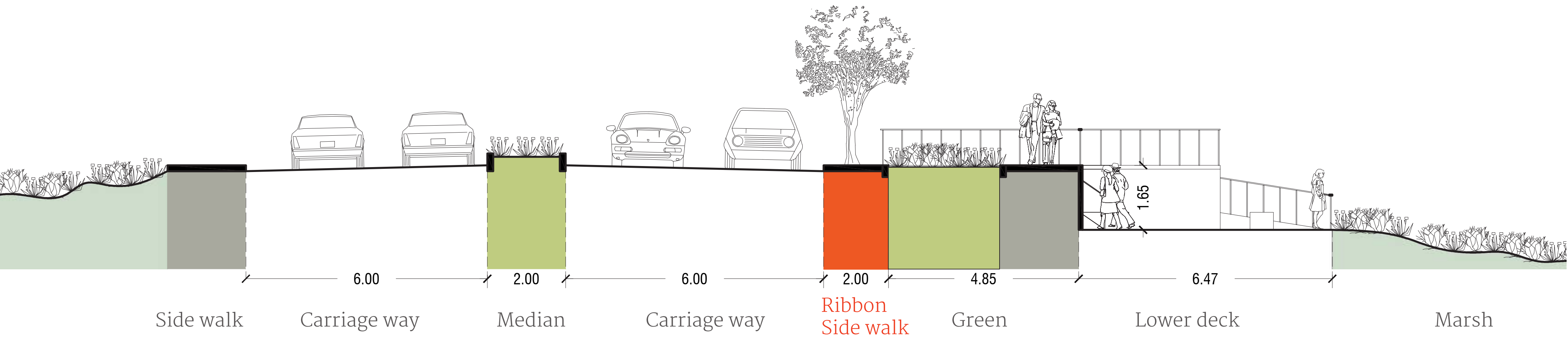
Plan



The lower level deck allows for a tangible (ground level) experience of the marsh and its habitats. Being sunken allows to be isolated from traffic and be at one with nature.
These decks are made possible by cut and fill along the edges that prevents flooding, and also adds an articulation along the linear ribbon walk.

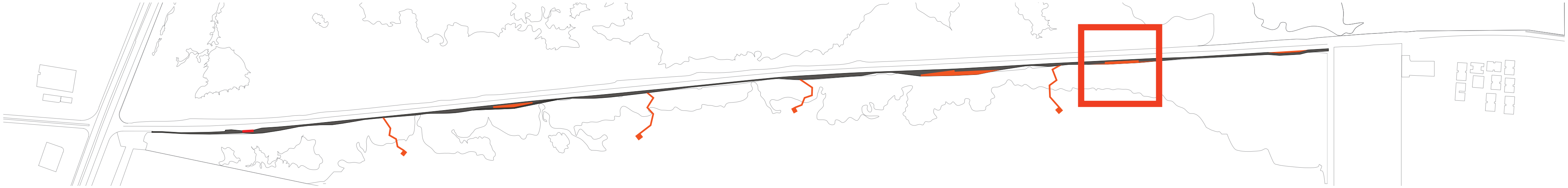


Section

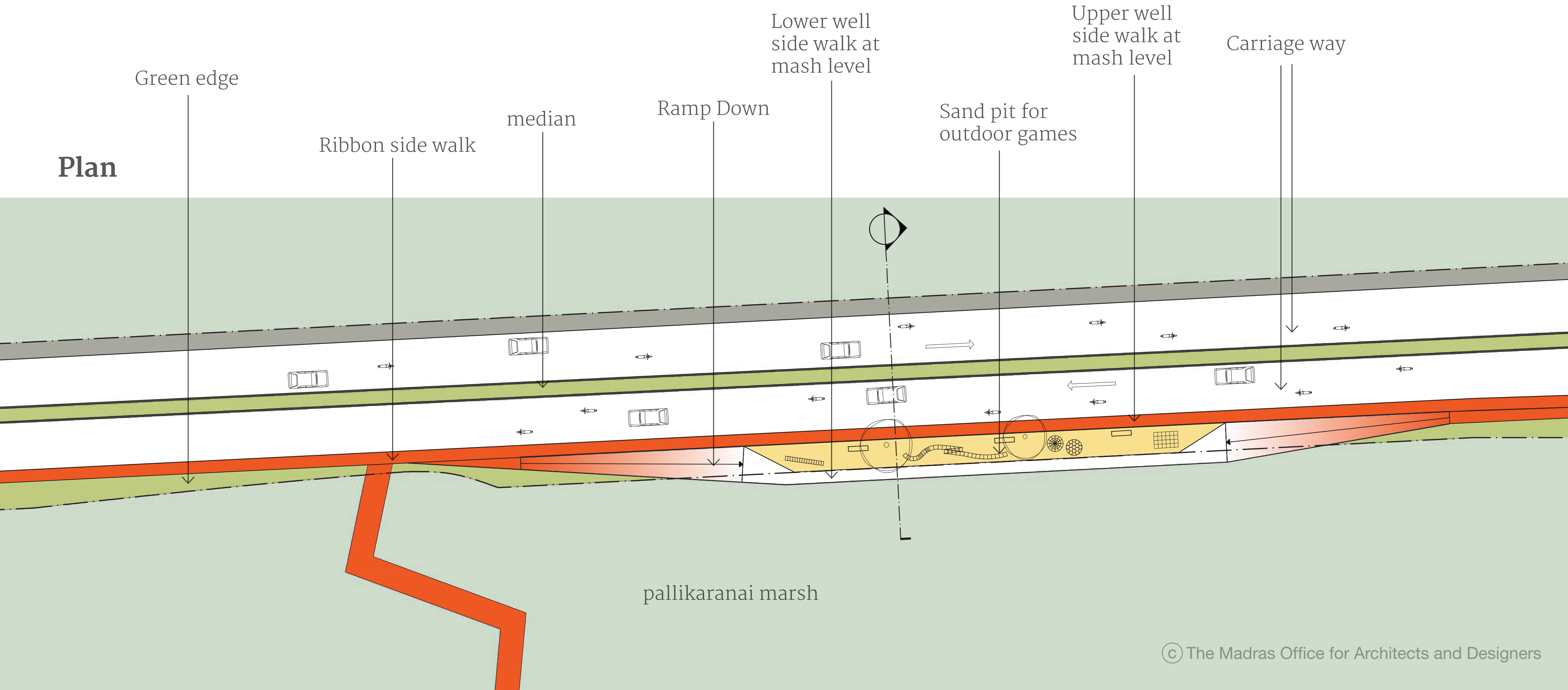


View
Lower Deck

Play Area
Out door games

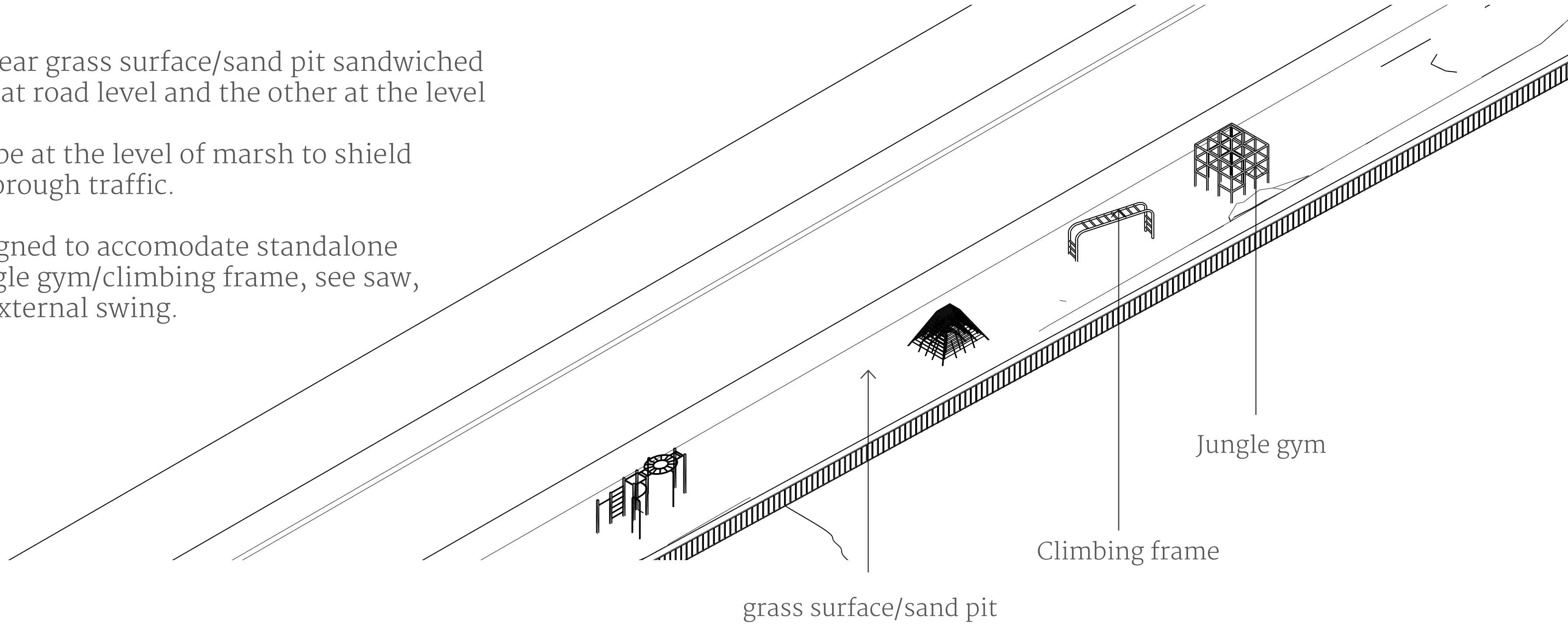


Plan



The play area will be a linear grass surface/sand pit sandwiched between ribbon sidewalk at road level and the other at the level of the marsh.
The level of sand pit will be at the level of marsh to shield playing children from thorough traffic.

The play area will be designed to accomodate standalone play equipments like jungle gym/climbing frame, see saw, a minature slide and an external swing.



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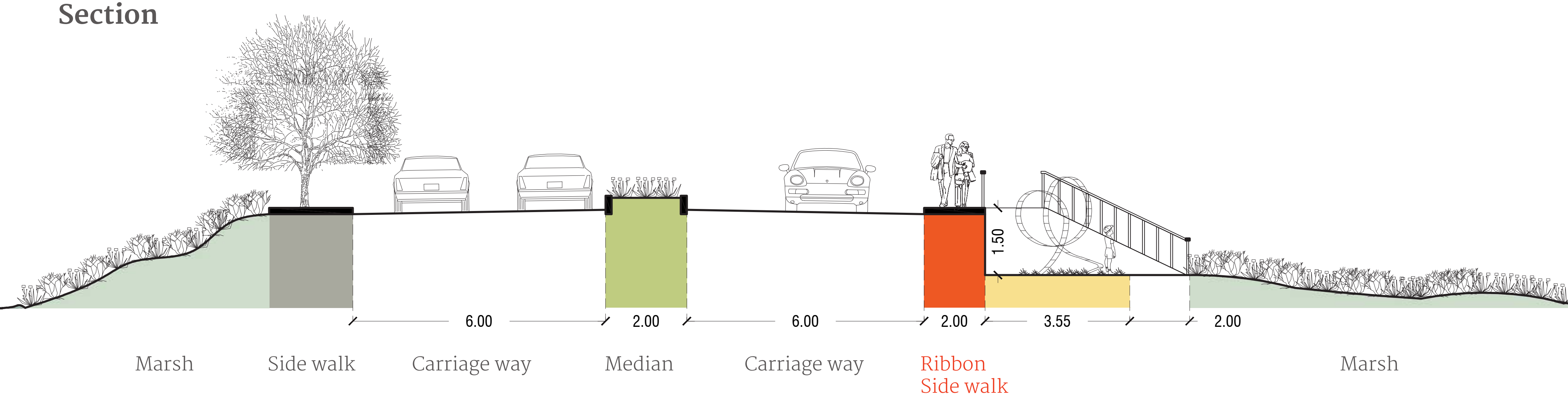
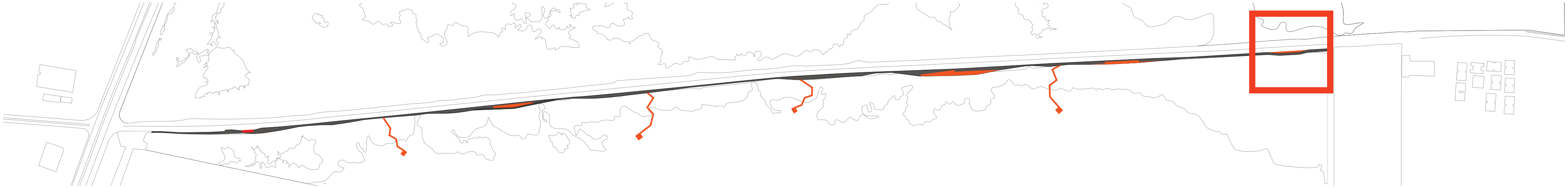
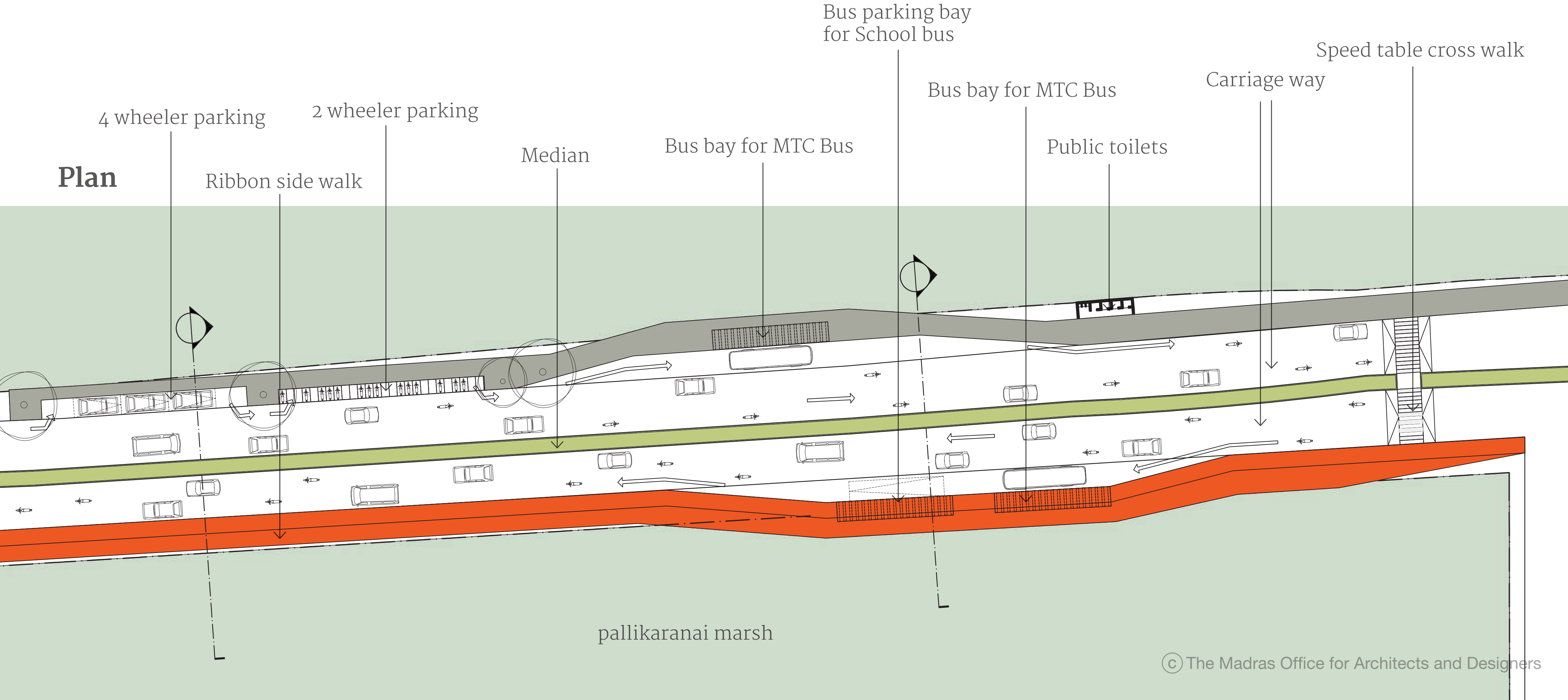


View
Play Area

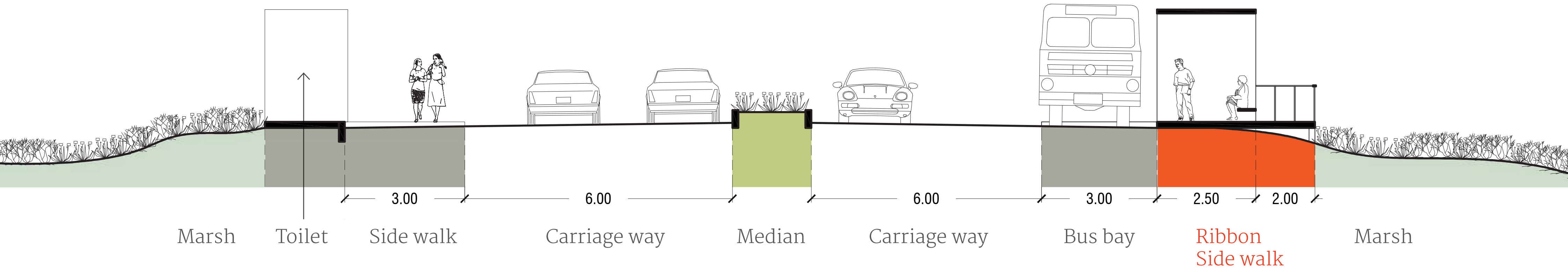
Entry East
Public Utilities



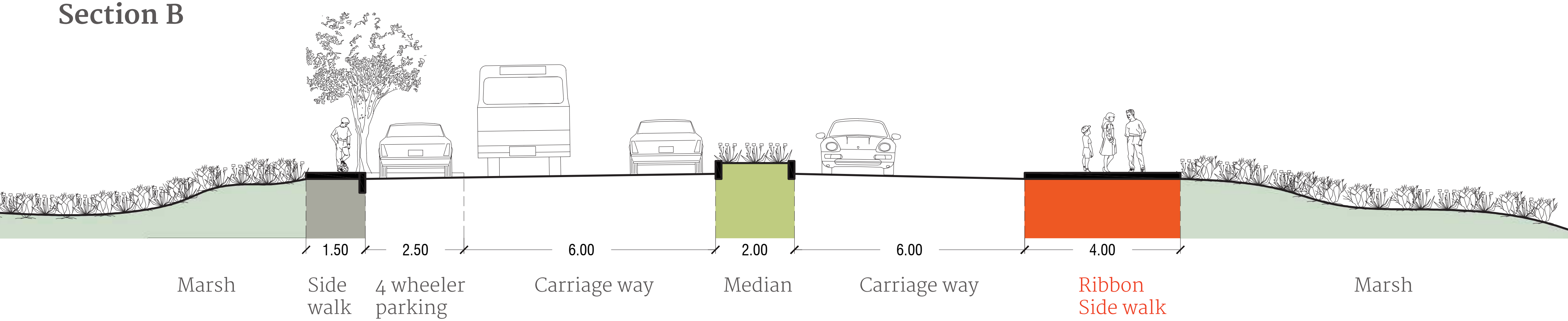
Plan



Section A



Section B



The Ribbon Walk Project
at Pallikaranai Marsh

2014
MOAD
The Madras Office for Architects and Designers

SL. No.	Activity		Width (m)	Length (m)	Area (sq.m)	Total Area (sq.m)
1	Ribbon Sidewalk		2	2697.1	5394.2	**6758.84**
			varying		1364.64	
2	Boardwalk				794.125	**794.125**
3	Landscape	8 no.s				**1716.313**
4	Median			2592		
5	Sidewalk					**3856.257**
6	Activity Areas	tunnel 1			330.5	**1431.763**
		play area			273.825	
		tunnel 2			827.438	
7	Birdwatching Decks	3 nos.			1008.43	**1399.598**
	Tower	1 no.			391.168	
8	Toilets	2 nos			30	**30**
9	Speed Tables	4 no.s			168	
10	Parking	2 wheeler (26 scooters)			140.087	**885.649**
		4 wheeler (5 + 3 cars)			148.834	
		Bus bays (2+2)			596.728	

Annexure

List of plants listed in 2002

S.No	Scientific Name	Status
1	*Abutilon indicum*	Frequent
2	*Acalypha indica*	Common
3	*Achyranthes aspera*	Frequent
4	*Alternanthera sessilis*	Common
5	*Amaranthus spinosus*	Common
6	*Amaranthus viridis*	Common
7	*Asteracanthus longifolius*	Frequent
8	*Bacopa spp*	Frequent
9	*Boerhavia diffusa*	Frequent
10	*Brachiaria* spp	Frequent
11	*Calotropis gigantea*	Common
12	*Cardiospermum halicacabum*	Frequent
13	*Cassia occidentalis*	Common
14	*Cleome viscosa*	Common
15	*Coccinia grandis*	Frequent
16	*Crotalaria pallida*	Frequent
17	*Croton bonplandianus*	Common
18	*Cynodon dactylon*	Common
19	*Cyperus rotundus*	Common (local)
20	*Cyperus* spp	Common (local)
21	*Datura metel*	Frequent
22	*Dolichos* spp	Frequent
23	*Echinochloa* spp	Frequent
24	*Eclipta prostrata*	Frequent
25	*Eichhornia crassipes*	Abundant/dense
26	*Evolvulus alsinoides*	Frequent
27	*Gomphrena celesioides*	Frequent
28	*Heliotropium indicum*	Common
29	*Heliotropium curassavicum*	Frequent (local)
30	*Hydrilla verticillata*	Common (local)
31	*Hygrophila auriculata*	Rare
32	*Ipomoea carnea*	Frequent
33	*Jatropha gossypifilia*	Rare
34	*Lantana camara*	Common (local)
35	*Lemna* spp	Abundant (local)
36	*Leucas aspera*	Common
37	*Mukia maderaspatana*	Common
38	*Nymphaea pubescens*	Common (local)
39	*Ottelia alismoides*	Rare
40	*Parthenium hysterophorus*	Frequent

List of Plants listed in 2005

S.No	Family	Species	Remarks
1	Acanthaceae	*Hygrophila auriculata*	Medicinal
2	Acanthaceae	*Ruellia tuberosa*	Introduced, Ornamental
3	Aizoaceae	*Mollugo oppositifolia*	Medicinal
4	Aizoaceae	*Trianthema triquetra*	Coastal Plant
5	Amaranthaceae	*Alternanthera tenella*	Introduced, Edible
6	Amaranthaceae	*Amaranthus viridis*	Edible
7	Amaranthaceae	*Amaranthus spinosus*	Edible
8	Asclepiadaceae	*Calotropis gigantea*	Medicinal
9	Asteraceae	*Eclipta prostrate*	Medicinal
10	Chenopodiaceae	*Suaeda monoica*	Coastal
11	Chenopodiaceae	*Suaeda nudiflora*	Coastal
12	Commelinaceae	*Commelina benghalensis*	Common
13	Convolvulaceae	*Cressa cretica*	Medicinal, Coastal Plant
14	Convolvulaceae	*Ipomea eriocarpa*	Occasional
15	Cucurbitaceae	*Mukia maderaspatana*	Medicinal
16	Cucurbitaceae	*Cucumis melo*	Edible
17	Cyperaceae	*Cyperus compressus*	Sedge
18	Cyperaceae	*Cyperus platyphyllus*	Sedge
19	Cyperaceae	*Cyperus stoloniferus*	Sedge
20	Cyperaceae	*Fimbristylis triflora*	Sedge
21	Cyperaceae	*Fimbristylis polytrichoides*	Sedge
22	Euphorbiaceae	*Ricinus communis*	Medicinal
23	Euphorbiaceae	*Acalypha indica*	Medicinal
24	Euphorbiaceae	*Euphorbia repens*	Introduced
25	Euphorbiaceae	*Phyllanthus maderaspatensis*	Medicinal
26	Euphorbiaceae	*Croton bonplandianus*	Common
27	Euphorbiaceae	*Sauropus bacciformis*	Wild relative
28	Fabaceae	*Indigofera linnaei*	Common
29	Fabaceae	*Crotalaria pallida* var *obovata*	Introduced, Ornamental
30	Fabaceae	*Aeschynomene indica*	Aquatic plant
31	Fabaceae	*Alysicarpus monilifer*	Common
32	Fabaceae	*Tephrosia purpurea*	Common
33	Fabaceae	*Tephrosia hookeriana*	Occasional
34	Fabaceae	*Macroptilium lathyoides*	Legume
35	Lamiaceae	*Hyptis suaveolens*	Introduced
36	Malvaceae	*Sida acuta*	Common
37	Malvaceae	*Sida cordata*	Medicinal
38	Mimosaceae	*Prosopis juliflora*	Exotic, Fuel

S.No	Family	Species	Remarks
39	Nymphaeaceae	*Nymphaea pubescens*	Aquatic
40	Pedaliaceae	*Pedalium murex*	Medicinal
41	Poaceae	*Eragrostis riparia*	Native Grass
42	Poaceae	*Eragrostis maderaspatana*	Native Grass
43	Poaceae	*Cynodon barberi*	Endemic, Native Grass
44	Poaceae	*Chloris montana*	Native Grass
45	Poaceae	*Paspalidium flavidum*	Native Grass
46	Poaceae	*Eriochloa procera*	Native Grass
47	Poaceae	*Paspalum vaginatum*	Wild relative, Native Grass
48	Poaceae	*Panicum repens*	Wild relative, Native Grass
49	Poaceae	*Brachiaria reptans*	Native Grass
50	Poaceae	*Echinochloa colona*	Wild relative, Native Grass
51	Poaceae	*Dactyloptenium ctenoides*	Native Grass
52	Poaceae	*Sporobolus coromandelianus*	Coastal, Native Grass
53	Poaceae	*Sporobolus virginicus*	Coastal, Native Grass
54	Poaceae	*Iseilema anthephoroides*	Endemic, Native Grass
55	Poaceae	*Zoysia matrella*	Native Grass
56	Polygalaceae	*Polygala bulbothrix*	Occasional
57	Polygalaceae	*Polygala telephoides*	Aromatic
58	Pontederiaceae	*Eichhornia crassipes*	Introduced
59	Portulacaceae	*Portulaca oleracea*	Introduced, Edible
60	Portulacaceae	*Portulaca tubersosa*	Wild relative
61	Rhamnaceae	*Ziziphus mauritiana*	Edible
62	Solanaceae	*Datura innoxia*	Introduced, Medicinal
63	Solanaceae	*Solanum surattense*	Medicinal
64	Sterculiaceae	*Melochia corchorifolia*	Common
65	Turneraceae	*Turnera ulmifolia*	Introduced, Ornamental
66	Typhaceae	*Typha angustata*	Mat-making
67	Verbenaceae	*Lippia nodiflora*	Medicinal
68	Zygophyllaceae	*Tribulus terrestris*	Medicinal

Amphibians of Pallikaranai Marsh

S.No	Common English Name	Scientific Name	Status
1	Indian Pond Frog	*Euphlyctis hexadactylus*	Common
2	Skipper	*Euphlyctis cyanophlyctis*	Common (local)
3	Burrowing Frog	*Tomopterna rolandae*	Rare
4	Jerdon's Bull Frog	*Hoplobatrachus crassus*	Common
5	Paddy Field Frog	*Limnonectes limnocharis*	Frequent
6	Painted Frog	*Kaloula taprobanica*	Common
7	Marbled Frog	*Ramanella variegata*	Rare
8	Indian Toad	*Bufo melanostictus*	Common
9	Common Tree Frog	*Polypedates maculatus*	Frequent

Reptiles of Pallikaranai Marsh

S.No	Common English Name	Scientific Name	Status
1	Garden Lizard	*Calotes versicolor*	Common
2	Fan-throated Lizard	*Sitana ponticeriana*	Rare
3	Common Skink	*Mabuya carinata*	Common
4	Garden Skink	*Lygosoma punctata*	Rare
5	White-spotted Garden Skink***	*Lygosoma albopunctata*	Occasional
6	Indian Monitor Lizard	*Varanus bengalensis*	Rare
7	Spotted Gecko	*Hemidactylus brooki*	Common
8	Termite-hill Gecko	*Hemidactylus triedrus*	Rare
9	House Gecko	*Hemidactylus frenatus*	Common
10	Bark Gecko	*Hemidactylus leschenaulti*	Common
11	Blind Snake	*Rhamphotyphlops braminus*	Frequent
12	Striped Keelback	*Amphiesma stolata*	Frequent
13	Olive Keelback	*Atretium schistosum*	Common
14	Checkered Keelback	*Xenochrophis piscator*	Common
15	Rat Snake	*Ptyas mucosus*	Frequent
16	Green Vine Snake	*Ahaetulla nasutus*	Frequent
17	Cobra	*Naja naja*	Rare
18	Krait*	*Bungarus caeruleus*	Unclear
19	Russell's Viper	*Vipera russelli*	Rare
20	Pond Turtle	*Melanochelys trijuga*	Frequent
21	Flapshell	*Lissemys punctata*	Common

Mammals of Pallikaranai Marsh

S.No	Common English Name	Scientific Name	Status
1	Spotted Deer	*Axis axis*	Rare
2	Bonnet Macaque	*Macaca radiata*	Rare
3	Indian Pipistrelle	*Pipistrellus coromandra*	Common
4	Leaf-nosed Bat	*Hipposideros* sp	Common
5	Three-striped Palm Squirrel	*Funambulus palmarum*	Common
6	Bandicoot	*Bandicota bengalensis*	Rare
7	House Rat	*Rattus rattus*	Common
8	Mice	*Mus spp*	Frequent
9	Jackal	*Canis aureus*	Rare
10	Mongoose	*Herpestes edwardsii*	Rare

Butterflies of Pallikaranai Marsh

S.No	Common English Name	Scientific Name	Status
1	Lime Butterfly	*Papilio demoleus*	Rare
2	Mottled Emigrant	*Catopsilia pyranthe*	Common
3	Common Crow	*Euploea core*	Common
4	Plain Tiger	*Danaus chrysippus*	Frequent
5	Glassy Tiger	*Parantica aglaea*	Common
6	Peacock Pansy	*Junonia almana*	Frequent
7	Tawny Coaster	*Acraea violae*	Frequent

Molluscans of Pallikaranai Marsh

S.No	Common English Name	Scientific Name	Status
1	Window-pane Oyster	*Placenta placenta*	Sub-fossil
2	Ark Shell	*Arca spp*	Sub-fossil
3	Oyster	*Crassostrea spp*	Sub-fossil
4	Apple Snail	*Pila virens*	Common
5	Freshwater Mussel	*Lamellidens marginalis*	Common (local)
6	Freshwater Snail	*Palidomus* sp	Common
7	Freshwater Snail	*Thiara* sp	Common
8	Freshwater Snail	*Lymnaea* sp	Common
9	Ram's Horn Snail	*Indoplanorbis exustus*	Common

Crustaceans of Pallikarnai Marsh

S.No	Common English Name	Scientific Name	Status
1	Freshwater Shrimp		Common
2	Prawn	*Palaemon* sp	Rare
3	Fresh water prawn	*Macrobrachium rosenbergii*	Common (local)
4	Pond Crab	*Paratelphusa* sp	Common
5	Mud Crab	*Scylla serrata*	Rare

Landfill Mining and Bioremediation

LANDFILL MINING

Landfill mining was first described in 1953 in an article that documented the processes used at a landfill operated by the City of Tel Aviv, Israel which was then a method used to recover the soil fraction to improve the soil quality in orchards (Shual and Hillel, 1958; Savage et al., 1993)[1 2].

Landfill mining is conducted in a number of ways. The equipment used for reclamation projects is similar to technologies already in use by the mining and construction industry and also in some solid waste management processes like Refuse Derived Fuel factories. However, the steps taken and their sequence, as well as the specific machinery used, may differ depending on the waste characteristics, climatic conditions, and the technologies available in a given location, as well as the final treatment(s) planned. At present, processing at the landfill site can be accomplished by means of equipment mounted on trailers. The equipment usually consists of conveyor belts, a coarse screen, a fine screen, and a magnet. The following is a suggestion of a potential process that can be adopted for Perungudi:

1. Excavation – The technology involved in the excavation of landfilled waste has not changed much since the Tel Aviv project in the 1950s. Generally, excavation is conducted using techniques similar to those used for open face mining. Equipment involved may be a front-end loader, a clamshell, a backhoe, a hydraulic excavator, or a combination of these. Excavated material either may be directly processed on-site or be stockpiled for later processing, either in-situ or at a processing facility (Vasudevan, Vedachalam, and Sridhar; 2003)[3].

2. Processing – Processing begins with the segregation of the excavated mass into discrete streams. The number and composition of the streams depends upon

[1] Shual and Hillel (1958). “Composting municipal garbage in Israel”, Tavruau, July– December.
[2] Savage, G.M., Golueke, G., Stein, E.L., von, Landfill Mining: Past and Present, Biocycle, 34(5), 58-61
[3] N. Vasudevan., S.Vedachalam, D. Sridhar; 2003, Study on the Various Methods of Landfill Remediation, VIT

the desire and extent of resource recovery. The following techniques can be used in the suggested order or in combinations appropriate to the given conditions at hand.

i. Manual Separation - Bulky items such as large pieces of wood, rocks, long pieces of cloth, etc. Are removed by hand before mechanical processing begins. Equipment involved in manual separation usually includes a sorting belt (Shah 2013).

ii. Screening – Size separation usually happens at two or more stages in the process. It is done by passing the waste through trommel screens, most commonly rolling drums with different mesh sizes. Trommels are attached to the conveyors at various stages of processing and are inclined to allow oversize materials to pass along them. Also including spikes inside the trommels helps act as bag bursters to free items that may be inside plastic bags (Shah 2013).

iii. Magnetic separation – Electro-magnets are used in this step so they can be switched on or off to allow removal of ferrous metals. However, not all metals can be removed by magnets. Stainless steel and copper, for example, are only weakly magnetic or are not magnetic at all (Shah 2013).

iv. Drying – The partially decayed waste is dried, either under the sun, by hot air, or by a combination of both. This important step in the process differs in each facility depending on the investment or land availability (Shah 2013).

v. Air separation – In this step, fans are used to create a column of air moving upwards. Light materials are blown upwards, and dense materials fall. The air carrying light materials, like paper and plastic bags, enters a separator where these items fall out of the air stream. (Shah 2013) *vi. Density-Based Separation – An additional technique that can be incorporated is density-based separators. The most common of these is the ballistic separation technique. Ballistic separation is based on a fast moving conveyor belt which flings items into the air. Those that carry furthest tend to be denser (Shah 2013)[4].*

3. Recovery – After processing, the recovery of materials into streams should follow. Based on earlier sample studies compiled by Water, Engineering and Development Center (WEDC) of Loughborough University, the materials highlighted in Table 1 can be expected in Perungudi waste dump (Ed.Coad; 1997)[5].

Materials	Constituents (%) at Perungudi based on average of 12 samples	Constituents (%) at Kodungaiyur based on average of 46 samples
Textile	2.3	0.6
Wood	11.6	0.5
Plastic	11.0	1.9
Rubber and Leather	14.5	0.5
Metal	0.2	0.1
Glass	0.8	0.4
Stone	18.	28.3
Soil	40.1	67.8
Sieve Size	< 20mm	< 20mm

Judging from available information and mechanical processing efficiencies, recovery of soil could be expected to fluctuate between 85% and 95%, ferrous metals from 70% to 90%, and plastic from 50% to 75%. Purity of these materials could be expected to be 90% to 95% for soil, 80% to 95% for ferrous metals, and 70% to 90% for plastic. The higher percentage of purity for each material category would generally be attributed to relatively complex processing designs (Strange; WRF)

[4] Dharmesh Shah 2013; Understanding Refuse Derived Fuel, Global Alliance for Incinerator Alternatives
[5] Coad A. 1997. Lessons from India in Solid Waste Management. WEDC, UK.

Note on Accelerated decomposition

The stability of buried organic wastes is essential to landfill mining and reclamation. Mining insufficiently decomposed wastes would result in an unacceptable generation of nuisances and negative impacts with regard to health and safety and the environment. Landfill mining should ideally not be attempted before the land-filled wastes are sufficiently stabilised. This prerequisite and other factors related to management of a completed landfill have led to an increase in studies on accelerating decomposition of organic matter in landfills[6].

BIOREMEDIATION

Bioremediation operates on the principle of biogeochemical cycling. When cleanup occurs in the same place without the excavation of the contaminated coil or material, it is referred to as in situ bioremediation. When there is deliberate relocation of the contaminated material (soil and water) to a different place to accelerate biocatalysis, it is referred to as ex situ bioremediation. Bioremediation, including Phytoremediation and Rhizoremediation has been successfully applied for cleanup of soil, surface water, ground water, sediments and ecosystem restoration (M.V Prasad and R. Prasad; 2012)[7]. In the case of Perungudi, ex situ bioremediation is the advised. An independent assessment and feasibility study should be carried out to understand the potential and nature of bioremediation needed at Perungudi.

[6] Kit Strange; Landfill Mining Preserving Resources through Integrated Sustainable Management of Waste Technical Brief from the World Resource Foundation

[7] Majeti Vara Prasad and Rajendra Prasad, 2012. Nature's Cure for cleanup of contaminated environment – a review of bioremediation strategies.

The Restoration Initiative for the Perungudi MSW Dump Yard

The following factors organized into clusters were utilized for defining and developing the restoration programme for the Perungudi dump yard.

1. The cluster of natural (abiotic) factors

1. Area available approx. 75 ha.
2. The candidate area is located within a marsh : average annual rainfall around 1200 mm
3. North and Western zones are inlets for precipitation run off
4. Wind peaks during the late hours from the Easterly direction
5. Local soil type is Recent alluvium gneiss, while available substrate is solid waste requiring topsoil topping
6. Possibility of using treated or partially treated sewage to be considered

2. The cluster of operational factors

1. Human foot print of visitors
2. Irregular patch with significant edge condition
3. Presence of significant quantity of non biodegradable waste.

3. The cluster of greening and maintenance

1. Integrity of the dump yard to be broken, smaller patches to be created with minimal or constructed connectivity
2. Multi species, gallery like planting; actual composition of species in accordance with the zonation.
3. Certain species need to be restricted: for instance, leaf shedding species, wide canopy species etc.
4. Focus on shrubs, herbs and grasses to enable natural recruitment and improve soil quality through mulching
5. All trees recommended native to India, with few being strict natives to the landscape
6. Shrubs will have a mix of native and garden species (75:25)
7. Issues pertaining to maintenance, minimizing threats

The Restoration Design

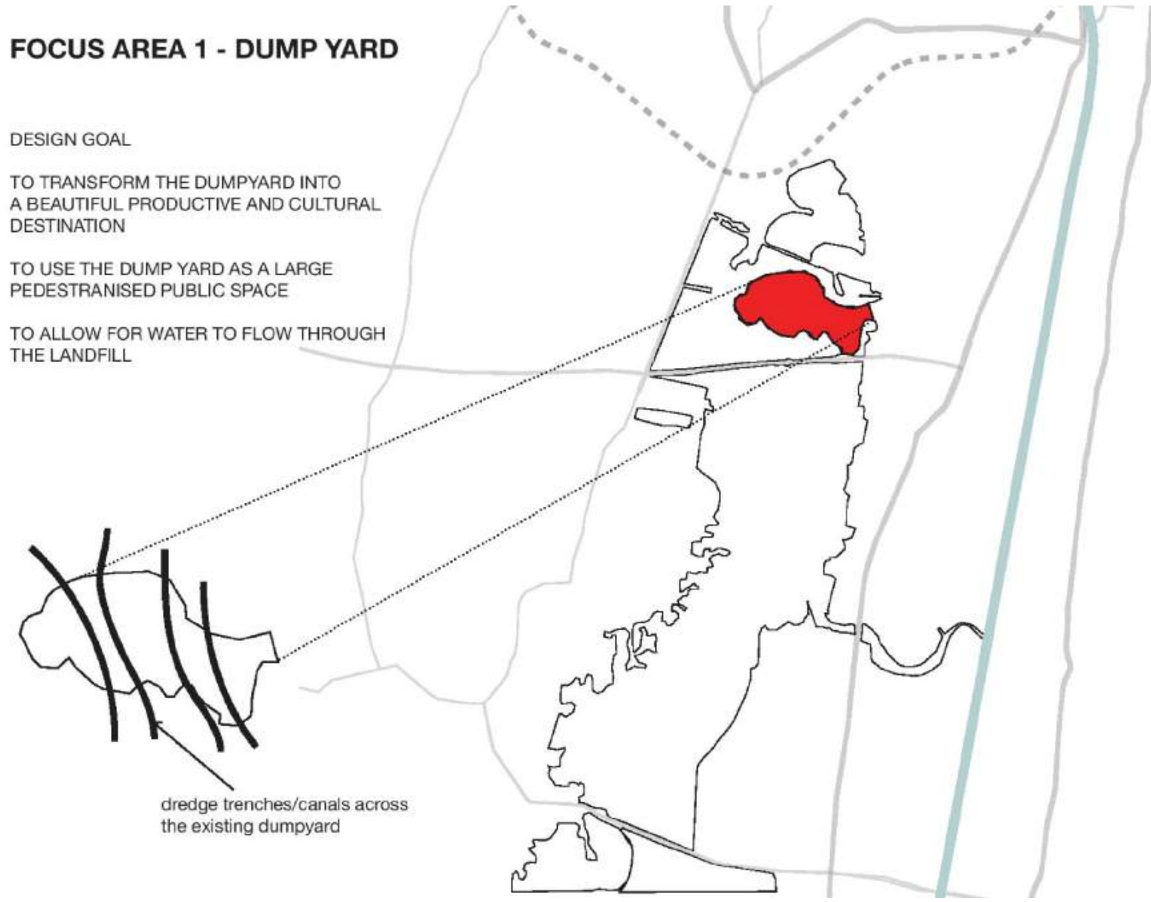
Using the factors detailed in the clusters, the following sequence of activities are being proposed for the restoration of the Perungudi dump yard: While some of the activities are stand alone in nature, in certain instances, such as those pertaining to planting, the activities would be concurrent and overlapping.

1. Based on the existing hydrological flows in the landscape, the quantum of water holding of the marsh, and the need to decimate the integrity of the dump yard, the first step would be to dig trenches on a North-West, South –East gradient within the dump yard.

2. The concern that contaminants and pollutants from the dump yard would percolate into the southern segment of the marsh, which is a Reserve Forest is quite erroneous for the following reasons: a) the draining of water (irrespective of the levels of pollution) is an ongoing process since the dump yard is located within the wetland, and there are dedicated culverts to facilitate the drainage of water b) the natural flow of water would over a period of time, flush the contamination and pollutants c) there would be continued presence of some organic pollutants given the fact that the marsh drains 250 sq. km of south Chennai

3. Once the dump yard is trenched, the patches could be studied for their contour and restoration activities such as strengthening of bunds through the use of plants, enriching the top soil etc.

4. The restoration initiative does not recommend for a complete cessation of the solid waste management activities, but emphasizes on the need to have a sanitary landfill within a small patch wherein activities that foster recycling and reuse could be taken up.



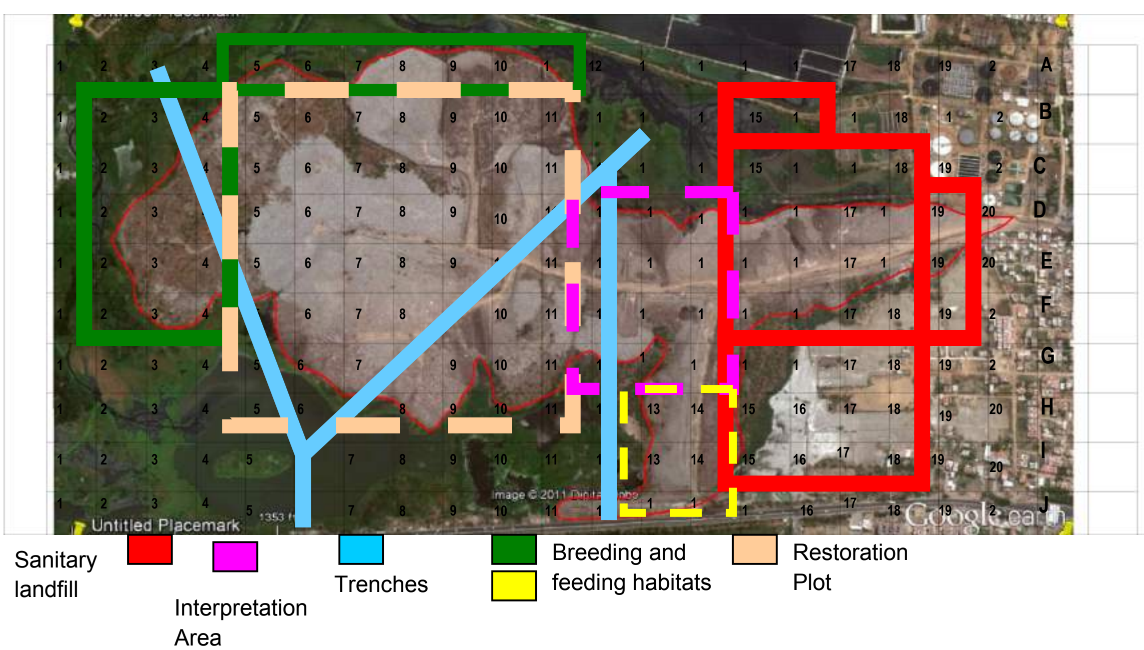

section along proposed public space above dumpyard

5. The intervention for each of the patches would be as follows; it is to be noted that the area of restoration exceeds the 75 ha. to include peripheral areas such as weigh bridge area of the dump yard, existing mud roads etc.

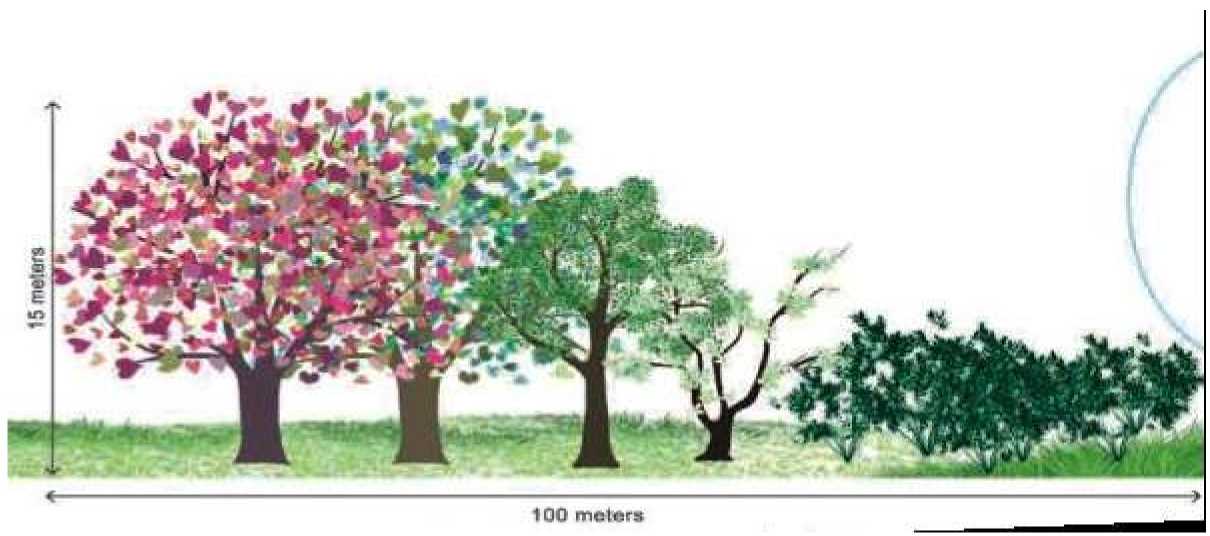
Intervention	Area
Sanitary landfill:	33 Ha
Breeding/ feeding habitat for birds	22 Ha
Restoration Plot:	49 Ha
Interpretation Area	12 Ha
Public facilities:	6 Ha

6. The location of the each of the afforestated patches is depicted in the following diagram.

Grid Map of the Landfill: 1 grid =

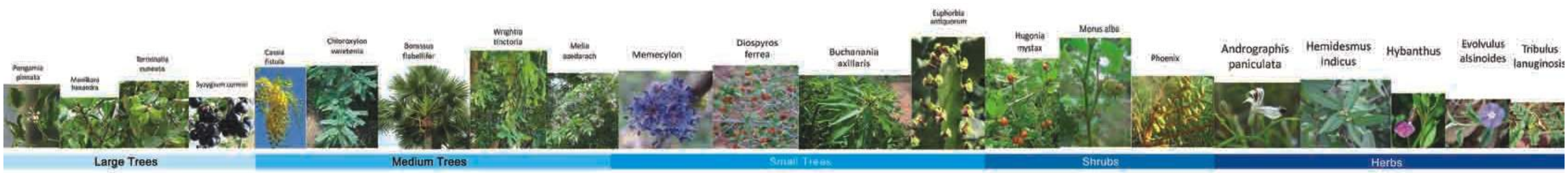


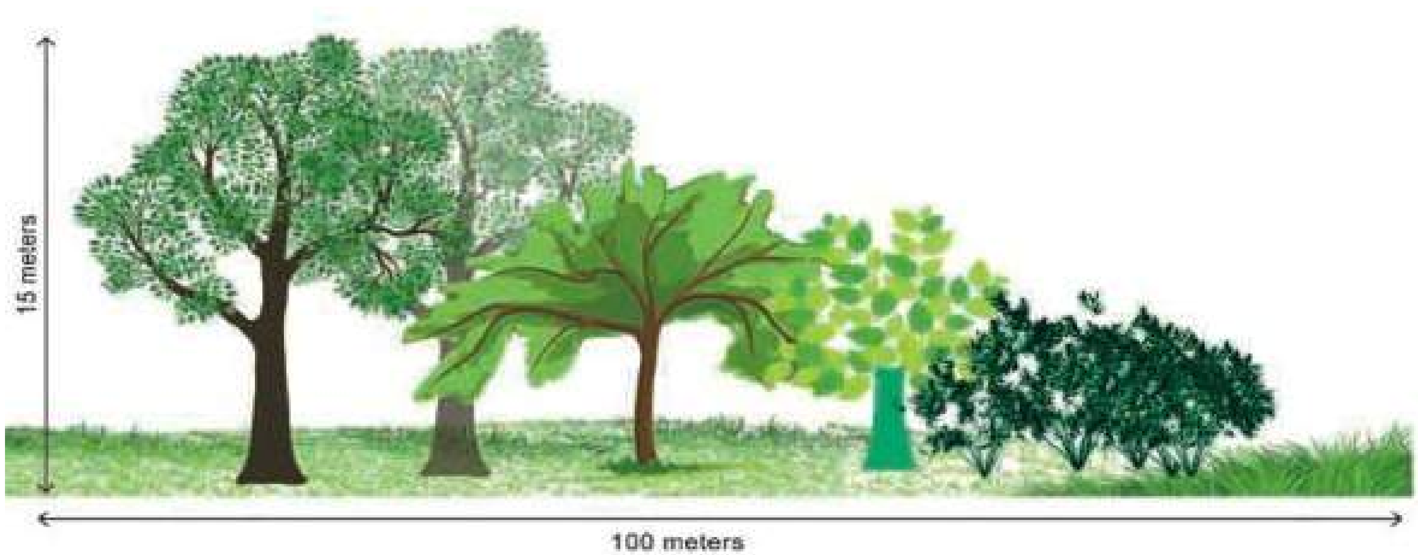
The following diagram details the design for greening initiative within the patches dedicated for restoration and breeding. It also provides a cross section view of the proposed design.



The list of plant species recommended for planting are as follows:

Large tree	Medium Tree	Small Tree	Shrub	Grass / Succulents
Pongamia pinnata	*Salix tetrasperma*	*Pandanus odoratissimus*	*Acorus calamus*	*Colocasia esculenta*
Syzygium cumini	*Caryota urens*	*Memecylon edule*	*Calamus rotang*	*Tylophora indica*
Terminalia cuneata	Thespesia populnea Lagerstroemia speciosa Saraca asoca	*Memecylon umbellatum*	*Breynia vitis-idaea*	*Sauropus bacciformis*
			Phyllanthus maderaspatensis *Glycosmis mauritiana* *Ipomoea carnea* *Canna indica*	*Canscora heteroclita* *Cryptocoryne retrospiralis* *Epipremnum pinnatum* cv *aureum* *Monstera deliciosa* *Rhaphidophora pertusa* *Theriophonum minutum* *Amorphophallus sylvaticus* *Commelina diffusa* Burm *Nymphea* spp *Ludwigia adscendens* *Vetiveria zizanioides* *Dactyloctenium aegyptium* *Echinochloa colona* Lily (white flowers) *Paspalidium flavidum* *Saccharum spontaneum* *Arundo donax*


Pongamia pinnata
Syzygium cumini
Cassia fistula
Chloroxylon swietenia
Borassus flabellifer
Wrightia tinctoria
Melia azedarach
Memecylon
Diospyros ferrea
Buchanania axillaris
Euphorbia antiquorum
Hugonia mystax
Morus alba
Phoenix
Andrographis paniculata
Hemidesmus indicus
Hybanthus
Evolvulus alsinoides
Tribulus lanuginosis
Large Trees
Medium Trees
Small Trees
Shrubs
Herbs


15 meters
100 meters

Recommended plant species for the restoration zone are detailed in the following table:

Large tree	Medium Tree	Small Tree	Shrub	Grass / Herbaceous
Pongamia pinnata	*Borassus flabellifer*	*Premna latifolia*	*Jasminum angustifolium*	*Aerva lanata*
Syzygium cumini	*Buchanania axillaris*	*Memecylon edule*	*Carissa spinarum*	*Heliotropium indicum*
Terminalia cuneata	*Calophyllum inophyllum*	*Memecylon umbellatum*	*Phoenix pusilla*	*Andrographis paniculata*
				Blepharis maderaspatensis
Diospyros malabarica	*Diospyros montana*	*Diospyros ferrea*	*Sansevieria roxburghiana*	
Madhuca longifolia	*Psydrax dicoccos*	*Euphorbia antiquorum*	*Glycosmis mauritiana*	*Ecbolium viride*
Syzygium cumini	*Sapindus emarginatus*	*Gardenia gummifera*	*Scutia myrtina*	*Merremia aegyptia*
Limonia acidissima	*Madhuca indica*	*Grewia flavescens*	*Tarenna asiatica*	*Phyllanthus virgatus*
Azadirachta indica	*Mimusops elengi*	*Pavetta indica*	*Glycosmis mauritiana*	*Hemidesmus indicus*
Pterocarpus santalinus	*Diospyros chloroxylon*	*Ixora pavetta*	*Smilax zeylanica*	*Perotis indica*
				Amorphophallus sylvaticus
Lannea coromandelica	*Litsea glutinosa*		*Premna corymbosa*	
Manilkara hexandra	*Cassia fistula*		*Tylophora indica*	*Habenaria viridiflora*
			Cassia auriculata	

Checklist for the possible contents of a Restoration Plan

The effectiveness of the restoration initiative for the Perungudi dump yard could be monitored using the following checklist:

- ✓ Background to the project, stakeholders involved
- ✓ Restoration goals, targets and milestones
- ✓ Site location and project boundaries
- ✓ Rainfall and other climatic considerations
- ✓ Physical properties of the soil and landforms over the site
- ✓ Physical features (including infrastructure) and their location
- ✓ Land use history and prior disturbance at and adjacent to the site
- ✓ Current location, state and 'trajectory' of native vegetation (if present)
- ✓ Condition and distribution of other relevant habitat features currently present
- ✓ Proximity to other habitat/remnant vegetation
- ✓ Current and potential future threats that need to be addressed in order to reach the restoration goal (include site threats and project risks)
- ✓ Management unit locations and their management context (maintain, improve, reconstruct or works exclusion zone)
- ✓ Desired habitat goal state (e.g. vegetation composition and structure)
- ✓ Management actions, with an implementation schedule prioritized over time and space (with flexibility for adjustment according to adaptive management as the project progresses)
- ✓ Standard operating procedures and access to the site
- ✓ Indicative resource requirements
- ✓ Monitoring and evaluation goals, indicators and schedule
- ✓ Location of reference sites (if applicable)
- ✓ The process of reporting and review

- ✓ Contacts and references (including previous reports)
- ✓ In conclusion, the bioremediation and restoration of the Perungudi dump yard is based on a comprehensive study of the landscape, its character and ecosystem functions. It takes a balanced view of the urbanization process and is designed to convert a problem into a desired output that fulfills the need of the citizens of Chennai for a green public space.