Republic of India
Tamil Nadu Disaster Risk Reduction Agency (TNDRRA)
Chennai Metropolitan Development Authority (CMDA)
Tamil Nadu State Water Resources Department (TNWRD)
Greater Chennai Corporation (GCC)

# Republic of India

# THE PROJECT FOR FORMULATION OF COMPREHENSIVE FLOOD CONTROL MASTER PLAN IN URBANIZED RIVER BASINS IN CHENNAI

## Final Summary Report

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Japan International Cooperation Agency

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# Table of Contents

# List of Figures

# List of Table

# Chapter 1. Scope of the Master Plan and Study Area

## 1.1 Scope of the JICA Flood Control Master Plan

A flood control master plan is a comprehensive roadmap designed to address flood disasters by integrating a wide range of measures, both structural and non-structural. Unlike a feasibility study (F/S) or detailed design (D/D), which focuses on evaluating the viability or planning for specific projects, a master plan offers a long-term, holistic vision. It provides a coordinated approach to managing flood risks, identifying multiple interrelated measures, and laying out an implementation plan to achieve a target safety level over time, typically in phases.

Unlike scattered actions or isolated projects that may address only parts of the problem, a master plan takes a comprehensive and integrated approach. It ensures that various measures work together to achieve the target safety level and considers the interconnectedness of upstream and downstream of the basin as well as the interaction between fluvial and pluvial floods. This is especially crucial in urbanized basins such as the Chennai Basins.

The JICA comprehensive flood control master plan for urbanized river basins in Chennai includes results of study disciplines and components such as river flood control (Chapter 2), urban flood control (Chapter 3), urban planning and residual risk management (Chapter 4), coastal and river mouth studies (Chapter 5), proposals for improving flood disaster management (Chapter 6), economic analysis (Chapter 7), strategic environmental assessments (Chapter 8) and a phased-based implementation plan and overall recommendations for the successful implementation of the master plan (Chapter 9). It also contributes to the Third Urban Development Master Plan for Chennai. By integrating these components, the plan aims to reduce flood risks and enhance resilience in a sustainable and coordinated manner.

Implementing a flood control master plan requires collaboration among stakeholders, including government agencies, local communities, and technical experts. It also demands long-term commitment, as achieving the desired safety levels and resilience takes significant time and effort. Regular monitoring and periodic reviews are essential to ensure the plan's effectiveness and relevance. For example, annual stakeholder meetings can help track progress and address challenges, while a more comprehensive review every five years allows for the necessary evaluation and review of the implementation plan based on evolving conditions and situations.

It is important to emphasize again that a master plan is not a feasibility study or a detailed design for a specific project. It is also not limited to addressing a single aspect of flood control. Instead, it is a broad, strategic framework that considers multiple facets of flood control. By adopting this integrated approach, the JICA flood control master plan ensures that flood risks are managed sustainably and comprehensively, providing a clear pathway to achieving safety and resilience in flood-prone areas over the long term.

## 1.2 Urbanized Basins in Chennai

Table 1-1 Provides general information about four basins in the study area and other significant administrative boundaries. The combined area of all four basins is 6,153 km². However, it is important to note that a portion of the Kosasthalaiyar basin lies within Andhra Pradesh State and, as such, is excluded from this study. Consequently, the total area for these four basins within Tamil Nadu State is 5,102 km². Additionally, while the entire Kovalam basin, spanning 782 km², has been modeled and investigated, only the northern part, covering approximately 293 km², is considered part of Chennai's urbanized river basins. Therefore, the total study area for developing the flood control master plan is 4,613 km².

The basin delineation has been conducted using a 2.5 m resolution Digital Terrain Model (DTM). It is worth noting that the Cooum River origin is located very close to the Kosasthalaiyar River at the Kesavaram Anicut.

Various canals, including the Buckingham Canal, are in the basin. Buckingham Canal is a significant waterway parallel to the Bay of Bengal. The Buckingham Canal can be divided into three segments: the south Buckingham Canal in the Kovalam basin (24 km), the central Buckingham Canal between the Adyar and Cooum Rivers (7 km), and the north Buckingham Canal after the Cooum River until the Ennore Creek in the Kosasthalaiyar River (17 km).

Greater Chennai Corporation (GCC) is the civic body responsible for governing and administering the urban areas of Chennai. Chennai Metropolitan Area (CMA) with an area of 1189 km2 is an extensive urban agglomeration that includes Chennai and its surrounding areas. The New Chennai Metropolitan Area (New CMA) with an area of 5904 km2 is an expansion plan by the Tamil Nadu government to further develop the urban areas surrounding Chennai since October 2022.

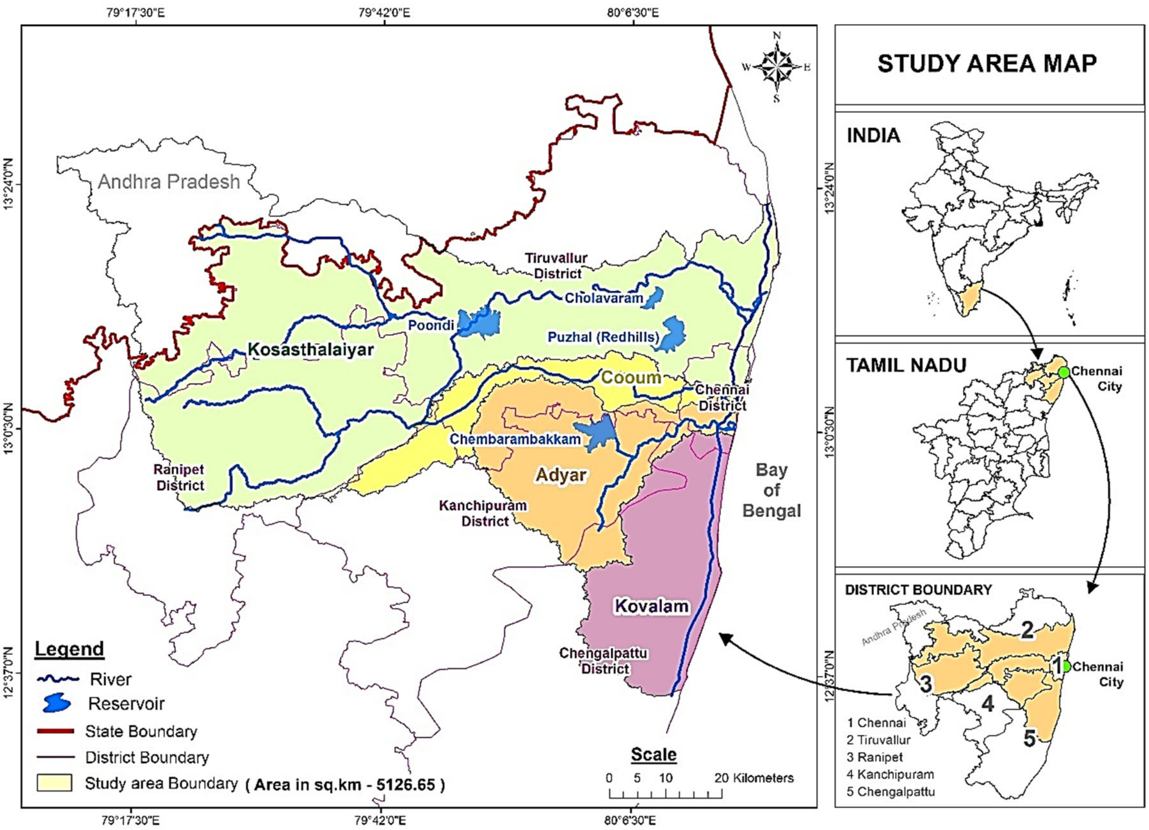
Four major dams and reservoirs in Chennai are Poondi Reservoir (Kosasthalaiyar Basin), Chembarambakkam Reservoir (Adyar Basin), Red Hills Reservoir (Kosasthalaiyar Basin), and Cholavaram Lake (Kosasthalaiyar Basin). Figure 1-1 Shows four target basins, rivers, dams, and other related administrative boundaries.

As the terms Fluvial Flood and Pluvial Flood have been used in this master plan, it is important to define them here. Fluvial flooding in Chennai occurs when rivers overflow due to heavy rainfall, causing water to exceed the river's capacity and inundate surrounding areas. This type of flooding is typically prolonged and widespread, affecting riverbanks and low-lying lands. Pluvial flooding, or urban flooding, occurs when intense rainfall overwhelms urban drainage systems, causing water to pool on the surface. This type of flooding can happen even without nearby rivers, especially in urban areas where the drainage system is inadequate to handle heavy rainfall.

**Table 1-1: Basin Area, River Length, and Admin Areas**

| Basin/Admin | Area ($km^2$) | Main River Length (km) | Avg. Annual Rainfall (mm) |
|---|---|---|---|
| Adyar Basin | 854 | ~ 43.6 | 1333.0 |
| Cooum Basin | 435 | ~ 73.7 | 1281.6 |
| Kosasthalaiyar Basin | 4,082 (3,031 in TN) | ~ 136 (~69.3 from Poondi Dam) | 1037.7 |
| Kovalam Basin | 782 (293 in north) | No main river | 1302.0 |
| Buckingham Canal | N/A | ~ 48 km in the Study Area | N/A |
| GCC | 426 | N/A | 1366.6 |
| CMA | 1,189 | N/A | 1363.4 |
| New CMA | 5904 | N/A | N/A |

*Source: JICA Expert Team*

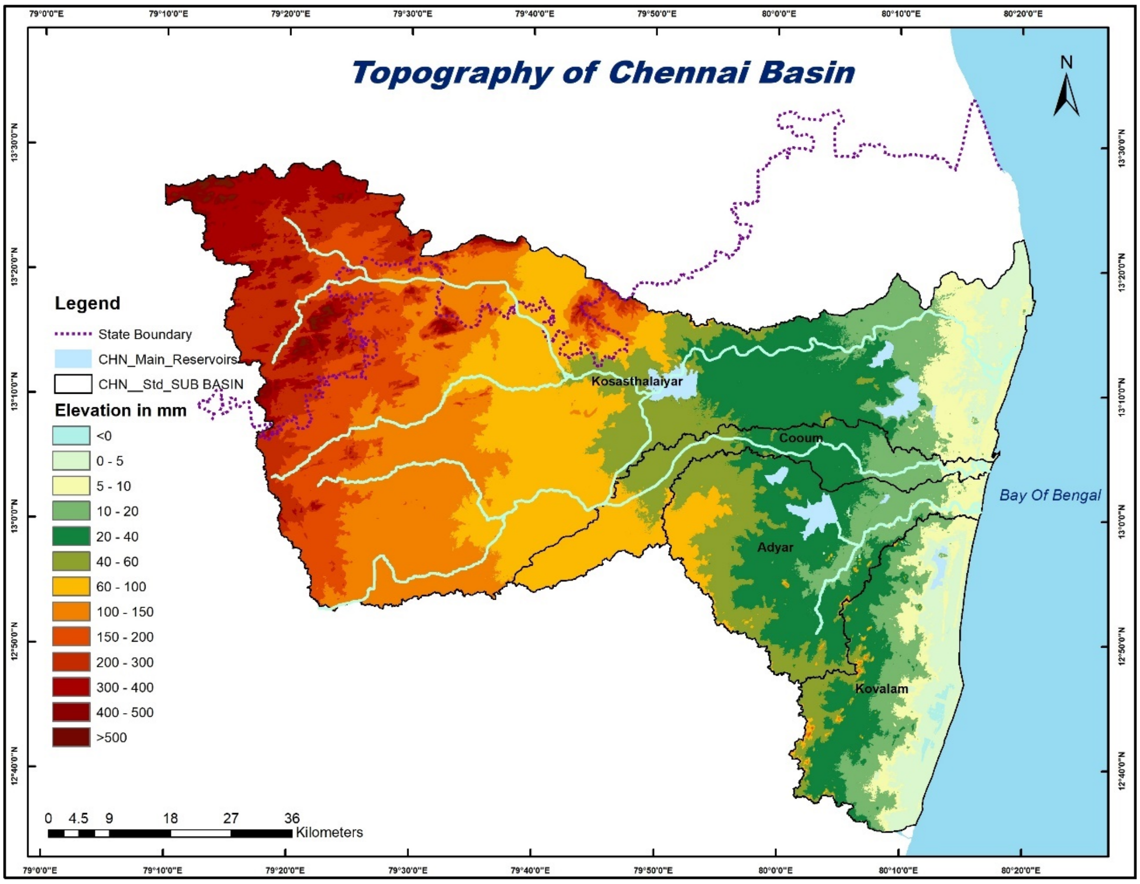



*Source: JICA Expert Team*

**Figure 1-1: Target Basins and Administrative Boundaries**

## 1.3 Topography of the Study Area

The study area exhibits a distinctive low-lying and flat topography, as depicted in Figure 1-2. Due to their low-lying nature, these basins are prone to flood and waterlogging. The majority of the Adyar, Cooum, and Kovalam basins are located within low-lying areas, with elevations under 20 meters above mean sea level (MSL). In contrast, the Kosasthalaiyar basin maintains a low and flat topography until reaching the Poondi Dam, where it rises to relatively higher elevations upstream. Table 1-2 Summarizes the topographic characteristics of the basins and rivers.




*Source: JICA Expert Team*

**Figure 1-2: Topography of the Study Area**

**Table 1-2: Basin Topographic Specifications**

| Basin Name | Highest Elevation Across Basin (above MSL) | Elevation at River Origin (above MSL) | Avg. River Slope (Origin to Outlet) |
|---|---|---|---|
| Adyar | 175m | 29.7m | 0.70 m/km<br>1:1420 |
| Cooum | 101m | 65.5m | 0.91 m/km<br>1:1100 |
| Kovalam | 169m | N/A | N/A |
| Kosasthalaiyar (Poondi Dam U/S) | 545m | 177.5m | 2.96 m/km<br>1:340 |
| Kosasthalaiyar (Poondi Dam D/S) | 63m | 35.2m | 0.50 m/km<br>1:2020 |

*Source: JICA Expert Team*

## 1.4 Socio-economic Overview

Chennai, the capital of the state of Tamil Nadu, is the fourth largest metropolitan city in India. The Chennai Metropolitan Area (CMA) consists of the city of Chennai, eight municipalities, etc. The estimated population for each administrative boundary and basin is shown in Table 1-3.

**Table 1-3: Estimated Population (2022 Est.)**

| Admin/Basin | Population (2022 Est.) |
|---|---|
| GCC | 6,221,000 |
| CMA | 11,503,000 |
| New CMA | 15,900,000 |
| Tamil Nadu State | 76,536,000 |
| Adyar Basin | 3,524,000 |
| Cooum Basin | 2,095,000 |
| Kovalam Basin | 2,678,000 |
| Kosasthalaiyar Basin | 5,107,000 |
| **Total Four Basins** | **13,404,000** |

*Source: JICA Expert Team using various statistical information and projections*

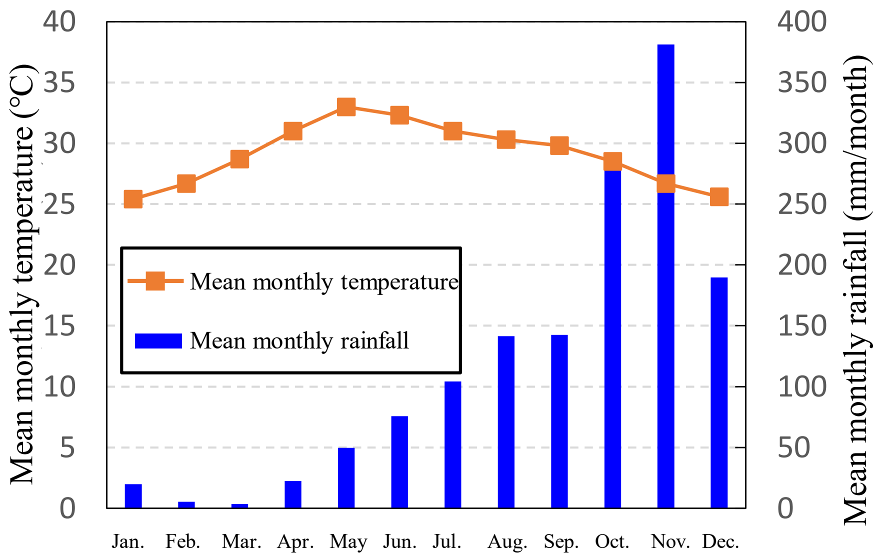
Tamil Nadu state's Gross State Domestic Product (GSDP) was approximately USD 320.3 billion in FY2022, with a Compound Annual Growth Rate (CAGR) of 11.27% over the past eight years. This stands for 8.8% of India's GDP[1], making it the second largest contributor after Maharashtra state. The CMA had a per capita income of $1,764 in 2018, 31% higher than the national average.[2].

## 1.5 Hydrological and Physical Characteristics of Study Basins

### 1.5.1 Rainfall and Climate

Chennai, located on the southeastern coast of India, experiences a tropical climate influenced by the Bay of Bengal. The rainy months typically span from October to December, with November being the wettest month, receiving a significant portion of the yearly rainfall as in the Figure 1-3.

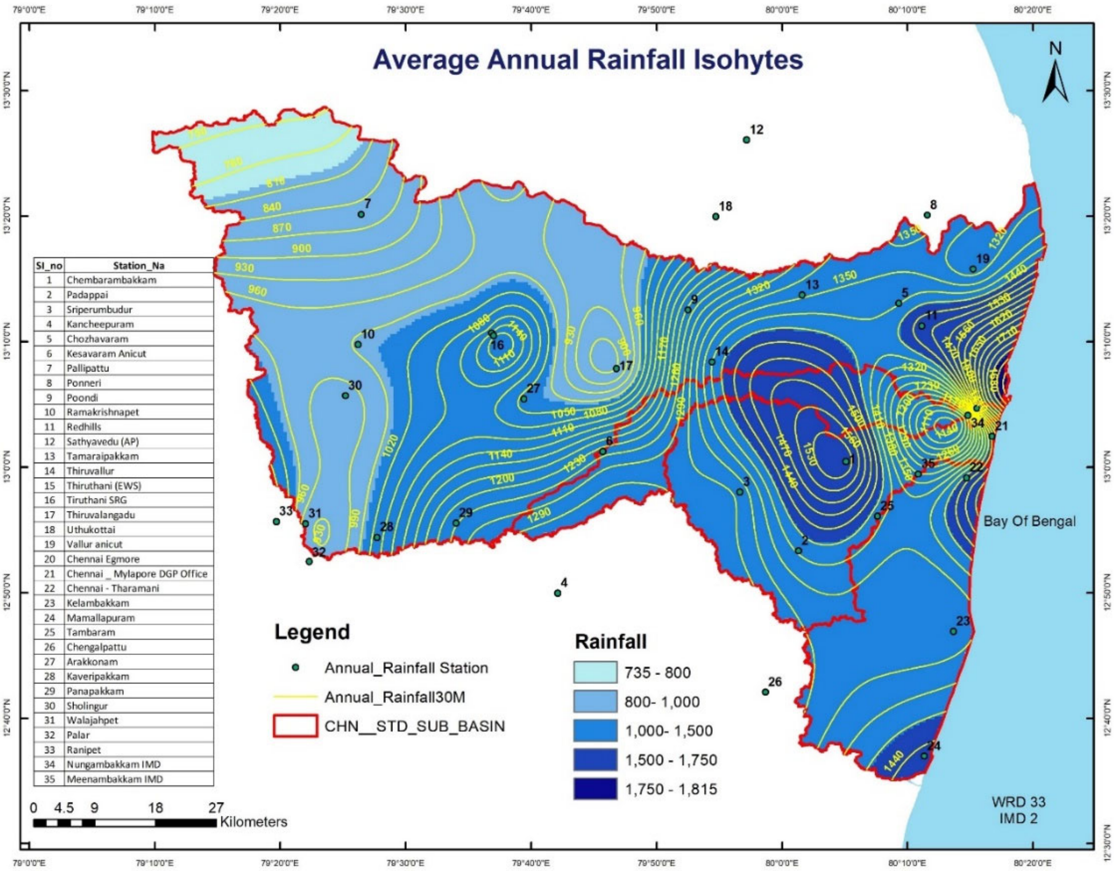
The long-term (30 years) average annual rainfall for each basin is as follows: Adyar Basin (1,333.0 mm), Cooum Basin (1,281.6 mm), Kovalam Basin (1,302.0 mm) and Kosasthalaiyar Basin (1,037.7 mm). Figure 1-4 Shows isohyets for average annual rainfall from 1991 to 2021. Areas near the Bay of Bengal and the middle part of the Adyar (Chembarambakkam Dam) and Cooum Basins receive more rainfall. In the Kosasthalaiyar Basin, the area upstream of Poondi Dam receives much less rainfall compared to the downstream region.




*Source: JICA Expert Team based on IMD data from 1991 to 2020*

**Figure 1-3: Average Monthly Rainfall and Average Monthly Temperature in Major Cities**

[1] https://www.msmetamilnadu.tn.gov.in/why-tamilnadu.php
[2] https://www.cgijaffna.gov.in/uploads/pdf/Presentation-on-tamil-nadu-1.pdf

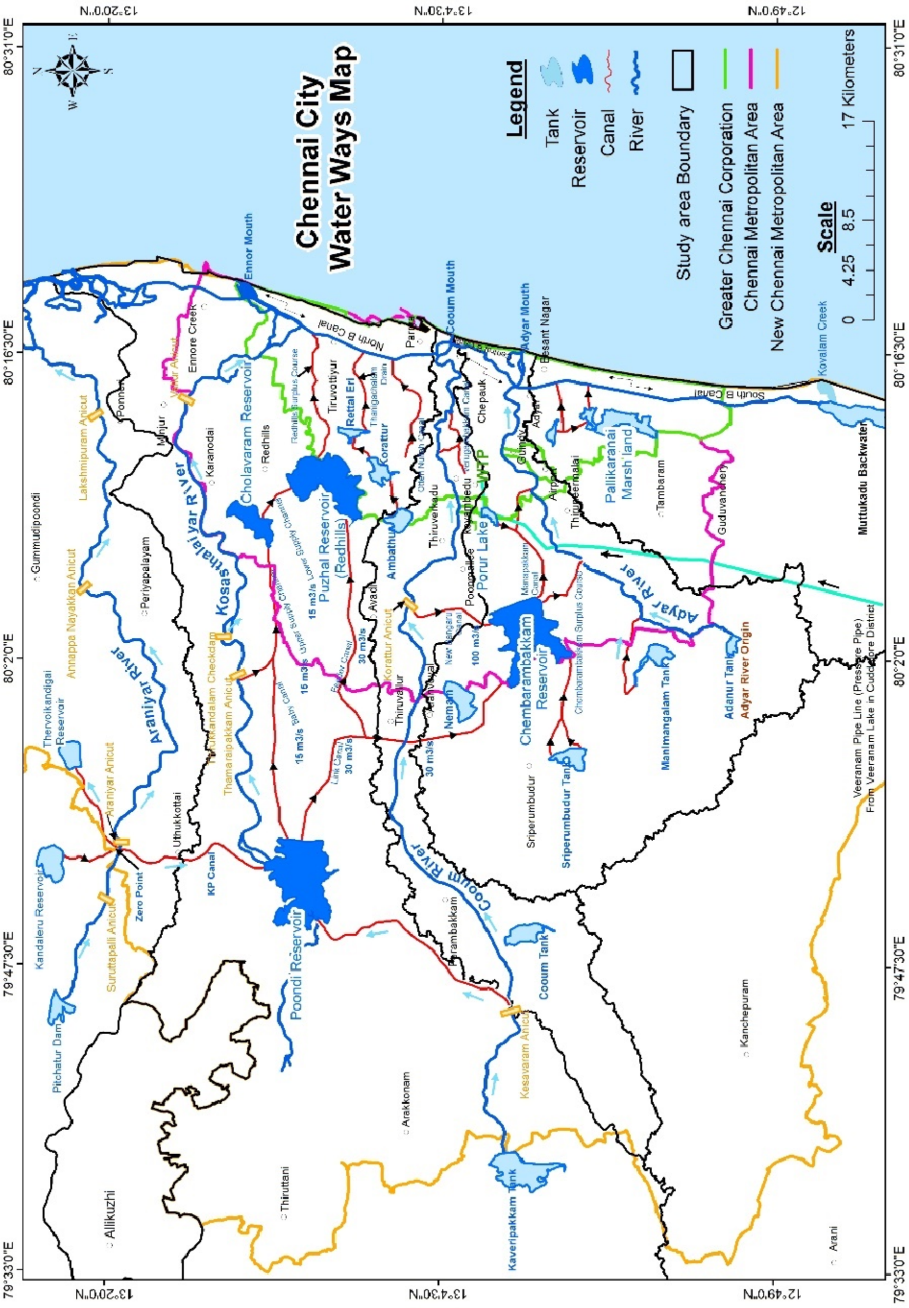



*Source: JICA Expert Team using WRD and IMD Stations*

**Figure 1-4: Average Annual Rainfall Isohyets from 1991 to 2021**

### 1.5.2 Water Bodies and Drainage System

It is important to note the complex system of major rivers, natural canals, man-made canals, and drainage systems in the study areas. Figure 1-5 Provides an overview of major rivers, canals, drainage systems, key dams, and the most important water bodies and tanks in the study areas.



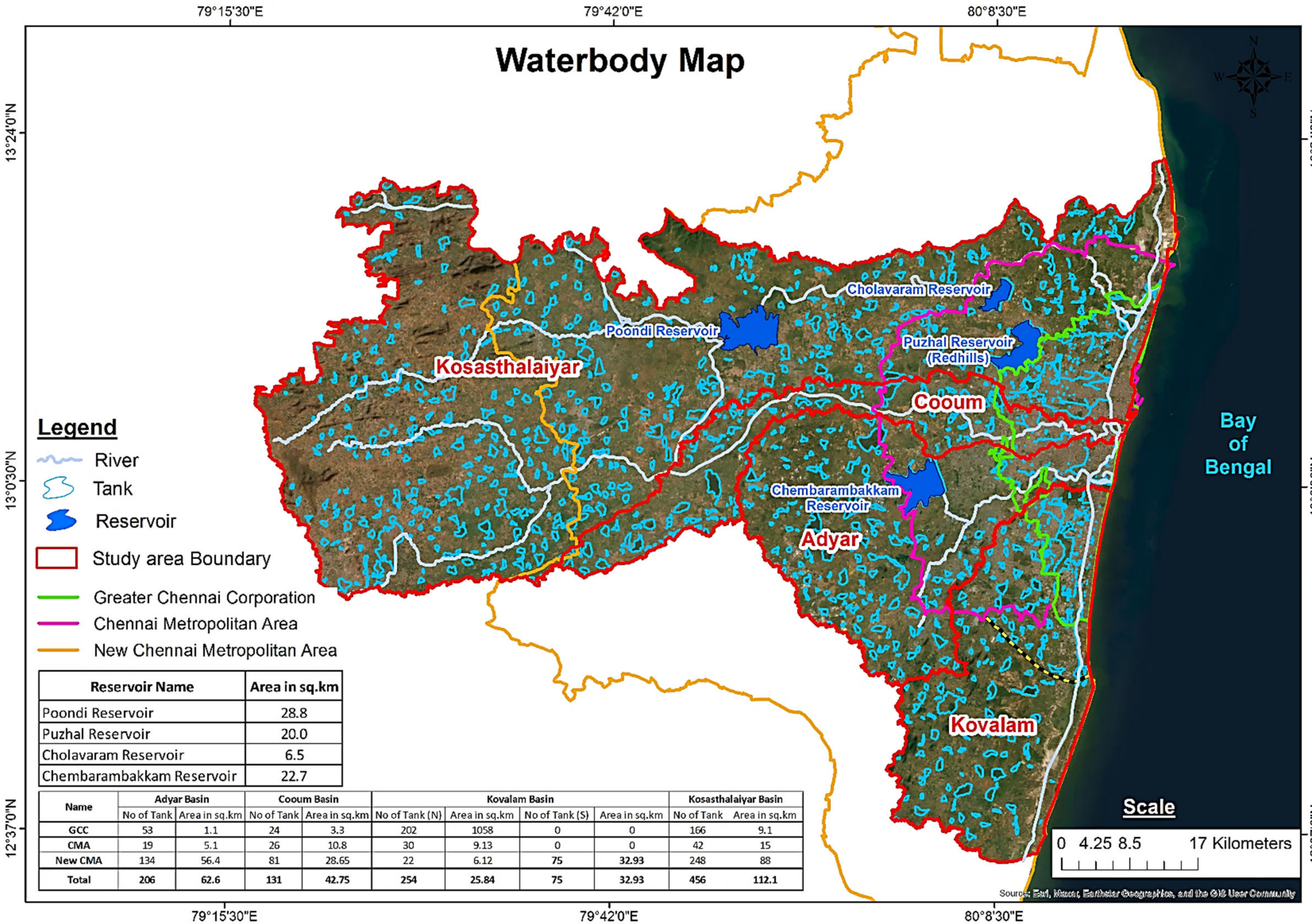

*Source: JICA Expert Team using WRD and IMD Stations*

**Figure 1-5: Water Infrastructure and Hydrographic Features of the Basin**

Chennai has various water bodies, lakes, and tanks that contribute significantly to the region's water resources and environmental balance. In Chennai's historical context, "Ery" refers to traditional water bodies and tanks that once graced the city's landscape. Urbanization, expansion, and encroachments resulted in the disappearance or degradation of numerous Erys, as they were transformed into residential and commercial areas. This transformation severely affected Chennai's hydrological balance, leading to issues such as increased vulnerability to flooding. Figure 1-6 Shows the location and other details of remaining water bodies, locally referred to as tanks, based on the information collected from TNWRD.

### 1.5.3 Land Use and Land Cover (LULC) and Important Infrastructures

Figure 1-7 Illustrates the land use/land cover in the study area, focusing specifically on the New CMA as of 2023. Figure 1-8 Shows important urban infrastructures for transportation.

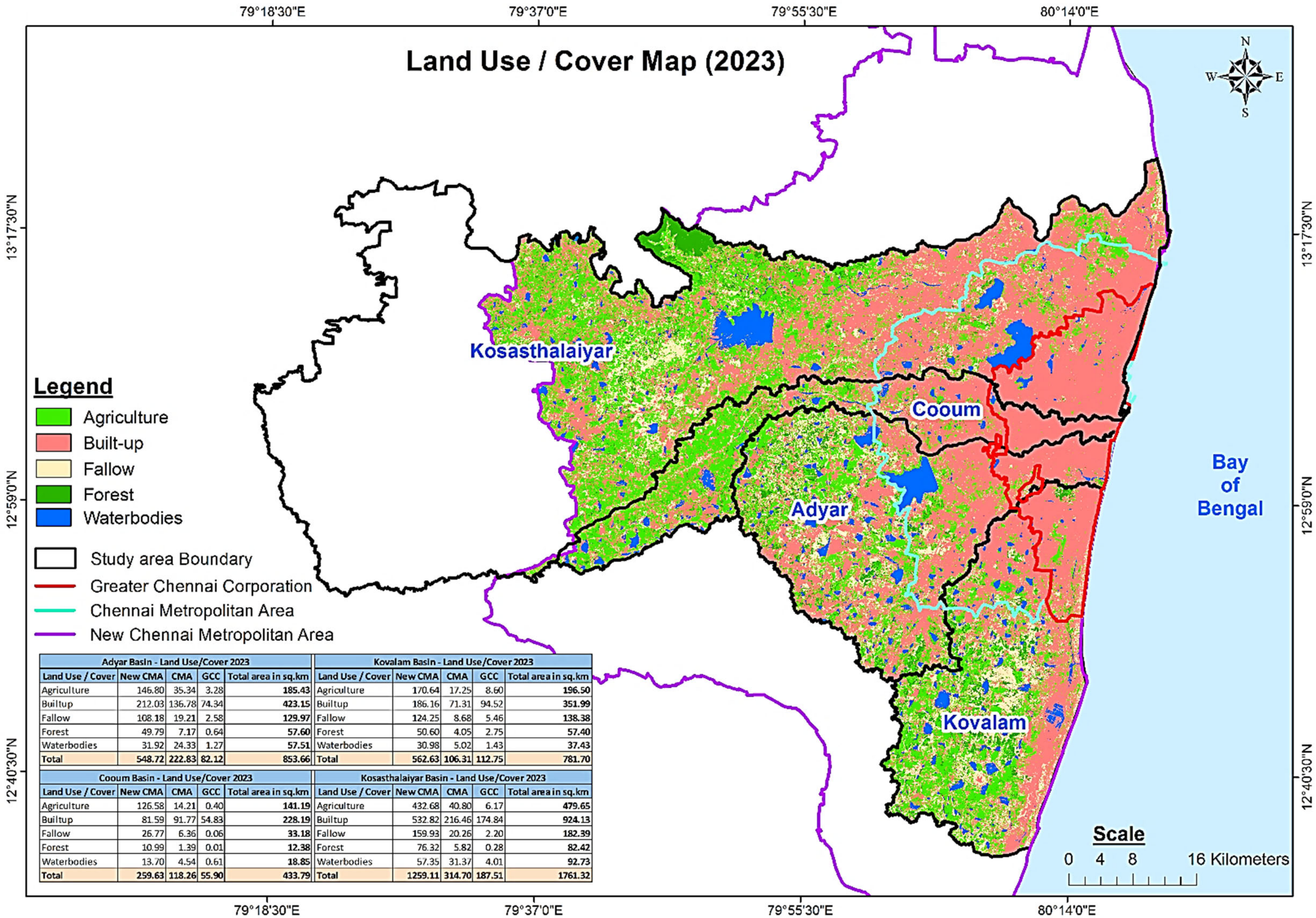



| Reservoir Name | Area in sq.km |
|---|---|
| Poondi Reservoir | 28.8 |
| Puzhal Reservoir | 20.0 |
| Cholavaram Reservoir | 6.5 |
| Chembarambakkam Reservoir | 22.7 |

| Name | Adyar Basin | | Cooum Basin | | Kovalam Basin | | | | Kosasthalaiyar Basin | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No of Tank | Area in sq.km | No of Tank | Area in sq.km | No of Tank (N) | Area in sq.km | No of Tank (S) | Area in sq.km | No of Tank | Area in sq.km |
| GCC | 53 | 1.1 | 24 | 3.3 | 202 | 1058 | 0 | 0 | 166 | 9.1 |
| CMA | 19 | 5.1 | 26 | 10.8 | 30 | 9.13 | 0 | 0 | 42 | 15 |
| New CMA | 134 | 56.4 | 81 | 28.65 | 22 | 6.12 | **75** | **32.93** | 248 | 88 |
| **Total** | **206** | **62.6** | **131** | **42.75** | **254** | **25.84** | **75** | **32.93** | **456** | **112.1** |

*Source: JICA Expert Team using TNWRD data*

**Figure 1-6: Basins and Other Hydrological Elements of the Study Area**




**Adyar Basin - Land Use/Cover 2023**

| Land Use / Cover | New CMA | CMA | GCC | Total area in sq.km |
|---|---|---|---|---|
| Agriculture | 146.80 | 35.34 | 3.28 | **185.43** |
| Builtup | 212.03 | 136.78 | 74.34 | **423.15** |
| Fallow | 108.18 | 19.21 | 2.58 | **129.97** |
| Forest | 49.79 | 7.17 | 0.64 | **57.60** |
| Waterbodies | 31.92 | 24.33 | 1.27 | **57.51** |
| **Total** | **548.72** | **222.83** | **82.12** | **853.66** |

**Kovalam Basin - Land Use/Cover 2023**

| Land Use / Cover | New CMA | CMA | GCC | Total area in sq.km |
|---|---|---|---|---|
| Agriculture | 170.64 | 17.25 | 8.60 | **196.50** |
| Builtup | 186.16 | 71.31 | 94.52 | **351.99** |
| Fallow | 124.25 | 8.68 | 5.46 | **138.38** |
| Forest | 50.60 | 4.05 | 2.75 | **57.40** |
| Waterbodies | 30.98 | 5.02 | 1.43 | **37.43** |
| **Total** | **562.63** | **106.31** | **112.75** | **781.70** |

**Cooum Basin - Land Use/Cover 2023**

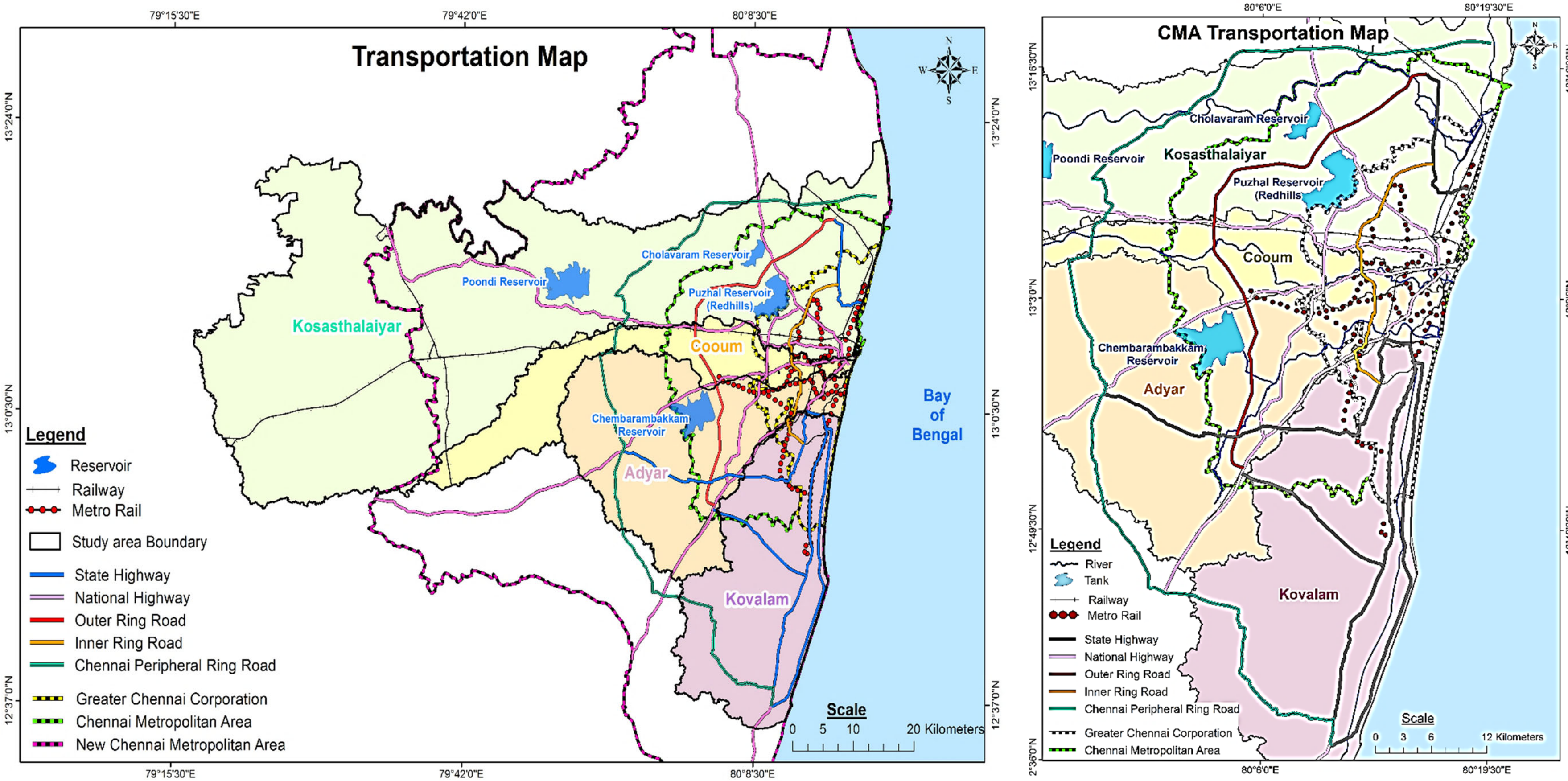
| Land Use / Cover | New CMA | CMA | GCC | Total area in sq.km |
|---|---|---|---|---|
| Agriculture | 126.58 | 14.21 | 0.40 | **141.19** |
| Builtup | 81.59 | 91.77 | 54.83 | **228.19** |
| Fallow | 26.77 | 6.36 | 0.06 | **33.18** |
| Forest | 10.99 | 1.39 | 0.01 | **12.38** |
| Waterbodies | 13.70 | 4.54 | 0.61 | **18.85** |
| **Total** | **259.63** | **118.26** | **55.90** | **433.79** |

**Kosasthalaiyar Basin - Land Use/Cover 2023**

| Land Use / Cover | New CMA | CMA | GCC | Total area in sq.km |
|---|---|---|---|---|
| Agriculture | 432.68 | 40.80 | 6.17 | **479.65** |
| Builtup | 532.82 | 216.46 | 174.84 | **924.13** |
| Fallow | 159.93 | 20.26 | 2.20 | **182.39** |
| Forest | 76.32 | 5.82 | 0.28 | **82.42** |
| Waterbodies | 57.35 | 31.37 | 4.01 | **92.73** |
| **Total** | **1259.11** | **314.70** | **187.51** | **1761.32** |

*Source: JICA Expert Team using CMDA land use GIS data*

**Figure 1-7: Land Use of Study Area in the New CMA in 2023**




*Source: JICA Expert Team using ADB study data*

**Figure 1-8: Transportation Infrastructures in the Study Area**

## 1.6 Past Major Floods in Chennai

Chennai has experienced several significant floods that have left a lasting impact. Notable floods occurred in 1943, 1976, 1985, 1991, 1996, 1998, 2002, 2005, 2008, 2015, 2020, 2021 and 2023. The Table 1-4 It is extracted from the "Flood Risk Reduction: Final Report," provided by the Advisory Committee on Mitigation and Management of Flood Risk in Chennai Metro, published on March 6, 2023. This table originates from the work conducted by the SECON-JBA Study Team in 2021. It provides a summary of significant flood events from 1976 to 2021. It is important to note that there were notable rainfall/flood incidents before 1976, including instances like 520mm of rainfall in 24 hours on October 21, 1845, 460mm in 24 hours on October 24, 1857, and 358mm of rainfall in 48 hours on October 6 and 7, 1943, as documented in the 2nd Chennai Urban Master Plan. Chapter 7 of this study provides more details on flood disaster damage.

In 2023, Chennai received the highest amount of rainfall since the rain and subsequent floods in 2015. Nungambakkam and Meenambakkam observatories recorded 530mm and 520mm of rain between December 2 and 4, 2023. Chennai recorded a total of 921.4 mm of rain between December 3 and 5.

**Table 1-4: Past Major Flood in Study Area**

| Flood Year | Type of Flooding | Daily Max. Rainfall (mm) | Date of Daily Max Rainfall | Total Rainfall During Monsoon (mm) |
|---|---|---|---|---|
| 1976 | Primary Fluvial | 452.4<br>Nungambakkam | 11/25/1976 | 1264.5 (Meenambakkam) |
| 1985 | Fluvial & Pluvial | 329.0<br>Nungambakkam | 11/13/1985 | 1271.7 (Nungambakkam) |
| 1996 | Fluvial | 450.0<br>Cholavaram &Thamaripakkam<br>347.0<br>Nungambakkam | 6/14/1996 | 1704.6 (Nungambakkam) |
| 2005 | Fluvial & Pluvial | 312.0<br>Tambaram | 12/13/2005 | 2108.0 (Nungambakkam) |
| 2015 | Fluvial & Pluvial | 494.2<br>Tambaram<br>475.0<br>Chembarambakkam | 12/2/2015 | 2066.9 (Tambaram) |
| 2021 | Primary Pluvial | 237.1<br>Mylapore - DGP Office | 12/31/2021 | 1816.0 (Cholavaram)<br>1785.0 (Mylapore) |
| 2023 | Fluvial & Pluvial | 293.4mm<br>Nungambakkam | 12/4/2023 | 921.4 (Nungambakkam) |

*Source: Advisory Committee on Mitigation and Management of Flood Risk in Chennai Metro "Flood Risk Reduction: Final Report, "2023, originates from the work conducted by the SECON-JBA Study Team in 2021*

## 1.7 Challenges of Flood Management in Chennai

Chennai faces a range of interconnected challenges related to both river and urban flood control, which are intricately linked and require a comprehensive master plan to address. These challenges encompass systemic issues as well as specific issues related to riverine and urban floods, which together compound the flood risk in the city. Below are the major systemic issues, followed by those specifically related to urban and riverine flooding.

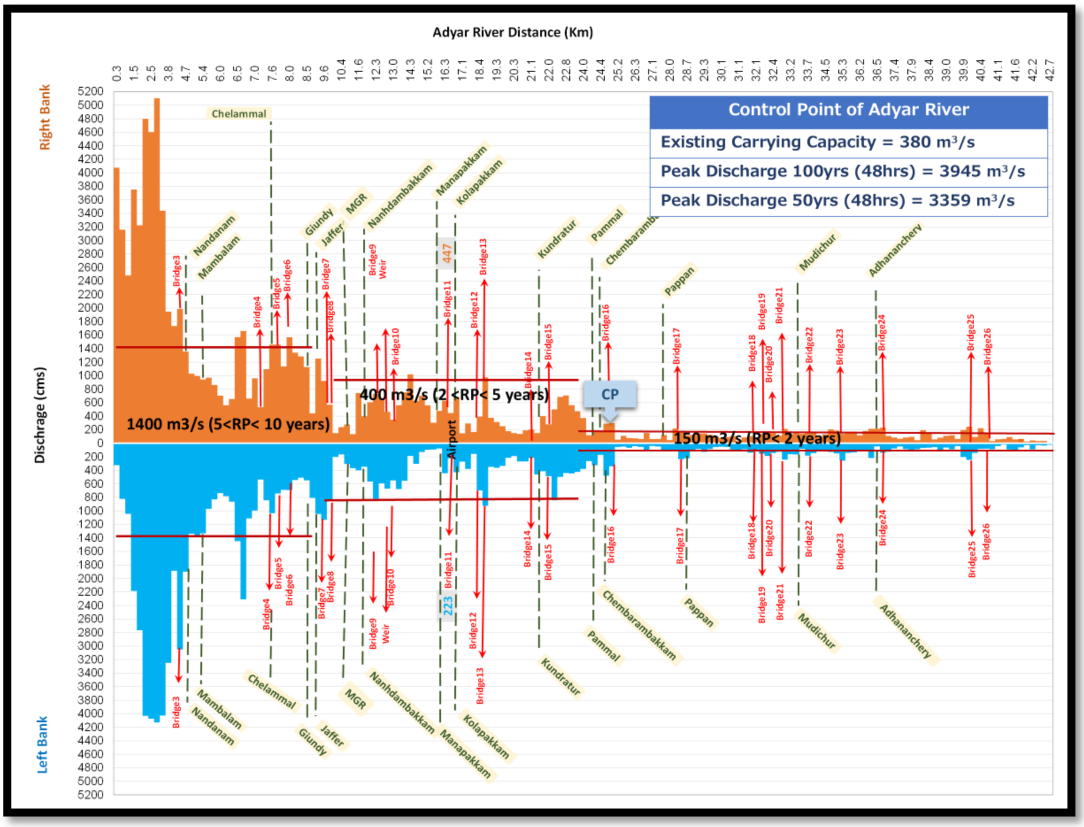
- Scattered Countermeasures and Lack of a Comprehensive Flood Control Master Plan: Flood control efforts in Chennai are currently fragmented, consisting of localized measures without an overarching, coordinated flood control master plan. This scattered approach hampers effective resource allocation and coordination, leaving the city vulnerable to flooding.

- Divided Responsibilities Among Stakeholders: Several agencies are involved in flood management, but the lack of proper coordination and information-sharing between them leads to inefficiencies. This is particularly evident in the management of micro-drainages and river flood control, where there is a lack of an integrated approach. Stakeholders operate in silos with competing financial and technical priorities, such as balancing flood control efforts with addressing other challenges like water supply and scarcity.
- Rapid Urbanization and Land-Use Changes: Chennai's rapid urbanization has significantly impacted the rainfall-runoff ratio, a key indicator of increasing flood risk. In 2006, when the Second Urban Development Master Plan for Chennai was developed, the rainfall-runoff ratio was 0.5. However, due to urban growth and increased impervious surfaces, this ratio has risen to 0.71 by 2024 for the CMA area, representing a significant increase in the amount of runoff generated.
- Encroachments and Reduced Natural Drainage: Encroachments along rivers, waterbodies, and tanks due to urban growth and improper planning and conservation have resulted in reducing the natural drainage capacity in rivers and also flood storage capacity in waterbodies and tanks. These changes disrupt the natural flow of floodwaters and increase the risk of floods. Moreover, encroachments along rivers and drains have reduced their carrying capacities, causing a rise in flow levels during heavy rainfall. It is important to note that rising water levels in rivers make it difficult for urban drainage systems to efficiently discharge floodwater due to backwater effects, leading to urban flooding. This interaction between riverine and urban flooding must be addressed together comprehensively within a master plan.
- Insufficient Observation Networks: There is a lack of real-time hydrological data and poorly gauged basins, limiting the capacity to predict and manage flood events proactively.

To effectively manage these interconnected issues, a comprehensive flood control master plan is crucial. Such a plan will address the root causes of increased runoff, inadequate drainage, and the growing urban pressures on natural water systems while also considering both riverine and urban flooding in an integrated manner.

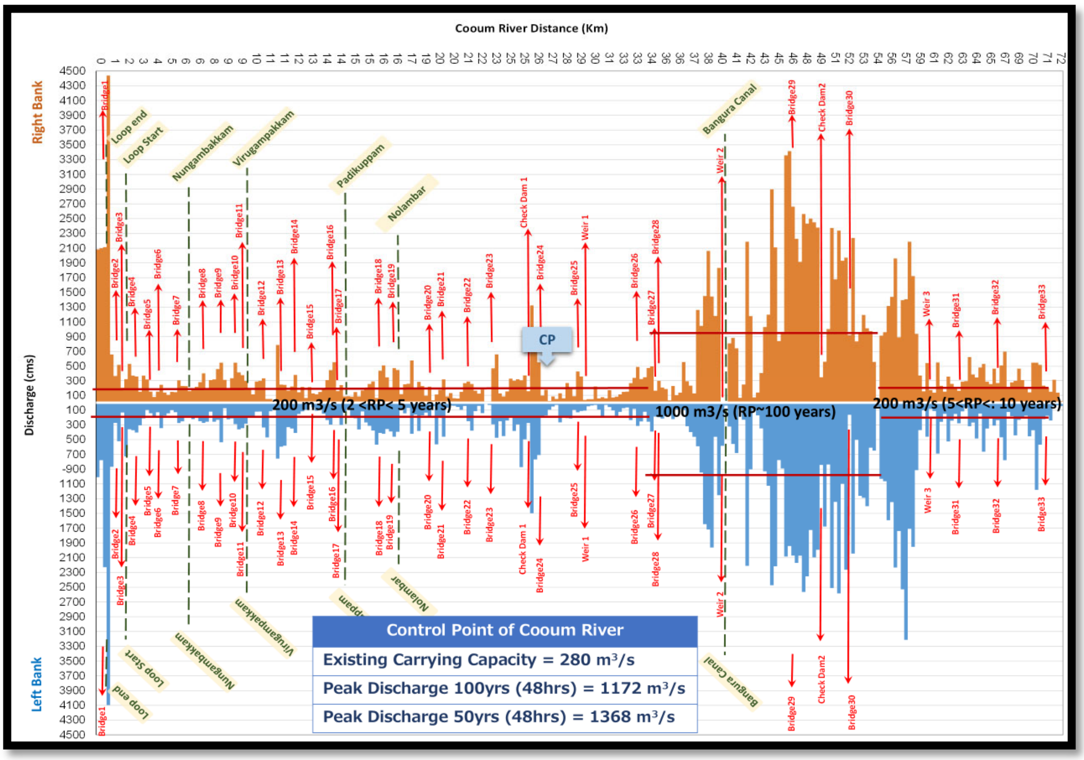
Figure 1-9 to Figure 1-11 Illustrates the carrying capacity of three major rivers: Adyar (at the confluence), Cooum (Pathiputtur), and Kosasthalaiyar (Vallur). It highlights the inadequate capacity of these rivers, reflecting a similar situation in other major waterways. The fundamental reason for this inadequate carrying capacity is rapid urbanization, which not only causes encroachments along the rivers but also increases runoff, further exacerbating the issue.

The challenges outlined above highlight the urgent need for a **comprehensive flood control master plan** for Chennai (Figure 1-12). Such a plan will integrate risk assessment, proactive flood management strategies, improved coordination among stakeholders, and infrastructure development. Addressing the physical limitations in river carrying capacities and urban flood control requires a systematic and multi-sectoral approach. Without an effective, long-term plan, Chennai remains vulnerable to the devastating impacts of flood events.



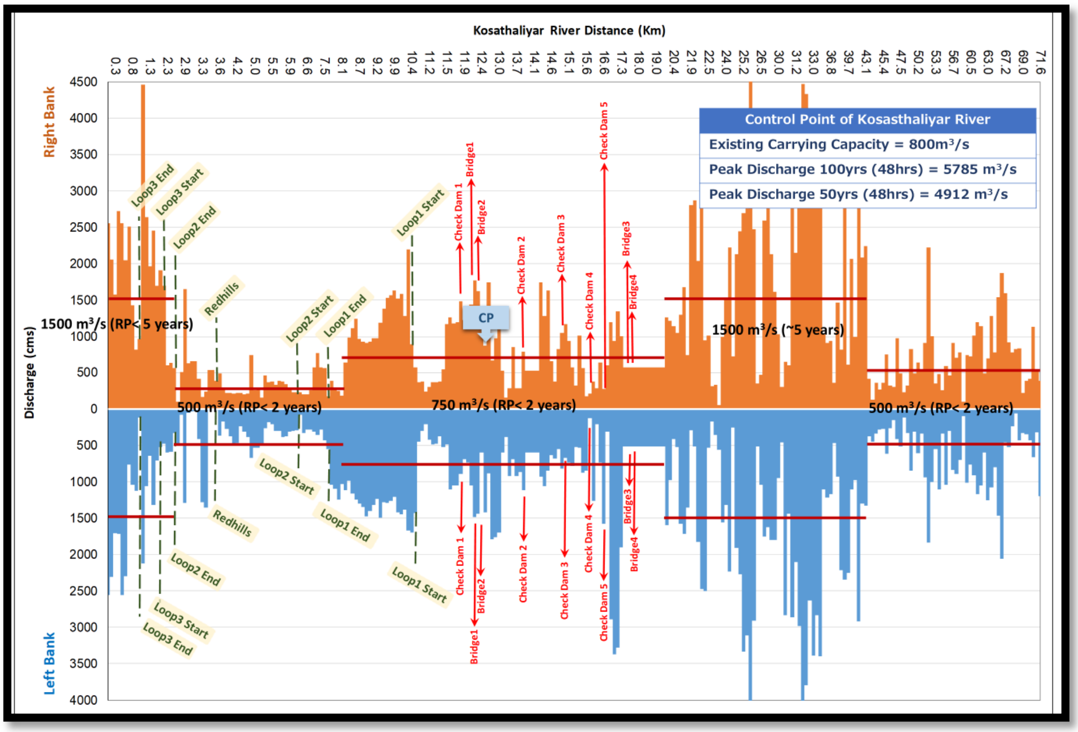

*Source: JICA Expert Team*

**Figure 1-9: Inadequate Carrying Capacity of the Adyar River**



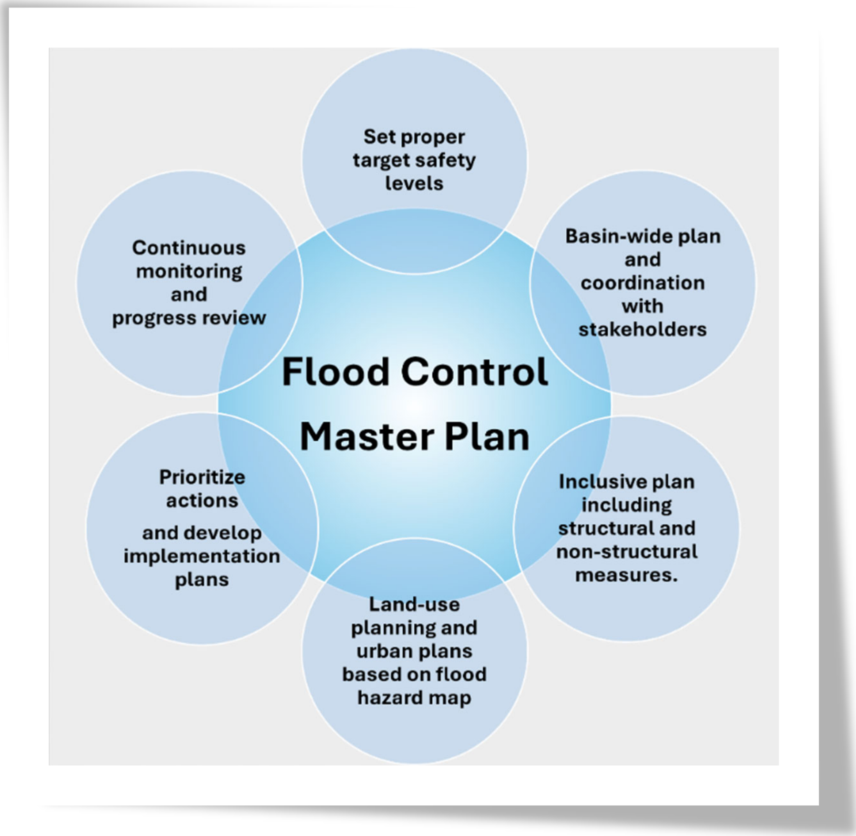

*Source: JICA Expert Team*

**Figure 1-10: Inadequate Carrying Capacity of the Cooum River**




*Source: JICA Expert Team*

**Figure 1-11: Inadequate Carrying Capacity of the Kosasthalaiyar**




*Source: JICA Expert Team*

**Figure 1-12: Inadequate Carrying Capacity of the Cooum River**

# Chapter 2. River Flood Control

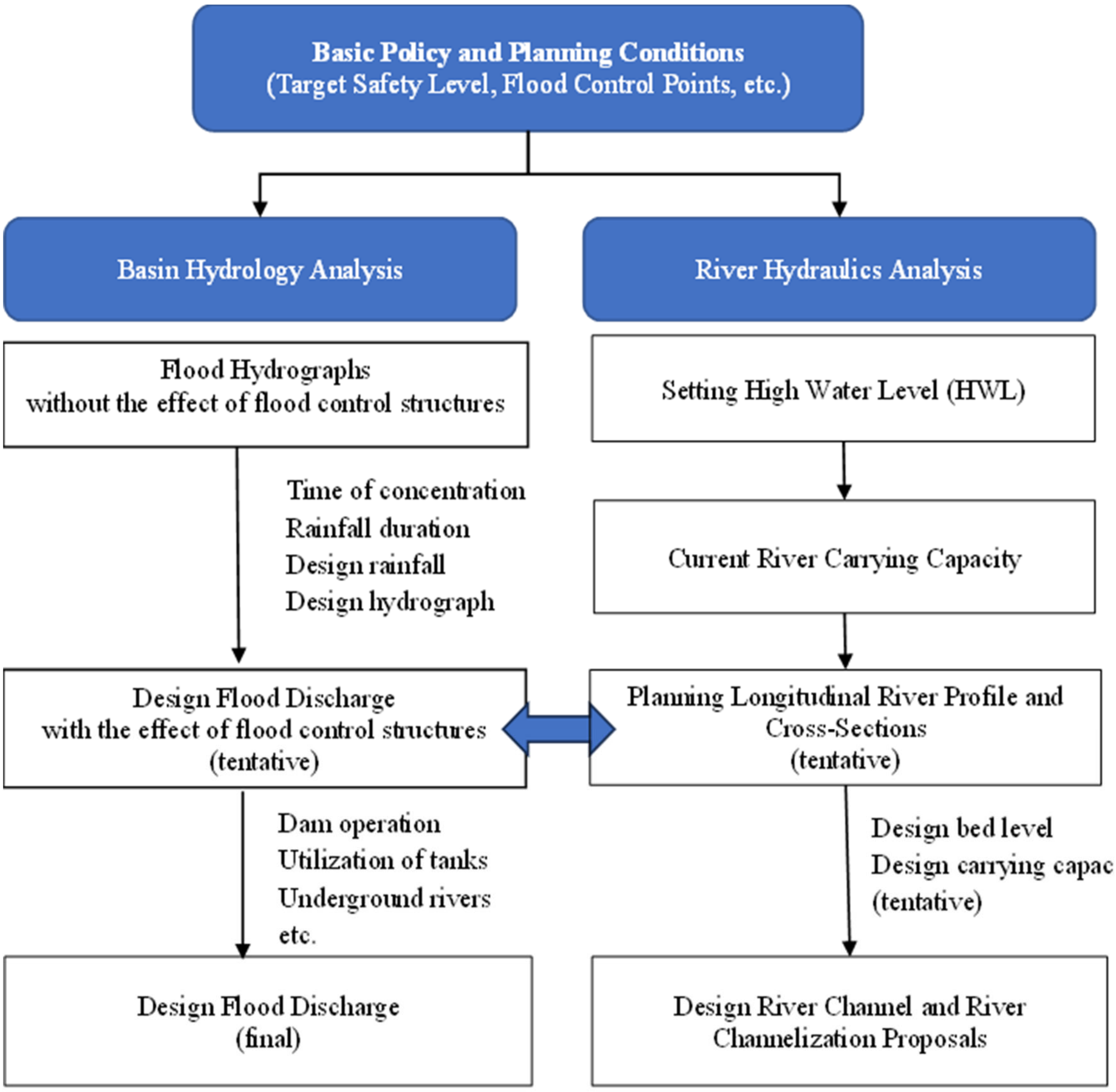
## 2.1 Background and Study Flowchart

The formulation of a comprehensive flood control master plan for the urbanized river basins of Chennai must address both riverine flooding (fluvial) and urban flooding (pluvial). This chapter focuses on river flood control measures for the entire Adyar River (including Chembarambakkam Dam surplus), the entire Cooum River (from Kesavaram Anicut), and the Kosasthalaiyar River system from Poondi Dam (including Red Hills surplus). The proposed measures include interventions such as river channelization through deepening and widening, flood storage in upstream reservoirs and tanks, and the installation of underground river and tidal gates etc.

Figure 2-1 Shows the study process for river flood control. The analysis begins by establishing the target safety level, followed by determining the design hydrograph without considering the effect of flood control facilities. Subsequently, the flow rate, considering storage facilities, is calculated as the Design Flood Discharge. In river channel planning, the design water level for flood protection (High Water Level) is first determined, and then a channel design is developed to ensure this level does not exceed the left and right banks.

Flood control measures generally prioritize managing floods within the river channel, with flood storage facilities addressing excess flows. In this study, special emphasis has been placed on maximizing flood storage in existing tanks and water bodies in each basin for an effective flow reduction downstream. Additionally, river channelization has been considered to improve the carrying capacity of the river. In this context, social impacts such as potential land acquisition and resident relocation have been carefully evaluated. The plan has been divided into two phases: in the first phase, emphasis is placed on river deepening to minimize social impacts, while the second phase, intended for long-term implementation, considers river widening. Moreover, to further reduce social impacts, river channel planning evaluates feasible alternatives, including the potential use of underground drainage channels, to determine the optimal solution.

This revision aligns with the feedback by addressing social considerations and alternative strategies in river channel planning. This approach is necessary due to the extremely low discharge capacity of the river, the presence of numerous tanks and water bodies, and the priority given to tank improvement for flood storage in the cost-benefit (C/B) analysis.




*Source: JICA Expert Team*

**Figure 2-1: Study Flowchart**

## 2.2 Scope of Study and Planning Conditions

A flood control master plan is a comprehensive strategy aimed at addressing flood risks by incorporating both structural and non-structural measures. The difference between a master plan with a feasibility study (F/S) or a detailed design (D/D) has been explained in Chapter 1. It provides a coordinated framework for managing flood risks, identifying various interconnected measures, and outlining an implementation plan to achieve a target safety level over time, typically in phases. In this section, the scope of the study and target rivers for riverine flood control, along with basic policies, are outlined.

### 2.2.1 Study Area

The target rivers for fluvial flood control are the Adyar River System (~43.6 km), Cooum River System (73.7 km), and Kosasthalaiyar River System from Poondi Dam (69.3 km). Figure 2-2 This chapter shows the scope of the study area. Further details and specifics about these rivers and their basins are explained in Chapter 1, particularly in the section. 1.2 to 1.4.

### 2.2.2 Target Safety Levels

Several factors must be considered when determining the target safety level, including the socio-economic importance of the study area, population density, river basin characteristics, and other aspects such as environmental, geographical, technical, and political considerations. Additionally, effective communication with local authorities and technical experts is crucial in setting the appropriate safety level.

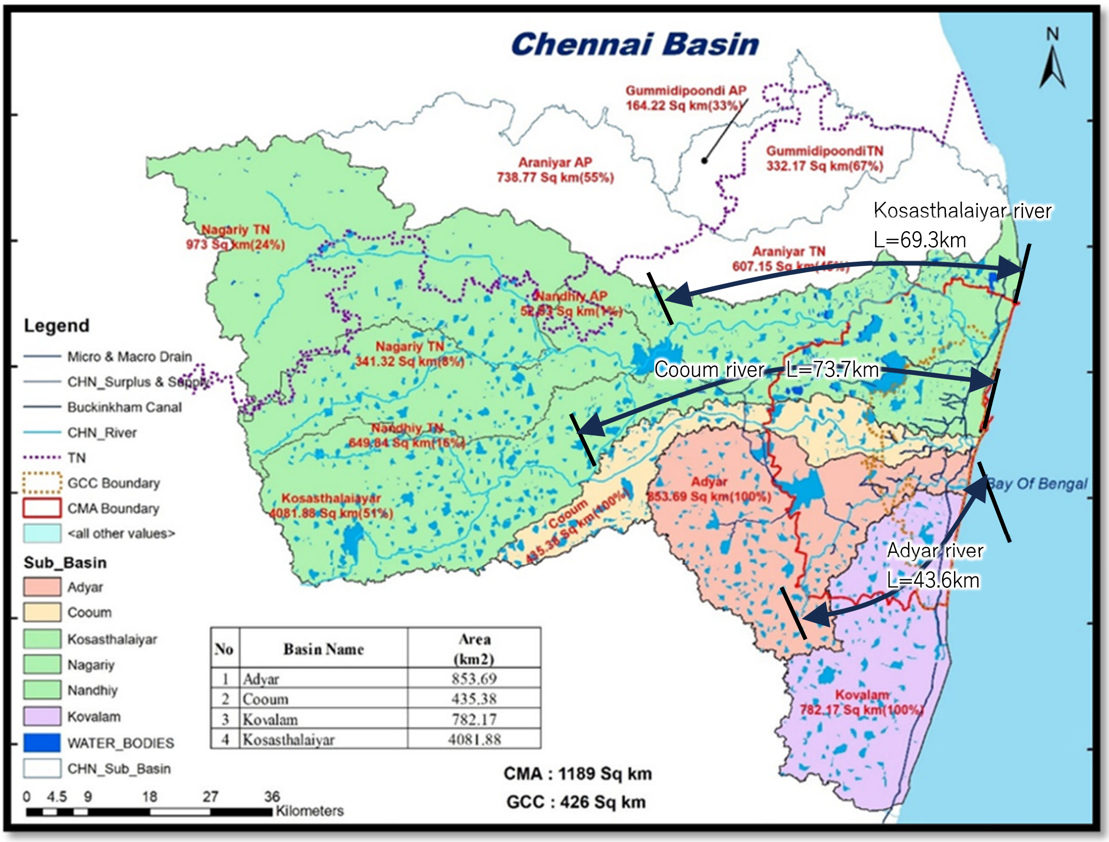
Chennai, the fourth-largest city in India, is expected to have a population exceeding 12 million in the Chennai Metropolitan Area (CMA, 1189 km²) by 2024. The city plays a vital role in socio-economic activities. The basins of the Adyar, Cooum, and Kosasthalaiyar Rivers, which are part of this study, cover areas of over 400 km², with dense urban populations and a high concentration of socio-economic activities.

Drawing on Japanese experience, the rivers in the study area can be classified similarly to Class 1 rivers in Japan. These rivers are the highest priority due to their significant importance, often assigned higher safety levels compared to other river classes.

Given the city's importance, it was agreed with local counterparts (C/Ps) that the target design scale for the river flood (fluvial flood) control master plan should be based on a 100-year return period for rainfall probability. This target safety level aligns with the recommendations of the Chennai Flood Advisory Committee Report (2023) and adheres to national and local standards and guidelines.

### 2.2.3 Target Year for the Implementation of the Master Plan

The JICA Flood Control Master Plan is designed for implementation in two phases. In consultation with the local counterparts (C/Ps), Phase 1 is targeted for completion within 10 years (e.g., 2026 to 2035), with Phase 2 starting after the completion of Phase 1 (e.g., from 2036 onwards). This study suggests that the full implementation of the master plan should occur over 20 years. However, the timeline, particularly for Phase 2, may be subject to change due to shifts in assets and economic conditions. Therefore, it is expected that the full implementation may take longer than 20 years. Local authorities must prepare for the gradual implementation of the master plan, with annual monitoring of progress and periodic reviews every 5 years or so.




*Source: JICA Expert Team*

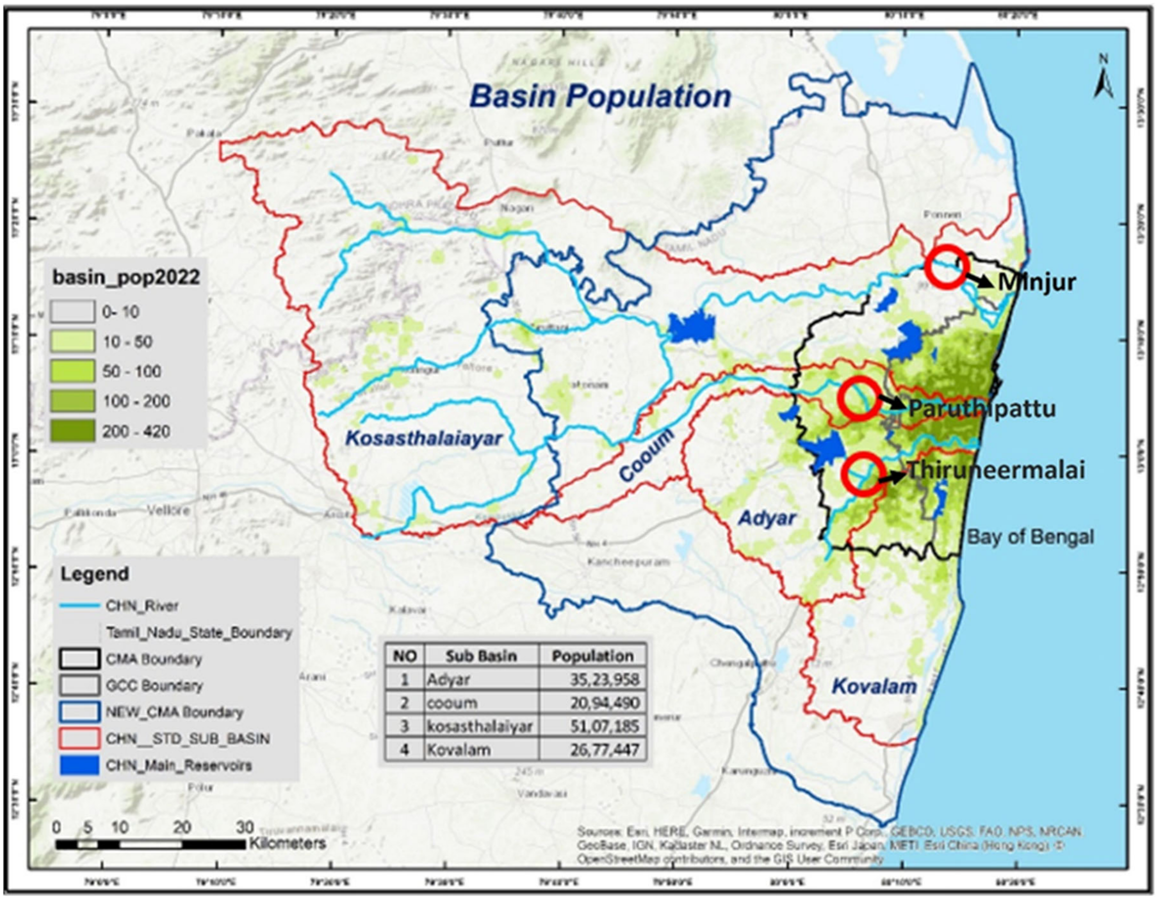
**Figure 2-2: Scope of the Study Area for the River Flood Control**

### 2.2.4 Flood Control Points

Flood control points were identified upstream of areas with significant asset accumulation within the Chennai Metropolitan Area (CMA) requiring flood protection, at weirs and check dams where flow control is feasible, and downstream of large tributary confluences. Figure 2-3: Flood control pointsFigure 2-3 Shows the locations of these flood control points and population distribution in the study area. The specific points are as follows:

Adyar River: Downstream confluence of Chembarambakkam Surplus to Adyar at Thiruneermalai
Cooum River: Downstream of Paruthippattu Weir
Kosasthalaiyar River: Downstream of Vallur Anicut

It is worth mentioning here that the JICA Flood Control Master Plan provides a comprehensive river flood control strategy for the entire river system. The flood control points are hypothetical locations used to facilitate the study. For example, it can be used to demonstrate limitations in the river's carrying capacity at the locations of the flood control points, even though the calculations are made for the entire river system.




*Source: JICA Expert Team*

**Figure 2-3: Flood control points**

## 2.3 Hydrology and Hydraulic Analysis

### 2.3.1 Rainfall Statistics and Design Rainfall

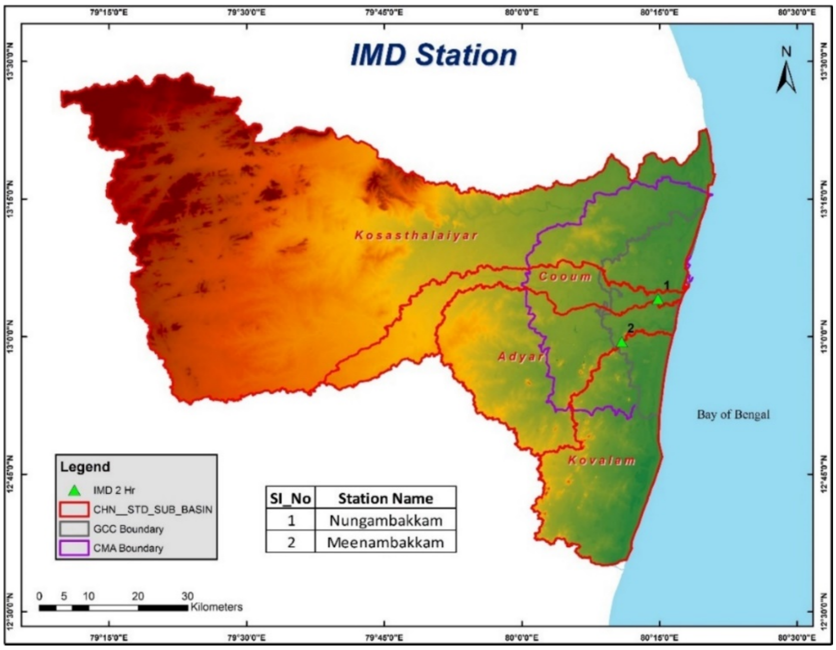
This section details key parameters related to design rainfall, including concentration time, rainfall duration, design rainfall hyetographs, and hydrographs. Before presenting the detailed results, it is important to highlight the availability and limitations of long-term rainfall data in the study area. Table 2-1 Summarizes the collected data and its temporal scale. As indicated, only two stations within the study area have long-term hourly rainfall data, while the remaining stations provide long-term daily rainfall data. These limitations must be considered when interpreting the results of this study.

**Table 2-1: List of collected rainfall data**

| Institution | Number of observation stations | Period | Data type |
|---|---|---|---|
| IMD | 2 (Inside the target river basins) | 1969-2021 | Hourly |
| TNWRD | 46 (35 stations: Inside, 11 stations: Outside) | 1991-2021 | Daily |
| CRA | 37 (34 stations: Inside, three stations: Outside) | 1991-2021 | Daily |

*Source: JICA Expert Team*

Figure 2.3 shows the locations of the Indian Meteorological Department (IMD) stations that record hourly rainfall data. To improve the accuracy of the hydrological analysis, it is necessary to expand the network of hourly rainfall observations across the entire study area. This will enable a more precise evaluation of the hydrological conditions and allow for the revision of design parameters and rainfall hyetographs.




*Source: JICA Expert Team*

**Figure 2-4: Location of Two IMD Rainfall Stations with Hourly Observation**

#### 2.3.1.1. Design Rainfall Duration

Rainfall duration was determined based on the concentration-time (Tc), representing the time for rainfall to travel from the basin's furthest point to the outlet. Due to the lack of hourly rainfall and discharge data, two methods were used:

Method 1: Empirical equations were applied to estimate the concentration time based on topographical gradients using four different approaches.

Method 2: A uniform rainfall over the basin was modeled to simulate the time from the onset of rainfall to peak discharge, considered as the concentration time.

The second method, which better represents actual basin response, indicated a concentration-time of 36 to 48 hours. Consequently, a 48-hour rainfall duration was adopted for the design rainfall calculation.

#### 2.3.1.2. Rainfall Statistical Analysis and Peak Rainfall

Probable rainfall for different return periods (2 to 400 years) and durations (24, 48, …, and up to 144 hours) has been analyzed using the "Hydrologic Statistics Utility" software by the Japan Institute of Country-ology and Engineering (JICE). This analysis utilized daily rainfall data from 1991 to 2021 (31 years) and applied four probability distribution models: Exponential Distribution, Gumbel Distribution, Square Root Error Term, and Generalized Extreme Value Distribution. The calculated 48-hour maximum rainfall for a 100-year return period in the study area is as follows: Adyar Basin: 493 mm, Cooum Basin: 371 mm, Kosasthalaiyar Basin: 299 mm and Kovalam Basin: 460 mm. Since Kovalam lacks a dominant river system, its flood is categorized as urban flood (pluvial flood), and further detailed rainfall statistics are detailed in Chapter 3 of the JICA Flood Control Master Plan, as this chapter is dedicated to river flood control.

To account for climate change, a multiplier of 1.1 was applied to the design rainfall (48hrs, 100-year return period), resulting in adjusted values: Adyar Basin: 542 mm, Cooum Basin: 408 mm and Kosasthalaiyar Basin: 329 mm.

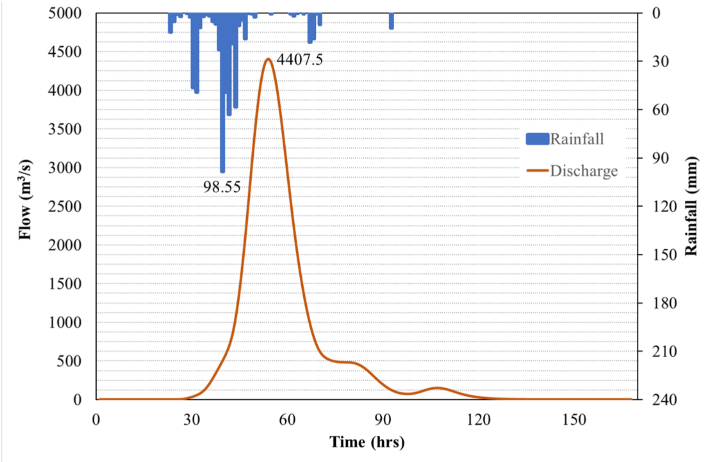
The 1.1 multiplier is derived from Japan's rainfall multiplier for climate change, based on the ratio of future (2080–2100) to present (1984–2004) climate conditions. This value, used tentatively, requires revision as more rainfall data for Chennai becomes available. The 10% increase due to climate change considerations was discussed and agreed upon with local counterparts (C/Ps).

### 2.3.2 Design Rainfall Hyetographs and Flood Hydrographs

The design rainfall hyetographs and corresponding flood hydrographs were developed using the following methodology:

1. Identification of Target Flood Events: Ten historical flood events that caused significant damage in the Chennai Metropolitan Area were identified and analyzed as representative extreme events.
2. Scaling Historical Rainfall of the Selected Major Flood to Design Rainfall: The historical hyetographs of the selected floods were scaled by a factor such that their cumulative 2-day rainfall matched the calculated design rainfall. This step ensures alignment with the probabilistic rainfall return periods derived in the study. It is worth mentioning that the scale factor between 1.0 and 2.5 has been considered in this study.
3. Selection of Design Rainfall Hyetograph: Using the scaled hyetographs, runoff simulations were conducted in the HEC-HMS model. The simulated hydrograph with the highest peak discharge was selected as the design flood hydrograph, representing the worst-case scenario for flood management.
4. Results: The selected design rainfall hyetographs vary for each river basin, reflecting differences in basin characteristics such as size and basin physiography, etc. The chosen representative major flood events for the design hyetographs are as follows: Adyar River: 2005 flood event, Cooum River: 2015 flood event, Kosasthalaiyar River: 1996 flood event.

The variation in the selected major flood events for each basin highlights the importance of considering their unique hydrological and geomorphological characteristics. For instance, the selected rainfall hyetograph for the Adyar Basin is based on the 2005 flood event, whereas for the Cooum Basin, it is based on the 2015 flood. This distinction arises from the differing shapes and behaviors of the basins. The Adyar Basin, being fan-shaped, experienced concentrated rainfall during the 2005 event, primarily over Adyar and Kovalam. In contrast, the Cooum Basin, which is long and narrow, was impacted by widespread rainfall across the study area during the 2015 event, moving towards the downstream reaches. As an example, Figure 2-5 Shows the hyetograph derived from the 2005 flood of the Adyar River to produce the 100-year return period flood hydrograph at the flood control points located downstream of the confluence with Chembarambakkam Dam.

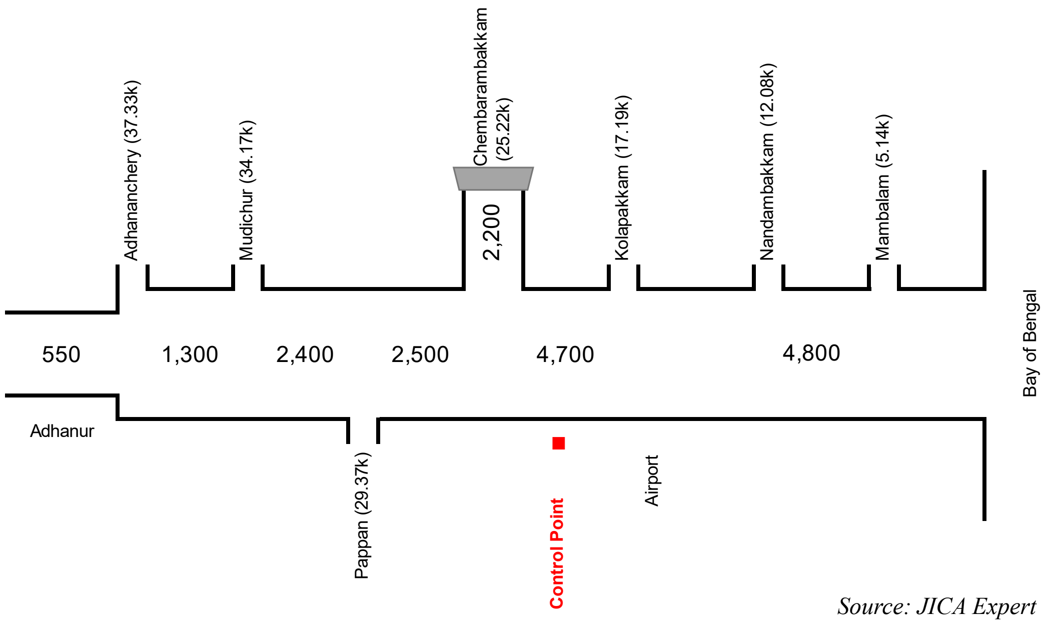



*Source: JICA Expert Team*

**Figure 2-5: Flood Hydrograph in Adyar Basin for 2005 flood scaled for 100-year RP**

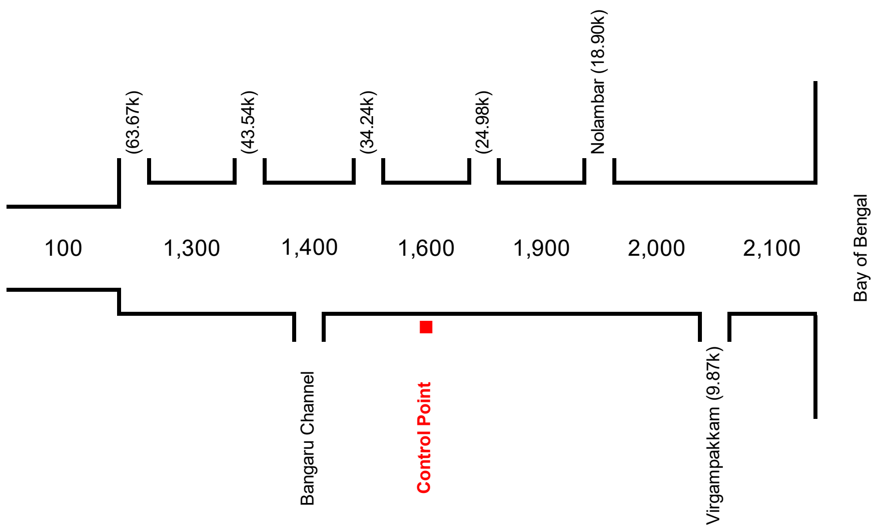
### 2.3.3 Pre-Regulation Design Discharge Distribution

The discharge distribution along the rivers was calculated under natural runoff conditions, excluding the effects of dams or other hydraulic structures for flood control (Pre-regulation). This represents the flow distribution without flood control measures, using the 100-year return period flood based on the selected rainfall patterns: the 2005 pattern for Adyar, 2015 for Cooum, and 1996 for Kosasthalaiyar. The design hydrograph incorporates a 10% increase in rainfall to account for climate change impacts.



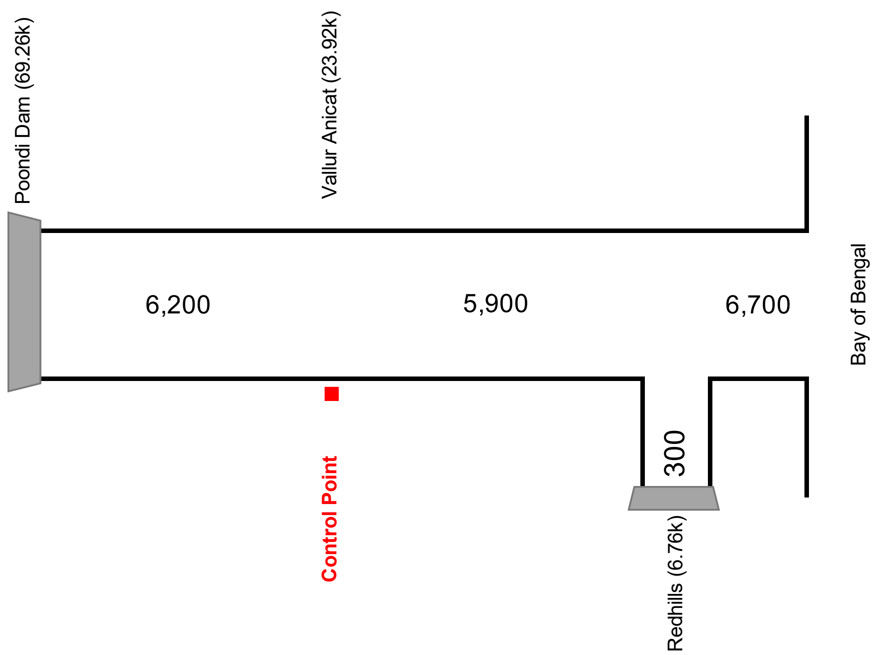

*Source: JICA Expert Team*

**Figure 2-6: Pre-regulation Design Discharge Distribution in Adyar River (100-year RP)**




*Source: JICA Expert Team*

**Figure 2-7: Pre-regulation Design Discharge Distribution in Cooum River (100-year RP)**




*Source: JICA Expert Team*

**Figure 2-8 Pre-regulation Design Discharge Distribution in Kosasthalaiyar River (100-year RP)**

## 2.4 Basic Principle for Flood Control Measures

In the Adyar, Cooum, and Kosasthalaiyar Rivers, the current discharge capacity is approximately one-tenth of the basic high-water level. Given this limitation, relying on a single measure is insufficient, and a combination of appropriate measures is necessary.

- River works that do not require land acquisition:
    - Construction of levees (embankments)
    - River channel dredging or excavation

- Increasing the storage capacity of tanks and water bodies
- Optimizing dam discharge operations
- Diversion channel proposals
- River works/channelization that does require land acquisition (deepening and widening)
- Implementation of underground bypass tunnels

The table on the next page summarizes the outcomes of applying each measure individually. Based on the analysis, embankments are not recommended in this Master Plan due to several drawbacks: they may increase inland flooding, require extensive land acquisition, and disrupt economic activities by necessitating the reconstruction of nearly all bridges and associated access roads. In the following table, a circle (○) indicates an acceptable level. A triangle (△) signifies that there are some observations or concerns. A cross (×) means it is not acceptable.

Similarly, diversion channels would require significant land acquisition, making them impractical except for localized applications. River channel widening alone would also be a major undertaking with considerable impact.

Considering these factors, this Master Plan recommends a combination of river channel deepening and widening, reservoir capacity expansion, improved dam discharge operations, and underground bypass tunnels instead of embankment construction. However, due to the high cost of underground bypass tunnels, their use is limited to managing excess flow in the Adyar River, which cannot be addressed by other measures.

Moving forward, the counterpart agency will be responsible for further improvement of the proposal in the master plan.

**Table 2-2: Comparison of Main Countermeasures (Case Study: Adyar Basin)**

| | Embankment | Deepening Rivered | River channel widening | Flood Storage in tanks |
|---|---|---|---|---|
| **Overview** | At the reference point, the water level is about 10m higher than the ground level inside the bank, and including the margin, a bank height of 11.5m is required (the width of the embankment site must have a 20% gradient, a top width of 5m, and a bank of about 50m per side). | - Excavation of approximately 10m is required at the reference point. | A widening of about 400m is required at the reference point. | ・Even if all the major reservoirs in the basin are used up at the reference point, the discharge capacity will be around 3,200 m3/s, and it will be difficult to reduce it to the current discharge capacity (500 m3/s) [Rating: ×] |
| **Social Impact** | ・Land acquisition is required for 100m on both sides of the river, and negotiations are difficult in the urbanized downstream area.<br>・All 26 bridges will need to be replaced, and there are concerns about the impact on the surrounding commercial facilities required to raise the access roads.<br>・Concerns over new inland flooding due to poor drainage caused by embankments<br>[Rating: ×] | ・All 26 bridges need to be rebuilt, or their pier foundations need to be affixed<br>・Concerns over the impact on underground structures crossing the river<br>[Rating: ×] | ・It will be difficult to widen the river by 400m in the urbanized downstream area.<br>・Replace all 26 bridges<br>[Rating: ×] | ・Because the reservoir capacity is almost 100%, it is difficult to empty it by pre-discharging.<br>[Rating: ×] |
| **Environmental Impacts** | The current river environment is largely maintained<br>[Rating: ○] | - The low tide area will be increased from the current 7 km to 22 km, raising concerns that saltwater will invade the groundwater and cause it to become salty, which will have a major impact on plants and animals that use freshwater environments. [Rating: ×] | If the compound cross-section river channel shape is adopted, the current river environment will be largely maintained.<br>[Rating: ○] | ・There are concerns that the temporary disappearance of the water body will hurt the plants and animals currently using the reservoir.<br>[Rating: △] |
| **Cost** | ・Earth filling volume: 19 million m3<br>・Site area: 3.6 million m2<br>・Additional costs will be incurred for installation on bridge sections.<br>[Rating: △] | Excavated soil volume: 20 million m3<br>・Bridge foundation costs<br>・More maintenance is needed at the river mouth than at present [Rating: △] | Excavated soil volume: 87 million m3<br>・Site area: 11 million m2<br>・Separate bridge replacement costs required [Rating: △] | Excavated soil volume: 0.32 million m3<br>[Rating: ○] |
| **Total Evaluation** | The high height of the levees raises concerns about land acquisition and the risk of inland flooding. | Apart from maintaining the river channel and preventing saltwater intrusion, | The cost of land acquisition is huge, making this plan difficult to implement on its own. | Inability to cope with the problem by simply expanding the reservoir capacity |

*Source: JICA Expert Team*

**Table 2-3: Comparison of Main Countermeasures (Case Study Continue: Adyar Basin)**

| | **Improving dam discharge operations** | **Diversion Channel (Open Channel)** | **Diversion Channel (Underground Bypass Tunnel)** |
|---|---|---|---|
| Concept | A plan to release water from the Chembarambakkam Dam in advance in hopes of reducing flooding. | A plan to divert water from the upstream urban area into a spillway and reduce the amount of water passing through downstream. | A proposal to reduce the amount of water passing through downstream by constructing an underground outfall. |
| Overview of the Plan | ・WB is considering a planned discharge volume of 820m3/s at 1/100 scale | ・To install a 3000m3/s class spillway, a river width of 200-400m and a length of about 15km are required. | The actual figures and plans in Japan and other countries are around 100 to 200 m3/s, making this measure difficult to implement alone. |
| Social impact | ・If the flood prediction turns out to be wrong and there is little rainfall, there is concern that it could affect storage capacity.<br>[Rating: △] | ・The coastal areas of the Adyar River are urbanized, making it difficult to develop new spillways.<br>[Rating: ×] | - Because the project utilizes an underground area, it requires less house relocation and land acquisition, so the project can be implemented quickly.<br>[Rating: ○] |
| Environmental impacts | ・Current river environment is generally maintained<br>[Rating: ○] | ・Concerns about the impact of excavating important areas, such as along the coast<br>[Rating: ×] | ・The current environment will not be altered, so the impact will be minimal<br>[Rating: ○] |
| Cost | ・The cost is about the same as the cost of a rain gauge, water level gauge, and forecasting system.<br>[Evaluation: ○] | Excavated soil volume: 87 million m3<br>・Site area: 11 million m2<br>・A new bridge needs to be built at the spillway crossing point [Rating: ×] | ・In the case of a scale of 200 m3/s<br>Length: 12km<br>・The cost is high<br>[Rating: △] |
| Total Evaluation | Effective if you can operate it reliably | Land acquisition costs are huge, and route selection is difficult | It is appropriate to use it as a complement to other countermeasures. |

*Source: JICA Expert Team*

## 2.5 Proposed River Channelization Package

In this section, proposed measures have been discussed aimed at achieving the target safety levels for rivers in the study area. These measures involve both structural and non-structural interventions, with a focus on improving river channelization, improving flood storage in waterbodies and tanks, and constructing an underground river system. The subsequent sections will detail these measures and their anticipated impact on flood management in the region.

### 2.5.1 Proposed River Channelization Package

To enhance flood safety, structural measures such as deepening, widening, and strengthening riverbanks have been proposed for the three major rivers in the study area—Adyar, Cooum, and Kosasthalaiyar—and two additional surplus rivers, Chembarambakkam Dam Surplus and Redhills Surplus. The primary objective of these measures is to increase the carrying capacity of these rivers. In conjunction with channel improvements, enhancements to waterbodies and tanks, as discussed in later sections, will further aid in managing floodwater and reducing the risk of overflow during heavy rainfall events.

#### 2.5.1.1. Setting of Design High Water Level (HWL) and Embankment Height

The design of high-water level (HWL) is an essential parameter for the JICA Flood Control Master Plan. It represents the water level that occurs when the designed flood discharge flows through the improved river channel. This level serves as the basis for the design of river ed deepening, widening, embankments, revetments, and other river-related infrastructure. Setting the HWL correctly is critical to ensuring that floodwaters are contained within the riverbanks and that adjacent infrastructure is protected from inundation.

In the case of the rivers in Chennai, the HWL has been set to match the ground level of the left and right banks for two primary reasons:

First, setting the HWL higher than the natural ground elevation near the riverbanks would necessitate the construction of levees. However, in the event of a breach in the embankment or levee, the flood risk would be concentrated at the breach site, increasing the potential for flooding.

Second, a higher HWL and construction of high elevation embankment than ground elevation would disrupt the connection between the urban drainage system and the river, making it difficult for floodwater to flow into the river and exacerbating inland flooding.

Therefore, to mitigate these risks, the HWL has been set at the ground level of the riverbanks. Given that the rivers in Chennai currently do not have many embankments, the proposed method to set HWL based on the ground elevation aligns with this existing condition.

#### 2.5.1.2. Steps Toward Setting HWL and Considerations

River Mouth: For the river mouth (0 km), the HWL is set at M.S.L + 0.5 m (Spring High Tide Level at the Bay of Bengal). This level has been established below the current embankment elevation to ensure that it remains consistent with the natural flow dynamics of the river.

Sea Level Rise Risk: Future predictions for sea level rise in Chennai have a high degree of uncertainty, primarily due to variations in greenhouse gas emission scenarios and the use of regional climate models for South Asia and Southeast Asia rather than localized models specific to Tamil Nadu or southern India. As a result, most future projections for sea level rise present a wide range of possibilities, making it challenging to apply them for precise flood management planning. However, observed past sea level rise trends have been studied, and it has not been incorporated into the HWL setting, as two key studies indicate that past sea level rise has been minimal. A recent report (2024) by the Center for Science and Technology Policy and Research (CSTEP) found that sea level in Chennai rose by 0.68 cm from 1987 to 2021, averaging 0.066 cm per year. Additionally, the Center for Climate Risk Assessment and Adaptation Planning (CCRAP) reported (2017) a relative sea level rise of 5.5 cm along the Chennai coast over the past 100 years (1916–2015). These observations suggest that sea level rise poses a minimal risk to flood management efforts in the region.

HWL Gradient Slope: The gradient for the HWL has been set to match the current riverbed slope, which is critical for maintaining natural river flow and minimizing the risk of erosion or overflow.

Points of HWL Gradient Change: The design of the HWL gradient considers topographic variations and the use of check dams to control the flow of water and ensure effective flood management.

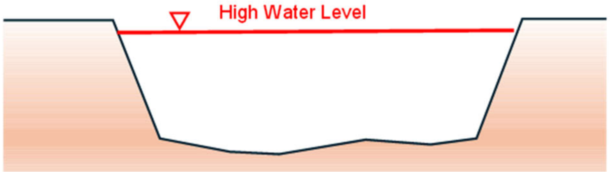
#### 2.5.1.3. Freeboard and Considerations for Existing Embankment and Bridges

According to the guidelines developed by the Central Water Commission of India (CWC), the design embankment height should include a freeboard of about 1.5 meters above the high-water level. A similar approach is followed in Japan. However, for incised river courses, where the design high water level is almost the same as the ground elevation in Chennai rivers, constructing embankments is not recommended because it could increase the risk of inland flooding, as described in the previous section.

In Chennai, the riverbank areas are used as roads, and many bridges are built to match the current riverbank height. If the water level is higher than the ground elevation, adding a freeboard would be required for building new embankments, which would lead to several issues. These include the increased risk of inland flooding, raising road levels, rebuilding bridges, and developing new access roads. To avoid these challenges, the design embankment height will not consider the freeboard in areas with incised channels. Three following cases have been considered in setting freeboard considering CWS guidelines, as shown in the following figures.
Case 1: If the current embankment/riverbank height is higher than the design high water level, no freeboard has been considered.
Case 2: If the current embankment/riverbank height is less than the design high water level, the new embankment height will be set by adding the freeboard.
Case 3: The design embankment height for bridges will include the freeboard, taking into account the bridge girder layout.

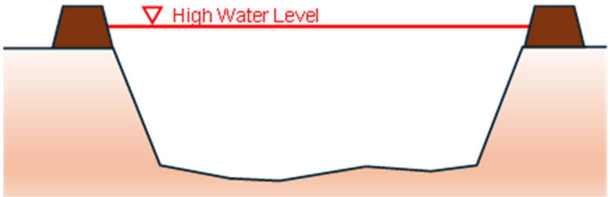
**Case 1: No Need Freeboard**

Current embankment/riverbank height > design high water level



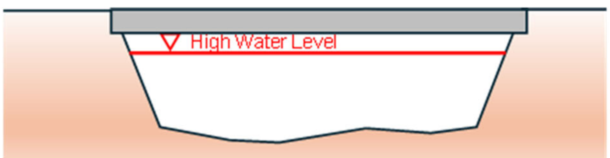

**Case 2: 1.5m Freeboard**

Current embankment/riverbank height < design high water level




**Case 2: 1.5m Freeboard**

Considering existing bridges

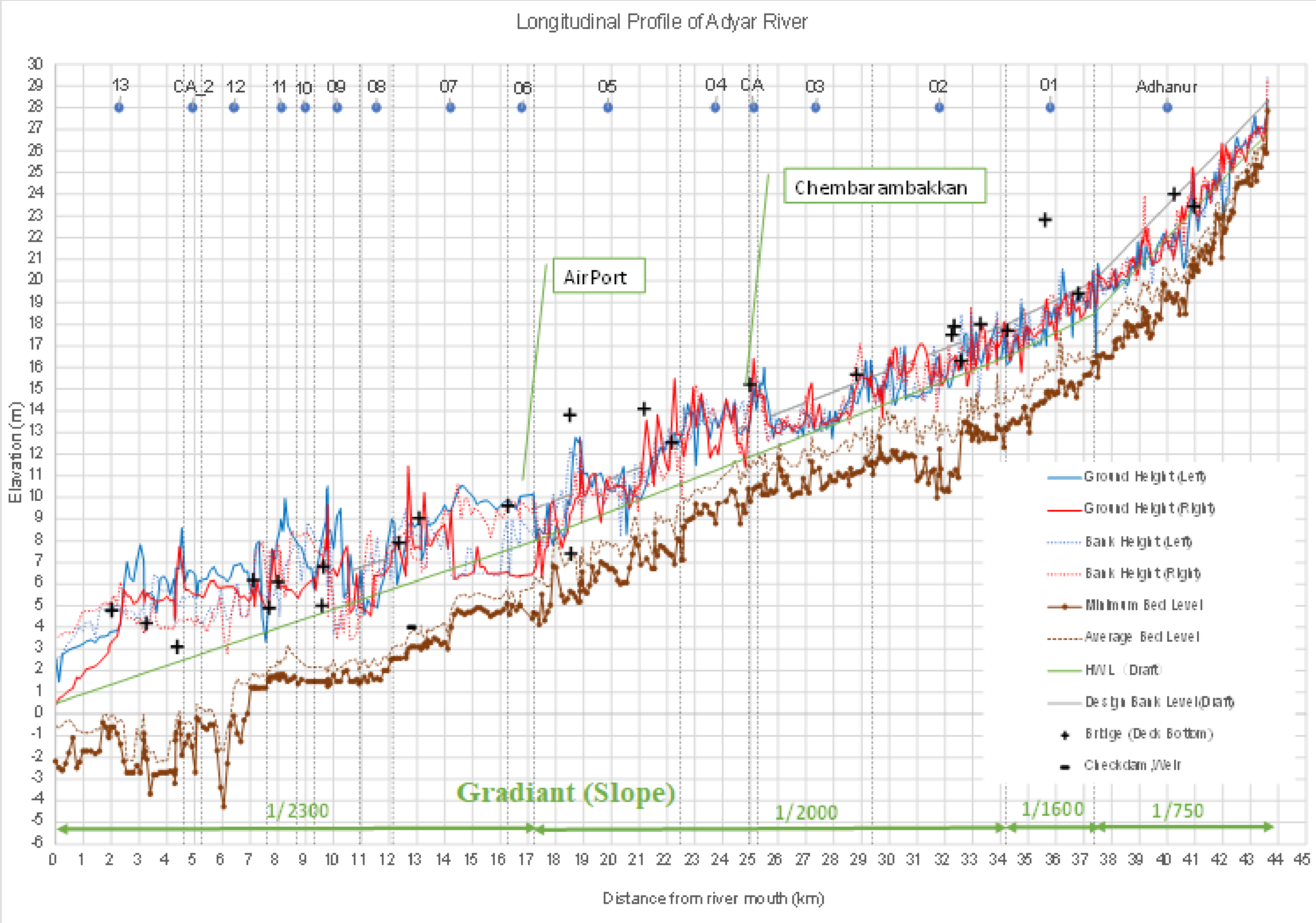



*Source: JICA Expert Team*

**Figure 2-9: Conceptual Diagram of Design High Water Level and Embankment Height**

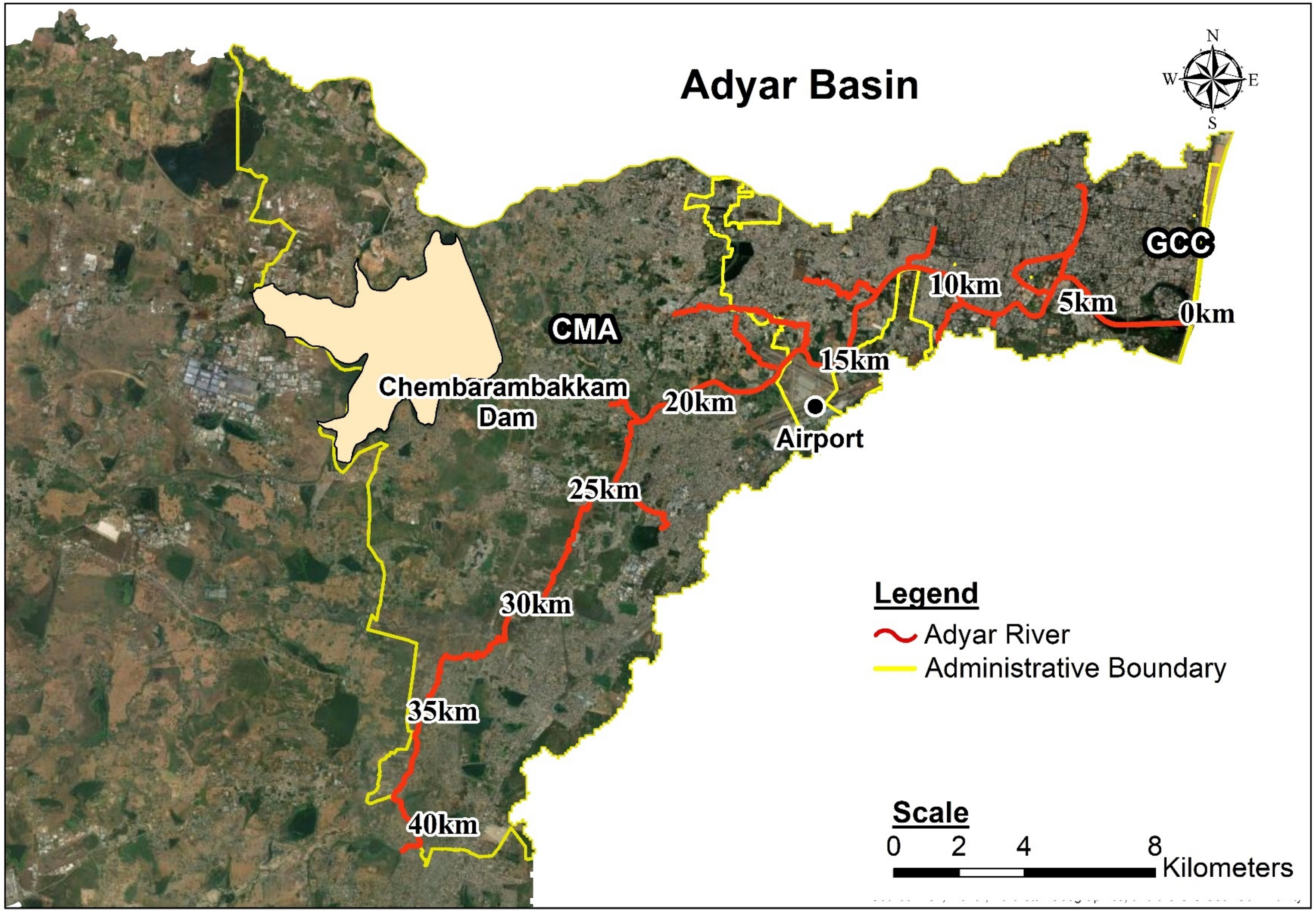
### 2.5.2 Setting High Water Level and Designing Riverbank Height

The following figures show the results of the high-water level and embankment height.



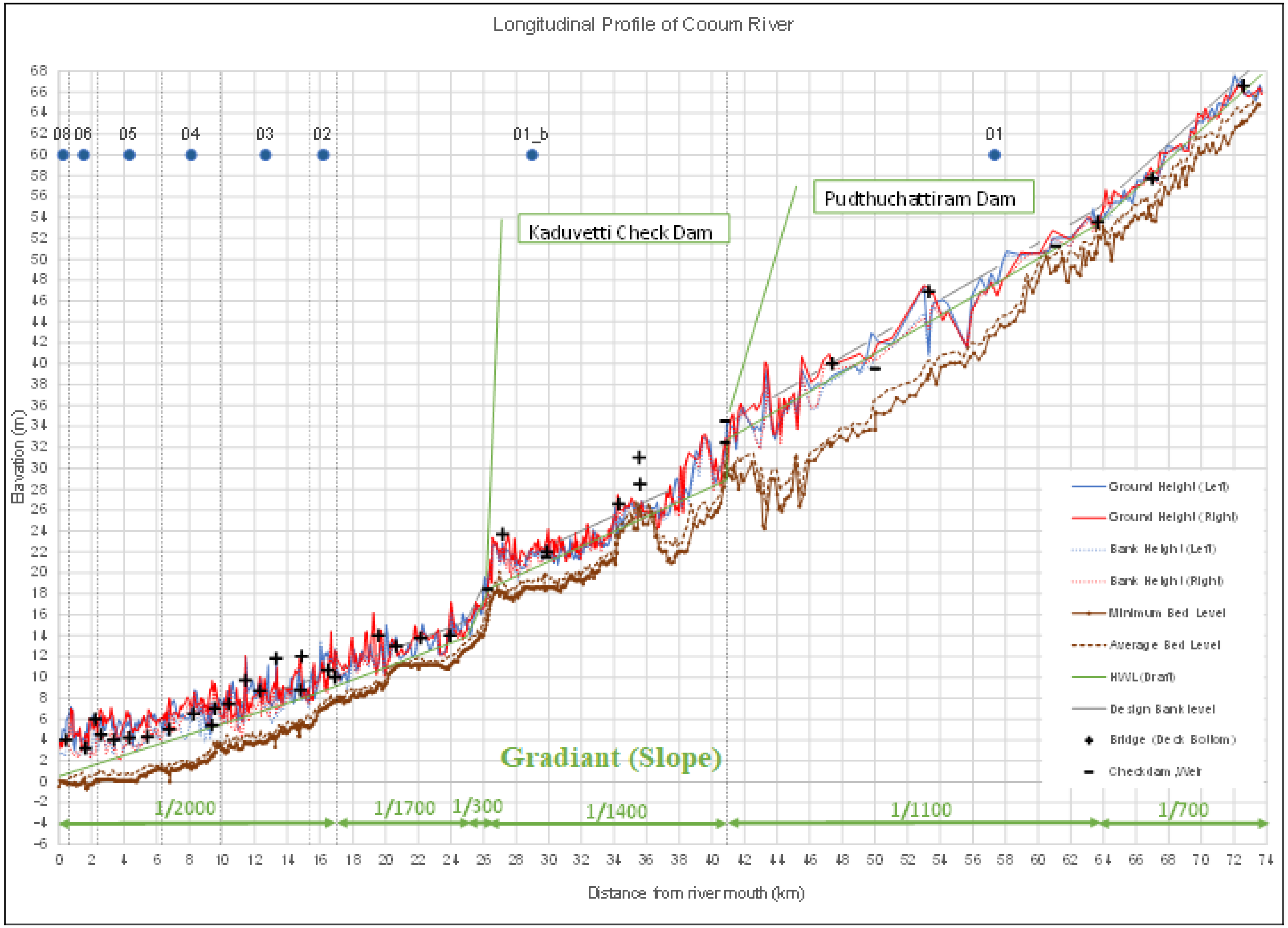

*Source: JICA Expert Team*

**Figure 2-10: HWL and Design Longitudinal Profile of Adyar River**



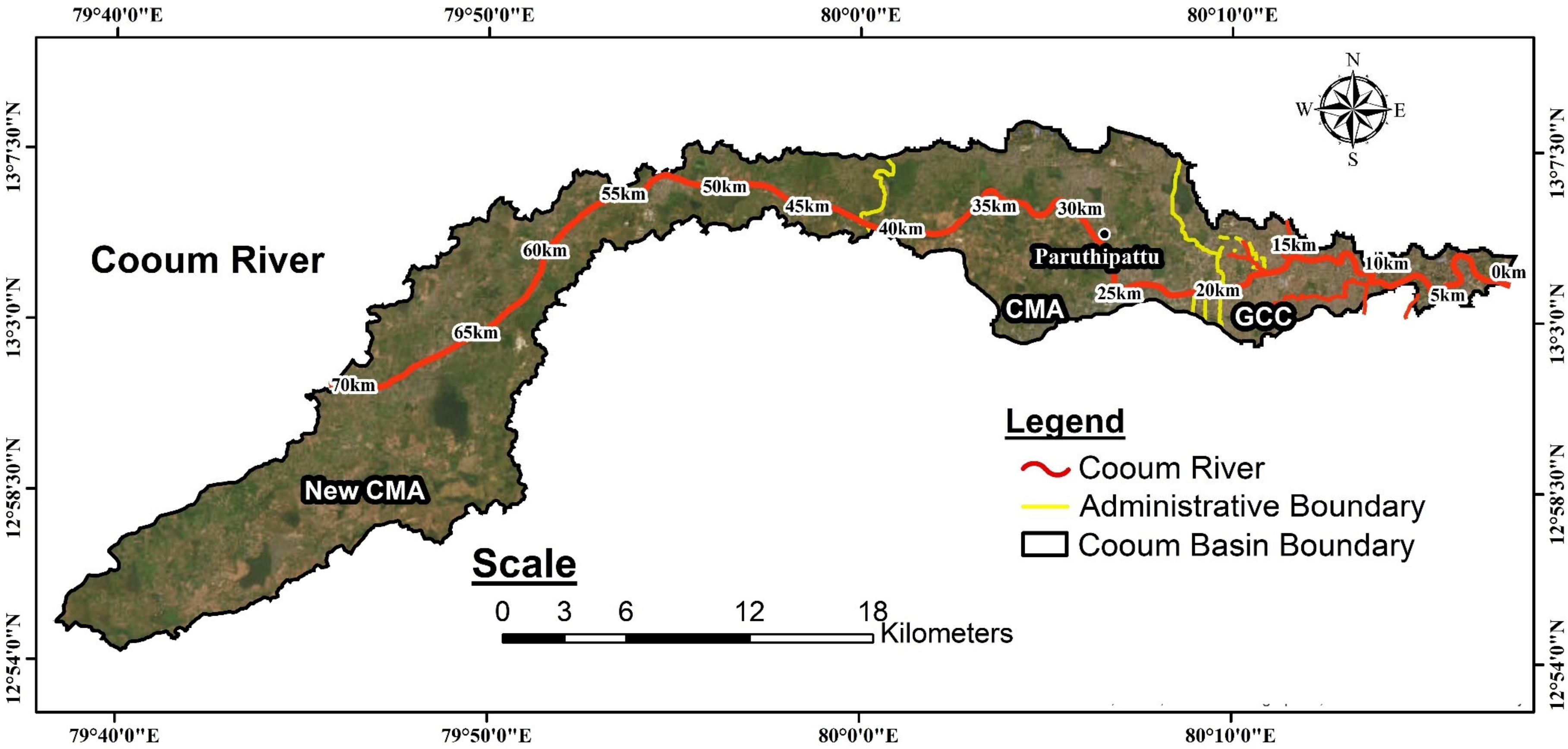

*Source: JICA Expert Team*

**Figure 2-11: Adyar River: Plan View and Chainage at 5 km Intervals**



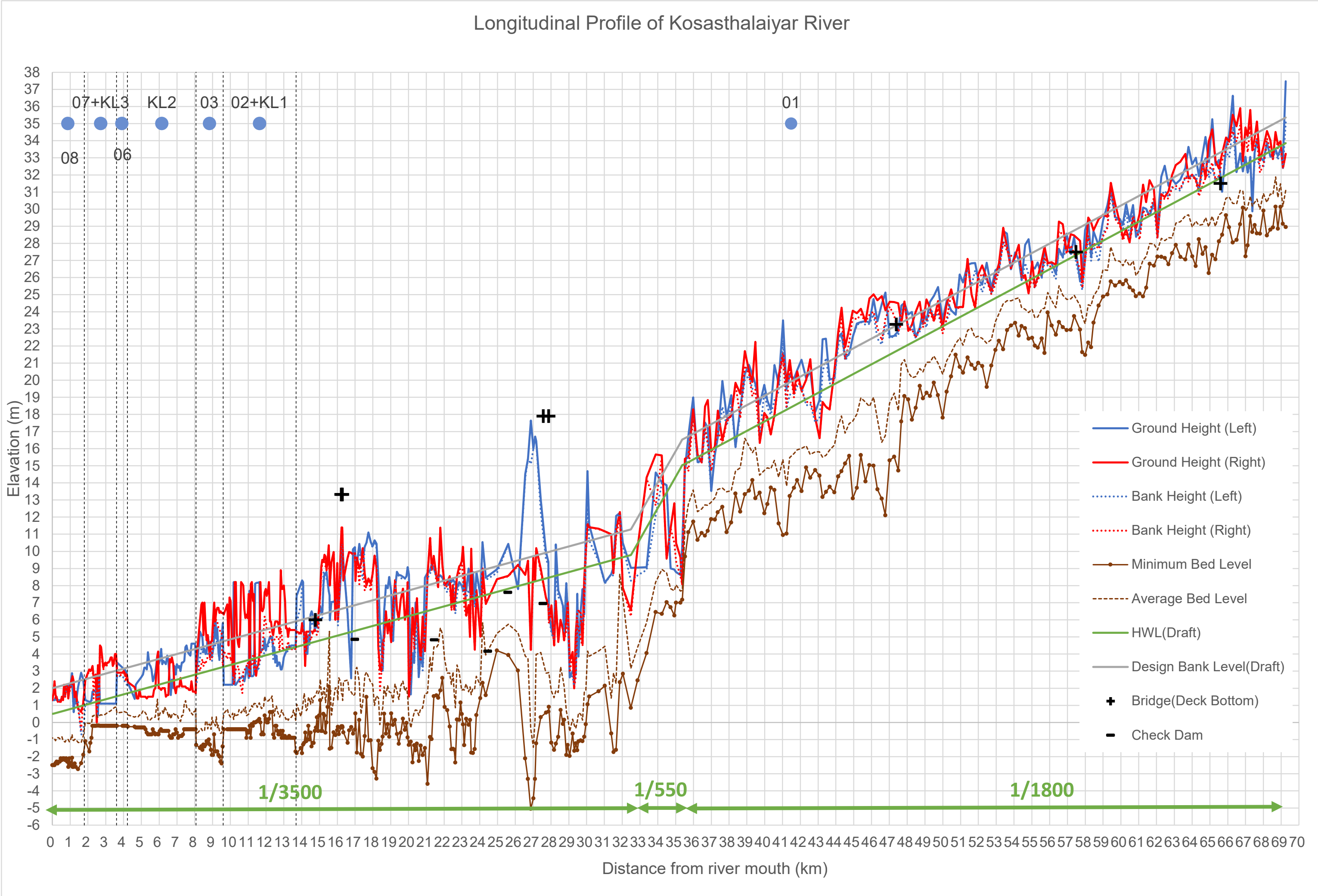

*Source: JICA Expert Team*

**Figure 2-12: HWL and Design Longitudinal Profile of Cooum River**



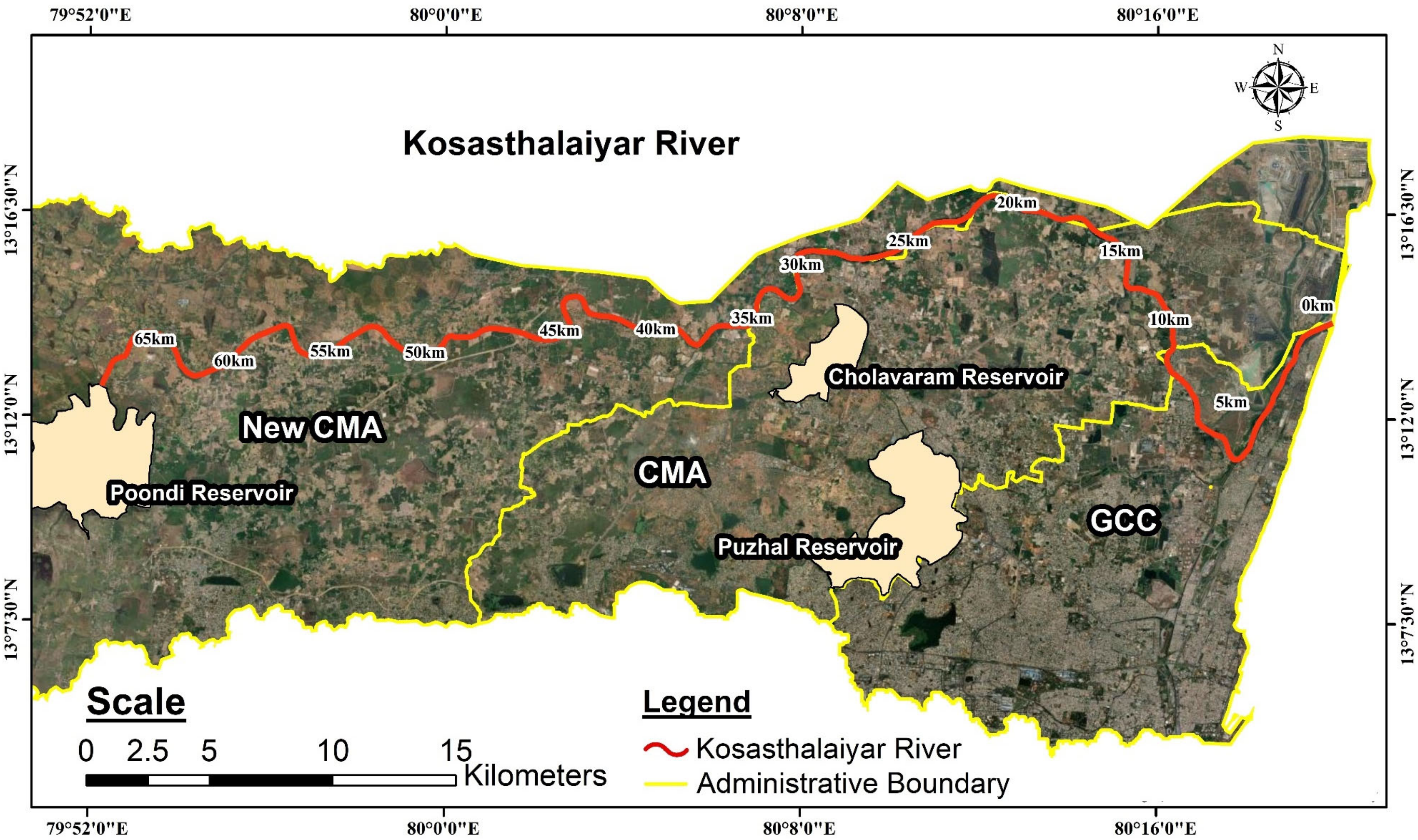

*Source: JICA Expert Team*

**Figure 2-13: Cooum River: Plan View and Chainage at 5 km Intervals**




*Source: JICA Expert Team*

**Figure 2-14: HWL and Design Longitudinal Profile of Kosasthalaiyar River**




*Source: JICA Expert Team*

**Figure 2-15 Kosasthalaiyar River: Plan View and Chainage at 5 km Intervals**

### 2.5.3 Considerations in Designing River Channelization (Deepening and Widening)

#### 2.5.3.1. Considerations and Challenges for River Widening

As explained in Section 2.5.1.1, the JICA Flood Control Master Plan avoids proposing an increase in the existing embankment or riverbank height. Instead, the Master Plan sets the design High Water Level (HWL) at the existing ground level. The following key assumptions have been considered for river channelization under the JICA Flood Control Master Plan:

The current river width in Chennai is inadequate to effectively manage floodwaters. To address this, a river buffer zone of 15 to 30 meters has been proposed in the 3rd CMA Urban Development Master Plan, and Tamil Nadu Water Resources Department (TNWRD) agrees with this proposal.

The JICA Flood Control Master Plan adopts a strategic approach to river widening, proposing an increase of 25 meters on both the left and right banks, resulting in a total widening of 50 meters in many areas. Moreover, a 5-meter-wide service road has been considered on each side in addition to 25m widening. However, this strategy is not uniformly applied across all river sections. Detailed proposals for the necessary widening of each river's reach are presented in the subsequent sections.

It is important to acknowledge that widening the rivers in Chennai, given the existing urbanization and socio-economic dynamics, is a challenging task. The densely populated areas, existing settlements, and infrastructure along the riverbanks are shown in Table 2-4, make it a time-intensive and sensitive process. Recognizing these difficulties, the JICA Flood Control Master Plan proposes to prioritize other countermeasures in the first phase of implementation, with river widening planned predominantly for the second phase and during the implementation of the 3rd CMA Urban Development Master Plan after enough consultation with the public and proposals to minimize socio-economic impacts. This phased approach ensures that adequate time and resources are allocated to carefully consider the socio-economic impacts and to develop effective mitigation strategies.

**Table 2-4: Estimated Affected Number of Residential and Commercial Buildings**

**Adyar River**

| Section [km] | Widening width [m] | No. of affected properties |
|---|---|---|
| 0.0 - 20.06 | 50 | Residential building 5000-6000<br>Commercial building 3000-4000 |
| 20.06 - 24.31 | 50 | Residential building 800-1000<br>Commercial building 600-800<br>Part of the area is adjacent to military land. |
| 24.31 - 28.44 | 50 | Residential building 500-600<br>Commercial building 300-400 |
| 28.44 - 33.54 | 50 | Residential building 400-500<br>Commercial building 200-300 |
| 33.54 - 36.72 | 25 | Residential building 200-300<br>Commercial building 100-150 |
| 36.72 - 39.80 | 25 | Residential buildings 120- 160<br>Commercial building 40-80 |
| 39.80 - 42.60 | none | Residential Building 0<br>Commercial Building 0 |
| Chembarambakkam Surplus (River) | none | Residential Building 0<br>Commercial Building 0 |

**Cooum River**

| Section[km] | Widening width [m] | No. of affected properties |
|---|---|---|
| 0.00 - 9.83 | 50 | Residential building 1200-1500<br>Commercial building 500-800 |
| 9.83 - 18.84 | 50 | Residential building 3500-4500<br>Commercial building 1500-2000 |
| 18.84 - 25.42 | 25 | Residential building 700-850<br>Commercial building 300-400 |
| 25.42 - 79.02 | none | Residential Building 0<br>Commercial Building 0 |

**Kosasthalaiyar River**

| Section [km] | Widening width [m] | No. of affected properties |
|---|---|---|
| 0.00 - 4.24 | 25 | Residential building 200-250<br>Commercial building 30-50 |
| 4.24 - 13.66 | 50 | Residential building 300-400<br>Commercial building 200-300 |
| 13.66 - 32.86 | 50 | Residential building 200-300<br>Commercial building 100-150 |
| 32.86- 72.00 | none | Residential Building 0<br>Commercial Building 0 |
| Redhills Surplus (River) | none | Residential Building 0<br>Commercial Building 0 |

*Source: JICA Expert Team*

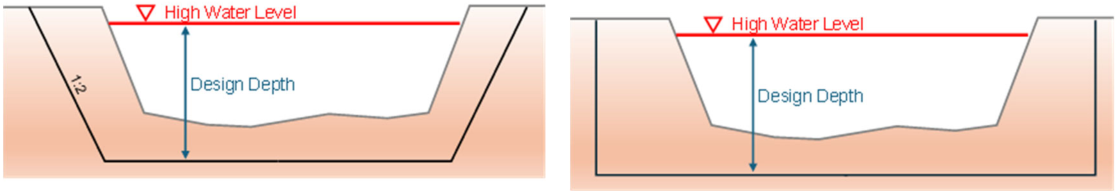
2.5.3.2. Considerations and Challenges for River Channel Deepening

The water depth for the river channel will be aligned with the previously determined High Water Level (HWL) to ensure effective flood management. Discussions with the Counterparts (C/Ps), particularly with TNWRD, confirm that there are no significant technical limitations on excavation depth, provided it does not adversely impact groundwater levels or exacerbate issues such as seawater intrusion or tidal effects. Additionally, careful consideration will be given to the management of excavated soil, which should be efficiently utilized in other projects within Tamil Nadu State. This approach not only enhances the channel's carrying capacity and maintains the desired flow levels but also ensures sustainable and integrated resource use.

To accommodate the new channel design, bridges that currently fail to clear the HWL will be reconstructed in the future. The design water depth that is proposed in the coming sections has been calculated as the difference between the HWL and the post-excavation riverbed elevation, ensuring that the required flow capacity is achieved across all sections of the river. This approach balances technical feasibility with the need to improve flood resilience.

2.5.3.3. River Channel Cross-Sectional Considerations

The standard slope of the embankments has been set at 1:2 (20% gradient), as depicted in Figure 2-16. However, in sections where the current river width is too narrow to accommodate sufficient flow capacity with this slope, an alternative approach will be adopted. In such constrained areas, the design will focus on maximizing flow capacity by implementing vertical embankments, ensuring the channel meets the required hydraulic performance standards while adapting to spatial limitations.




*Source: JICA Expert Team*

**Figure 2-16: Schematic of the Future River Channel Cross-sections**

### 2.5.4 Designing River Width and Depth and the Proposed River Channelization

This section provides the proposed design water depth (calculated as HWL minus the riverbed elevation after deepening) and river width for the Adyar, Cooum, and Kosasthalaiyar rivers, with special considerations for the Adyar and Kosasthalaiyar rivers. Before presenting the results, the methodology for determining the design water depth and river width is explained using the Adyar River as an example.

Figure 2-17 shows the carrying capacity of the Adyar River from upstream to downstream under four different design depths. All calculations in this section, conducted for each cross-section, use uniform flood conditions with a fixed HWL.

The first scenario, with a design depth of 4 meters, represents no deepening, while the last scenario, with a depth of 7 meters, assumes a riverbed deepening of 3 meters. In all four graphs, the solid black line shows the river's current carrying capacity without any widening, while the solid yellow line represents the target carrying capacity for a 100-year return period.

The yellow line calculation assumes upstream waterbodies and tanks are improved to enhance flood storage by 75%, equating to 88 MCM of additional storage in 50 selected tanks and waterbodies in the Adyar basin as an example. Dashed lines with black dots indicate scenarios with the river widening by 25 meters in total (12.5 meters on each side) and 50 meters in total (25 meters on each side).

The Adyar river reach identified by the red ellipse in the figure indicates areas where only deepening is required and reaches marked by blue circles highlight areas that need both deepening and widening. The purple ellipse represents areas that require special consideration, as explained below.

In the purple ellipse section (10.98k to 12.08k) downstream of Chennai Airport, even with a design water depth of 7m (about 3m deepening) and a widening of a total of 50m, the design high water flow rate of 2,700$m^3$/s could not be secured. Since this section does not have sufficient flow capacity even when ensuring maximum flow capacity as a straight wall cross-section, it was decided to construct an underground river (flow rate 200 m3/s) from the upstream part of the Chennai Airport underpass into the Bay of Bengal.

Table 2-5 provides the river channelization details for the Adyar River from 0.00 km (river mouth at the Bay of Bengal) upstream to a distance of 43.61 km from the river mouth. For each section of the river, the design water depth (HWL minus the riverbed elevation after deepening), the average proposed river width, and the approximate river widening are proposed based on the detailed calculations shown in Figure 2-17, as explained above.

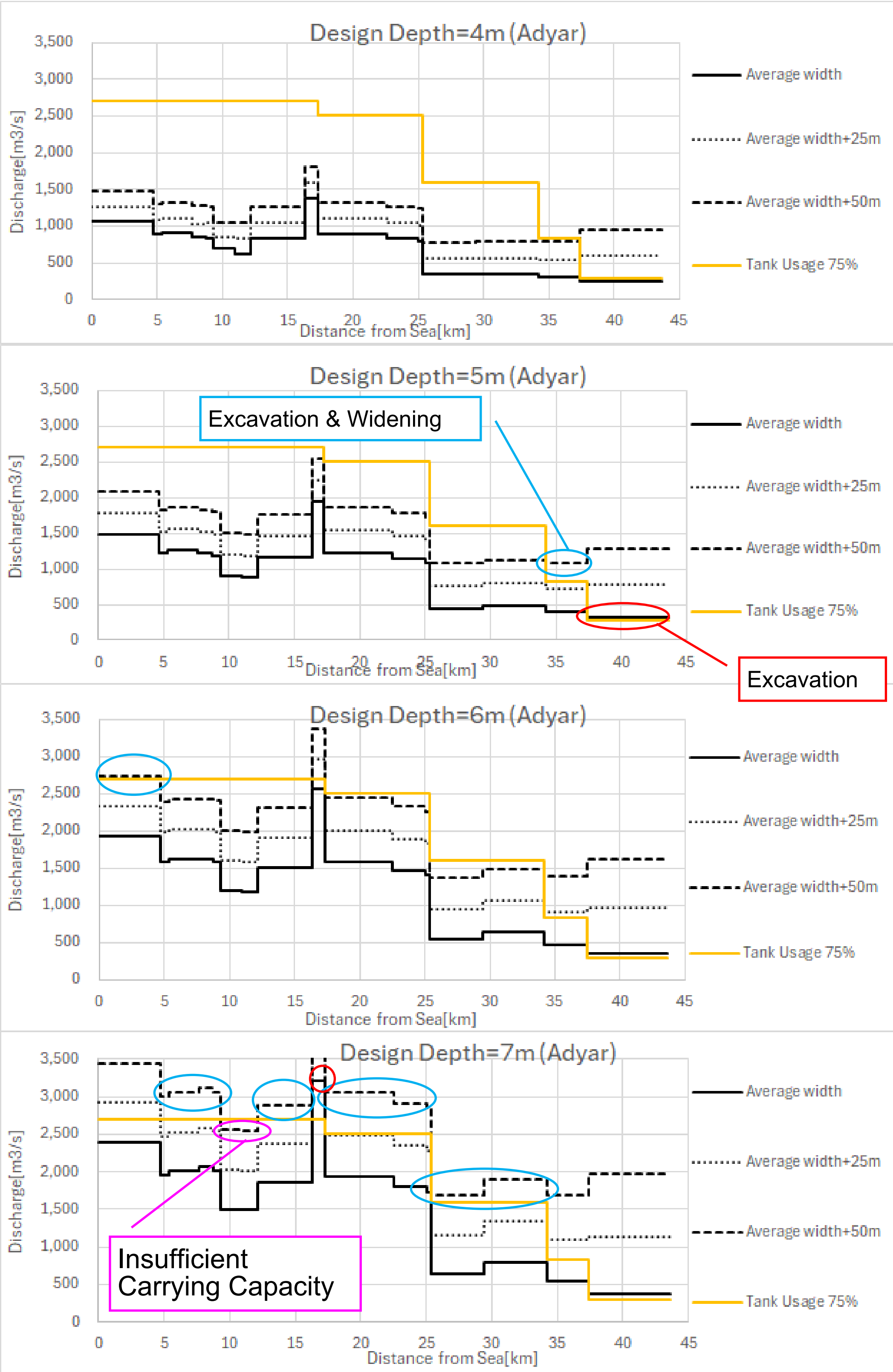
Similar calculations have been conducted for the Cooum and Kosasthalaiyar rivers, and the results are provided in Table 2-6 and Table 2-7. Although the design bed height is higher in some sections of these rivers, this adjustment is made to account for the flow capacity evaluation, and the rivers will not be backfilled.

As a result of this channel deepening, the water levels at the flood control points are anticipated to decrease by 10.3 meters at Adyar, 7.3 meters at Koum, and 10.2 meters at Kosasthalaiyar compared to current levels, assuming no inundation occurs under a 1/100 flood scenario.

**Table 2-5 Adyar River Channelization Details**

| Distance From Sea (km) | | | Design Depth (m) | Avarege River Width (m) | Widening (m) |
|---|---|---|---|---|---|
| 0.00 | ~ | 4.54 | 6.0 | 146.73 | 50 |
| 4.66 | ~ | 5.14 | 7.0 | 125.37 | |
| 5.32 | ~ | 7.56 | | 127.95 | |
| 7.64 | ~ | 8.58 | | 109.53 | |
| 8.72 | ~ | 9.29 | | 107.23 | |
| 9.34 | ~ | 10.91 | | 91.21 | |
| 10.98 | ~ | 12.08 | | 82.24 | |
| 12.17 | ~ | 16.24 | | 120.60 | |
| 16.34 | ~ | 17.19 | | 185.26 | 0 |
| 17.29 | ~ | 22.46 | | 118.18 | 50 |
| 22.53 | ~ | 24.92 | | 111.87 | |
| 25.00 | ~ | 25.22 | | 59.46 | |
| 25.35 | ~ | 29.37 | | 56.54 | |
| 29.41 | ~ | 34.17 | | 45.65 | |
| 34.23 | ~ | 37.33 | 5.0 | 48.30 | |
| 37.44 | ~ | 43.61 | | 34.12 | 0 |

*Source: JICA Expert Team*




*Source: JICA Expert Team*

**Figure 2-17: Process for designing Water Depth and River Width in Adyar River**

**Table 2-6: Cooum River Channelization Details**

| Distance From Sea (km) | | | Design Depth (m) | Avarege River Width (m) | Widening (m) |
|---|---|---|---|---|---|
| 0.00 | ~ | 0.48 | 4.0 | 174.11 | 0 |
| 0.66 | ~ | 2.34 | 6.0 | 89.42 | |
| 2.41 | ~ | 6.23 | 7.0 | 68.94 | 50 |
| 6.32 | ~ | 9.87 | | 70.62 | |
| 9.99 | ~ | 15.33 | | 69.14 | |
| 15.39 | ~ | 16.96 | 6.0 | 81.47 | |
| 17.02 | ~ | 18.90 | 5.0 | 94.48 | |
| 18.96 | ~ | 24.98 | | 92.33 | |
| 25.04 | ~ | 26.37 | 4.0 | 96.42 | 0 |
| 26.43 | ~ | 34.24 | | 87.75 | 50 |
| 34.30 | ~ | 40.93 | - | 202.67 | - |
| 40.96 | ~ | 43.54 | | 209.97 | |
| 43.79 | ~ | 63.67 | | 204.05 | |
| 63.83 | ~ | 73.68 | | 105.89 | |

*Source: JICA Expert Team*

**Table 2-7: Kosasthalaiyar River Channelization Details**

| Distance From Sea (km) | | | Design Depth (m) | Avarege River Width (m) | Widening (m) |
|---|---|---|---|---|---|
| 0.00 | ~ | 1.74 | 3.0 | 589.99 | 0 |
| 1.85 | ~ | 3.58 | 4.0 | 505.56 | 0 |
| 3.63 | ~ | 4.18 | 5.0 | 221.13 | 50 |
| 4.24 | ~ | 8.05 | 7.0 | 110.62 | 130 |
| 8.08 | ~ | 9.57 | | 115.88 | 50 |
| 9.63 | ~ | 13.66 | 5.0 | 289.62 | 0 |
| 13.72 | ~ | 31.65 | - | 277.07 | - |
| 31.87 | ~ | 32.48 | | 563.21 | |
| 32.86 | ~ | 35.37 | | 294.74 | |
| 35.52 | ~ | 69.26 | | 274.81 | |

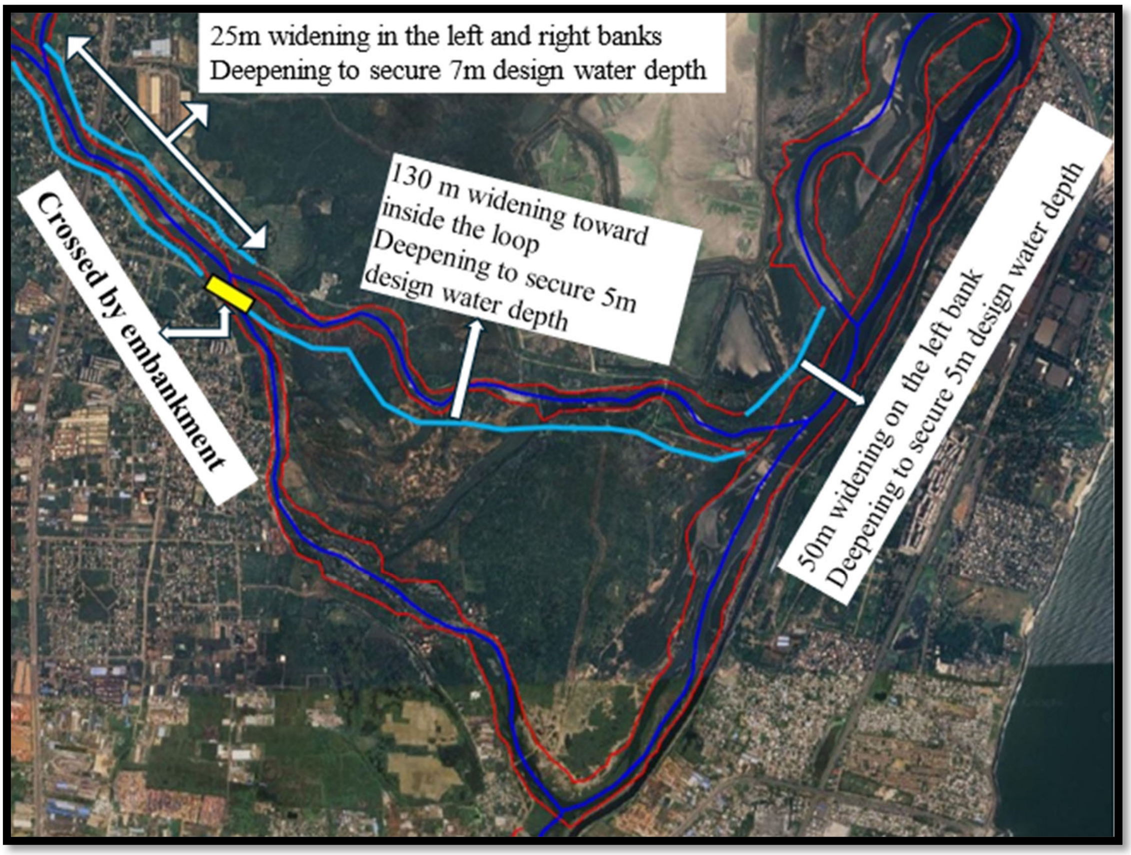
*Source: JICA Expert Team*

2.5.4.1. Special Considerations for the Downstream of Kosasthalaiyar River and Redhills

In the downstream section of the Kosasthalaiyar River, certain loops divide the river flow into the left (north) and right (south) branches. Specifically, the loops between 4.24 km and 8.05 km from the river mouth cause backwater effects on the right side of the loop, contributing to flooding downstream, including in the Redhills Surplus. To address this issue, a special river channelization proposal for this area is as follows:

The left channel (northern branch), which is shorter in length, will remain as the main Kosasthalaiyar River, while the right channel (southern branch) will be closed at the upstream branch point by constructing an embankment. This will ensure that the left channel primarily handles flood discharge from the Kosasthalaiyar River, while the right channel will eliminate backwater effects and facilitate the easy discharge of floodwaters from the Redhills River. This modification will shift the confluence of the Redhills River downstream, reducing flooding by lowering backwater levels from the Kosasthalaiyar River.

The channel improvement on the left bank will utilize unused land within the loop. By widening the channel, the design water depth will be set to 5 meters, matching that of the downstream section.

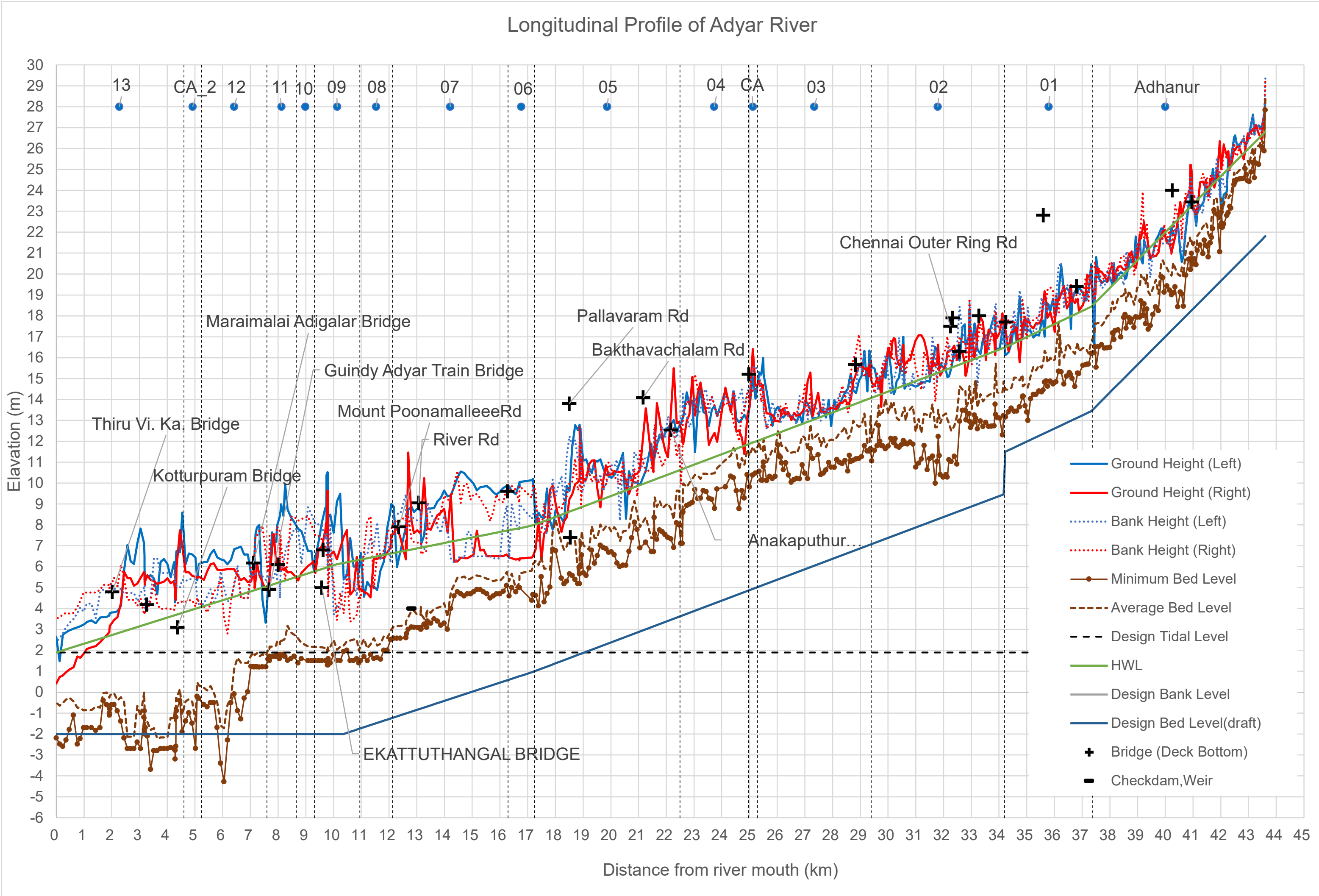



*Source: JICA Expert Team*

**Figure 2-18: Kosasthalaiyar River Loop 2 Section Renovation Plan**

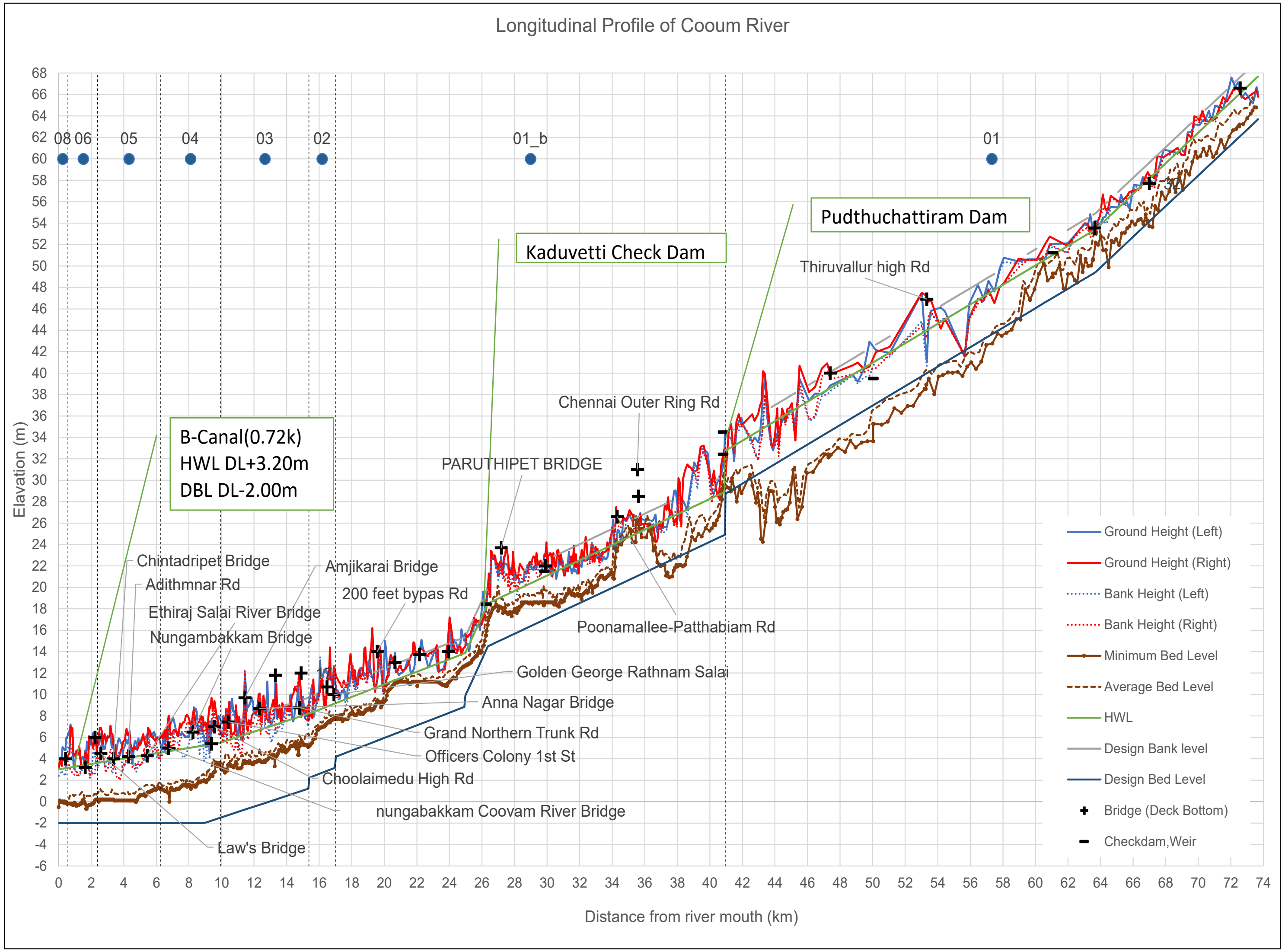
### 2.5.5 Design Riverbed Profile

The following figures illustrate the designed riverbed profiles for the Adyar River, Cooum River, Kosasthalaiyar River, and Redhills surplus channels. The excavation depth required for river deepening can be determined from these figures for each river.



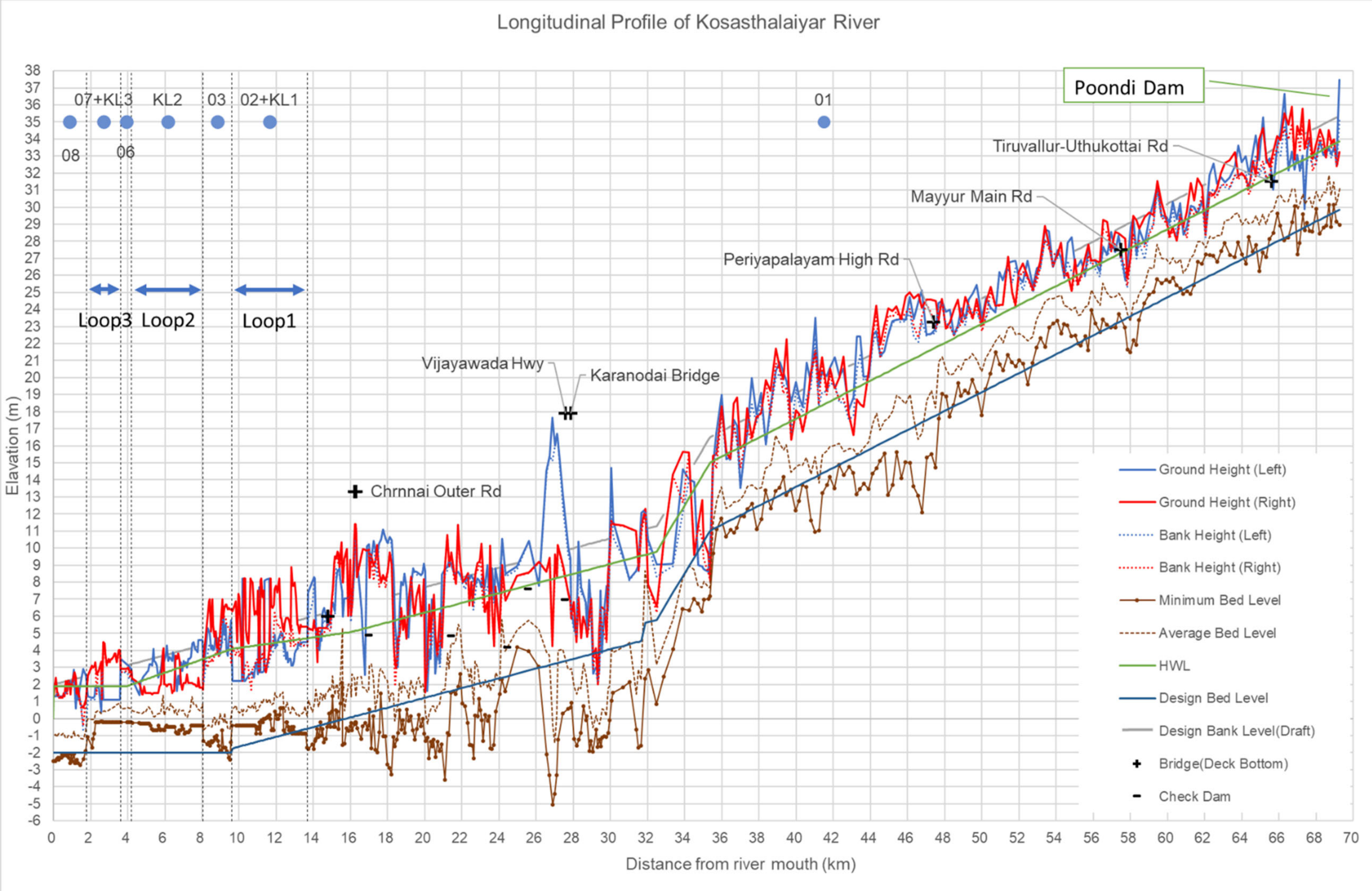

*Source: JICA Expert Team*

**Figure 2-19: Design Riverbed Elevation Profile of Adyar River**



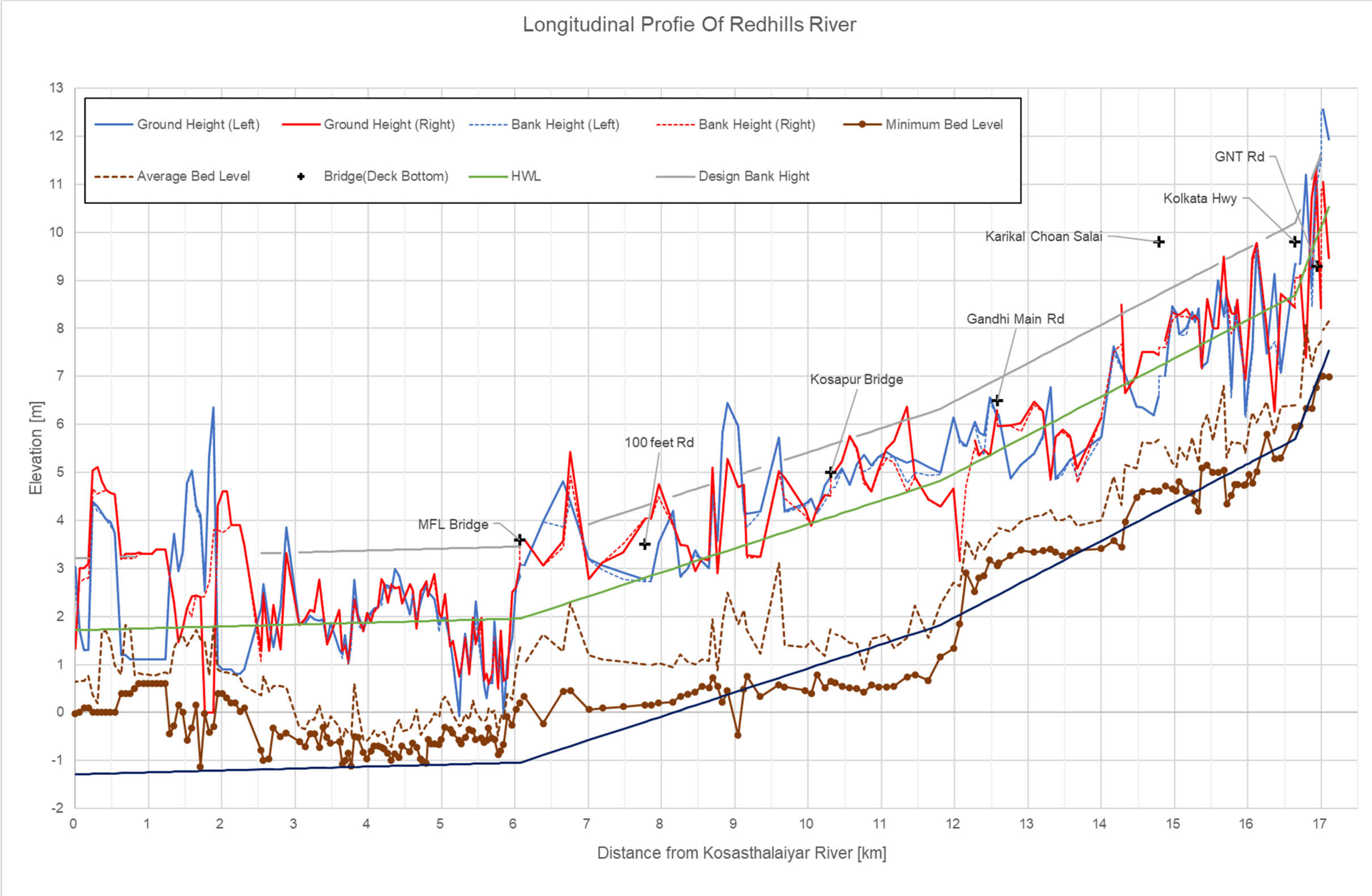

*Source: JICA Exert Team*

**Figure 2-20: Design Riverbed Elevation Profile of Cooum River**




*Source: JICA Expert Team*

**Figure 2-21: Design Riverbed Elevation Profile of Kosasthalaiyar River**




*Source: JICA Expert Team*

**Figure 2-22 Design Riverbed Elevation Profile of Redhills River**

## 2.6 Flood Storage in the Selected Tanks and Waterbodies

### 2.6.1 Background and Basic Policy

Tanks and waterbodies, primarily under the jurisdiction of TNWRD, have been selected for flood storage improvement. These options require minimal land acquisition, making them practical and feasible after coordination and discussions with the Counterpart Agencies (C/Ps). This approach has been mutually agreed upon by the TNWRD, ensuring alignment and support for the proposal.

This study collected information on the existing tanks and waterbodies from the Tamil Nadu Water Resources Department (TNWRD). Table 2-8 provides an overview of the status of tanks in each river basin.

**Table 2-8: Tanks and Waterbodies Areas**

| Basin | Basin Area (km²) | Existing Tank Area (km²) | Major Dam Area (km²) | % of Basin Area Covered by Tanks | % Including Dam Areas |
|---|---|---|---|---|---|
| **Adyar** | 854 | 62.6 | 22.7 (CBM Dam) | 7.33% | 9.99% |
| **Cooum** | 435 | 42.75 | N/A | 9.83% | N/A |
| **Kosasthalaiyar (in TN)** | 3031 | 206.9 | 55.4 (Three Dams) | 6.83% | 8.65% |
| **Kovalam (North Part)** | 293 | 16.7 | ~7.0 (Pallikaranai Marshland) | 5.67% | 8.07% |

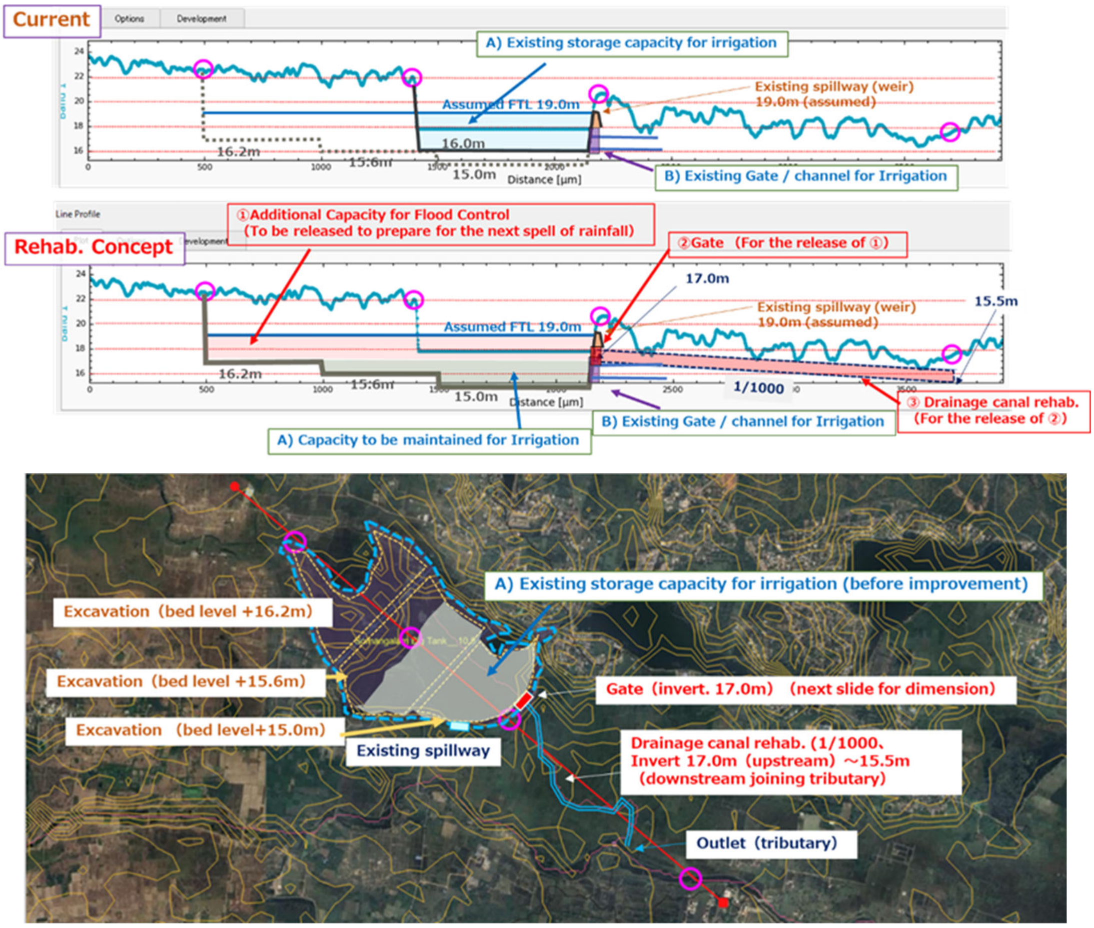
*Source: JICA Expert Team using information from TNWRD*

A policy for utilizing selected tanks and waterbodies for flood storage was agreed upon with the counterpart agencies and incorporated into the JICA Flood Control Master Plan. Selected waterbodies were analyzed based on their condition, as compared to the 2011 topographic sheets, to evaluate encroachments or potential area expansions. The study also assessed the connecting drainage systems and identified missing links, creating an inventory of tanks and their interconnections. This analysis was based on TNWRD data and other sources such as satellite images. A detailed and updated bathymetry of the selected tanks and waterbodies is essential during the implementation of the JICA Flood Control Master Plan.

### 2.6.2 Basic Design Concept

Enhancing the capacity of existing tanks involves multiple measures such as dredging and excavation (up to the sill level in tanks with gates), utilizing foreshore areas for expansion (where available), and raising the elevation of surrounding bunds with reinforcement using revetments. These interventions aim to improve functionality while maintaining compatibility with existing infrastructure.

The improvement plan for existing tanks is demonstrated by the Somangalam Tank in the Adyar Basin. Currently, the tank has a storage capacity of about 1.23 MCM. Due to sedimentation in the upstream sections, the water depth is concentrated in the downstream area, reaching up to 3.5 meters. Figure 2-23 illustrates the proposed improvements for this tank.




*Source: JICA Expert Team*

**Figure 2-23: Concept for improving an existing tank (example of Somangalam Big Tank)**

Improvement Approach: The improvement approach includes excavating shallow upstream areas uniformly to depths of 3~4 meters, ensuring that the excavation aligns with the sill level of the gates. This ensures compatibility with the existing spillways and intake structures.

Storage Expansion: It will result in an increase of approximately 2.51 MCM in flood storage capacity, leading to an average depth of 3.4 meters over a revised area of 1.10 km². If feasible, expansion into available foreshore areas will further increase the storage capacity. The surrounding bunds will be elevated and reinforced with revetments to enhance structural stability and prevent erosion.

Operational Enhancements: It includes two drainage gates (1.2 m x 1.2 m) that will allow controlled discharge of 2.1 MCM of water (from +19.0 m to +17.2 m) over seven days, effectively managing floodwaters. Additionally, the open drainage channels connecting to the Adyar River tributaries will be upgraded to dimensions of 5 meters in width and 2 meters in depth, capable of handling a flow of 10 m³/s. Before the monsoon season, the tank will be emptied, and water levels will be managed after each rainfall to maintain the flood control capacity.

### 2.6.3 Selected Tanks and Waterbodies for Flood Storage

In the following sections, the selected tanks and waterbodies for flood storage are presented for all four basins of the study, using maps and tables. It is important to note that while we provide tank and missing link data for the Kovalam Basin, the detailed flood control measures for the

Kovalam Basin are covered in Chapter 3, as its flooding categorized as pluvial or urban flooding.

2.6.3.1. Selected existing Tanks in Adyar Basin

50 waterbodies have been selected in the Adyar Basin to provide a combined flood storage capacity of 88 MCM after improving 75% of their existing storage capacity over an area of 47.4 km² in an average depth of 3.4 meters. The current combined capacity of these 50 tanks is approximately 59 MCM, covering a total area of around 43.1 km². Figure 2-24 shows the locations of these 50 selected tanks, grouped into 8 clusters based on their outlet connections. Additionally, the details of the selected tanks in the Adyar Basin and their link inventory (whether missing or existing) have been studied to outline the drainage links between them, highlighting the status of existing and missing connections.

2.6.3.2. Selected Existing Tanks in Cooum Basin

31 waterbodies have been selected in the Cooum Basin to provide a combined flood storage capacity of 38.0 MCM after improving 75% of their existing storage capacity over an area of 23.1 km² in an average depth of 3.2 meters. The current combined capacity of these 31 tanks is approximately 22.9 MCM, covering a total area of around 19.0 km². Figure 2-25 shows the locations of these 31 selected tanks, grouped into 6 clusters based on their outlet connections.

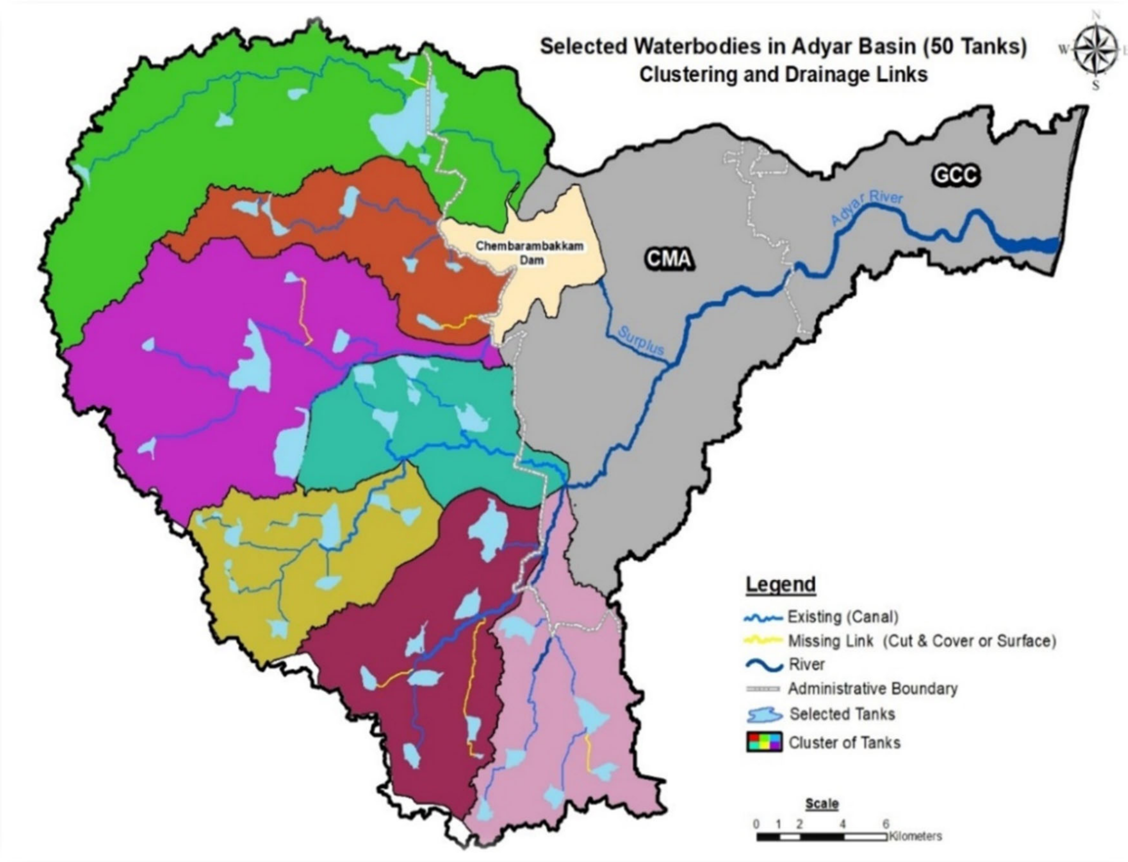
Additionally, the details of the selected tanks in the Cooum Basin and their link inventory (whether missing or existing) have been studied to outline the drainage links between them, highlighting the status of existing and missing connections.

2.6.3.3. Selected Existing Tanks in Kovalam Basin

61 waterbodies have been selected in the Cooum Basin to provide a combined flood storage capacity of 22.5 MCM after improving 75% of their existing storage capacity over an area of 13.9 km² in an average depth of 3.0 meters. The current combined capacity of these 61 tanks is approximately 19.2 MCM, covering a total area of around 16.7 km². Figure 2-26 shows the locations of these 31 selected tanks, grouped into 11 clusters based on their outlet connections. Additionally, the details of the selected tanks in the Kovalam Basin and their link inventory (whether missing or existing) have been studied to outline the drainage links between them, highlighting the status of existing and missing connections.

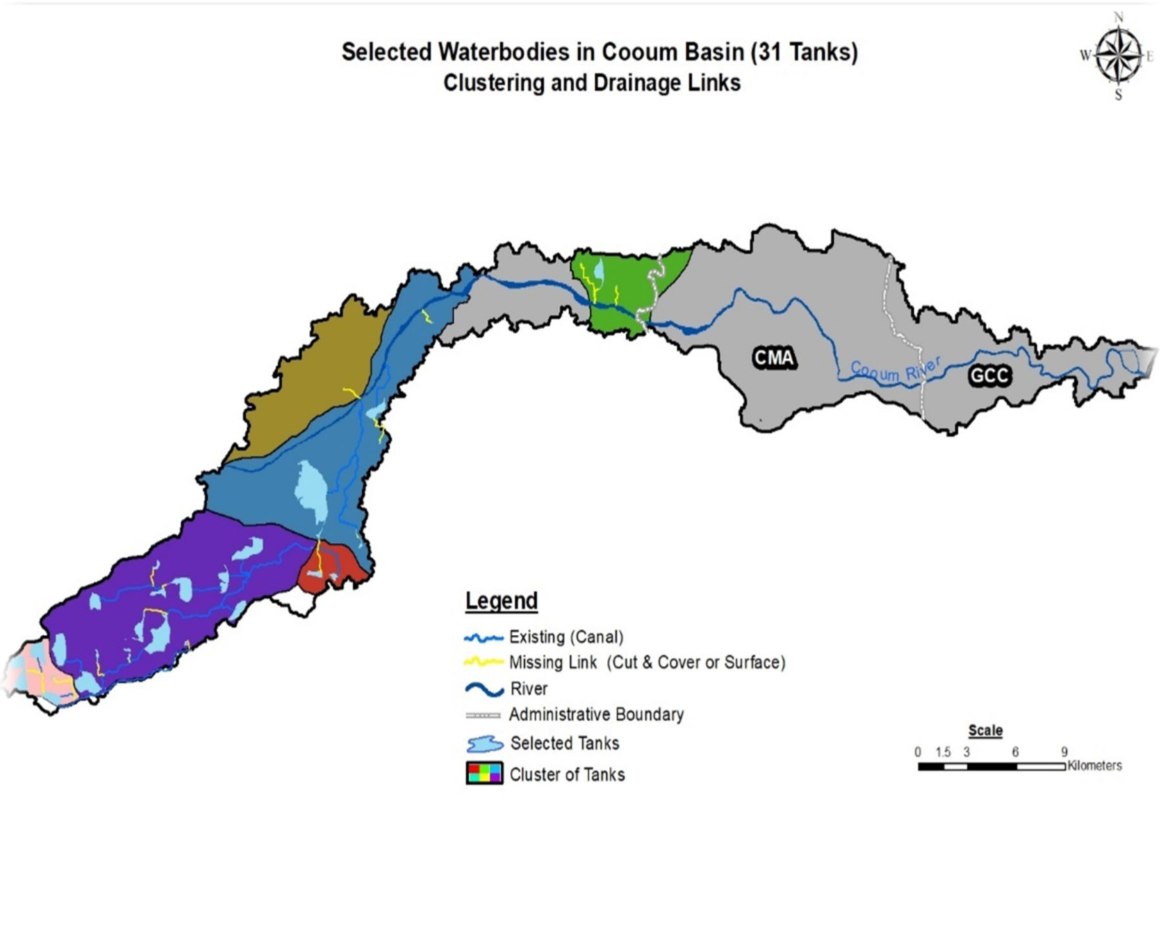
2.6.3.4. Selected Existing Tanks in Kosasthalaiyar Basin

112 waterbodies have been selected in the Kosasthalaiyar Basin to provide a combined flood storage capacity of 161 MCM after improving 75% of their existing storage capacity over an area of 81.2 km² in an average depth of 3.4 meters. The current combined capacity of these 112 tanks is approximately 115.2 MCM, covering a total area of around 75.0 km². Figure 2-27 shows the locations of these 112 selected tanks, grouped into 10 clusters based on their outlet connections. Additionally, the details of the selected tanks in the Kosasthalaiyar Basin and their link inventory (whether missing or existing) have been studied to outline the drainage links between them, highlighting the status of existing and missing connections.



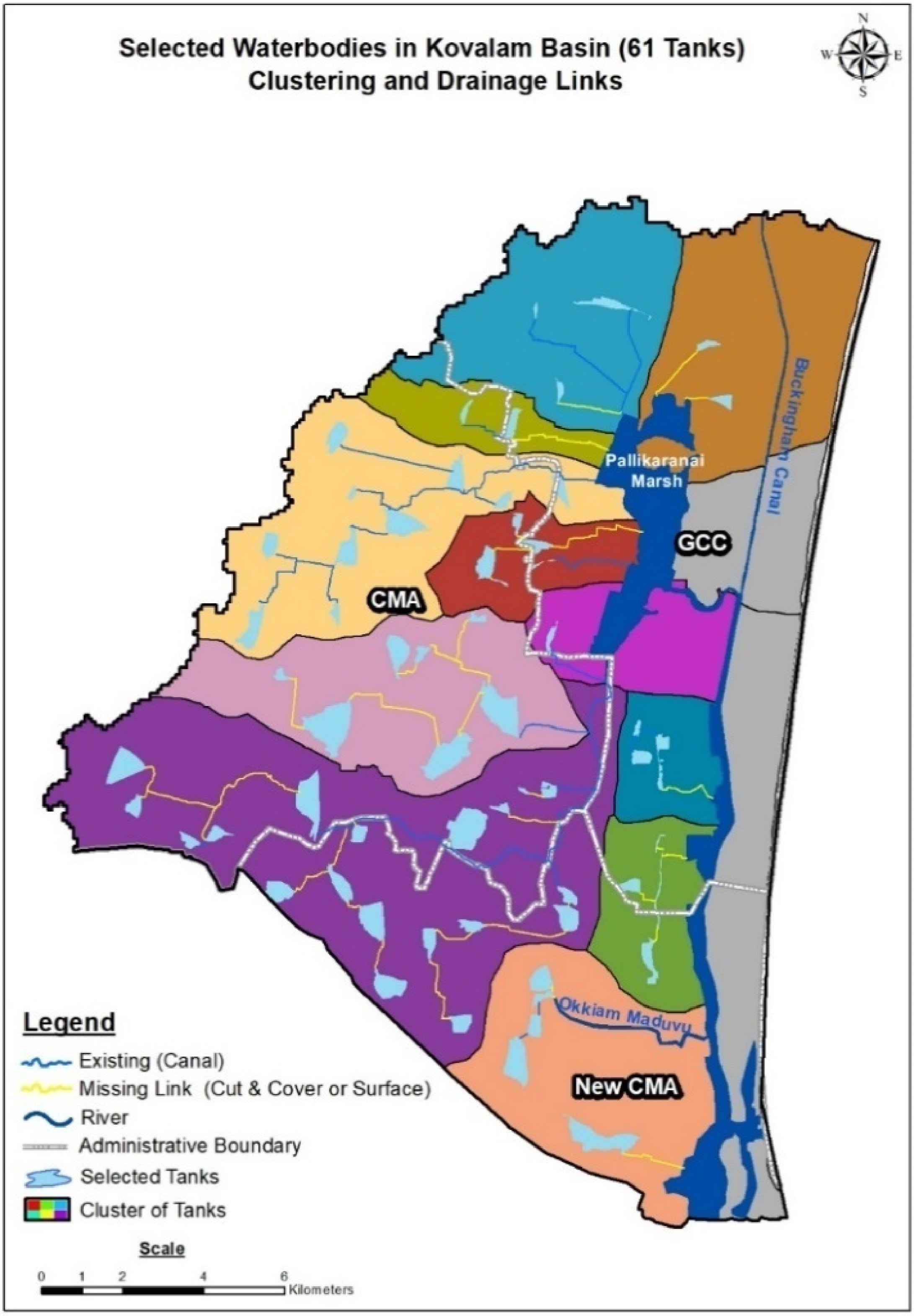

*Source: JICA Expert Team*

**Figure 2-24: Location of Selected Tanks in the Adyar Basin (50 tanks)**



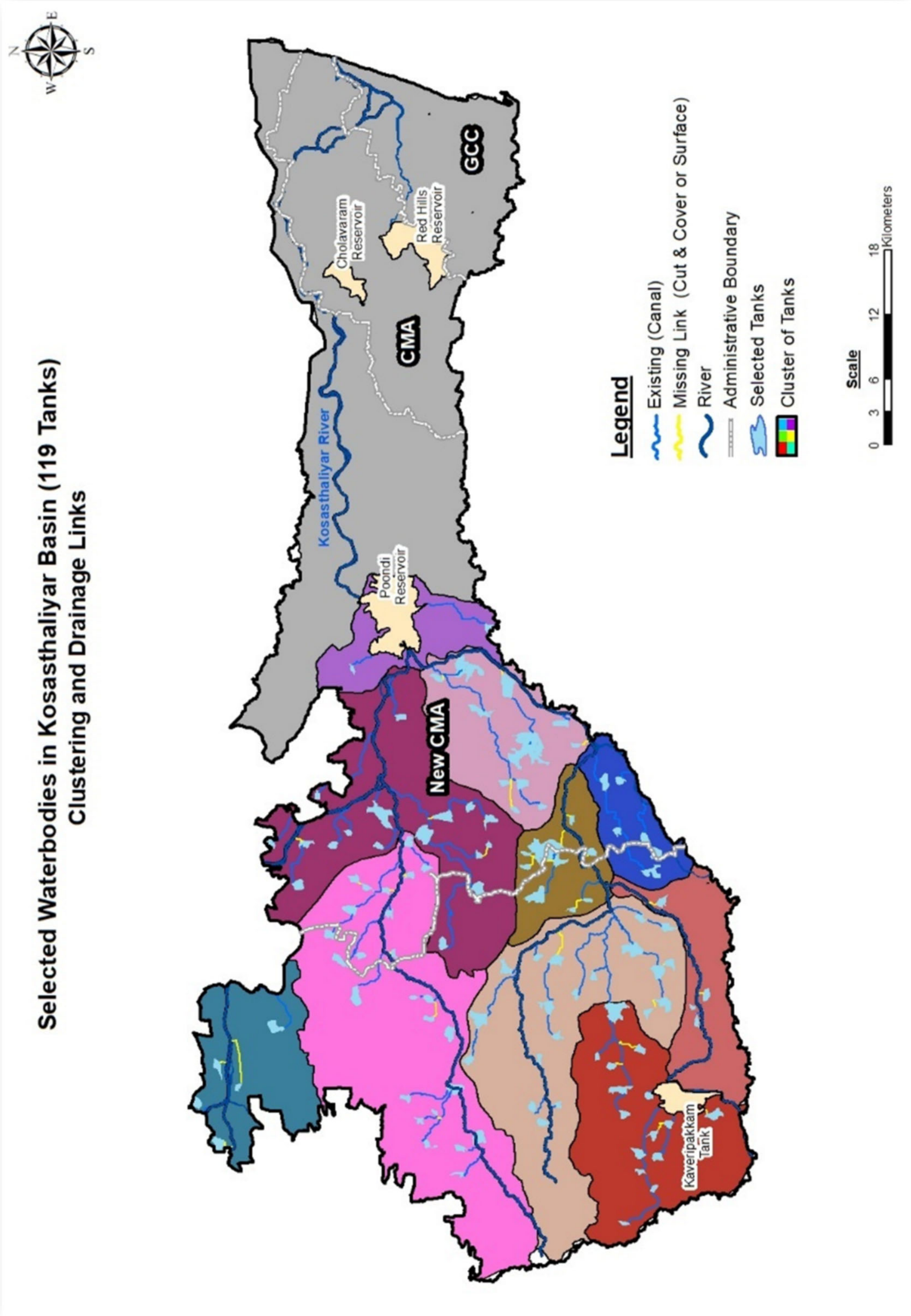

*Source: JICA Expert Team*

**Figure 2-25: Location of Selected Tanks in the Cooum Basin (31 tanks)**




*Source: JICA Expert Team*

**Figure 2-26: Location of Selected Tanks in the Kovalam Basin (61 tanks)**

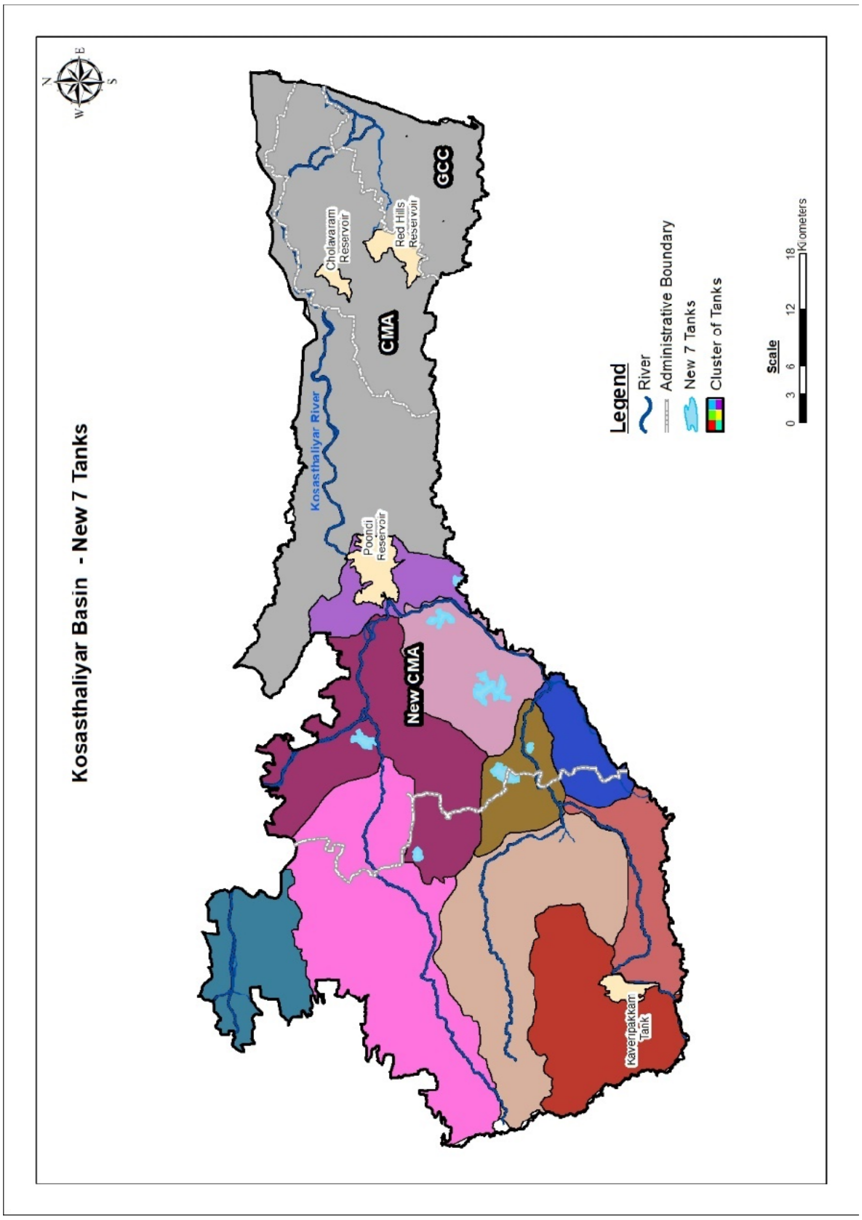



*Source: JICA Expert Team*

**Figure 2-27: Location of Selected Tanks in the Kosasthalaiyar Basin (112 Existing Tanks and 7 New Tanks)**

#### 2.6.3.5. Proposing 7 New Tanks in Kosasthalaiyar Basin

For the Kosasthalaiyar River, given the presence of unused and undeveloped land within the basin, consideration was given to enhancing flood control capacity by both improving existing tanks and developing new ones. Seven potential sites for new tanks have been identified. The construction approach for these new tanks will mirror the improvement strategy for the existing tanks, ensuring adequate storage capacity by uniformly excavating the ground surface at each site. The total area of the seven proposed new tanks is 12.25 km². By excavating these tanks to an average depth of 3.4 meters, similar to the existing tanks, a storage capacity of 42 MCM can be achieved. Figure 2-28 shows the location of these 7 new tanks and Table 2-9 shows detailed information about their connecting drains.




*Source: JICA Expert Team*

**Figure 2-28 Location New Tanks in the Kosasthalaiyar Basin (7 Tanks)**

**Table 2-9: Seven New Tanks in Kosasthalaiyar Basin and Their Links Inventory**

| S.No | Cluster | Tank Name | Tank Area in km2 | Canal Start_Point | Canal End_Point | Existing/Missing/Partial | Canal Length in km |
|---|---|---|---|---|---|---|---|
| 1 | KOS_SB_07 | New Tank 1 | 2.97 | New Tank 1 | Perumuchi Banal Eri Canal | Existing | 0.302 |
| 2 | KOS_SB_09 | New Tank 2 | 4.68 | New Tank 2 | Beddekalakattur Big Tank | Existing | 0.145 |
| 3 | KOS_SB_09 | New Tank 3 | 2.03 | New Tank 3 | Pandur Tank Canal | Existing | 0.031 |
| 4 | KOS_SB_08 | New Tank 4 | 0.80 | New Tank 4 | Polur big tank Canal | Partial ( Existing Toposheet & Cut & Cover or Surface) | 8.481 |
| 5 | KOS_SB_10 | New Tank 5 | 0.64 | New Tank 5 | Poondi Reservoir | Existing | 8.298 |
| 6 | KOS_SB_07 | New Tank 6 | 0.37 | New Tank 6 | Big Canal | Missing Link (Cut & Cover or Surface) | 0.530 |
| 7 | KOS_SB_08 | New Tank 7 | 2.12 | New Tank 7 | Nagari River | Existing | 1.323 |

*Source: JICA Expert Team*

### 2.6.4 Simulating Effect of the Flood Storage in the Selected Tanks

The table below shows the flood control capacity that can be achieved by rehabilitating existing tanks and developing new tanks along the Adyar River, Cooum River, and Kosasthalaiyar River.

**Table 2-10 Summary of Flood Storage in Selected Tanks**

| Summary of Flood Storage Capacity Estimation | Adyar Basin | Cooum Basin | Kosasthaliyar Basin |
|---|---|---|---|
| **Average excavation depth** | 3.4 m | 3.2 m | 3.4 m |
| **The selected number of waterbodies, tanks, and areas** | 50 (43.1 $km^2$) | 31 (19$km^2$) | 112 (81.3 $km^2$) |
| **a) Additional flood storage capacity by improving existing tanks and water bodies** | 88 MCM | 38 MCM | 161MCM |
| (1) Capacity of tanks after improvement (MCM) | 146.6 MCM<br>(43.1$km^2$*3.4m=146.6) | 60.8 MCM<br>(19$km^2$*3.2m=60.8) | 276.5 MCM<br>(81.3$km^2$*3.4m=276.5) |
| (2) Current capacity of tanks and water bodies | 58.5 MCM | 22.8 MCM | 115.2 MCM |
| Additional flood storage capacity=(2) - (1) | 88MCM<br>(146.6-58.5=88.1) | 38MCM<br>(60.8-22.8=38) | 161MCM<br>(276.5-115.2=161.3) |
| **b) Flood storage capacity of new tanks** | No need | No need | 42 MCM (7 new tanks, 12.25$km^2$)<br>(12.25$km^2$*3.4m=41.7) |
| **Total flood storage capacity in tanks and waterbodies (a+b)** | **88 MCM** | **38 MCM** | **203MCM** |

*Source: JICA Expert Team*

The HEC-HMS model was employed to evaluate the effects of flood storage in tanks and water bodies. Table 2-11, Table 2-12, and Table 2-13, summarize the simulation results for peak discharge (100-year and 50-year return periods) at flood control points along the Adyar River, Cooum River, and Kosasthalaiyar River under five distinct scenarios:

- Scenario 1: No improvements are made to tanks and waterbodies, representing the existing situation or baseline.
- Scenario 2: A 25% increase in the storage capacity for flood storage is achieved by improving the existing tanks and waterbodies through measures such as desilting and excavation.
- Scenario 3: A 50% in the storage capacity for flood storage capacity is implemented by further enhancing the capacity of tanks and water bodies.
- Scenario 4: A 75% increase in flood storage capacity is achieved, meeting the safety level required for a 100-year return period flood. This is the selected capacity for the master plan.
- Scenario 5: A near-maximum increase of 90% in flood storage capacity is considered, representing the upper limit of potential improvements.

**Table 2-11: Simulating the Effect on Peak Discharge in the Adyar Basin**

| Decreases in Peak Flood Hydrograph at Confluence with CBM Surplus | | | | | |
|---|---|---|---|---|---|
| Return Period | No Storage | 15 MCM (25%) | 42 MCM (50%) | 87 MCM (75%) | 102 MCM (90%) |
| 50 | 3789 m3/s | 3510 m3/s | 3027 m3/s | 2530 m3/s | 2251 m3/s |
| 100 | 4417 m3/s | 4167 m3/s | 3687 m3/s | 3194 m3/s | 2894 m3/s |

*Source: JICA Expert Team*

**Table 2-12: Simulating the Effect on Peak Discharge in the Cooum Basin**

| Decreases in Peak Flood Hydrograph at Paruthippattu | | | | | |
|---|---|---|---|---|---|
| Return Period | No Storage | 10 MCM (25%) | 27 MCM (50%) | 38 MCM (75%) | 43 MCM (90%) |
| 50 | 1313 m3/s | 1172 m3/s | 1001 m3/s | 890 m3/s | 859 m3/s |
| 100 | 1522 m3/s | 1395 m3/s | 1208 m3/s | 1070 m3/s | 1018 m3/s |

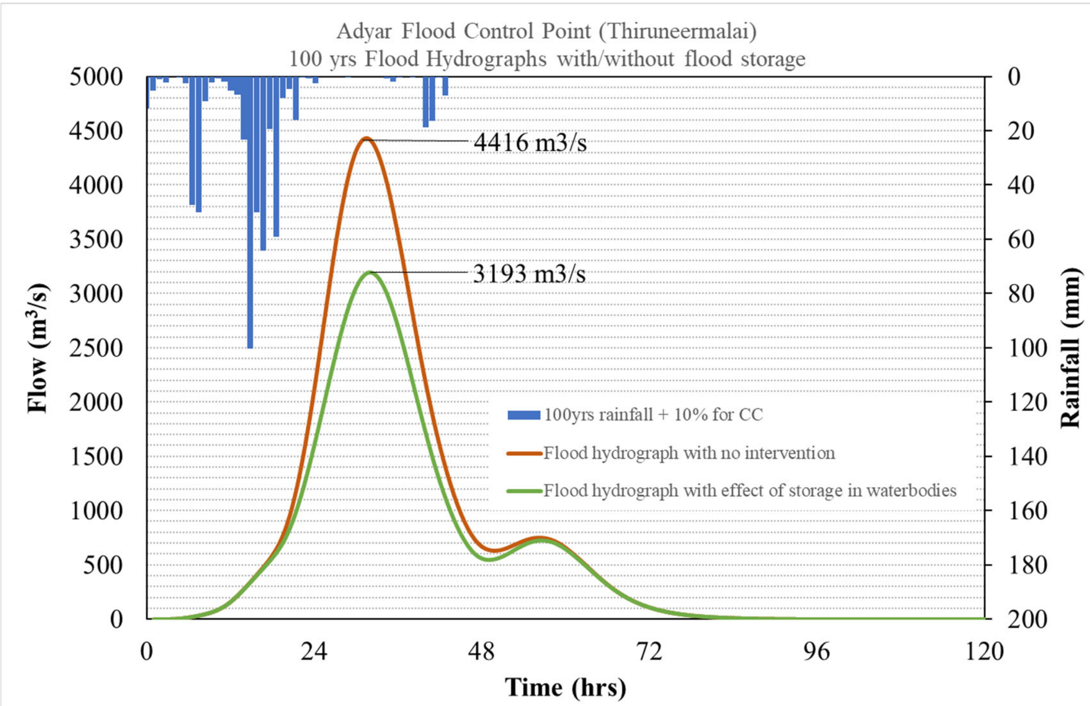
*Source: JICA Expert Team*

**Table 2-13: Simulating the Effect on Peak Discharge in the Kosasthalaiyar Basin**

| Decreases in Peak Flood Hydrograph at Poondi Dam (Dam Inflow) | | | | | |
|---|---|---|---|---|---|
| Return Period | No Storage | 52 MCM (25%) | 138 MCM (50%) | 203 MCM (75%) | 225 MCM (90%) |
| 50 | 5022 m3/s | 3978 m3/s | 2561 m3/s | 2016 m3/s | 1839 m3/s |
| 100 | 6152 m3/s | 5166 m3/s | 3502 m3/s | 2598 m3/s | 2426 m3/s |

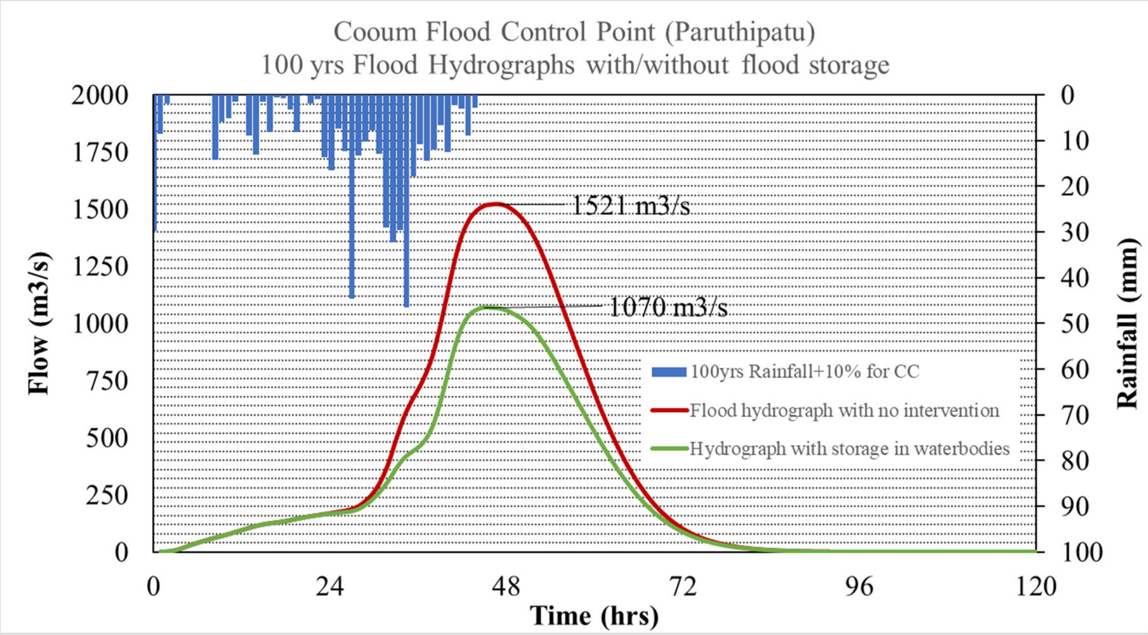
*Source: JICA Expert Team*

Figure 2-29, Figure 2-30, and Figure 2-31, shows the effect of utilizing waterbodies and tanks for flood storage under the scenario of increasing their storage capacity by up to 75% in the flood control points.



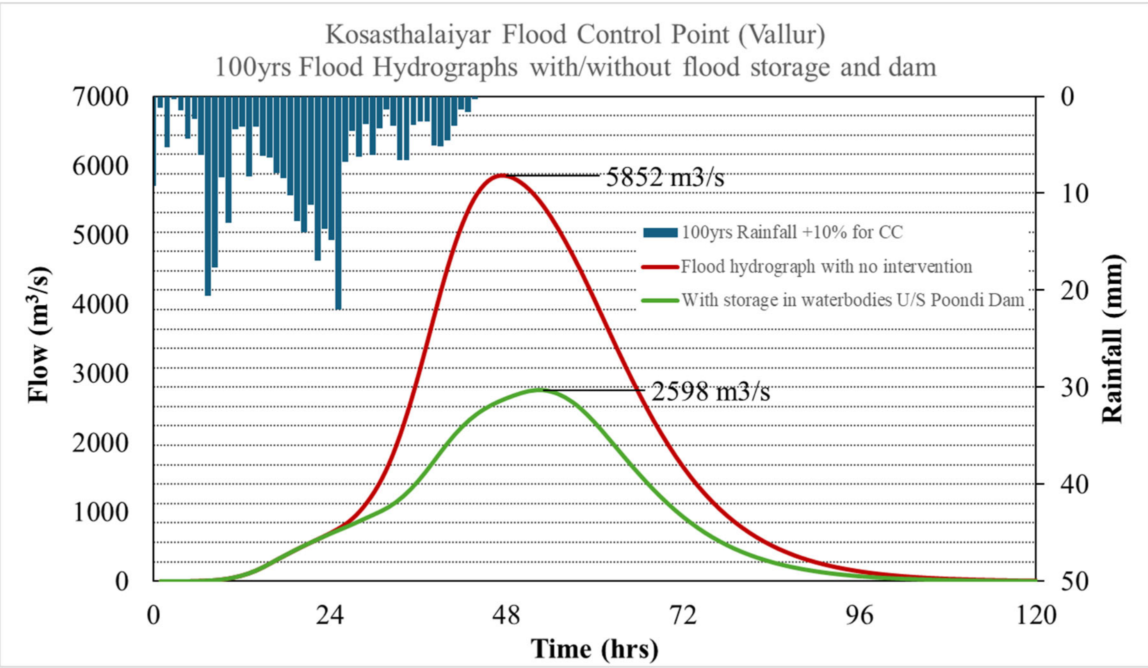

*Source: JICA Expert Team*

**Figure 2-29: Comparison of Adyar Flood Hydrograph with Post-Improvement of Tanks**




*Source: JICA Expert Team*

**Figure 2-30: Comparison of Cooum Flood Hydrograph with Post-Improvement of Tanks**




*Source: JICA Expert Team*

**Figure 2-31: Comparison of Kosasthalaiyar Flood Hydrograph with Post-Improvement of Tanks**

### 2.6.5 Flood Storage upstream of Kosasthalaiyar Basin outside of the new CMA

In the upstream area of the Kosasthalaiyar basin, outside the new CMA, the predominant land uses include agriculture for rural areas and villages, natural forests, and waterbodies. Most of the tanks and waterbodies in this area are formed based on natural topography and they are uncontrolled. Some of them are used for agriculture.

For the master plan, it is important to limit excessive flood generation and runoff from this area. JICA Food Control Master Plan has been proposed to reduce excessive flood generation and runoff from the original 945 m³/s to 400 m³/s for a 100-year return period flood. This represents a reduction of approximately 545 $m^3/s$ in runoff generation compared to the current flood levels for the same return period.

One potential solution was the construction of a new dam in this region. However, initial studies by TNWRD (Tamil Nadu Water Resources Department) indicated concerns over environmental impacts, lack of funds, and challenges related to the operation and maintenance of such dams far from Chennai. Consequently, this option was ruled out.

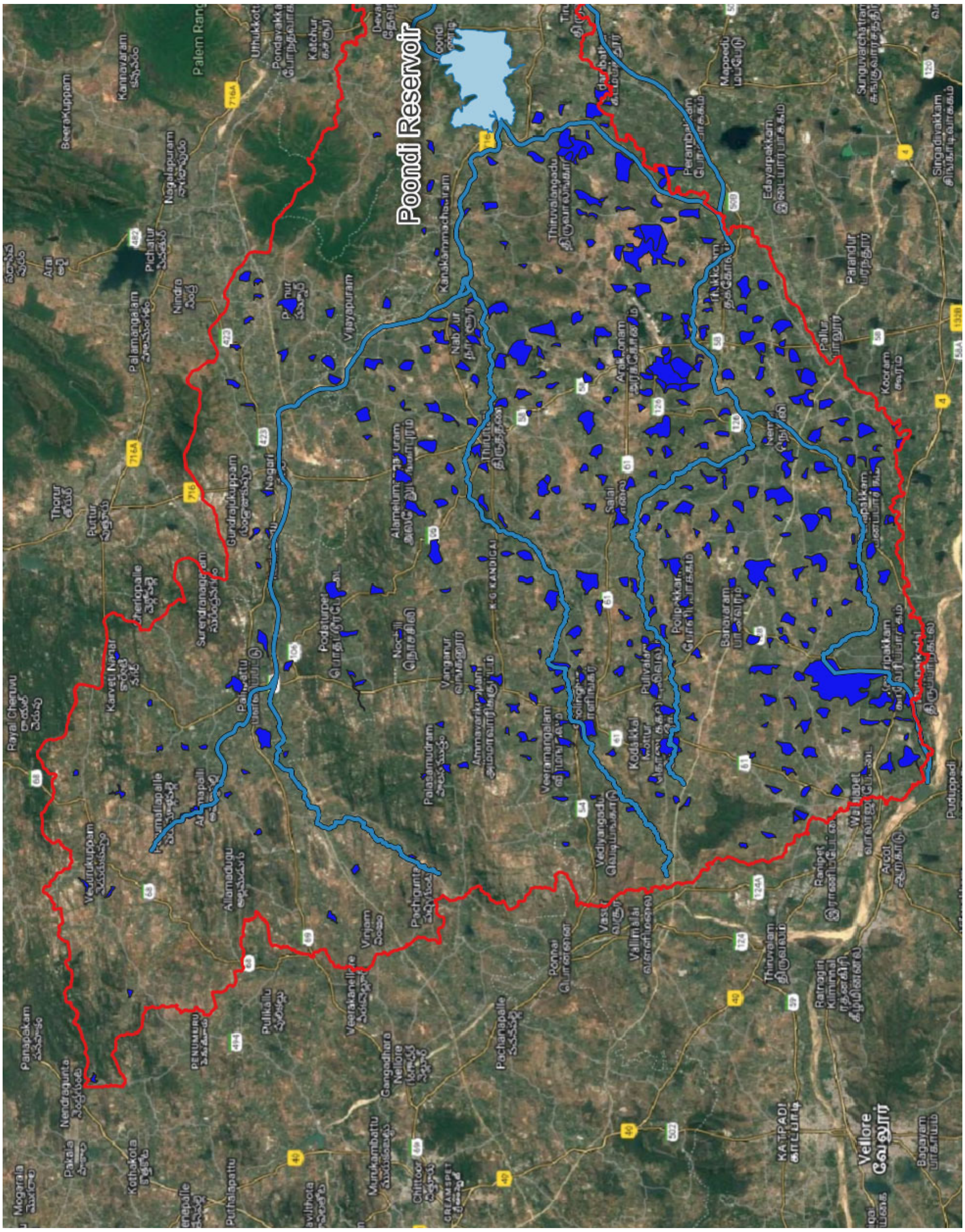
A second proposal, discussed with TNWRD, was the construction of flood control embankments or dikes along the new CMA boundary. It is an elevated structure that acts as a barrier to prevent runoff flowing to the New CMA area and downstream and can also be used as roads, serving a dual purpose of flood protection and transportation. While this idea was welcomed by TNWRD to prevent natural floods from entering the new CMA, concerns over funding availability, socio-environmental impacts, lack of detailed study, and uncertainties regarding the realization of implementation of such a long flood control embankment, make it difficult to secure firm written approval for this option.

As a third and selected option in the JICA Flood Control Master Plan, the use of existing tanks and waterbodies was explored. In this regard, 380 natural tanks and water bodies in the upstream area of Poondi Dam have been identified. The simulation result using HEC-HMS shows a flood storage depth of only 0.5 meters (less than 2 feet) in these 380 tanks and waterbodies are sufficient to retain floodwaters generated in this area, preventing them from flowing downstream toward Poondi reservoir during a 100-year return period flood.

Currently, these tanks and waterbodies are naturally functioning as flood storage areas. However, two key concerns must be addressed for their long-term preservation and protection. The first is the risk of encroachment, especially as Chennai expands into the New CMA area. Encroachment could lead to the disappearance or significant reduction of these tanks and water bodies. Preserving and maintaining them in their current state is crucial to ensure they can continue to reduce runoff effectively.

The second issue is sedimentation, which affects the depth and functionality of these areas. While sedimentation is not yet an immediate problem, it should be monitored through regular checks and maintenance. Conducting bathymetric surveys will provide a clearer understanding of sedimentation patterns and their impact on flood storage. Local authorities should prioritize efforts to protect and preserve these areas, implement regular maintenance programs, and conduct detailed studies to ensure their long-term effectiveness in flood management.

The locations of these tanks and water bodies are displayed in the figure below. It has been confirmed to maintain a flood storage capacity of 0.5 meters in these tanks and water bodies. The local authorities aim to protect them, even with the expansion of Chennai to the New CMA.

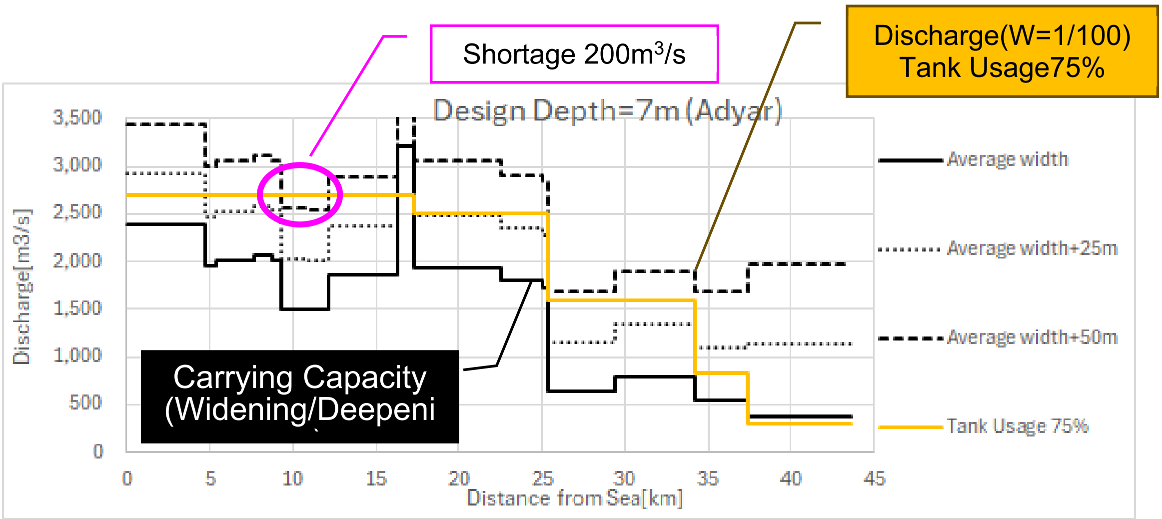



*Source: JICA Expert Team*

**Figure 2-32: Location of Selected 380 Natural Tanks Upstream of Poondi Dam**

## 2.7 Underground River Package

As a result of the study in the previous section, it was revealed that the Adyar River would not be able to discharge a 100-year flood by river channel improvement and basin storage facility construction alone in the section from 9.34 km to 12.08 km downstream of Chennai Airport (Figure 2-33), so the shortfall in discharge capacity of approximately 200 m3/s would be secured by an underground bypass tunnel.




*Source: JICA Expert Team*

**Figure 2-33: Shortfall in the Carrying Capacity of Adyar River for 100-year RP**

Table 2-14 compares the two options for addressing this shortfall: further widening and an underground bypass tunnel. The table shows that the cost would be higher for the underground bypass tunnel, but considering the social and economic impacts of this, including on the airport, the underground bypass tunnel was judged to be more appropriate.

In this table: A circle (○) indicates an acceptable level. A triangle (△) signifies that there are some observations or concerns. A cross (×) means it is not acceptable.

**Table 2-14: Comparison of Countermeasures for Insufficient Flow Capacity in the 9.34k to 12.08k Section**

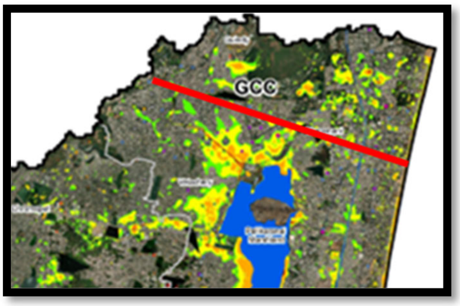
| | Further expansion | Underground bypass tunnel |
|---|---|---|
| Overview of the measures | ・Section: 9.34k to 12.08k (2.74km)<br>・Widening width 10m: total 60m | 200m3 /s will be diverted 18.3 km upstream from the airport |
| Certainty of measures | ・Can be reliably drained<br>[Rating: ○] | ・Can be reliably drained<br>[Rating: ○] |
| Social impact | ・Further widening occurs at 2.74 km.<br>(greater negotiation of house relocation, etc.)<br>・Difficult to widen on military land downstream of the airport [Rating: △] | ・The widening area can be reduced by a uniform 10 m because the 200 m3/s flood flow can be reduced downstream of the diversion point.<br>(possible to reduce building relocations of 1,000 residential and 500 commercial buildings).<br>・Reduced widening of military land downstream of the airport.<br>[Rating: ○] |
| Effect of developments on airport closures due to flooding | ・Since construction will be carried out sequentially from the downstream side, the effects will be seen slowly.<br>[Rating: △] | ・The development is relatively unaffected by land negotiations, etc., so the effects are seen early.<br>[Rating: ○] |
| Cost<br>Crore INR<br>(million USD) | ・Construction 5 (3.6)<br>・Preparation 450 (54)<br>・Total 460 (58)<br>[Rating: ○] | Underground bypass tunnel<br>・Construction 8,000 (960)<br>・Preparation 200 (24)<br>・Total 8,200 (990)<br>Effect of 10 m widening reduction<br>・Construction -30 -3.6)<br>・Preparation -4,400 (-530)<br>・Total -4,500 (-540)<br>Costs taking into account the effect of the widening reduction<br>・Construction 7,900 (950)<br>・Preparation -4,200 -500)<br>・Total 3,700 (450)<br>[Rating: △] |
| Total Evaluation | Although the cost is cheaper than the right proposal, it was ranked as the next best option due to the risk of a prolonged project with further house relocation.<br>[Rating: ○] | Although the costs are high, this proposal is adopted because it has a low social impact and allows the project to move forward quickly.<br>[Rating: ◎] |

*Source: JICA Expert Team*

The underground bypass tunnel will channel water from the Adyar River via an intake facility and inlet shaft into the tunnel, discharging into the Bay of Bengal using a siphon system for natural drainage. The tunnel has a longitudinal gradient of i=1/2,000 and an inner diameter of 11 meters.

The feasibility of natural drainage was examined using pressure calculations based on steady flow. The calculation result was 190 m3/s, which is roughly the planned flow rate of 200 m3/s, and natural drainage was generally possible. However, in actual operation, friction losses within the pipes may become greater, and losses due to various flood inflow characteristics may occur, so it is possible that natural drainage may not be possible. If such cases arise, it will be necessary to consider using pumps for drainage in the future.

As the bypass tunnel passes through the Kovalam district, it is expected to not only mitigate flooding in the Adyar River but also aid in draining inland water in the Kovalam basin in the Velachery area as in the Figure 2-34. Water intake facilities will be installed at suitable places in the Velachery area located along the tunnel's route.




*Source: JICA Edpert Team*

**Figure 2-34: Remaining Inundation in the Velachery Area**

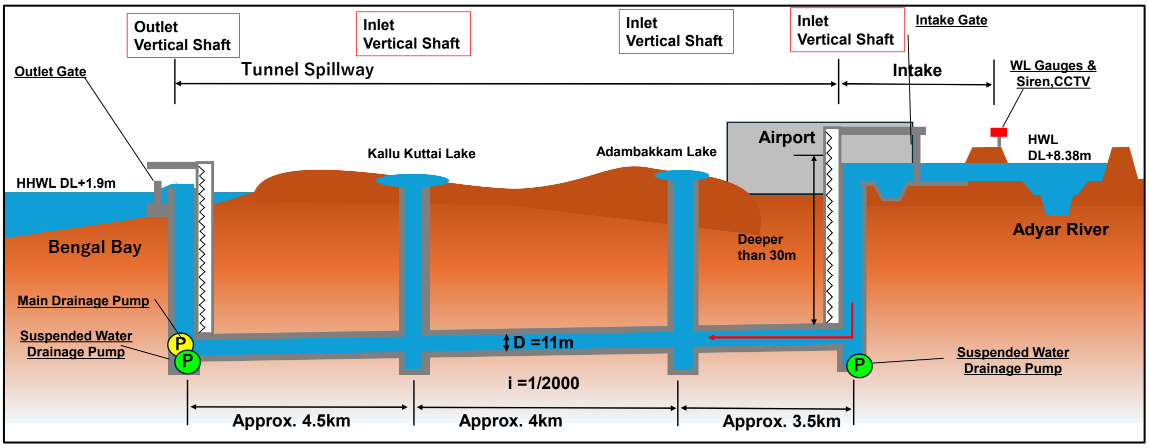
**Table 2-15: Underground Bypass Specifications**

| | | Unit | Route1 |
|---|---|---|---|
| Bypass Tunnel Length | | km | 12.5 |
| Inlet | Adyar River Kilopost | k | 18.009 |
| | Adyar River HWL | DL.+m | 8.38 |
| Outlet | Bengal Bay HHWL | DL.+m | 1.90 |
| WL Difference(Inlet-Outlet) Δ H | | m | 6.483 |
| WL Gradient(1/n) | | - | 1,928 |

*Source: JICA Expert Team*


*Source: JICA Expert Team*

**Figure 2-35: Location of the Underground Bypass Tunnel**




*Source: JICA Expert Team*

**Figure 2-36: Schematic Diagram of the Underground Bypass**

## 2.8 Non-Structural Measures

To comprehensively address river flood control, it is important to consider both structural and non-structural measures. Structural measures have been explained in the previous sections. In this section, a few non-structural recommendations have been provided. It is important to note that Chapter 4 and Chapter 6 of the JICA Flood Control Master Plan, focusing on urban planning and flood disaster management, offer a more holistic outlook of non-structural measures.

### 2.8.1 Flood Forecasting and Effect of Pre-releasing from Major Dams

The project, titled "Consulting Services for Planning, Setting up and Operationalizing a Real-Time Flood Forecasting and Spatial Decision Support System for Adyar, Cooum, Kosasthalaiyar, Nagariyar, Nandhiyar, and Kovalam Basins", focuses on establishing a robust flood forecasting and early warning for Chennai and its surrounding basins.

Funded by the World Bank under Loan No. 8488-IN (Project No. P150395), one of the objectives of this project is to provide reliable flood forecasting to enhance the operation of four major dams: Chembarambakkam Dam, Poondi Dam, Cholavaram Dam, and Red Hills (Puzhal Dam). An online system is currently under development at the designated URL (https://www.chennaifloodsdss.in/), and a control room for flood forecasting and early warning is also under construction.

A "What-If" analysis was carried out to simulate the effects of pre-release from Chembarambakkam Dam and Poondi Dam under various scenarios. This analysis considered pre-releasing water up to 24 hours in advance and assessed the impact of different storage levels in the dams. The study focused on evaluating the effect of varying storage levels, ranging from 80% to 95% full, on flood management. These dams primarily serve as water supply sources for Chennai, especially during the monsoon season, when Tamil Nadu Water Supply and Drainage (TNWRD) officials aim to maximize flood storage to prevent downstream flooding. The analysis incorporated rainfall events with a 100-year return period to assess the outflow under each pre-release scenario.

While the flood forecasting study is still ongoing, the initial findings emphasize the significant role of pre-release in reducing peak flood discharge in downstream areas, as shown in the accompanying table. However, due to the inherent uncertainty associated with flood forecasting, the master plan for flood management does not take pre-release from the major dams into account when determining peak flood discharge.

**Table 2-16: Simulation Effect of Pre-release for Different Scenarios**

| Dam | Pre-release Time and Discharge | Initial Dam Storage (% of Full Capacity) | Peak Outflow with Pre-release ($m^3/s$) | Peak Outflow in the JICA Master Plan ($m^3/s$) |
|---|---|---|---|---|
| Chembarambakkam | 12hrs 150$m^3$/s | 80% | 470 | 820 |
| | | 85% | 500 | 820 |
| | | 90% | 530 | 820 |
| | | 95% | 570 | 820 |
| Chembarambakkam | 24hrs 100$m^3$/s | 80% | 400 | 820 |
| | | 85% | 430 | 820 |
| | | 90% | 470 | 820 |
| | | 95% | 500 | 820 |
| Poondi | 24hrs 200$m^3$/s | 80% | 1430 | 2100 |
| | | 85% | 1460 | 2100 |
| | | 90% | 1500 | 2100 |
| | | 95% | 1550 | 2100 |

### 2.8.2 Operation of Tanks and Waterbodies

The flood storage capacity of selected waterbodies and tanks, as discussed in earlier sections, is a key component of this master plan. In addition to structural measures such as dredging tanks, expanding foreshore area, and elevating surrounding bunds/buffers of these waterbodies, the following four non-structural measures are proposed to ensure their effective management and operation:

1. Conservation and Protection of Selected Tanks and Waterbodies: It is essential to prevent further encroachment and changes in land use of these tanks and water bodies. As highlighted in the Urban Planning chapter of this report, conservation efforts should therefore be prioritized through spatial planning measures, such as designating these areas as protected zones in the Third Urban Master Plan or similar planning initiatives.

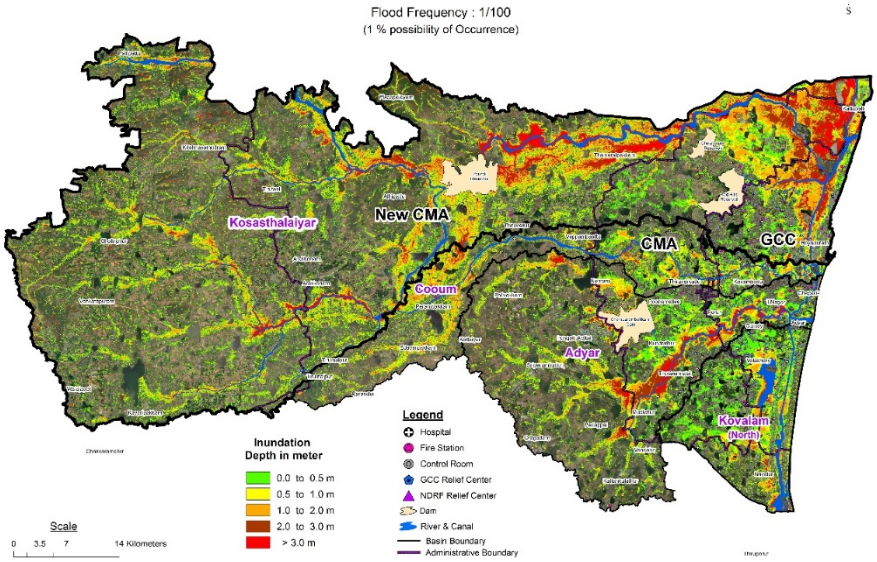
2. Lowering Water Levels in Tanks and Waterbodies Before Monsoon and Heavy Rainfall: Lowering water levels before the onset of the monsoon or heavy rainfall provides sufficient storage capacity to accommodate excess floodwaters. This proactive measure ensures that tanks and waterbodies are well-managed and prepared to handle incoming rainwater, thereby enhancing flood resilience.

3. Regular Monitoring and Maintenance of Waterbody Facilities: Routine checks and maintenance of critical infrastructure such as gates, connecting drains, and other facilities are vital. This involves clearing blockages, dredging, and cleaning drains regularly to ensure their ability to efficiently discharge excess water downstream.

4. Cluster-Based Management of Tanks and Waterbodies: Managing water bodies and tanks in clusters based on their outfalls and downstream connections, whether they discharge into dams or rivers—streamlines operations and addresses maintenance challenges. Cluster-based management ensures coordinated flow, improves operational efficiency, and strengthens flood control measures.

### 2.8.3 Flood Hazard Maps

Flood hazard maps have been developed at multiple scales to provide a comprehensive understanding of flood risks across various levels. These include basin-level maps as well as detailed maps for administrative regions such as CMA and Greater Chennai Corporation (GCC). Additionally, specific maps have been created for GCC's 15 zones and 200 wards, ensuring varying levels of detail to address localized flood risks effectively. The figure below shows the flood hazard map at basin level for a 100-year Return Period.

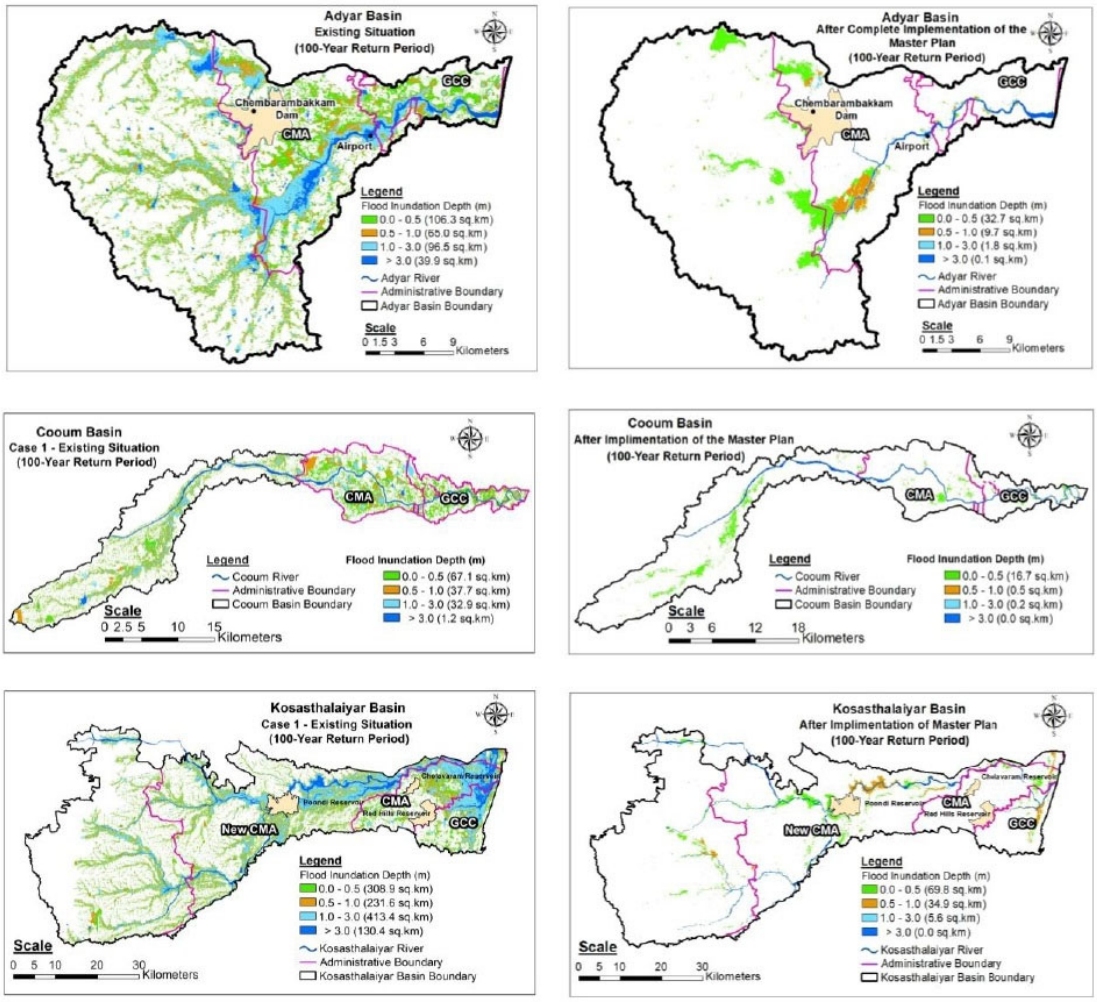



*Source: JICA Expert Team*

**Figure 2-37: Flood Inundation Map for 1/100 Flood**

## 2.9 Effect of Proposed Countermeasure

This section evaluates and visualizes the effect of implementing the master plan on river flood management within the study area. Figure 2-38 shows the current inundation extent under a 100-year return period flood event on the left and the projected conditions following the full implementation of the master plan on the right. The primary objective of the river flood control components within the JICA Flood Control Master Plan is to mitigate riverine flood hazards and achieve a target safety level corresponding to a 100-year return period. As shown in the figure, the plan effectively eliminates riverine flood inundation. The areas with minor residual inundation are primarily attributed to natural topographical depressions, resulting in localized waterlogging due to insufficient drainage infrastructure or the absence of effective stormwater drainage systems. These occurrences are not linked to riverine flooding but instead stem from pluvial flooding and stagnation, necessitating targeted local drainage interventions.

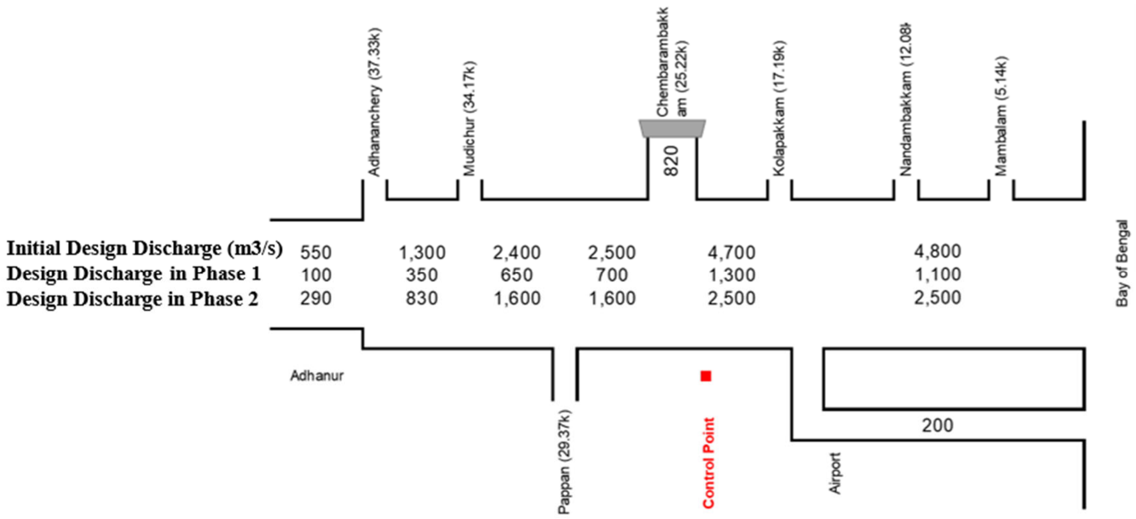



*Source: JICA Expert Team*

**Figure 2-38: Visualizing the Effect of the Master Plan on Flood with 100-year RP**

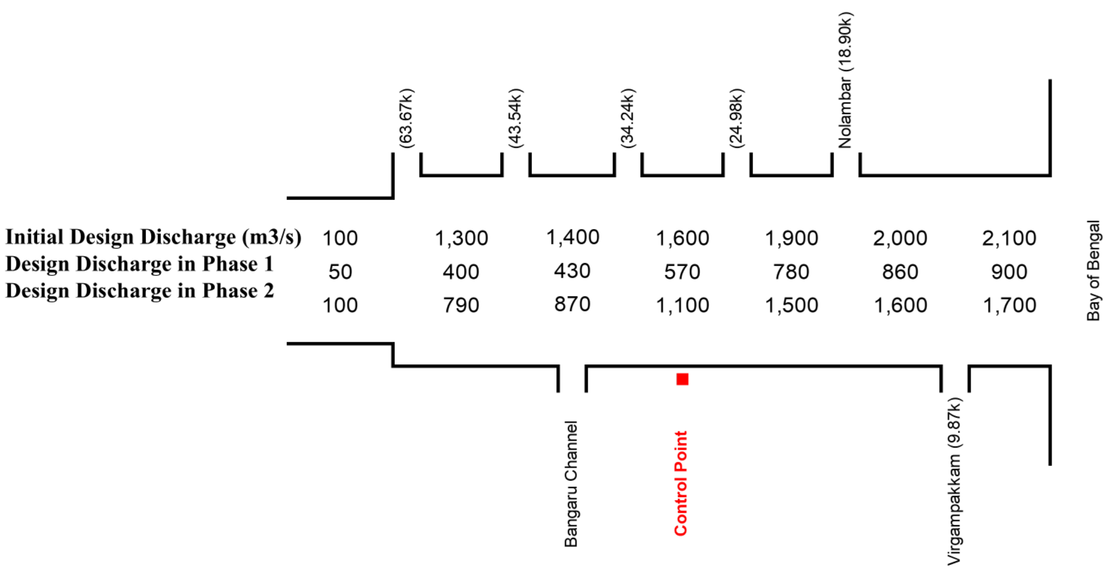
## 2.10 Distribution of Design Discharge at High-Water Level (HWL)

The discharge distribution for the high-water level (HWL) is a key component of the JICA Flood Control project. The discharge distribution along the three rivers is shown in Figure 2-39, Figure 2-40, and Figure 2-41. In developing these figures, TNWRD has confirmed that a 75% improvement in flood storage capacity in the selected tanks, as proposed in this Master Plan, is feasible, and this has been incorporated into the discharge distribution. The figures below show the discharge values, categorized as the pre-regulation design discharge with a higher value in the first row. The second, or middle line, represents the design discharge after Phase 1, which ensures safety for a 10-year return period flood. The bottom line shows the design discharge at the end of the full implementation of the master plan for Phase 2, providing safety for a 100-year return period flood, considering the 75% improvement in flood storage in the selected tanks as confirmed by TNWRD.



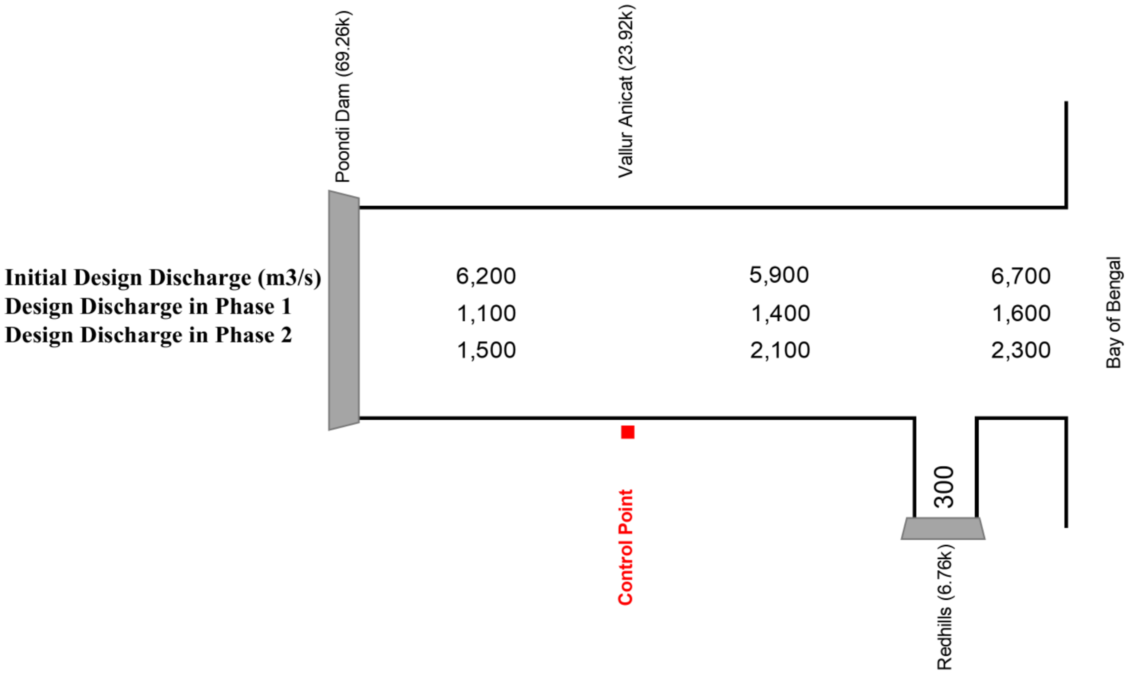

*Source: JICA Expert Team*

**Figure 2-39: Design High Water Discharge Distribution of Adyar River**




*Source: JICA Expert Team*

**Figure 2-40: Design High Water Discharge Distribution of Cooum River**




*Source: JICA Expert Team*

**Figure 2-41: Design High Water Discharge Distribution of Kosasthalaiyar River**

## 2.11 Recommendations

Based on the proposed considerations outlined in the previous section, the following technical recommendations are made for flood management and development:

**Prioritizing River Deepening Over Widening:** Given the significant challenges associated with river widening—particularly in densely urbanized areas along Chennai's riverbanks—and the socio-economic implications, river deepening should be prioritized. This approach offers several advantages, such as avoiding land acquisition and the displacement of settlements and businesses. However, river widening remains essential in Phase 2, requiring a strong commitment to fully implement the Master Plan and achieve the proposed target safety level.

**Preserving Current River Width and Preventing Encroachment:** Maintaining the existing river width and preventing further encroachment is crucial. This principle should also be extended to protect existing waterbodies and tanks.

**Balancing River Deepening and Tank Improvement:** Both River deepening and tank improvement contribute to reducing riverine flood risk. However, while tank and waterbody improvements take time and can be implemented progressively, river deepening can be executed more rapidly. Therefore, in the short term, prioritizing river deepening may be the more feasible option.

**Addressing Narrow Sections of the Adyar River:** Certain sections of the Adyar River have narrow channels, making it challenging to achieve the 10-year flood return period target within a short timeframe. Meeting the 100-year flood return period safety level will require significant long-term efforts from local authorities, along with strong public awareness initiatives.

# Chapter 3. Urban Flood Control Measures

## 3.1 Introduction and Background

The development of a comprehensive flood control master plan for the urbanized river basins of Chennai must address both riverine flooding (fluvial) and urban flooding (pluvial). This chapter focuses on urban flood control measures. The proposed interventions include measures such as channelization of drains through deepening and widening (where necessary), creation of flood storage in retention ponds, installation of gates and pumps, construction of bypasses and shortcuts, and other relevant structural measures.

Chennai experiences significant urban flooding due to several factors, including Encroachment on natural drainage systems, rapid urbanization, reduction in the number and size of water bodies and tanks, and insufficient and fragmented stormwater drainage infrastructure. These issues result in severe impacts on property, infrastructure, and public health, underscoring the critical need for robust urban flood management strategies.

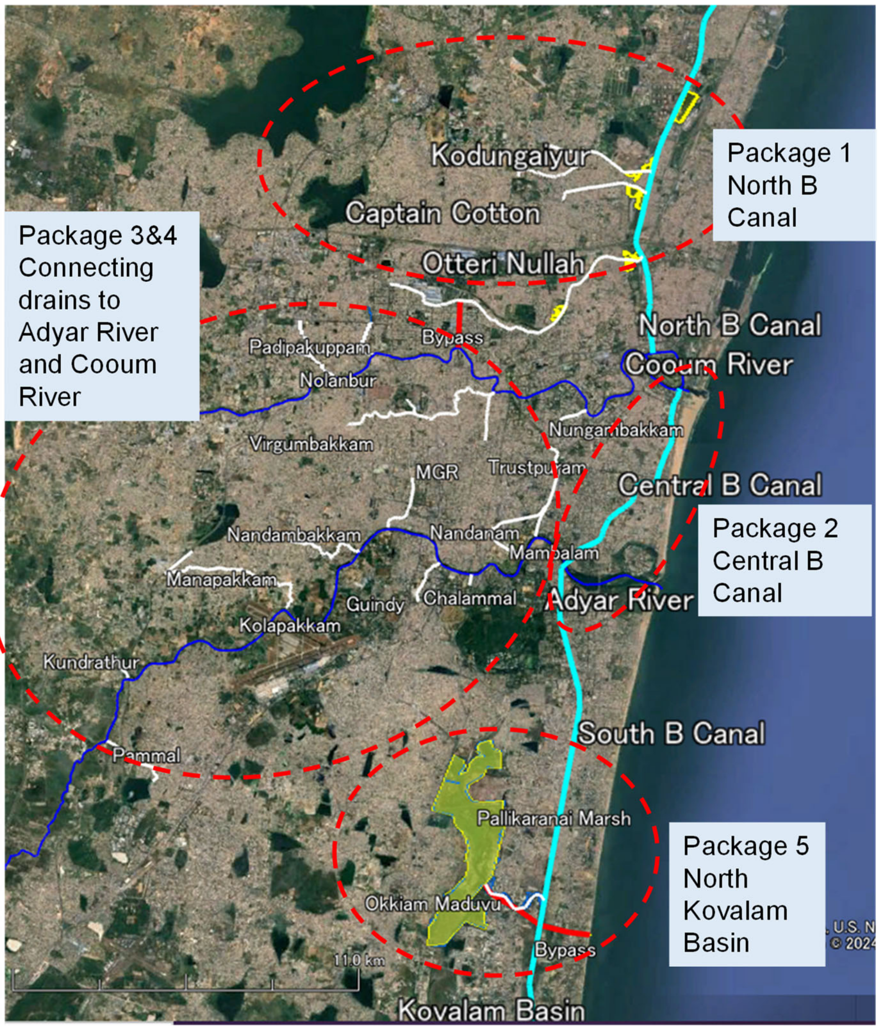
In the past, flooding in Chennai primarily resulted from riverine (fluvial) inundation caused by overflow from major rivers like the Cooum and Adyar. However, the floods of 2021 and 2023 highlighted a shift, with urban (pluvial) flooding becoming a significant concern. Intense rainfall overwhelmed the city's inadequate urban drainage systems, underscoring the urgent need for a dual approach to flood mitigation that addresses both river systems and urban infrastructure.

These recent events exposed critical vulnerabilities, including diminished river channel capacities due to encroachments, sediment accumulation, and insufficient maintenance. These factors contributed to backflow during periods of heavy rainfall, compounding the flooding issue and emphasizing the importance of integrated flood management strategies.

Flood mitigation efforts are spearheaded by the Greater Chennai Corporation (GCC) in collaboration with other municipalities and authorities within the CMA.

The primary areas of interest include The Buckingham Canal (North, Central, and South segments), the northern part of the Kovalam Basin, extending from Muttukadu at the mouth of the Kovalam River, connecting drains leading to the Adyar and Cooum Rivers and large drainage channels connected to the B Canal.

The locations of these facilities are presented in Figure 3-1.




*Source: JICA Expert Team*

**Figure 3-1: Project target connecting drains for Pluvial flooding**

## 3.2 Scope of Study

### 3.2.1 Urban Drainage Systems in Chennai

The urban drainage system in Chennai can be classified into the following three types.

a) Buckingham Canal (B Canal): Flows north to south through the Chennai urban area and is divided into the North (17 km in length), Central (7 km), and South (24 km) sections, as shown in Figure 3-2.

b) Connecting Drains: These drains discharge into the Adyar River, Cooum River, or B Canal as listed in Table 3-1 and shown in Figure 3-3, Figure 3-4 and Figure 3-5.

c) Waterbodies and Tanks: Chennai has various water bodies, lakes, and tanks that contribute significantly to the region's water resources and environmental balance.

d) Small-scale drainage channels: A network of small-scale drainage channels, including storm water drains (SWD, Storm Water Drain), that serve the function of local drainage.

In this study, the JICA Flood Control Master Plan focuses exclusively on components (a) and (b).

**South B Canal** | **Central B canal** | **North B canal**

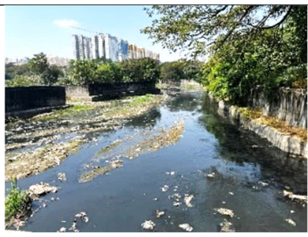
*Source: JICA Expert Team*

**Figure 3-2: B Canal Photos**

**Table 3-1: List of Major Connecting Drains to Rivers and B Canal**

| No. | Name | Length, km |
|---|---|---|
| A. Major Connecting Drains to Adyar | | |
| 1 | Nandhanam Drain | 1.087 |
| 2 | Mambalam Drain | 5.798 |
| 3 | Chellammal College Drain | 0.330 |
| 4 | Guindy Drain | 1.658 |
| 5 | MGR canal | 1.754 |
| 6 | Nandhambakkam drain | 3.334 |
| 7 | Manapakkam drain | 7.006 |
| 8 | Kolapakkam Drain | 2.923 |
| 9 | Kundrathur Drain | 1.396 |
| 10 | Pammal Drain | 2.527 |
| B. Major Connecting Drains to Cooum | | |
| 1 | Ambattur SIDCO Drain | 1.351 |
| 2 | Nungambakkam Drain | 1.347 |
| 3 | Nolambur Drain | 2.341 |
| 4 | Padikuppam Drain | 2.286 |
| 5 | Trustpuram Canal | 1.488 |
| 6 | Virugambakkam and Arumbakkam Drains | 6.60 |
| C. Major Connecting Drains to the North Buckingham Canal | | |
| 1 | Otteri Nallah | 10.322 |
| 2 | Captain Cotton Canal | 2.904 |
| 3 | Kodungaiyur Canal | 4.661 |
| D. Major Connecting Drain/River to the South Buckingham Canal | | |
| | Okkium Madavu drain | 2.794 |

**Nandhanam**



**Mambalam**

**Chellammal**

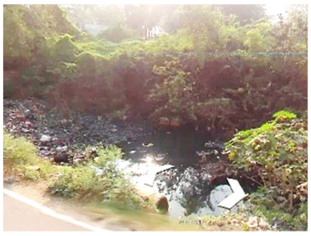

**Guindy**

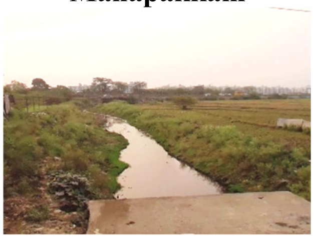

**MGR**

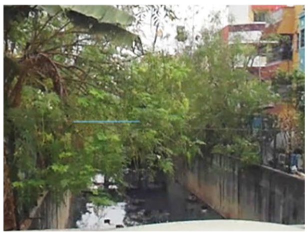

**Nandhanambakkam**


**Manapakkam**


**Kolapakkam**


**Kundrathur**


**Pammal**


**Ambattor SIDCO**


**Nungambakkam**


**Nolambur**


**Padikuppam**


**Trustpuram**


**Virugambakkam/Arumbakkam**

*Source: JICA Expert Team*

**Figure 3-3: Photos of Connecting Drains to Adyar River (10) and Cooum River (6)**


**Otteri Nallah**


**Captain Cotton**


**Kudungaiyur**

*Source: JICA Expert Team*

**Figure 3-4: Photos of Connecting Drains to North B Canal (3)**

### 3.2.2 Stormwater Drains (SWD)

Chennai has many SWDs, usually installed on roads that are at least 7 meters wide. The minimum size of the drain depends on the catchment area, land use, and discharge volume, but it is usually 600 x 750 mm. SWDs are required to have a straight-line shape, and inlets with rainwater infiltration functions that are expected to raise the groundwater level are also installed at intervals of 30 meters. However, despite these measures, due to inadequate maintenance, SWDs are not functioning adequately. SWDs are out of the scope of this study.

#### 3.2.3 North Kovalam Basin

Urban flooding is the primary challenge in the Kovalam basin, driven by the loss of water bodies and tanks, insufficient connecting drains, and the inadequate capacity of existing drainage infrastructure. The Pallikaranai Marsh, once vital for absorbing floodwaters, has experienced a significant decline in its ability to manage stormwater. Compounding this issue, Okkiam Maduvu, the channel designed to drain water from the marsh to the South Buckingham Canal, struggles to handle water flow during heavy rains. Additionally, the South Buckingham Canal faces limitations in discharging water into the Bay of Bengal due to its insufficient capacity and the backwater effect from Muttukadu.

These factors result in persistent flooding across the basin, with low-lying areas particularly vulnerable during storms. While the entire Kovalam basin has been modeled for flood risks, specific pluvial flood control measures have been proposed for a 290 km² urbanized portion in the northern part of the basin. This targeted approach aims to address urban flooding challenges comprehensively while mitigating the adverse impacts of extreme weather events in this critical area.

### 3.3 Planning Conditions and Basic Policies

This section outlines the planning conditions and fundamental policies that have been utilized to develop urban flood control components of the JICA Flood Control Master Plan.

#### 3.3.1 Basic Policies

The following key policies were adopted to develop the plan in this chapter:

- Design Rainfall Definition: Establish the design rainfall required for effective urban flood control.
- Discharge Capacity Determination: Set the discharge capacity corresponding to the design rainfall.
- Proposed Measures: Introduce improvements in drainage systems in an integrated manner with rivers and other drainage networks, water bodies, and retarding basins to manage flood discharge effectively.
- Backwater Mitigation: Install gates to address the impact of backwater from rivers.
- Green Spaces Utilization: Explore opportunities to use green spaces and open areas for sustainable flood management.

#### 3.3.2 Flood Control Safety Level

The following standards and guidelines are available for the flood control safety level at national and local levels:

1. The CPHEEO Guidelines (2019) recommend a 5-year return period rainfall probability for Class I cities, such as Chennai, and a 2-year return period for Class II cities.
2. The Advisory Committee's Recommendations, influenced by World Bank guidelines, include a design rainfall intensity of 68 mm/h and propose a 20% increase in the 5-year probability to account for climate change impacts.
3. The ADB-Funded Project for the Kosasthalaiyar River basin assumes a 2-year probability for stormwater drains (SWDs) and a 5-year probability for large-scale drainage systems.

To align with local conditions and stakeholder input, the project adopts a 10-year return period for the design rainfall. Furthermore, a 10% increase in design rainfall intensity has been incorporated to address potential climate change impacts, ensuring robust flood management.

#### 3.3.3 Target Year of the Plan

The implementation target for the urban flood control components of the JICA Master Plan has been established for 10 years. Accordingly, the plan's target year aligns with this timeframe, consistent with the following broader urban planning frameworks:

1. Chennai's Third Master Plan (2027–2046), which outlines a 10- to 20-year urban development strategy.
2. Japan's urban stormwater drainage planning practices.

The implementation timeline is structured into two distinct phases:

First Phase: The initial 5 years focus on implementing prioritized measures.

Second Phase: The subsequent 5 years concentrate on advanced and supplementary interventions.

### 3.4 Planned Rainfall and Hyetograph

As mentioned above, the planned rainfall amount adopted a 10% increase in climate change for a 10-year probability. However, for the North Kovalam basin, a 10% increase in climate change was used for the 100-year probability. The rainfall observation records used in the planning were obtained from the Meenumbakkam and Nungambakkam observation stations in Chennai (Figure 3-5 and Figure 3-6). The Intensity-Duration-Frequency or IDF curve has been created based on the observation data. The following is the method used to set the rainfall intensity formula and rainfall amount for each of the packages described below.

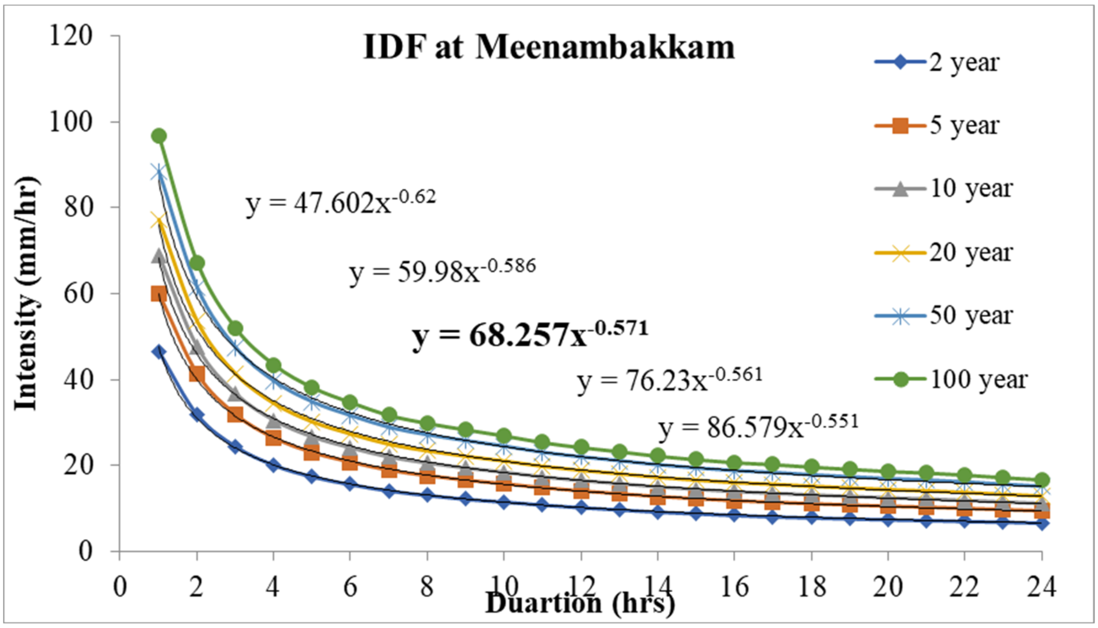
(1) Adyar River: The 10-year probability rainfall intensity equation was created based on data from the Meenumbakkam observation station, which is closest to Adyar River, and the flood concentration time was substituted into the equation.

(2) Cooum River: The 10-year probability rainfall intensity equation was created based on data from the Nungambakkam observation station, which is closest to the Cooum River, and the flood concentration time was substituted into the equation.

(3) Connecting drains to the North Buckingham Canal: Based on data from the Nungambakkam observation station, which is closest to the catchment area, the rainfall event in the 1996 flood, which caused severe flooding damage in the catchment area in the past, was used.

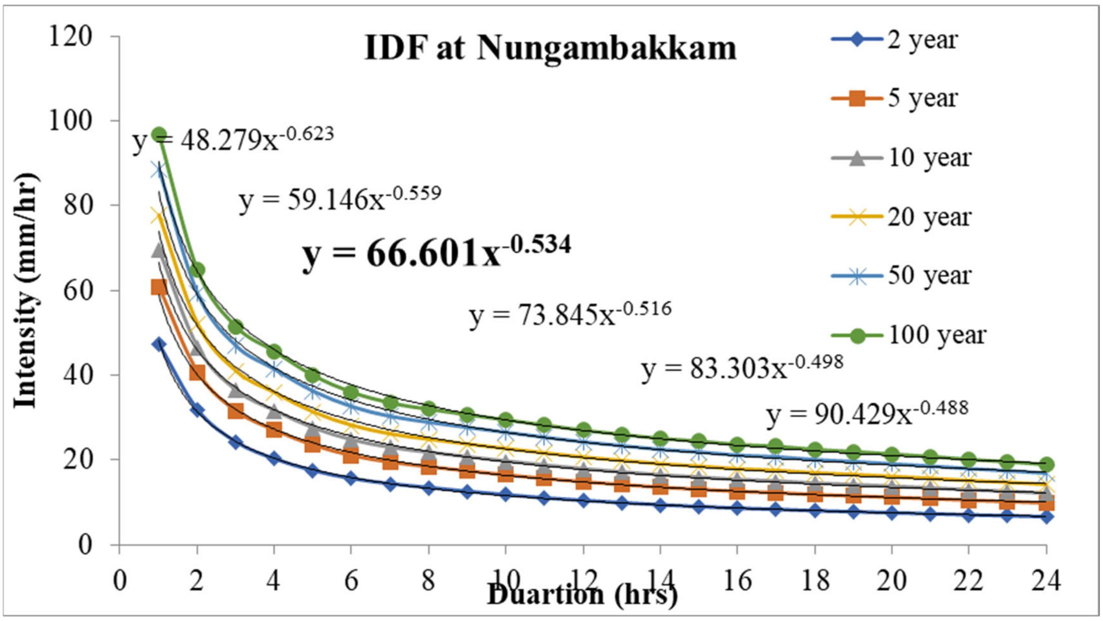
(4) Connecting drains to the Central Buckingham Canal: Rainfall data was obtained by substituting the flood concentration time of the drains assumed for the relevant basin into the 10-year probability rainfall intensity formula, based on data from the Nungambakkam observation station, which is the closest of the two observation stations to the basin.

(5) North Kovalam basin: The data used was based on the rainfall observed in 2015 at the Meenumbakkam observation station, which is closest to the Adyar River, and was extended to a 100-year probability.




*Source: JICA Expert Team*

**Figure 3-5: IDF Curve of 2 to100 years 24-hr at Meenumbakkam Station**




*Source: JICA Expert Team*

**Figure 3-6: IDF Curve of 2 to 100 years 24-hr at Nungambakkam Station**

## 3.5 Proposed Countermeasures for Urban Flood Control

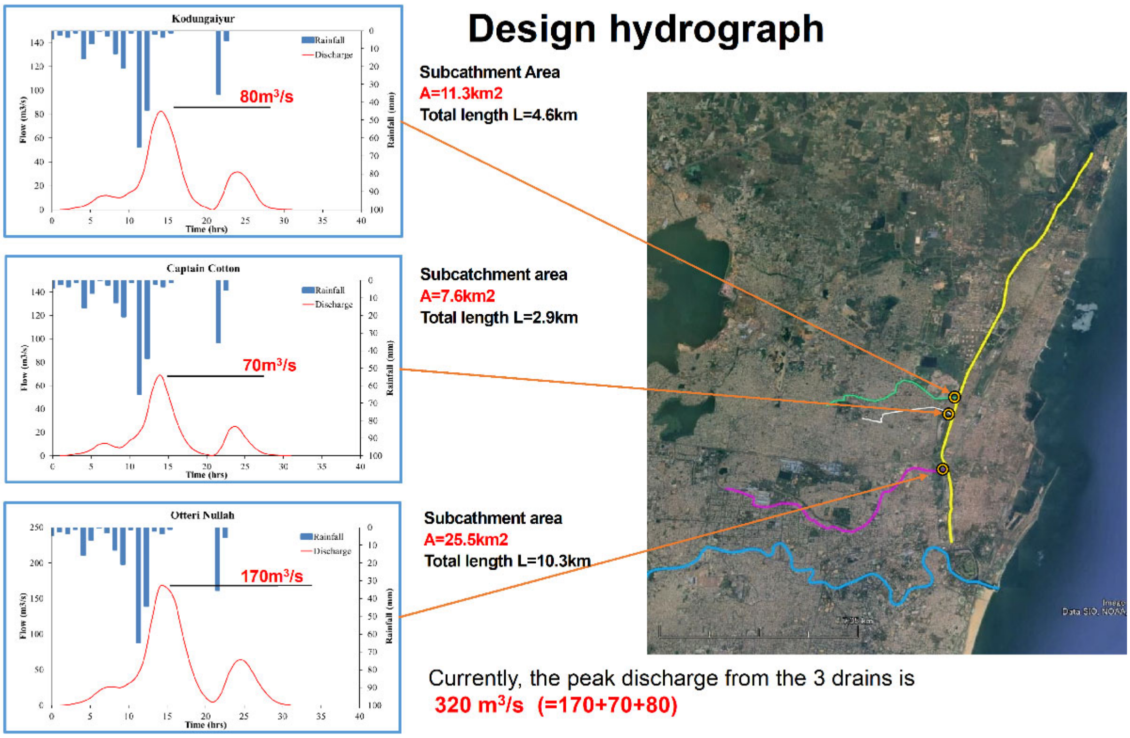
### 3.5.1 Flood Control in North Buckingham Canal Package

North Buckingham Canal (NBC) basin covers an area of about 50 km2 in the northern part of Chennai. On the left bank, three drains, Kodungaiyur, Captain Cotton, and Otteri Nullah, are connected. The drainage on the right bank flows directly into the Bay of Bengal.

In the NBC catchment area, the high-water levels of the NBC often prevent water from draining out of the connected drains, causing frequent flooding. To deal with this, the JICA Flood Control Master plan has considered improving the flow capacity of the NBC, installing bypass and retarding basins.

#### 3.5.1.1. Rainfall setting and hydrograph

The design rainfall used in the plan is based on the observed rainfall data at Nungambakkam station in 1996, as mentioned in 3.3. The below figure shows the hydrographs for the three drains. The total peak discharge is 320 m3/s.



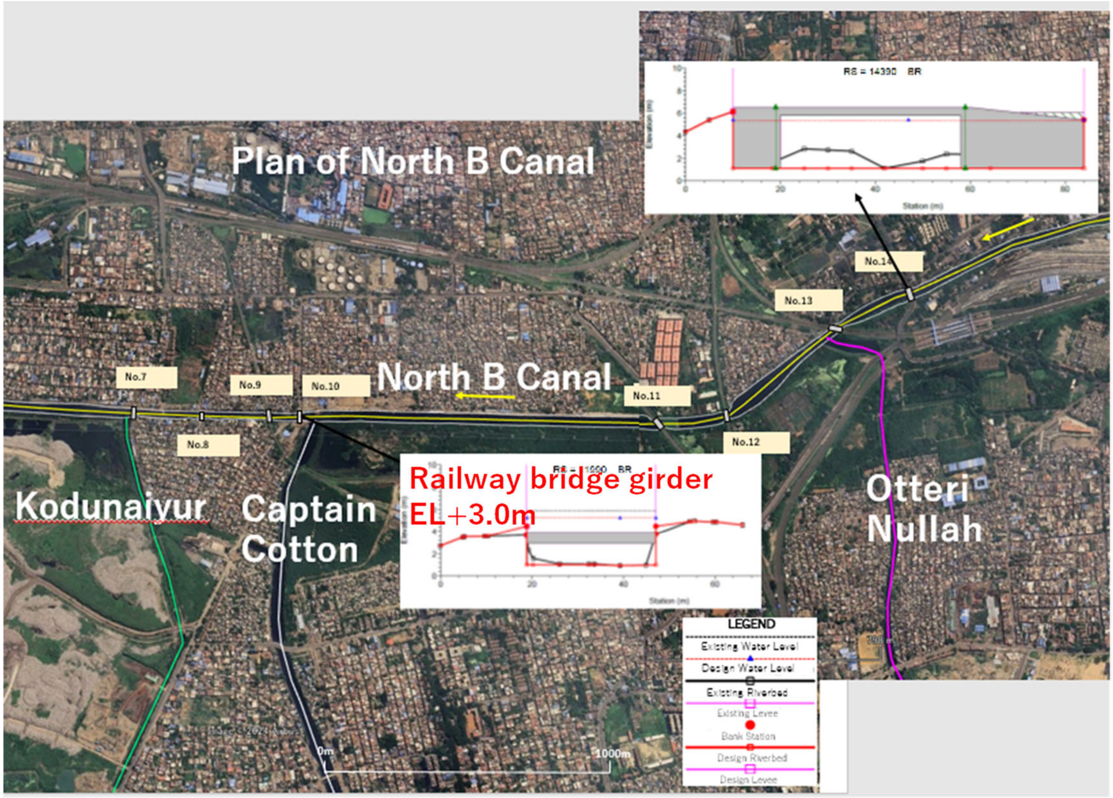

*Source: JICA Expert Team*

**Figure 3-7: Hydrographs for Three Connecting Drains to the NBC**

3.5.1.2. Current Situation and Carrying Capacity

The current flow capacity of the NBC is more than 100 $m^3$/s near the confluence of the Kosasthalaiyar River. On the other hand, in the middle reaches, it drops to 50-70 $m^3$/s, and at the point where the three main drainage channels converge, it drops to 40 $m^3$/s due to the low height of the levee. Kodungaiyur is 4.6 km long, and its current discharge capacity is 30 $m^3$/s. In some sections, the discharge capacity is insufficient. Captain Cotton is 2.9 km long, and its current discharge capacity is 23 $m^3$/s, with some sections lacking sufficient discharge capacity. Otteri Nullah is 10.3 km long, and its current discharge capacity is approximately 30 $m^3$/s. It, too, is facing a shortage of carrying capacity.

In addition, in the area where the three drains flow in, the railway bridge and other structures intersect with the NBC, and the height of the underside of the railway bridge girders is low at around EL +3.0m, and the riverbed height is also rising, so even if a small-scale flood occurs, the water level will rise, and there are concerns about the impact on railway facilities, etc(Figure 3-8).




*Source: JICA Expert Team*

**Figure 3-8: Railway bridge girder near Bay Bridge Station**

3.5.1.3. Development policy

The following process was used to determine the details of the improvements needed to ensure flood control safety in the relevant river basin.

1. **Priority is given to NBC**: Since the flooding damage in the relevant river basin is caused by the insufficient flow capacity of the NBC (the insufficient flow capacity of the drains tributaries is also due in part to the high-water levels in the NBC), priority is given to improving the NBC.

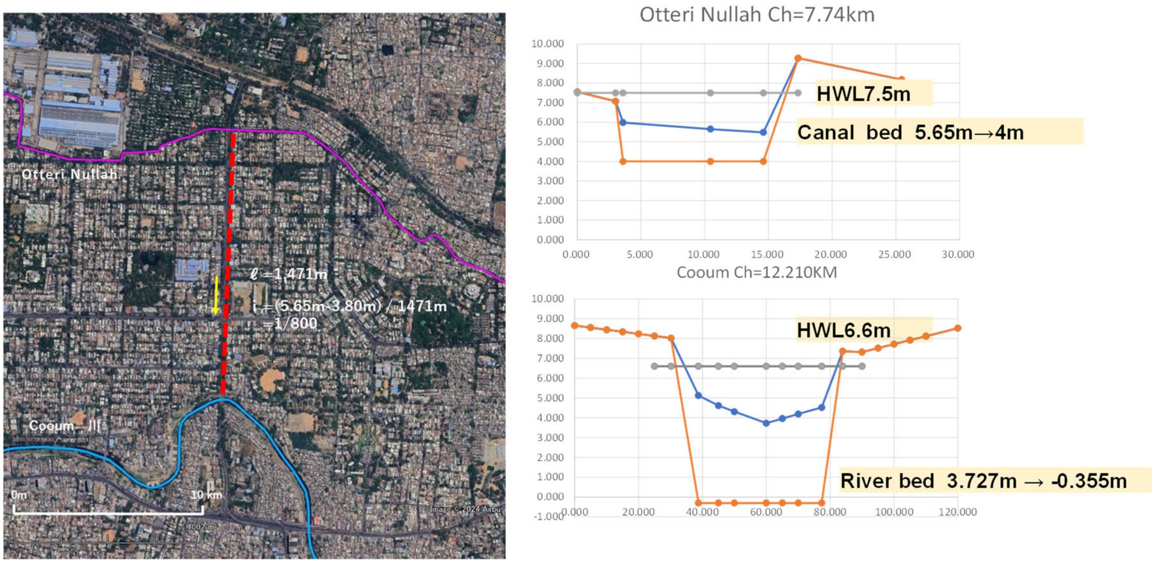
2. **Reducing the amount of water flowing into the NBC from each drain**: Measures will be implemented to reduce the amount of water flowing into the NBC from the three drains (e.g. examining suitable locations for retarding basins). In particular, consideration will be given to the Otteri Nullah drain basin, which accounts for approximately 50% of the NBC's discharge and has a significant impact on the NBC's maintenance. Furthermore, as a bypass drain to the Cooum River has already been constructed in the Otteri Nullah drain, we will consider reducing the inflow volume by expanding or improving this drain in the river or direction. Specifically, install a bypass to Cooum River (20m³/s) and retarding basin (20m³/s) (Figure 3-9 and Figure 3-10). This will reduce the total inflow to NBC from 320m³/s to 280m³/s.

3. **Understanding the maximum discharge capacity of the NBC**: Based on ②, we will evaluate the improvement of the discharge capacity through excavation of the river channel in the NBC and confirm the discharge capacity of the canal for the discharge volume of the 1/10-year probability scale (including climate change).

4. **NBC consideration of methods to deal with discharge volumes that cannot be handled by the NBC**: "Consideration of reducing discharge volumes using retarding basins at the end of each drain and along the NBC (including improving discharge capacity by excavating drains)" will be carried out. In addition, if this is not feasible, consideration of the construction of a bypass that would discharge directly into the Bay of Bengal will be carried

out.

5. As the construction of a bypass would involve land acquisition and the relocation of many houses, the basic approach would be to reduce the discharge by using a retarding basin (which would involve the relocation of fewer houses), and the construction of a bypass would be considered as an alternative option.



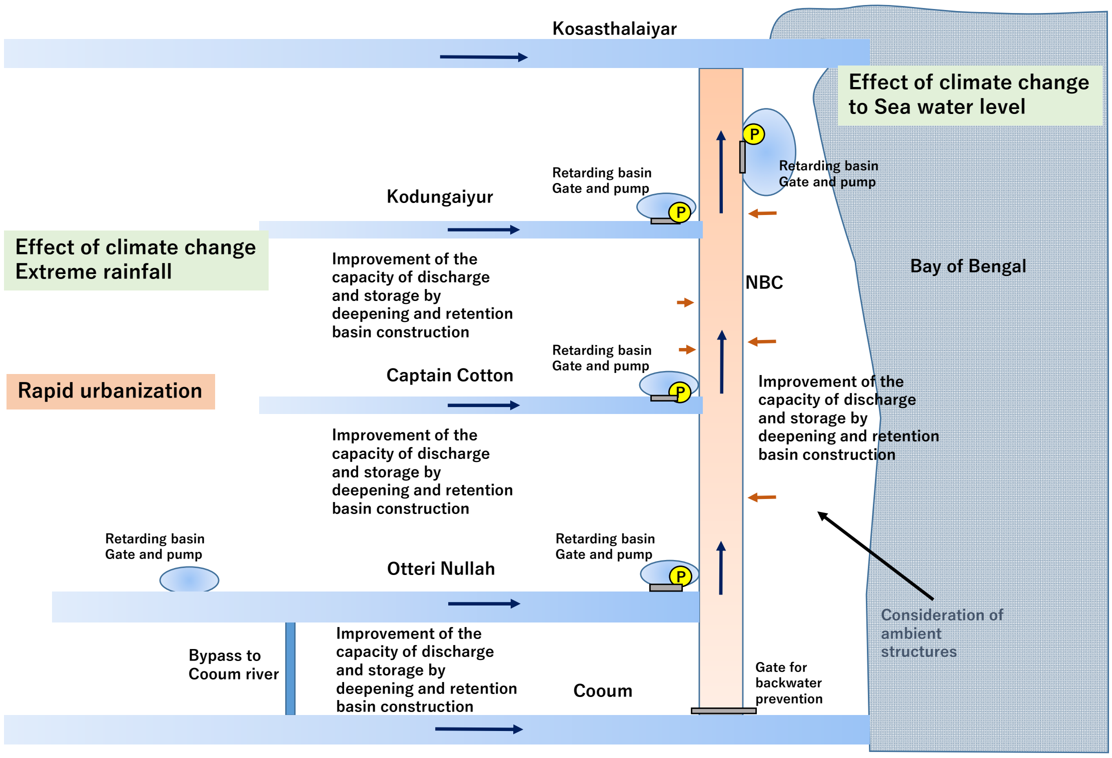

*Source: JICA Expert Team*

**Figure 3-9: Otteri Nullah to Cooum River Bypass Channel**


*Source: JICA Expert Team*

**Figure 3-10: Retarding Basin Development Plan in the Midstream if Otteri Nullah**

The below figure shows the improvement plan for the NBC and the connected drains.

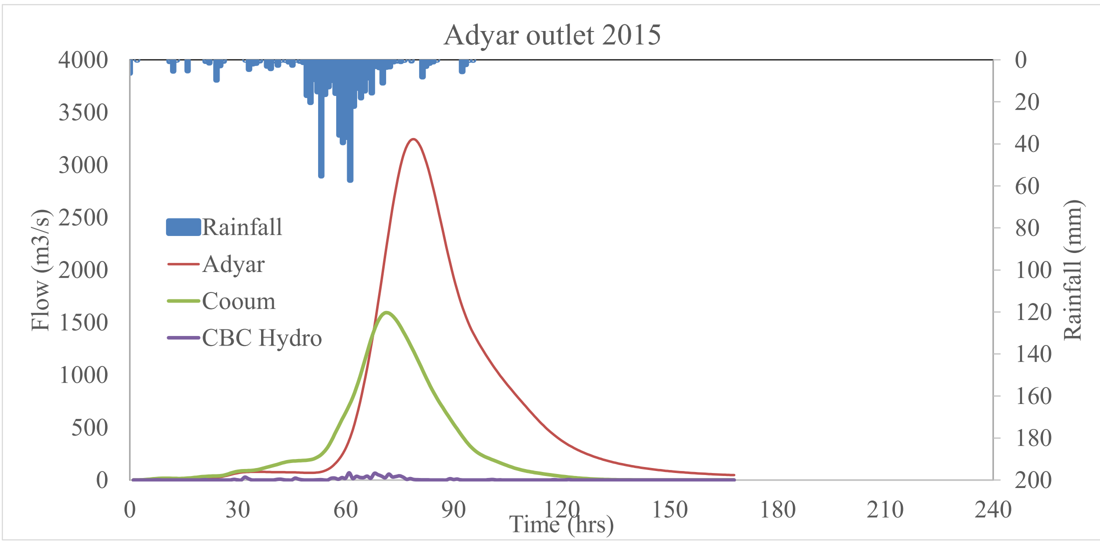



*Source: JICA Expert Team*

**Figure 3-11: Improvement Plan for NBC and connecting drains**

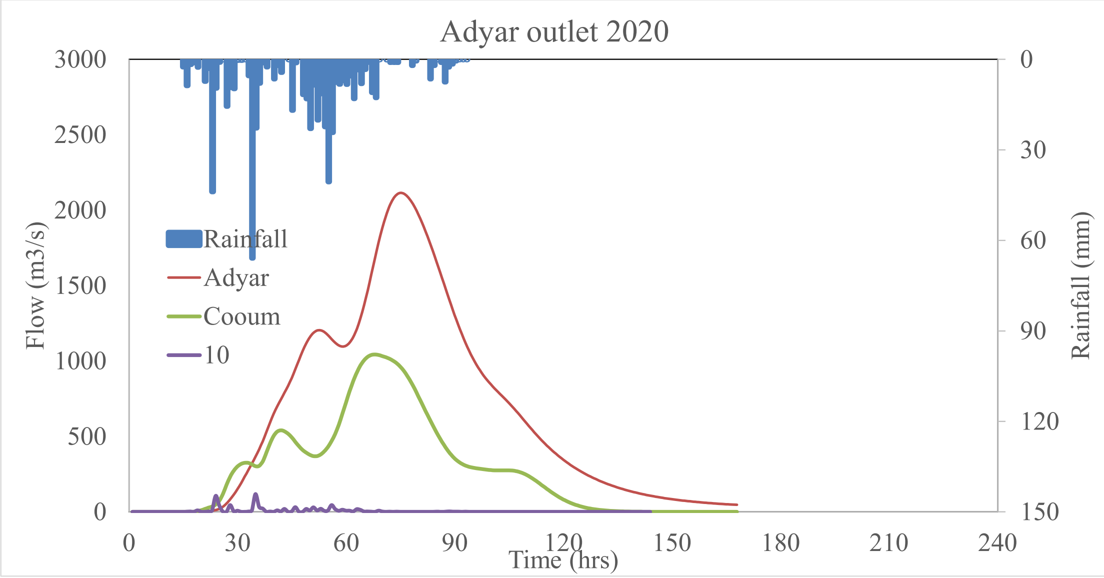
### 3.5.2 Flood Control in Central Buckingham Canal Package

Central Buckingham Canal (CBC) is a 9.18 km$^2$ area that lies between Adyar and Cooum Rivers and connects to both rivers. The topography is flat, with an average elevation of 5 m in the northern and central basins. Flooding in the CBC area is mainly caused by backflow from the Adyar and Cooum Rivers. These problems are exacerbated when the peak flood discharge from the CBC basin coincides with the peak flood discharge from two rivers, causing the water level to rise significantly and increasing the risk of flooding (Figure 3-12 and Figure 3-13). The current situation of CBC is that the flow capacity is 67 m$^3$/s on the left bank and 81 m$^3$/s on the right bank, and the raising and widening of the levees are restricted by railways and bridges.




*Source: JICA Expert Team*

**Figure 3-12: Hydrograph of Adyar and Cooum in the 2015 Event**




*Source: JICA Expert Team*

**Figure 3-13: Hydrograph of Adyar and Cooum in the 2020 Flood Event**

3.5.2.1. Dividing the catchment area and calculating the amount of runoff
The catchment area was divided into three sub-catchments for runoff analysis, and rainfall intensity was calculated using 10-year probability rainfall data that took into account the effects of climate change. The results of calculations using the rational formula gave a total peak discharge of 115 $m^3/s$ from the three sub-catchments.

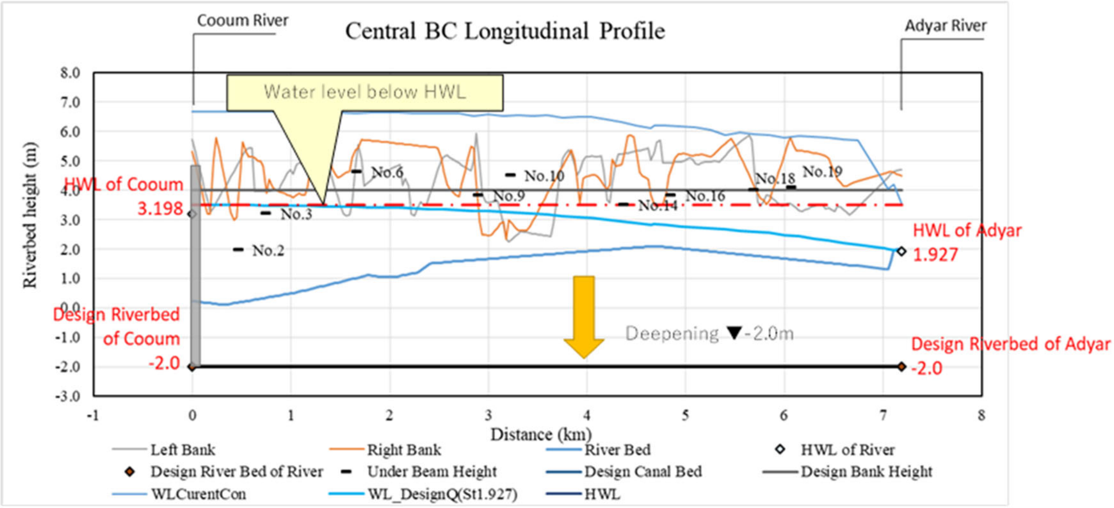
3.5.2.2. CBC Improvement Policy
- Excavation of the canal bed: Excavation up to -2m following the plan of the connecting river

- Raising the embankment and setting the HWL: Setting the height to 4.1m considering the height of the existing bridge girder, with a freeboard of 0.6m and setting the HWL to 3.5m.

- Installation of gates: The HWL of the Adyar River is 1.93m, while the Cooum River is 3.20m. To prevent backflow, the gate installed on the Cooum Riverside will be closed during floods, allowing gravity flow to the Adyar River based on the water level difference.

- In case peak outflows from the Adyar and the Cooum Rivers do not coincide: Open the gate on the Cooum River junction for gravity flow.

3.5.2.3. Results of calculation
Considering the current river channel width, three different calculations were carried out: 1) uniform 13m, 2) uniform 15m, and 3) a combination of 13m and 17m to match the current river channel width. In the case of 1) and 2), the calculated water level exceeded HWL 3.5m. The calculated water level in the case of 3) is shown in the below figure. The calculated water level was kept below HWL 3.5m, and it was shown that the prescribed peak discharge could be discharged into the Adyar River by gravity flow.



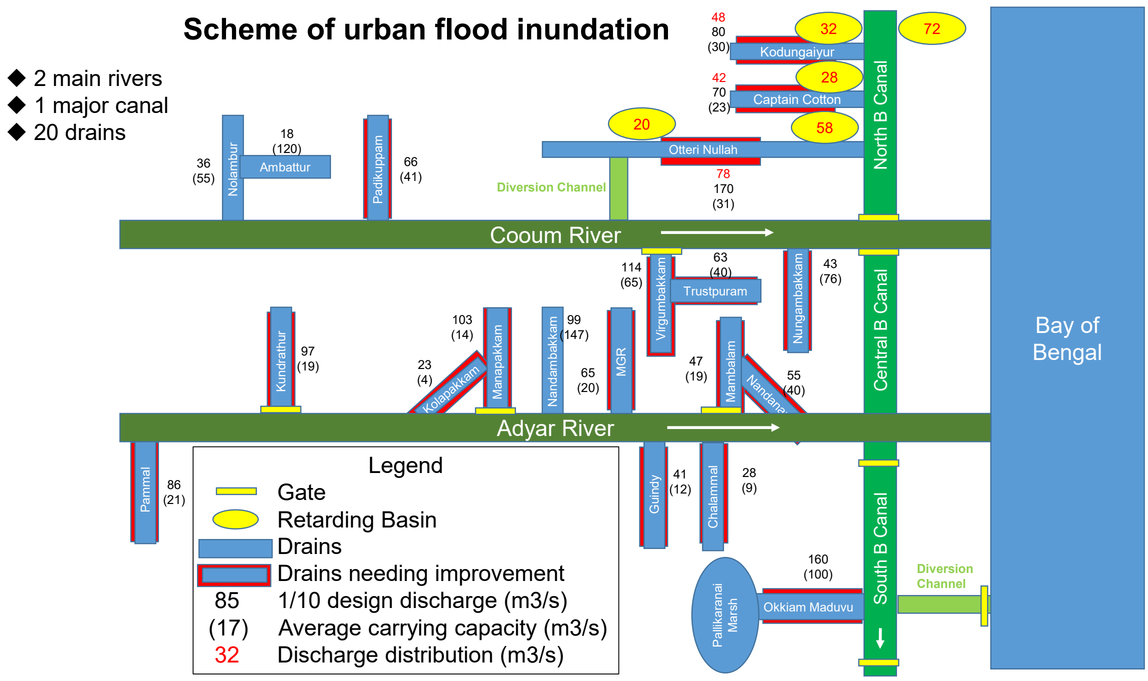

*Source: JICA Expert Team*

**Figure 3-14: Water level in CBC in case of Canal Width 13m and 17m**

3.5.3 Flood Control in Connecting Drains to the Adyar and Cooum Rivers

In the Table 3-1: List of Major Connecting Drains to Rivers and B Canal, a list of 10 major connecting drains to the Adyar River and 6 major connecting drains to the Cooum River is provided. These are secondary drains connected to the rivers as their primary outfalls, locally referred to as macro drainage systems.

The flow capacity of the 10 drains connecting to the Adyar River and the 6 drains connecting to the Cooum River was evaluated. The results of using the rational formula for design flow capacity and the HEC-RAS non-uniform flow model for existing flow capacity showed that the existing flow capacity of 9 drains in the Adyar River and 4 drains in the Cooum River was insufficient and that improvements were necessary. The measures indicated in the improvement plan mainly involved excavation of the drains without widening. The installation of retarding basins was also considered, but as a result of the investigation, it was decided that retarding basins were not necessary and that all of the issues could be addressed by improving the drains (Below figure).




*Source: JICA Expert Team*

**Figure 3-15: Drains Need for Improvement**

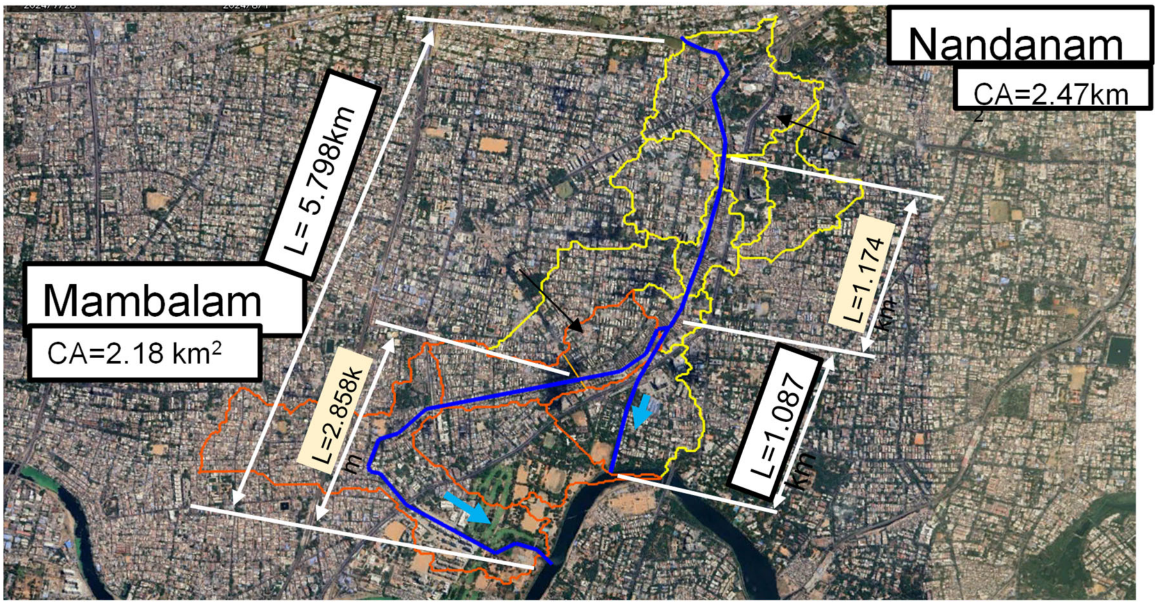
As an example, we will look at the Mambalam, which flows into the Adyar River. The catchment area is 2.18 km$^2$ (4.65 km$^2$ if the Nandanam area is included), the length is 5.798 km, the riverbed gradient is 1/935, and the current capacity is 19 m$^3$/s on average, while the design discharge is 47 m$^3$/s. The planned drain cross-section is set based on the following conditions, and the HWL that envelopes the calculated water level obtained by non-uniform flow calculations is set.

1. Excavated river channel: The basic approach is to use an excavated drain considering the acceptance of drainage from the surrounding area.

2. Planned flow rate: Set using uniform flow calculations with a cross-section (drain width × water depth) that can accommodate the planned flow rate.

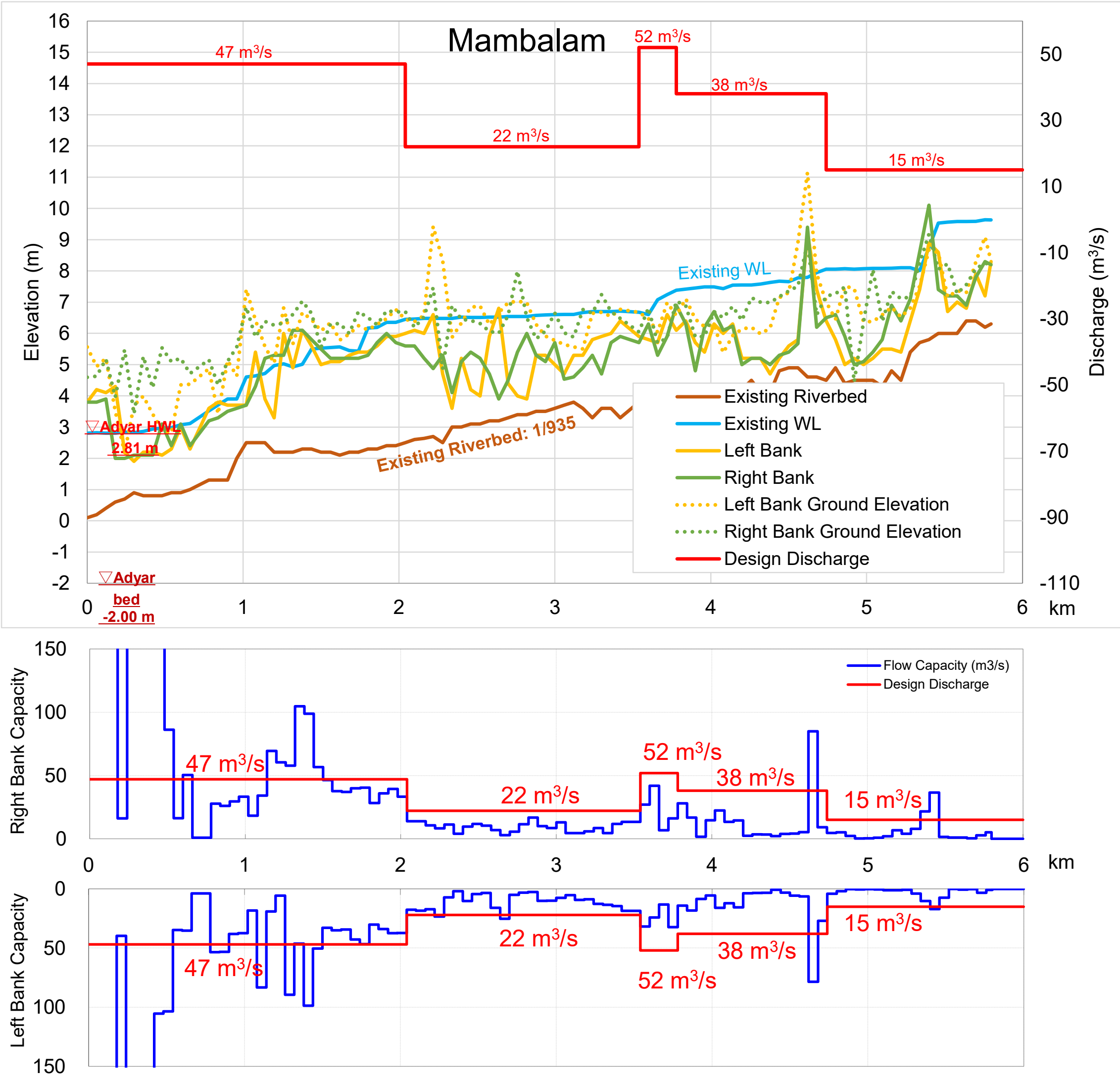
3. Drain width: Set to match the current drain width as much as possible due to land acquisition constraints.

4. Water depth: Set to be consistent longitudinally, considering the constructability of revetments and other structures.



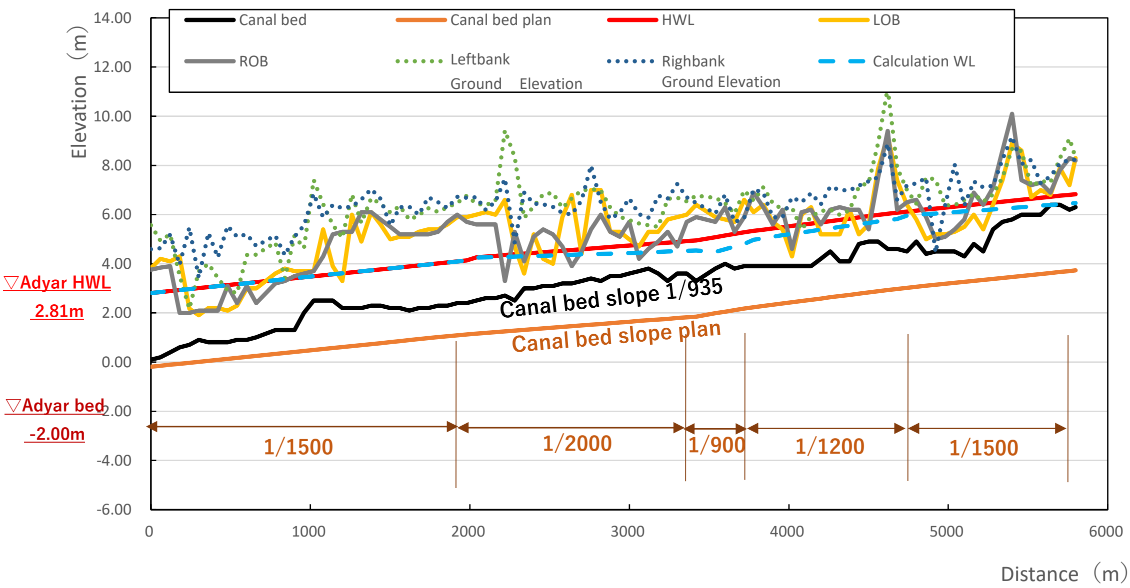

*Source: JICA Expert Team*

**Figure 3-16: Nandanam and Mambalam Drainage**




Source: JICA Expert Team

**Figure 3-17: Existing water level and capacity of Mamabalam**




Source: JICA Expert Team

**Figure 3-18: Longitudinal Profile Plan of the Mambalam**

## 3.6 Flood Control in the North Kovalam Basin Package

### 3.6.1 Evaluation of countermeasures for existing structures

The north Kovalam basin covers an area of 290 km², extending south of the Adyar River, with the Pallikaranai Marsh at its center. The basin contains 61 tanks, which are connected to the marsh by several drains, and does not have any large rivers. The only outflow from the Pallikaranai Marsh is the Okkiam Maduvu. The basin's elevation is approximately +4.0 meters above mean sea level (MSL). Most residential areas are situated at elevations between 3.0 and 3.5 meters above MSL, although there is also an urban area at an elevation of 2.5 meters.

Approximately 97% of the discharge from the B Canal, which has a designed flood discharge of 240 m³/s, flows southward towards Muttukadu, while the remainder flows northward towards the Adyar River. This is due to the B Canal being 100 meters wide in the Muttukadu area, but only about 18 meters wide towards the Adyar River. The width of Okkiam Maduvu is approximately 120 meters, and its current capacity is around 100 m³/s.

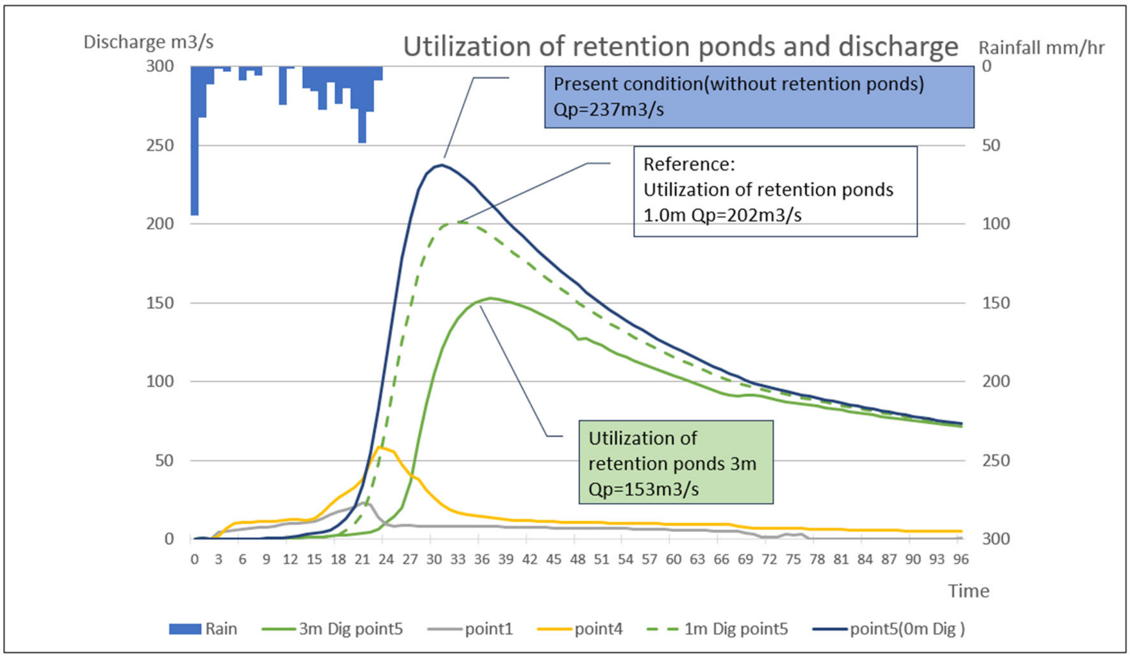
The results of the assessment of the North Kovalam basin inundation area is shown in the following Table 3-2. During a 100-year rainfall event, the water level rises to 4.4 m and the inundation area is as large as 49 km2. Based on these results, +2.50 m was set as the harmless water level where no flood damage occurs.

**Table 3-2: Discharge, Water level, and Flood Inundation Area (North Kovalam Basin)**

| Return Period | 24hours rainfall (mm) | Discharge (m3/s) | Water level (m) | Flood area (km2) | Flood area (escept 2.50 or less) |
|---|---|---|---|---|---|
| 1/100 | 405.1 | 237.1 | 4.402 | 49.1 | 23.8 |
| 1/70 | 383.2 | **214.9** | 4.254 | 47.7 | 22.5 |
| 1/50 | 362.4 | **194.0** | 4.107 | 46.3 | 21.0 |
| 1/40 | 348.7 | **179.6** | 4.001 | 45.2 | 19.9 |
| 1/30 | 331.0 | **160.9** | 3.857 | 43.6 | 18.4 |
| 1/20 | 308.6 | **143.5** | 3.715 | 42.0 | 16.8 |
| 1/10 | 267.4 | **111.6** | 3.431 | 38.6 | 13.3 |
| 1/5 | 224.5 | **82.1** | 3.128 | 34.6 | 9.3 |
| 1/2 | 164.2 | 40.7 | 2.589 | 26.7 | 1.4 |
| non-damage water level | | | 2.500 | 25.3 | 0.0 |

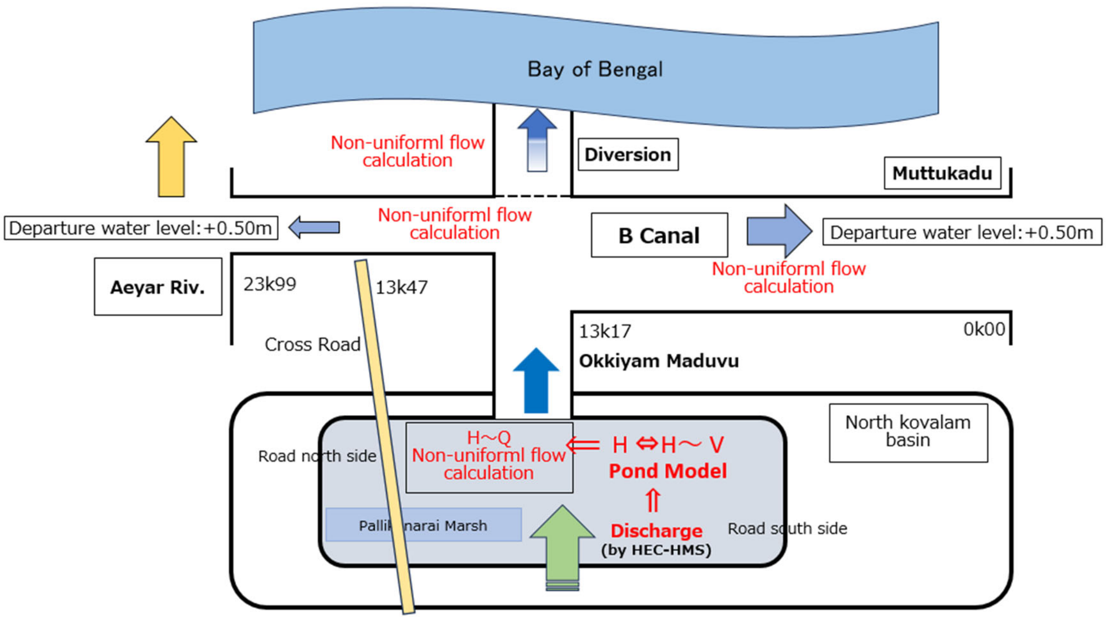
*Source: JICA Expert Team*

The urbanized area in the northern part of the Kovalam basin is also developing rapidly, similar to the Adyar River basin. Therefore, the plan should incorporate a 100-year safety factor. This means it must be designed to handle a 100-year rainfall event, with a total rainfall amount of 405 mm. A runoff analysis for the Kovalam basin was carried out using HEC-RAS, based on this rainfall data. The analysis showed that the peak runoff from Pallikaranai Marsh to Okkiam Maduvu is 237 $m^3/s$. As a result, the pre-regulation design flood discharge is set at 240 $m^3/s$. Considering the storage capacity of the tanks in the catchment area for flood control, and assuming that 3 meters of depth can be used for this purpose, the peak discharge was reduced to 153 $m^3/s$. Consequently, the design discharge was set at 160 $m^3/s$ (Figure 3-19). Additionally, considering the elevation of the land around Pallikaranai Marsh, the design high water level was set at +2.50m.




*Source: JICA Expert Team*

**Figure 3-19: Hyetograph and Design Discharge of the North Kovalam Basin**




*Source: JICA Expert Team*

**Figure 3-20: Layout of Proposed Countermeasures**

### 3.6.2 Flood Control Measures Proposal

To propose suitable countermeasures for lowering flood levels in the northern Kovalam basin during floods, several different scenarios have been analyzed, as shown in Figure 3-20. The following is an explanation of a few of these cases:

- Case 1: In this scenario, flood storage of 1.0-meter depth across all 61 tanks in the Kovalam basin has been assessed. The total area of these tanks is approximately 17.0 km². With a 1-meter storage depth, the storage capacity would be 17.0 million cubic meters (MCM), and the peak water level in the northern Kovalam basin would decrease by 0.2 meters.

- Case 2: Similar to Case 1, but with a flood storage depth of 3.0 meters in all 61 tanks. This would result in a 0.7-meter reduction in the peak water level.
- Case 3: This case involves improving the carrying capacity of the B Canal to lower the water level in the northern Kovalam basin during a flood event. However, this approach is not suitable due to the accumulation of a sandbar at Muttukadu, which complicates the discharge of water from the B Canal to the Bay of Bengal. Additionally, maintaining the riverbed height of the B Canal is challenging, and the water level at the river mouth fluctuates due to the rising water levels from flow entering from the south of Muttukadu.
- Case 5 (Proposed Plan): This case utilizes all possible measures, including using all 61 tanks with an average storage depth of 3.0 meters, constructing a new diversion channel from the B Canal to the Bay of Bengal and VGP area, and implementing a shortcut from the lower part of Okkiam Maduvu to the B Canal. With these measures, the peak water level would decrease by 1.55 meters (to MSL+2.87 meters) compared to the current condition. The proposed width of the diversion channel is 100 meters. This width is a tentative proposal and will be reduced in the next section.

Given the target internal water level of 2.5 meters, additional pump drainage is necessary to prevent flooding in low-lying urban areas with elevations between 2.87 meters and 2.5 meters.

#### 3.6.2.1. Study of the optimal width of the bypass

The effect of lowering the water level in Pallikaranai Marsh during flood events was investigated for bypass widths of 30m, 60m, and 100m. The results are shown in Table 3-3. In the case of 30m and 60m, the difference in peak water level reduction is 0.39m, but 0.03m in the case of 60m and 100m, so the water levels are almost the same.

The reason for the smaller reduction in water level as the width of the bypass increases is likely due to the decrease in the roughness coefficient of the bypass bottom, which occurs because of the shallower water depth in the spillway. This, in turn, reduces the flow velocity, leading to a smaller decrease in the peak water level in Pallikaranai Marsh. Additionally, although an elevation of 2.5 meters is set as the threshold where no damage from internal water will occur, areas, where the peak water level in Pallikaranai Marsh exceeds this value, will still require pump drainage.

**Table 3-3: Bypass width and water level reduction**

| | Pallikaranai | Water Bodies | Okkiyam Maduvu | B Canal | Diversion (B Canal to Bengal) | Water Level at Pallikaranai (m) | Water Level Reduction Effects (m) |
|---|---|---|---|---|---|---|---|
| Case0 | Present condition | Present condition | Present condition | Present condition | — | 4.42 | |
| Case1 | | 1.0m excavation | | | | 4.22 | 0.20 |
| Case2 | | 3.0m excavation | Present condition | Present condition | — | 3.71 | 0.71 |
| Case 3 | | | | Repair(Riverbed height=Current condition -2.0m) | — | 3.15 | 1.27 |
| Case4 | | | | present condition | 100m (tentative) | 3.13 | 1.29 |
| Case5 | | | Shortcut | Present condition | 100m (tentative) | 2.87 | 1.55 |

*Source: JICA Expert Team*

There was no significant difference in the peak water level in Pallikaranai Marsh between the 100-meter and 60-meter drainage channel widths, nor was there a difference in the area requiring pump drainage. When the project costs were also analyzed, the following results were obtained.

(1) In the case of the 100m drainage channel width, the project cost was larger than that of the 30m and 60m drainage channel widths due to the significant impact of land acquisition and compensation costs.

(2) When comparing a 60m-wide and a 30m-wide bypass, the 60m-wide bypass has a larger land acquisition cost and a smaller drainage pump cost. On the other hand, the 30m-wide bypass has a larger drainage pump cost, and the total project cost of the two cases is not very different. However, the drainage pump requires annual maintenance and periodic replacement costs.

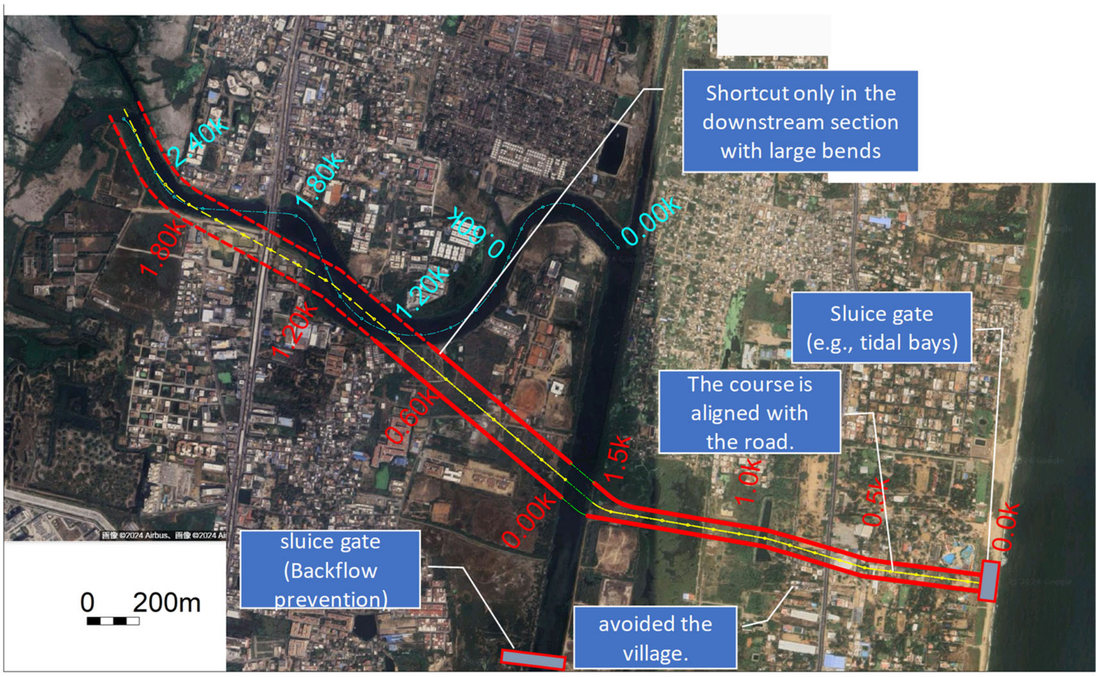
Therefore, from the perspective of both hydraulics and project costs, as well as maintenance and management, JET proposes that a 60m-wide bypass is the most suitable.

In summary, the Okkiam Maduvu bypass is 1.56 km long, 60 m wide, with a 1/3,000 riverbed gradient, while the Okkiam Maduvu shortcut diversion channel is 1.2 km long, 120 m wide, and has a 1/3,750 gradient; the bypass and shortcut layout and longitudinal profiles are shown in Figure 3-22 and Figure 3-21, respectively, and in the B Canal improvement work, embankments will be constructed where the current capacity is insufficient, maintaining the existing river width and gradient.

**Table 3-4: Bypass width and water level reduction**

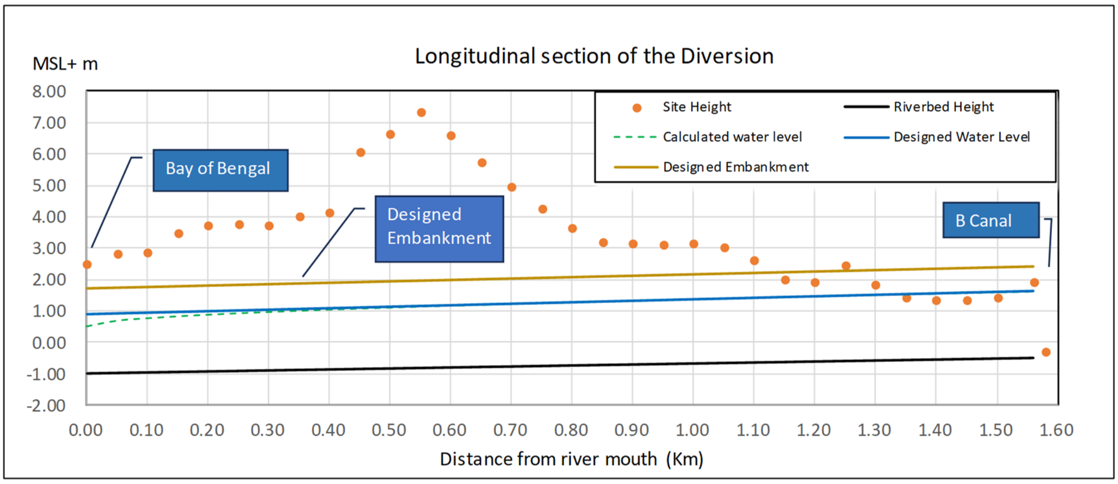
| Bypass width | Peak water level (Pallikaranai) (m) | Water level drop (m) | Flooded area (km$^2$) | (2) Flooding measures Area (km$^2$) | Capacity where pump drainage is needed (x10$^6$m3) |
|---|---|---|---|---|---|
| No bypass (Utilization of retention ponds 3.0m) | 3.85 | — | 43.5 | 18.3 | 7.4 |
| 30m | 3.29 | 0.56 | 36.8 | 11.6 | 4.7 |
| 60m | 2.90 | 0.95 | 31.4 | 6.1 | 2.5 |
| 100m | 2.87 | 0.98 | 31.0 | 5.7 | 2.3 |
| Internal water level target | 2.50 | | 25.3 | 0.0 | 0.0 |

*Source: JICA Expert Team*




*Source: JICA Expert Team*

**Figure 3-21: Short-cut from Okkiam Maduvu and bypass to the Bay of Bengal**




*Source: JICA Expert Team*

**Figure 3-22: Bypass Longitudinal Profile**

## 3.7 Non-Structural, Techno-Legal Framework, and Other Soft Measures

### 3.7.1 Rainwater harvesting

Rain Water Harvesting (RWH) has been mandatory since 2003 in Chennai and more than 890,000 systems have been installed to address water shortages and flooding. However, the effects of these systems are not being fully realized due to inadequate maintenance and insufficient enforcement of regulations. By optimizing RWH in areas prone to flooding, Chennai can improve its water security and increase its resilience to flooding.

### 3.7.2 Flood forecasting and hazard map creation

One trend in flood forecasting and hazard mapping is the real-time flood forecasting system that covers major river basins. This provides web-based real-time flood forecasting and guidance for dam operations and is scheduled for completion by 2025. The target is 6 to 48 hours for flood forecasting. The Chennai Coastal Flood Warning System (C-FLOWS), which complements this, integrates weather forecasts, hydraulic models, and tidal scenarios to predict inundation and enhance flood forecasting and disaster response.

### 3.7.3 Urban Planning and Institutional Arrangements

As part of the urban planning initiatives, the Third Urban Master Plan for Chennai proposes four main strategies: Urban development strategy, Rainfall/runoff ratio management strategy, Buffer Zones for Drainage Systems, Canals, and Tanks, and Residual risk management strategy. These are discussed in more detail in Chapter 4.

## 3.8 Evaluation, Priority, and Recommendations for Implementation

The measures described in this chapter do not work independently but are more effective when used in combination. For example, installing a gate at the end of a waterway can eliminate the effects of backwater from the river. However, since natural drainage from the waterway is not possible with the gate closed, a pump needs to be installed. In addition, since the B Canal can be expected to have a storage effect due to the embankment, the load on the bypass and pump can be reduced. Furthermore, it is also important to coordinate with measures in the river.

In terms of evaluation, it is possible to consider the following evaluation axes: cost, benefit, and feasibility. The retarding basins are ranked as having the highest priority. The implementation plan is summarized in the below table. Here, the aim is to implement the project within 10 years in one phase. River improvement measures are to be implemented within 5 years, and other measures are to be implemented within 10 years.

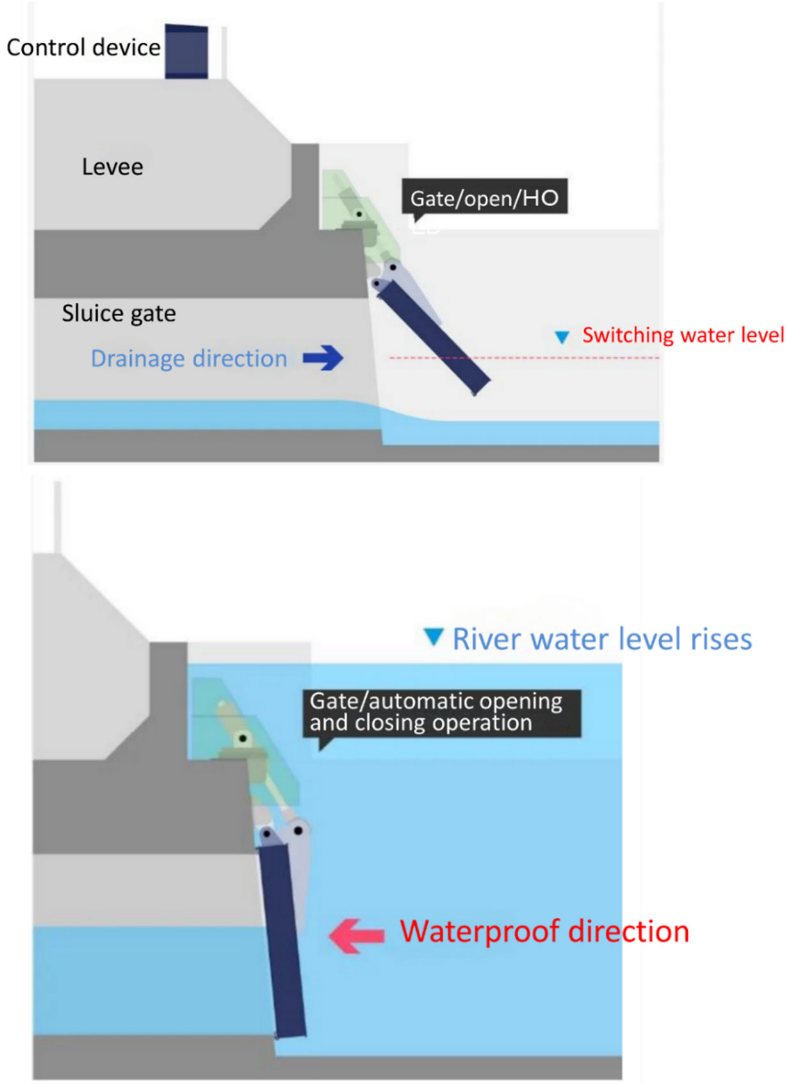
**Table 3-5: Implementation Plan**

| River/Canal | Countermeasures | Priority Rank | Phase1 (10 Years) | |
|---|---|---|---|---|
| | | | First 5 years | Second 5 years |
| Drains Connected to Adyar River | Retarding Basin | 1 | | |
| | Drains Channelization | 7 | | |
| | Gate | 4 | | |
| Drains Connected to Cooum River | Retarding Basin | 1 | | |
| | Drains Channelization | 5 | | |
| | Gate | 2 | | |
| Drains Connected to the North B Canal | Retarding Basin | 2 | | |
| | Drains Channelization | 2 | | |
| | Gate | 2 | | |
| Kodungaiyur Drainage | Retarding Basin | 3 | | |
| | Drain Channelization | 2 | | |
| Captain Cotton Drainage | Retarding Basin | 3 | | |
| | Drain Channelization | 3 | | |
| Otteri Nullah Drainage | Retarding Basin | 6 | | |
| | Drain Channelization | 2 | | |
| | Bypass to Cooum River | 2 | | |
| Central B Canal | Drain Channelization | 2 | | |
| | Gate | 2 | | |
| | Pump | 1 | | |
| Kovalam Basin | Using existing waterbodies | 3 | | |
| | Okium Maduvu Channelization | 2 | | |
| | Gates in B Canal | 3 | | |
| | Pumps | 3 | | |
| | Bypass | 2 | | |

## 3.9 Other Countermeasures

### 3.9.1 Proposal for Connecting Pipes or Culvers to Rivers and Other Macro-Drainages

In addition to drains, there are also structures connected to rivers and canals, such as drainage pipes. During flooding, when the water level of rivers etc. rises, backflow may occur through these drainage pipes. To prevent this, it is necessary to install flap gates or other structures as shown in Figure 3-23. The quantity and size of drainage pipes are summarized in Table 3-6. Regarding the installation of flap gates, the gate may be blocked by rubbish, etc. To prevent this, it is effective to remove river rubbish, etc. through maintenance and management, and to install abnormal detection devices, etc. In addition, depending on the size of the drainage pipe, it is also necessary to consider adopting a method other than flap gates.




*Source:https://www.kyowa-se.co.jp/product-service/afg-l/*

**Figure 3-23: Scheme of Flap Gate**

**Table 3-6: Number and size of small drains**

| Basin | Number* | Minimum size | Maximum size |
|---|---|---|---|
| Adyar | 65(10) | 0.4m | W5.6 H1.5 |
| Cooum | 24(1) | 0.1m | W7 H3.2 |
| Kosasthalaiyar | 4(0) | 0.6m | W1.6 H2.1 |
| North B Canal | 17(3) | 0.6m | W2.2 H1.9 |
| Central B Canal | 12(1) | 0.2m | W2.4 H1.7 |
| South B Canal | 47(8) | 0.3m | W9.8 H3.5 |

**Parenthesis show the number of small drains larger than 2 m in diameter or width*

*Source: JICA Expert Team*

### 3.9.2 Countermeasures for Low-laying Areas

The flood control target area in Chennai features generally flat topography with a slope from west to east. However, a closer look reveals several depressions or low-lying areas. The following map illustrates the areas estimated to have been flooded during the 2015 floods, all of which are located some distance from rivers. In these areas, stormwater cannot be drained by gravity runoff alone. Therefore, while utilizing vacant land for storage remains a fundamental measure, it is crucial to address stormwater accumulation in the deepest parts of these areas.

The appropriate countermeasures include pump drainage, underground storage, or a combination of both. Given the significant volume of accumulated water—ranging from 0.62 million m³ to

3.15 million m³—it will take both time and resources to implement these countermeasures. As a result, prioritizing the development of drainage systems while encouraging land use changes such as greening is a more feasible approach.

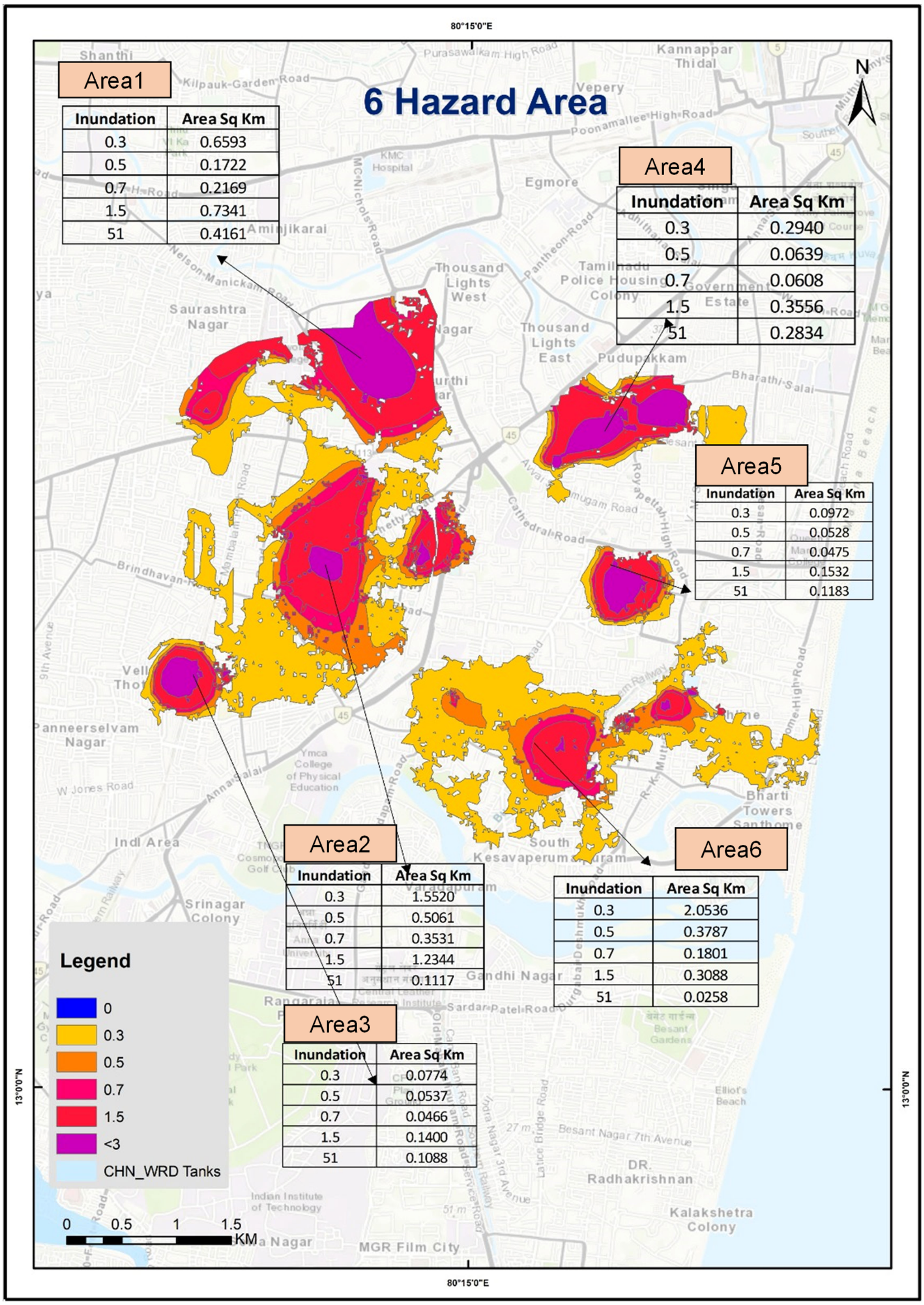





**Figure 3-24: Inundation in the Low-lying Area**

# Chapter 4. Urban Planning and Flood Management Strategies

## 4.1 Background and Context

Strategies and recommendations for urban planning, land use management, and residual risk management are key components for the formulation of a flood control master plan. The JICA Comprehensive Flood Control Master Plan in the urbanized River basin of Chennai (in this chapter referred to as JICA Flood Control Master Plan) provides critical inputs and recommendations for incorporation into the 3rd Urban Development Master Plan for Chennai, from 2027 to 2046 (in this chapter referred to as the 3rd CMA Master Plan).

This includes the development of inundation maps for Return Periods (RPs) of 2, 5, 10, 20, 50, and 100 years at the basin level. A comprehensive flood risk analysis was carried out, assessing impacts on population, infrastructure, and related factors. Four strategic recommendations were formulated, including guidelines for buffer zones around canals and water bodies. Additionally, the JICA Flood Control Master Plan identifies, and maps selected waterbodies and tanks for floodwater storage across four basins at a basin-wide level. Existing drainage networks linking these waterbodies were also mapped, with missing links identified. Efforts to cluster tanks and waterbodies were completed in all four basins to enhance their connectivity.

A significant objective of the JICA Flood Control Master Plan is to contribute to the 3rd CMA Master Plan by emphasizing the management of rainfall-runoff (R/R) ratios to mitigate future increases caused by urban development. A target R/R ratio of 0.8 is set for both fluvial and pluvial flood countermeasures. Should the ratio exceed this target, additional stormwater retention measures will be required, including calculating necessary storage capacities and exploring urban planning case studies. The plan also outlines strategies for managing residual risks during and after implementation.

These strategies and guidelines align with the 3rd CMA Master Plan, focusing on land use planning, building regulations, and urban development. Rooted in scientifically conducted flood hazard and risk assessments, they provide actionable proposals to address current and future challenges.

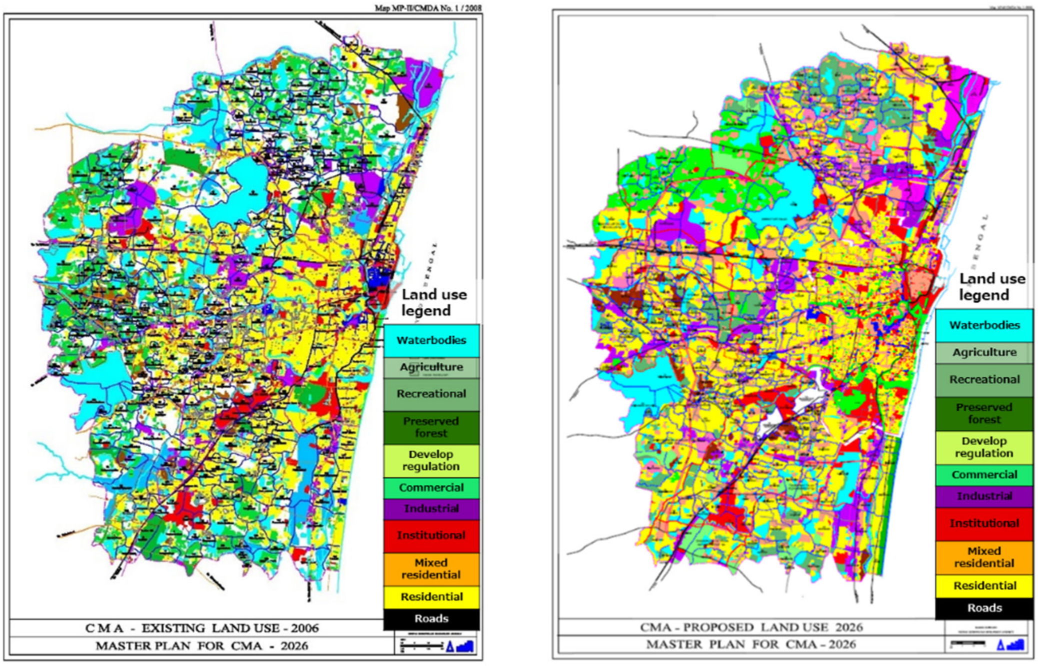
## 4.2 Setting the Scene and Review 2nd Urban Development Master Plan

### 4.2.1 Urbanization and Increase in Rainfall-Runoff Ratio

Figure 4-1 illustrates land use in 2006 and future projections based on the Second Chennai Urban Development Master Plan (2nd MP). It highlights that approximately 68% of the Chennai Metropolitan Area (CMA, 1,189 km²) was classified as non-urban, comprising green spaces, waterbodies, and undeveloped areas.

Between 2006 and 2024, urbanization significantly transformed land use, resulting in a rise in the rainfall-runoff (R/R) ratio from 0.52 (2006 estimates) to 0.71 (2024 estimates) due to the conversion of green spaces, agricultural land, and marshlands into urban areas. With Chennai's population projected to grow by 27% by 2035, the R/R ratio is anticipated to increase further to 0.9 if urban development continues at the current pace.

Under the JICA Flood Control Master Plan, the target R/R ratio for the CMA is set at 0.8 for both fluvial and pluvial flood countermeasures. The projected R/R ratio of 0.9 by 2035 would exceed this target, necessitating approximately 6.0 million cubic meters of additional stormwater storage to mitigate the impacts of increased runoff and maintain effective flood management.




*Source: CMDA Second Master Plan*

**Figure 4-1: CMA Land Use in 2006 (left) and Proposed Plan for 2026 (right)**

### 4.2.2 Flood Risk Management in the Second Master Plan

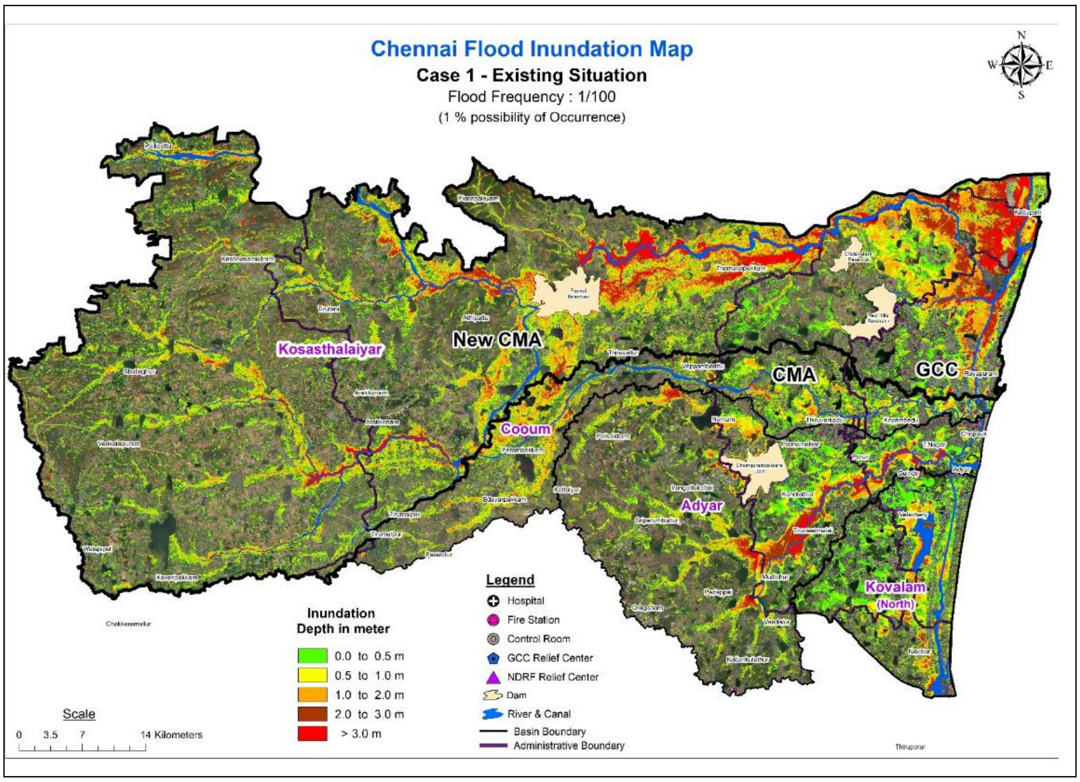
An analysis of the development regulations outlined in the Second Master Plan, which form the foundation for current land use and urban planning, reveals several critical points from a flood risk reduction perspective:

- The development strategy focuses on decentralizing economic activities from the CMA to suburban areas, including satellite cities outside the CMA.
- While flood risk is acknowledged, it has not been effectively integrated into mainstream urban planning practices.
- Water area management regulations in Chennai primarily emphasize groundwater conservation to ensure drinking water and agricultural irrigation, with limited recognition of the role of water bodies in flood management.
- The importance of green spaces as integral components of urban planning—contributing to natural water storage, water filtration, environmental improvement, and recreation—is not adequately acknowledged.
- Implementation procedures and monitoring mechanisms for the plan are not well-defined, leaving key elements, such as the preservation of waterbodies, largely unguaranteed.

These gaps highlight the need for more comprehensive strategies to integrate flood risk reduction into urban planning and land management.

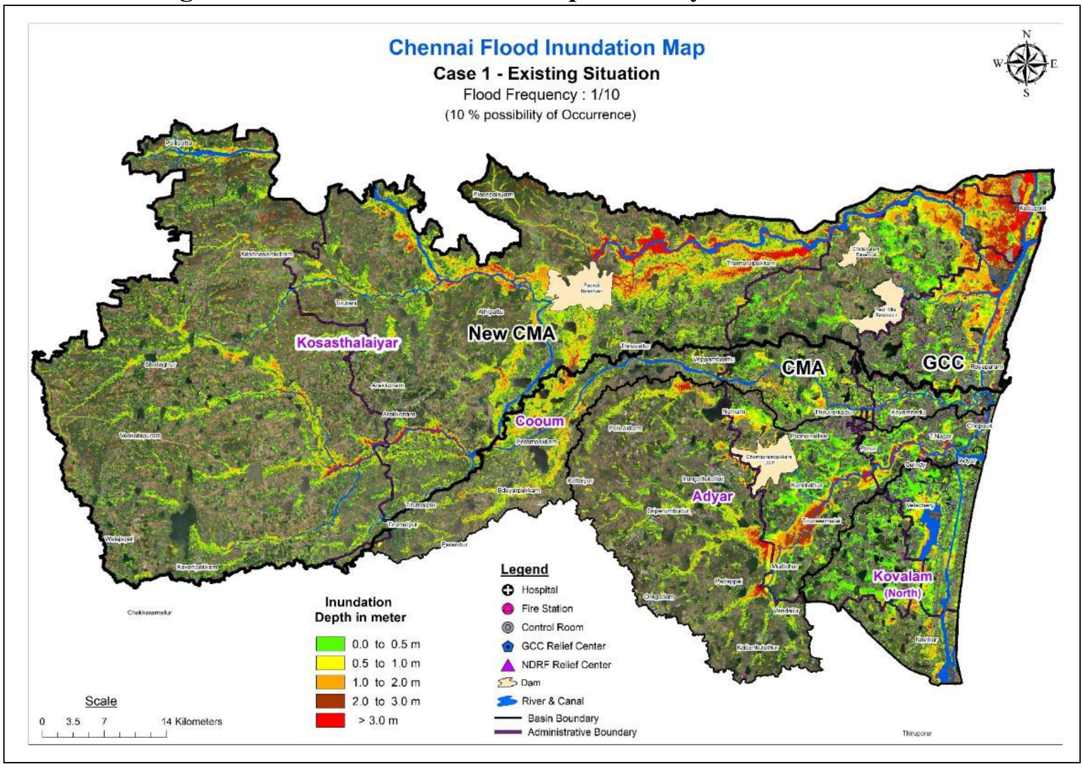
## 4.3 Flood Disaster Risk Analysis

Flood inundation maps for various return periods have been developed as part of the JICA Flood Control Master Plan, forming the basis for a detailed flood risk analysis. For a 100-year return period (RP) flood, approximately 46% of the Chennai Metropolitan Area (CMA) and 5.2 million people are at risk of being affected. In contrast, a 10-year return period flood would impact around 33% of the area and 3.7 million people. The following two figures illustrate the flood inundation maps for both 100-year and 10-year return periods, highlighting the extent of flooding under these scenarios.




*Source: JICA Expert Team*

**Figure 4-2: Flood Inundation Map for 100-year Return Period**




*Source: JICA Expert Team*

**Figure 4-3: Flood Inundation Map for 10-year Return Period**

## 4.4 Proposed Strategies and Recommendations

From the perspective of urban planning and land use, the JICA Flood Control Master Plan proposes four strategies aimed at mainstreaming flood control strategies to the 3rd CMA Master Plan, controlling rainfall-runoff (R/R) ratios, and managing residual risks. Each strategy is accompanied by guidelines focusing on land use, building regulations, and related measures.

**Table 4-1: Strategies and Recommendations in the JICA Flood Control Master Plan**

| Strategies and Actions | |
|---|---|
| **Strategy 1** | **Flood-Aware Urban Planning and Land Use Recommendations**<br>Utilize flood inundation maps to raise public awareness and recommendations for updating local guidelines and regulations for urban planning and development. |
| **Strategy 2** | **Conservation of Waterbodies and River Buffers Framework**<br>Protect existing waterbodies from urban encroachment, develop and maintain buffer zones for rivers and drains, and designate areas for future retarding ponds. |
| **Strategy 3** | **Rainfall/Runoff Ratio Control Strategies**<br>Safeguard agricultural lands and green spaces to enhance rainwater infiltration and mandate stormwater storage for new developments. |
| **Strategy 4** | **Residual Risk Management Strategies**<br>Managing residual risks associated with floods exceeding the return period (RP) during and after the implementation of the JICA Flood Control Master Plan. |

*Source: JICA Expert Team*

## 4.5 Strategy 1: Flood-Aware Urban Planning and Land Use

Flood-aware urban planning is a cornerstone of disaster management in the JICA Flood Control Master Plan, aligning closely with fluvial and pluvial flood control countermeasures. Flood inundation maps for different return periods (2, 5, 10, 20, 50, 80, and 100 years) have been developed for all four basins. These maps are critical for disaster risk analysis in the study areas, including assessments of affected populations, inundated areas with varying depths, and impacts on vital lifelines and infrastructure. Additionally, they help identify hotspots for consideration in the 3rd CMA Urban Development Master Plan.

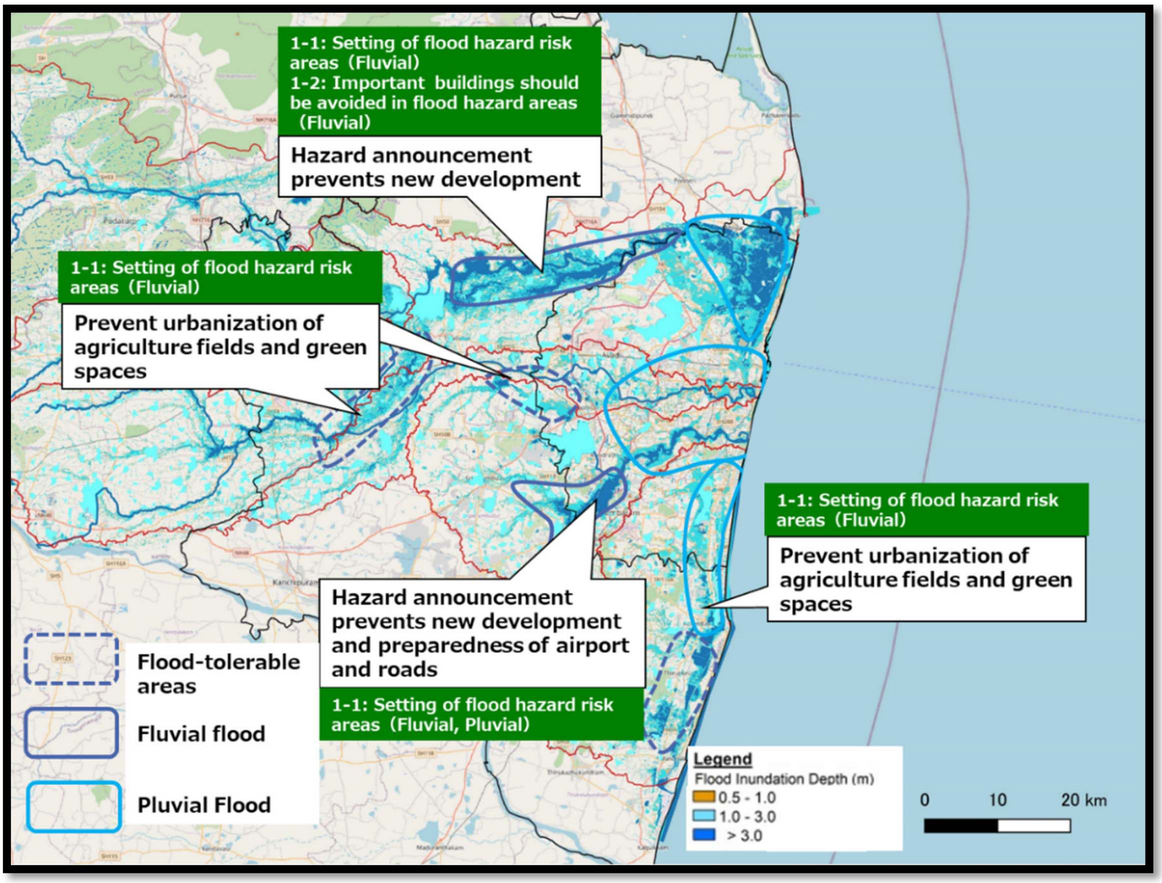
Among these return periods, the 100-year and 10-year inundation maps are particularly significant. The target safety level for fluvial flood control is based on a 100-year return period, while pluvial flood control focuses on a 10-year return period. The following section briefly explains the three major components of Strategy 1 of the urban planning Study of the JICA Flood Control Master Plan, intended for inclusion in the CMA 3rd Urban Development Master Plan together with other strategies that are coming in the next section.Figure 4-4illustrates the flood inundation maps and locations relevant to these three components of the strategy 1.

### 4.5.1 Component 1-1: Identification of Flood Prone Areas

As a key component of the 3rd CMA Urban Development Master Plan (2027–2046), the identification of flood-prone areas is foundational to flood-aware urban planning. Leveraging the flood inundation maps developed under the JICA Flood Control Master Plan, this initiative focuses on pinpointing flood hotspots with water depths of 0.5 meters or more, based on the 100-year return period flood data. These maps provide critical insights into inundation patterns across all basins, including areas currently lacking flood control plans. The information will guide zoning regulations, redevelopment priorities, and urban resilience strategies, ensuring that future urban development mitigates flood risks effectively and aligns with long-term planning goals for Chennai.

### 4.5.2 Component 1-2: Critical Facilities to be Away from the Flood-Prone Areas

Ensuring the safety of critical facilities is a core aspect of the 3rd CMA Urban Development Master Plan’s flood resilience strategy. For areas identified with flood hazards exceeding a 100-year return period, critical infrastructure such as evacuation centers, hospitals, fire stations, and disaster relief hubs must comply with the National Disaster Management Guidelines. Ideally, these facilities should not be located within flood-prone zones. In cases where relocation is impractical, such facilities must be constructed above the highest recorded flood levels to maintain their functionality during flood events. This approach ensures the resilience of essential services, safeguarding lives and enabling effective disaster response during extreme weather conditions.




*Source： JICA Expert Team*

**Figure 4-4: Strategy 1 on Flood-Aware Urban Planning and Land Use Recommendations**

## 4.6 Strategy 2: Framework for conservation of waterbodies rivers

This strategy comprises three components focused on the conservation of tanks and waterbodies and proposals for rivers/canal buffers, which are integral elements of the 3rd CMA Urban Development Master Plan and for the implementation of the JICA Flood Control Master Plan. The preservation and protection of tanks, water bodies, rivers, canals, and lakes, are essential for mitigating flood risks and enhancing the natural flood retention capacity. By incorporating buffer zones for rivers and canals, this strategy prevents further encroachment and development that may hinder natural flow and flood management efforts. The approach ensures that adequate space is preserved, providing room for river widening, maintenance, and sustainable flood control solutions. The locations of selected tanks and waterbodies for flood storage, as described in Chapter 2 of this master plan, will be considered when implementing these strategies. Figure 4-5 illustrates the locations relevant to these three components of strategy No. 2.

### 4.6.1 Component 2-1: Conservation of Existing Tanks and Rivers

The protection and conservation of existing tanks and waterbodies across the four basins are crucial for effective flood management. The JICA Flood Control Master Plan identifies 50 tanks in the Adyar Basin, 31 tanks in the Cooum Basin, 61 tanks in the northern part of the Kovalam Basin, and 119 tanks in the Kosasthalaiyar Basin, as detailed in Table 4-2. These selected tanks are minimum requirements for flood storage at the basin level during the implementation of the JICA Flood Control Master Plan. Additionally, 380 tanks have been identified in the upstream areas of the Kosasthalaiyar Basin, outside the New CMA. While the primary focus of the 3rd Urban Development Master Plan is on the CMA, there is potential for considering spatial planning for the New CMA as well. The JICA Flood Control Master Plan emphasizes the protection and conservation of all waterbodies and tanks, whether they are inside or outside the New CMA or upstream areas of the basins. These tanks play a vital role in enhancing flood storage capacity and should be safeguarded from encroachment or reduction.

The locations, connections, and drainage systems of these waterbodies are outlined in Chapter 2 of the JICA Flood Control Master Plan. Protecting both the tanks and their connecting drains is essential, as any disruption to these links hampers their utility for flood management. Buffer zones should be determined for each tank based on its specific context, and it is recommended that the existing boundaries of tanks and waterbodies, as shown in the 2011 Toposheet maps, be clearly defined and preserved to prevent future encroachment and ensure their flood storage functions. Moreover, the foreshore of tanks (in case) at the high flood level should be considered an integral part of tanks and water bodies.

**Table 4-2: Area and Flood Storage Capacity of the Selected Tanks**

| Basin | No. Tanks | Improve Flood Storage Capacity (MCM) | Area (km2) |
|---|---|---|---|
| Adyar | 50 | 88 | 47.4 |
| Cooum | 31 | 38 | 23.1 |
| Kovalam | 61 | 41 | 13.9 |
| Kosasthalaiyar | 119 | 203 | 171.1 |

*Source: JICA Expert Team*

Additionally, the JICA Flood Control Master Plan proposed buffer zones along rivers with widths ranging from 15 to 30 meters on both sides to allow for future river widening and maintenance. Similarly, buffer zones of 1 to 15 meters will be designated along canals and drainage systems, depending on their flow rates, as detailed in Table 4-3. These buffer zones will be marked on land use maps to ensure they are integrated into urban planning. For lakes and marshes, buffer zone boundaries will be defined by natural features such as topography, management roads, and embankments, ensuring adequate space for future improvements and maintenance activities.

**Table 4-3: Proposed Buffer Zone for Canals and Drainages**

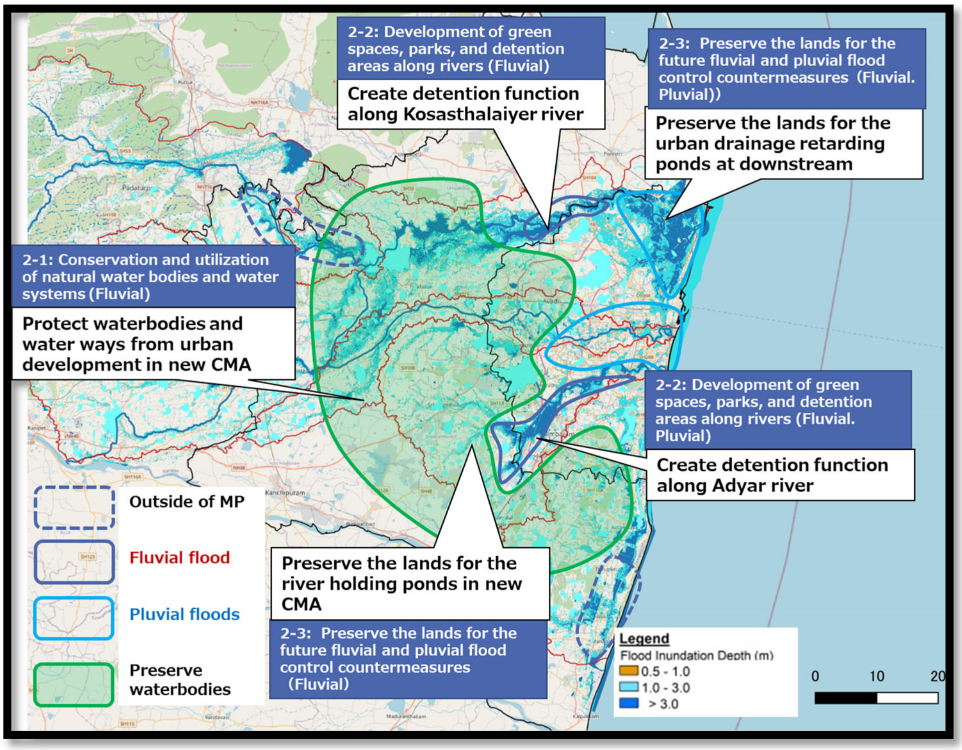
| Canal/Drains | Discharge at the Outlet (cusec) | Average Width (ft) | Proposed Buffer Zone (ft) | Examples |
|---|---|---|---|---|
| Open Surface | Class 1:<br>Larger than 1500 | N/A | 30 to 50 | Buckingham Canal, Kodungaiyur, Captain Cotton, Otteri Nullah, Padikuppam Drain, Virugambakkam-Arumbakkam, Nandanam, Mambalan, MGR, Nandambakkam, Manapakkam |
| | Class 2:<br>Between 500 to 1500 | | 10 to 30 | Ambattur SIDCO Drain, Nungambakkam Drain, Nolambur Drain, Trustpuram Canal Guindy, Kolapakkam |
| | Class 3:<br>Less than 500 | | 5 to 10 | Chelammal |
| Fully Covered | All | All | No buffer | All covered drainages including cut &covers |
| Partially Covered | All | All | 5 to 10 ft in open spaces | |
| Open Surface SWD | N/A | larger than 5ft | 3 to 10 ft | Under the control of GCC or other municipalities |
| | | Less than 5ft | No buffer | |

### 4.6.2 Component 2-2: Development of green detention areas along rivers

To further improve flood resilience, this component focuses on the development of green spaces, parks, and detention areas along rivers, particularly in flood hazard zones with a 100-year return period. Agricultural lands, green spaces, parks, and other open areas will be strategically developed to function as detention basins, helping to reduce flood risks by improving water retention and infiltration. These areas will be developed in coordination with river and urban drainage plans, ensuring that they contribute to flood management while enhancing the urban landscape. The integration of green infrastructure into urban areas will provide both environmental and recreational benefits, fostering sustainable urban growth while mitigating the impacts of flooding.

### 4.6.3 Component 2-3: Preservation of Lands for Future Flood Control

Preserving land for future flood control measures is a key element of this strategy. In addition to the waterbodies and tanks mentioned in Component 1 of this strategy, several locations for urban flood retention have been proposed in Chapter 3 of the JICA Flood Control Master Plan, specifically along the connecting drains to the North Buckingham Canal. These areas have been identified for the construction of detention ponds and other flood management infrastructure required for both the JICA Flood Control Master Plan implementation in the North Buckingham Canal and its three major connecting drains. These lands will be protected through land use regulations and indicated on land use maps to ensure their availability for future flood mitigation projects. By reserving these areas in advance, the city will be better equipped to implement effective flood control measures as urbanization continues, strengthening the city’s resilience to floods and safeguarding critical infrastructure and communities.




*Source: JICA Expert Team*

**Figure 4-5: Components of Strategy 2 on Conservation of Tanks and River Buffers**

## 4.7 Strategy 3: Rainfall-Runoff Control Strategies

Urban planning plays a vital role in managing rainfall-runoff (R/R) ratios, which can exacerbate flooding. A key strategy is to preserve open and green spaces, particularly for rainwater storage and infiltration. In the face of new urban development, it is crucial to maintain a balance between the built environment and natural stormwater storage functions. This will ensure that developments do not compromise the capacity of river basins to manage runoff efficiently. Figure4-6 shows the spatial distribution of the components for strategy No. 3

### 4.7.1 Component 3-1: Preservation of Green Spaces and Agricultural Land at Basin Level

The JICA Flood Control Master Plan proposes the preservation and conservation of green spaces and agricultural land in CMA and New CMA areas. This is essential to controlling runoff. These areas, particularly in low-population-density, non-urban parts of the basin, should be safeguarded from urban encroachment. By doing so, we maintain the natural functions of the landscape, ensuring that stormwater infiltration and retention can occur naturally. This preservation will help reduce the overall rainfall-runoff ratio, mitigating the impacts of future urbanization on flood management.

### 4.7.2 Component 3-2: Mandatory Stormwater Storage Facilities for New Developments

The JICA Flood Control Master Plan proposes in CMA and New CMA areas, any developments with land areas of 1,000 m² or more will be required to incorporate mandatory stormwater storage facilities, either ground or underground. This ensures that new developments control their effect on increasing runoff, preventing additional strain on the existing flood control and stormwater infrastructure. By mandating such facilities, the city will be better equipped to handle runoff during heavy rainfall events, reducing the risk of flooding and maintaining the natural flow of water through the drainage system. The table illustrates the required new storage capacity needed to manage a 1% increase in rainfall for each basin.

**Table 4-4: Required Storage to Control a One-unit Rainfall-Runoff Ratio**

| Basin | Area (km2) | Unit increase in R/R | Virtual Increased Area (km2) | Requires Flood Storage per km2 (m3/km2) | Required Additional Storm Water Storage (m3) |
|---|---|---|---|---|---|
| Adyar Basin within CMA | 304 | 0.01 | 3.04 | 50,000 m3/km2 Based on Tokyo Metropoliten Govermenet Standard | 152,000 |
| Cooum Basin within CMA | 174 | | 1.74 | | 87,000 |
| Kosasthalaiyar Basin within CMA | 501 | | 5.01 | | 250,500 |
| Kovalam Basin within CMA | 210 | | 2.1 | | 105,000 |
| Total CMA | 1,189 | | 11.19 | | 594,500 |

*Source: JICA Expert Team*

### 4.7.3 Component 3-3: Temporary Stormwater Storage in Public Areas

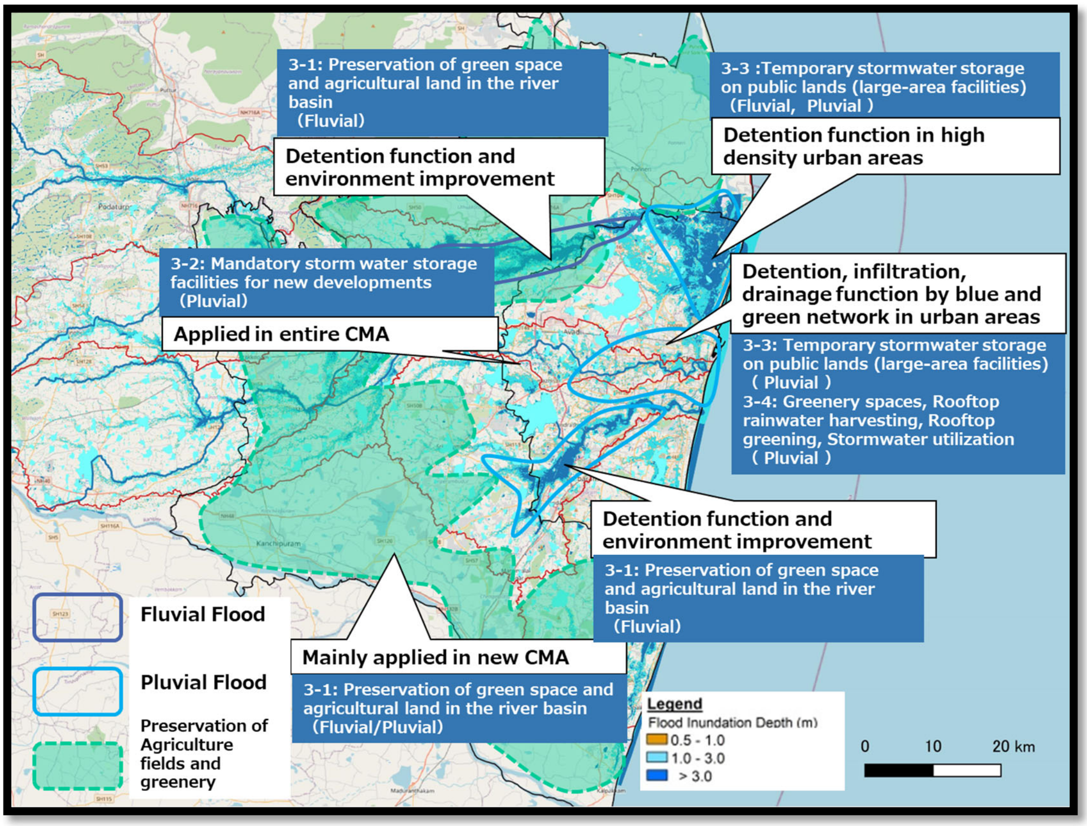
For areas within the 100-year return period flood hazard zones in the CMA, vacant public areas such as parks, playgrounds, and parking lots will be designated for use as temporary stormwater storage facilities. These large-area facilities will act as buffer zones to absorb excess rainfall during storms, providing relief to surrounding areas. The use of public spaces for this purpose is an efficient and cost-effective solution to managing stormwater while also maintaining accessible green spaces for residents.

### 4.7.4 Component 3-4: Rainwater Harvesting and Stormwater Management

For the CMA, new building developments larger than 1,000 m² will be required to dedicate at least 20% of their vacant space to greenery, including rooftop greening and rainwater harvesting systems. These measures will help manage stormwater runoff at the source by capturing rainwater and reducing the pressure on the stormwater infrastructure. Additionally, subsidies will be provided for individuals who install stormwater storage systems or engage in rainwater harvesting, promoting a decentralized approach to stormwater management across the city.

### 4.7.5 Case Study for the Required Stormwater Storage Volume

To evaluate the stormwater storage capacity needed to manage runoff in the river basins, the components of strategy No. 3 outlined in the above four components have been applied. The case studies estimate the potential storage capacities that can be achieved through various rainfall-runoff control measures. Based on these strategies, the total increase in flood detention capacity is estimated to be about 6.1 MCM as in Table 4-5.




*Source: JICA Expert Team*

**Figure4-6: Components of Strategy 3 on Rainfall-Runoff Ratio Control**

**Table 4-5: Estimated Increase in Detention Capacity by Implementation of Strategy No. 3**

| Component | Land Use/ Facilities | Detention Areas | Adyar (MCM) | Kovalam (MCM) | Cooum (MCM) | Kosasthalaiyar (MCM) | Total (MCM) |
|---|---|---|---|---|---|---|---|
| 3-1 | Agriculture | Agricultural land | 0.21 | 0.02 | 0.02 | 0.10 | 0.35 |
| 3-2 | Required Detention Pond | Detention ponds on-site | 0.09 | 0.07 | 0.05 | 0.11 | 0.33 |
| 3-3 | Public Housing (5% of areas) | Open space between housing, parking | 0.99 | 0.80 | 0.59 | 1.24 | 3.62 |
| 3-3 | Public Schools (2ha for 10% of schools) | Outdoor playground | 0.21 | 0.12 | 0.13 | 0.29 | 0.75 |
| 3-3 | Park (10% of Greenery) | Open spaces | 0.44 | 0.26 | 0.23 | 0.16 | 1.09 |
| Total | | | 1.94 | 1.28 | 1.02 | 1.90 | 6.14 |

*Source: JICA Expert Team*

It is useful to compare the total detention capacity of 6.1 MCM achieved by implementing the three components of Strategy No. 3 in Table 4-6, to the estimated storage facilities required to maintain the rainfall-runoff ratio at 0.8 and prevent it from rising to 0.9, as discussed in the other section. It is estimated that 6.0 million m³ of storage is necessary to prevent further increase in the rainfall-runoff ratio from 0.8 to 0.9. By implementing Strategy 3, it becomes possible to provide 6.1 MCM to achieve this objective. The total detention capacity of 6.1 MCM exceeds the required capacity by 0.1 MCM. However, the Kosasthalaiyar River Basin falls slightly short of the required storage, with a capacity of 1.9 million m³ compared to the required 2.5 million m³.

**Table 4-6:** Basin-wise Comparison Required Stormwater Storage Capacity with the Strategy 3

| Basin | Required basin storage capacity to prevent R/R from further increasing from 0.8 to 0.88 (MCM) | Estimated increase in detention capacity by strategy No. 3 (MCM) |
|---|---|---|
| Adyar Basin | 1.5 | 2.0 million m³ |
| Kovalam Basin | 1.1 | 1.2 million m³ |
| Cooum Basin | 0.9 | 1.0 million m³ |
| Kosasthalaiyar Basin | 2.5 | 1.9 million m³ |
| Total | 6.0 | 6.1 million m³ |

*Source: JICA Expert Team*

## 4.8 Strategy 4: Residual Risk Management

### 4.8.1 Categorization of Flood Risk

The elements for categorizing flood risk include the risk of flood damage occurring in flood hazard areas before the implementation of the MP project by phase of the MP project and the residual risk of flooding in flood hazard areas during or after the implementation of the MP project. In addition, there are three types of floods by source of origin: fluvial floods and pluvial floods, which are covered by the MP project, and small- and medium-scale inland flooding, which is not covered by the MP project and is covered by sewerage systems. The above elements are classified as follows in a matrix table with the probability of rainfall on the vertical axis and the project phase on the horizontal axis.

**Table 4-7: Categorization of Flood Risk**

| MP project / Flood RP | **Before the MP project start** | **After Phase 1 implemented** | **After all, countermeasures are implemented** |
|---|---|---|---|
| 10 years RP | Fluvial floods: All Existing Risk<br>Pluvial Floods: All Existing Risk | Fluvial floods: No Risk<br>Pluvial Floods: No Risk<br>**Pluvial Floods due to lack of Storm Water Drainage (SWD): Residual Risk ⑤** | Fluvial floods: No Risk<br>Pluvial Floods: No Risk<br>**Pluvial Floods due to lack of Storm Water Drainage: Residual Risk ⑤** |
| 100 years RP | Fluvial floods: All Existing Risk<br>Pluvial Floods: All Existing Risk | **Fluvial floods: Residual Risk ②**<br>**Pluvial Floods: Residual Risk ④**<br>**Pluvial Floods due to ck of Storm Water Drainage: Residual Risk ⑤** | **Fluvial floods: No Risk ③**<br>**Pluvial Floods: Residual Risk ④**<br>**Pluvial Floods due to lack of Storm Water Drainage: Residual Risk ⑤** |
| More than 100 years RP | Fluvial floods: All Existing Risk<br>Pluvial Floods: All Existing Risk | **Fluvial floods: Residual Risk ①**<br>**Pluvial Floods: Residual Risk ④**<br>**Pluvial Floods due to lack of Storm Water Drainage: Residual Risk ⑤** | **Fluvial floods: Residual Risk ①**<br>**Pluvial Floods: Residual Risk ④**<br>**Pluvial Floods due to lack of Storm Water Drainage: Residual Risk ⑤** |


| MP project / Flood RP | **Before the MP project start** | **After Phase 1 implemented** | **After all, countermeasures are implemented** |
|---|---|---|---|
| 10 years RP | Fluvial floods: All Existing Risk<br>Pluvial Floods: All Existing Risk | Fluvial floods: No Risk<br>Pluvial Floods: No Risk<br>**Pluvial Floods due to lack of Storm Water Drainage (SWD): Residual Risk ⑤** | Fluvial floods: No Risk<br>Pluvial Floods: No Risk<br>**Pluvial Floods due to lack of Storm Water Drainage: Residual Risk ⑤** |
| 100 years RP | Fluvial floods: All Existing Risk<br>Pluvial Floods: All Existing Risk | **Fluvial floods: Residual Risk ②**<br>**Pluvial Floods: Residual Risk ④**<br>**Pluvial Floods due to ck of Storm Water Drainage: Residual Risk ⑤** | **Fluvial floods: No Risk ③**<br>**Pluvial Floods: Residual Risk ④**<br>**Pluvial Floods due to lack of Storm Water Drainage: Residual Risk ⑤** |
| More than 100 years RP | Fluvial floods: All Existing Risk<br>Pluvial Floods: All Existing Risk | **Fluvial floods: Residual Risk ①**<br>**Pluvial Floods: Residual Risk ④**<br>**Pluvial Floods due to lack of Storm Water Drainage: Residual Risk ⑤** | **Fluvial floods: Residual Risk ①**<br>**Pluvial Floods: Residual Risk ④**<br>**Pluvial Floods due to lack of Storm Water Drainage: Residual Risk ⑤** |


*Source: JICA Expert Team*

### 4.8.2 Component 4-1: Land Use and Building Regulations in Residual Flood Risk Areas (Residual Risk ②)

This component addresses residual flood risks categorized as 2 (Figure 4-7). Residual risk category two refers to the flood risk that remains after Phase 1 of the JICA Flood Control Master Plan with the 100-year return period flood. The strategy focuses on preventing the planning of important facilities, as specified in Components 1-2 of Strategy 1, in areas with residual flood risk. To mitigate the risk, any development in these areas should be elevated above the highest recorded floodwater levels, ensuring minimal flood impact.

Moreover, this component addresses residual risk categories 2 after Phase 1, where the target safety level is a 10-year return period, but there remains a risk of flooding between 10 to 100 years. In these areas, the strategy proposes implementing building regulations to minimize flood damage, such as two-story housing with vacant ground floors to allow for floodwater flow and other land-use planning measures.

#### 4.8.3 Component 4-2: Proper Land Use of Undeveloped Land in Flood-Risk Areas (Residual Risk ⑤)

This is a strategy to review land use in areas at risk of flooding for 10-year floods due to SWD after the project is completed. The left side of the figure below shows the flood risk areas in the upper reaches of the Adyar River after the MP is completed for a 10-year RP flood and indicates that a flood risk of 0.0 to 1.5 m remains. The current land use on the right side of the figure below shows that the flood risk areas are currently farmland or green space.

To manage these types of residual risks, a key action is proposed for undeveloped land within flood-risk areas. If such land exists, its use will be reassessed to avoid any potential exacerbation of flood risks. Specifically, the strategy recommends shifting land use from development to non-development purposes, such as designating the area for open spaces, parks, or other flood-resilient functions. This proactive approach minimizes human and infrastructure exposure to flood risks and preserves the land as a natural buffer zone, enhancing the area's overall resilience to future flood events.

#### 4.8.4 Component 4-3: Relocation of Important Facilities (Residual Risk ①, ②, ④, ⑤)

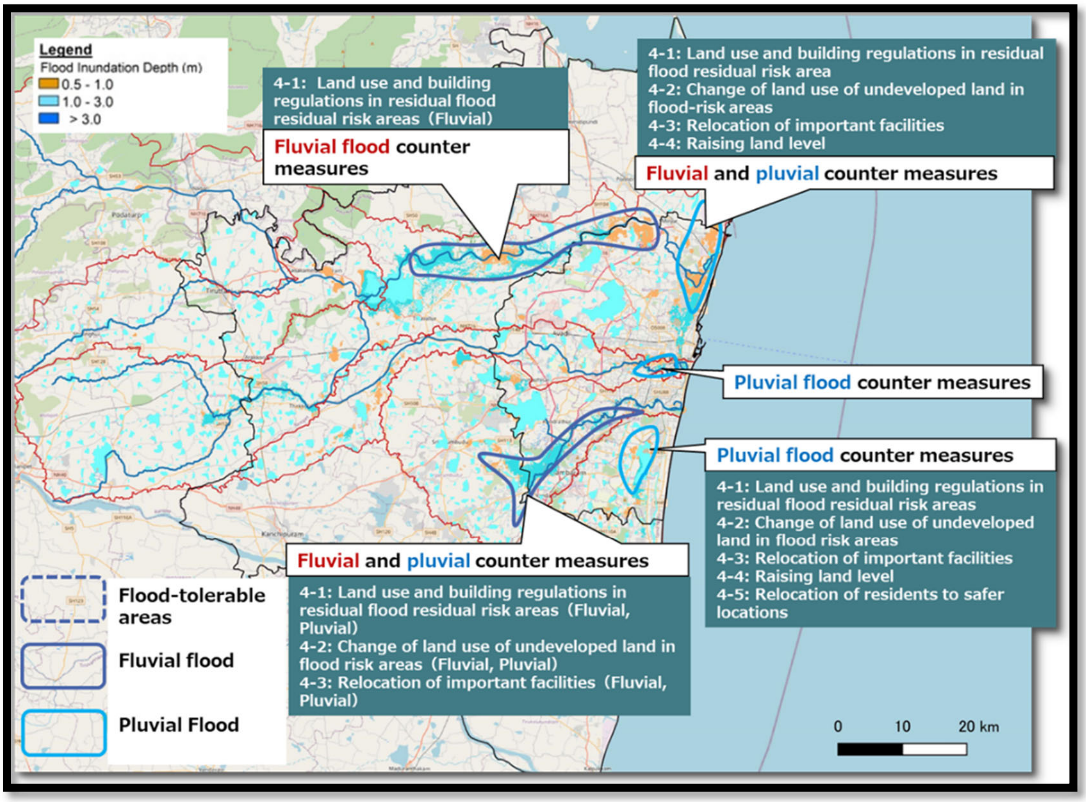
For 100-yr RP flood, facilities subject to land use restrictions that remain within flood hazard areas after Phase 1 of the MP Project and after the project is completed will be relocated outside the flood hazard areas when they are rebuilt. In that case, it shall be considered whether it will be rebuilt in its current location or relocated, based on factors such as whether it can function if it satisfies building regulations.

#### 4.8.5 Component 4-4: Raising Land Levels for New Developments and Redevelopment (Residual Risk ④)

For the hazard area of 100-yr RP flood after completion of the MP project, raising the land level through new development projects or redevelopment projects in flood hazard areas is considered.

##### 4.8.5.1. Component 4-5: Relocation of Residents to Safer Locations (Residual Risk ③: Kovalam only ⑤)

For the hazard area of 100-yr RP flood after completion of the MP project, if the slums or other facilities are located in flood hazard areas, the government's Rehabilitation Program will consider raising the priority of relocation, based on the flood risk, such as flood depth and flood frequency.




*Source: JICA Expert Team*

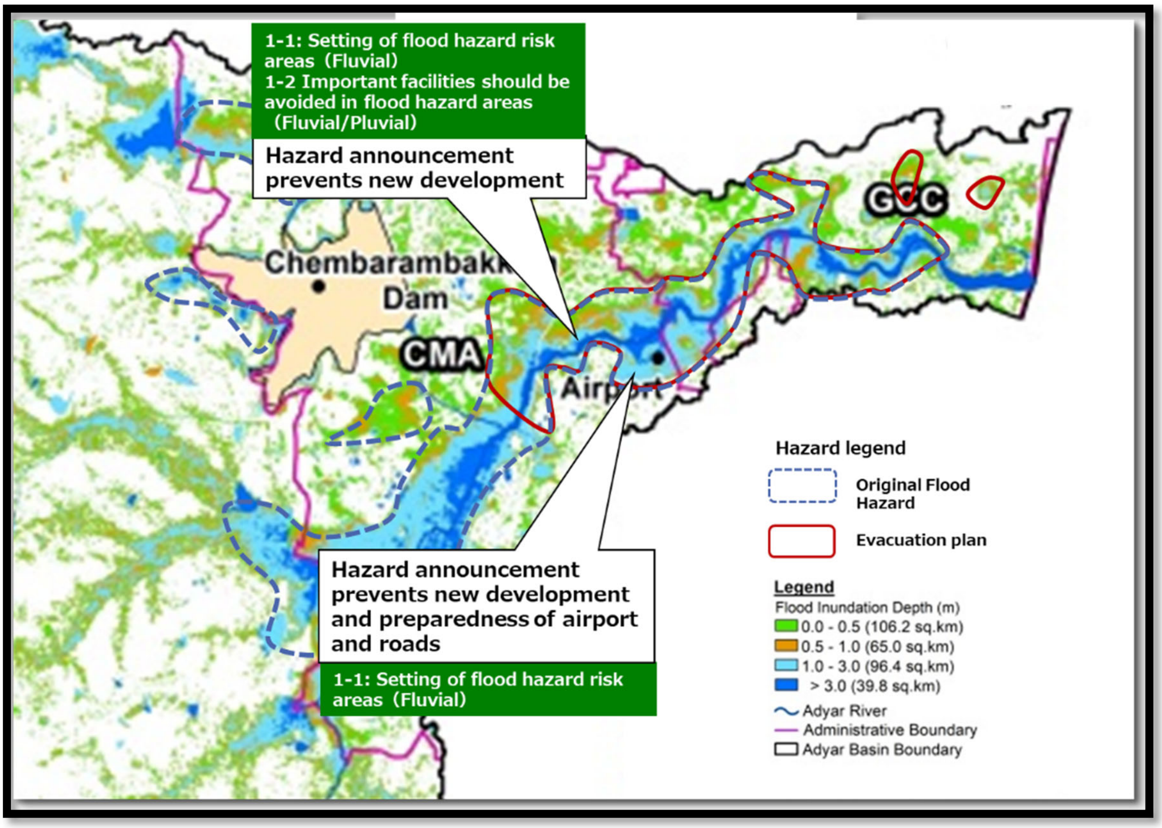
**Figure 4-7: Components of Strategy 4 on Residual Risk Management**

## 4.9 Showcasing the Four Strategies and Their Components for the Adyar Basin

The four strategies and their components have been tailored for application in the Adyar River Basin as a representative case, demonstrating their practical implementation. The following provides an overview of two applicable strategies in the Adyar Basin, with maps of the Adyar River Basin illustrating the locational aspects of these interventions.

### 4.9.1 Strategy 1: Flood-Aware Urban Planning and Land Use Recommendations

The strategy incorporates three key components to address flood risks in the Adyar Basin using flood-aware urban planning and land use recommendations. Component 1-1 focuses on delineating flood hazard areas with water depths exceeding 0.5m, spanning from downstream to upstream within the new Chennai Metropolitan Area (CMA). Components 1-2 emphasize keeping critical facilities away from these flood hazard areas to minimize risk and enhance safety. The spatial distribution of this strategy and its components across the Adyar Basin is shown in the figure below.

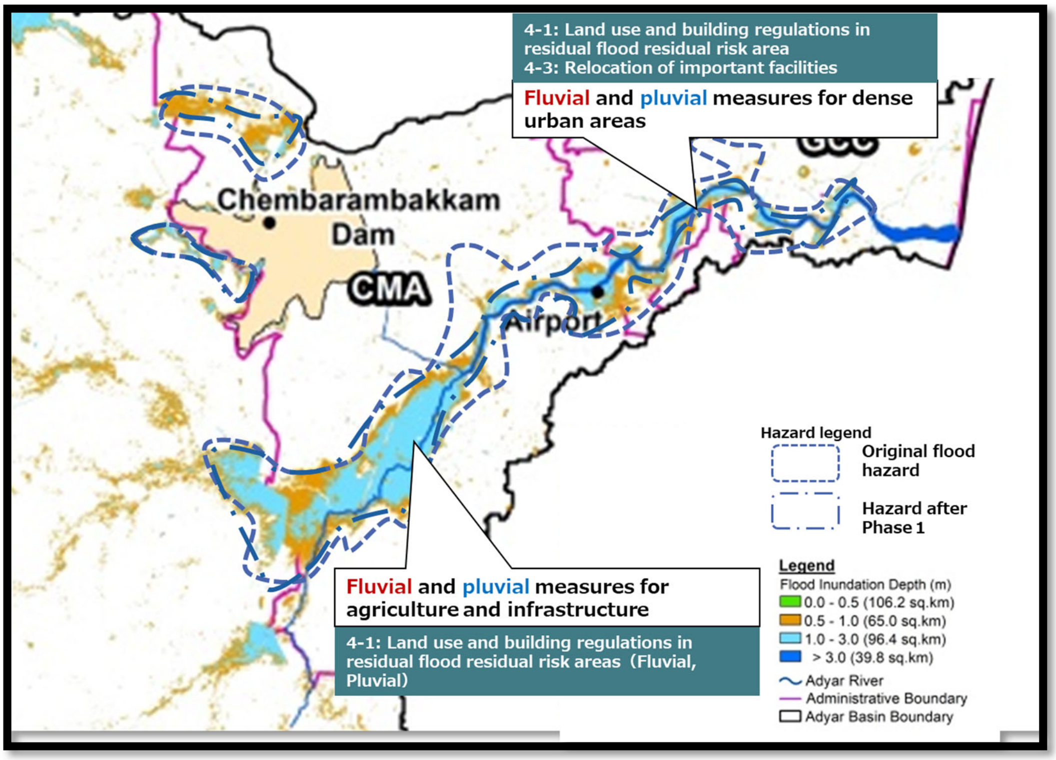



*Source: JICA Expert Team*

**Figure 4-8: Flood-Aware Urban Planning Strategies in the Adyar Basin (Pre-MP Project)**

### 4.9.2 Strategy 4: Residual Risk Management Guidelines

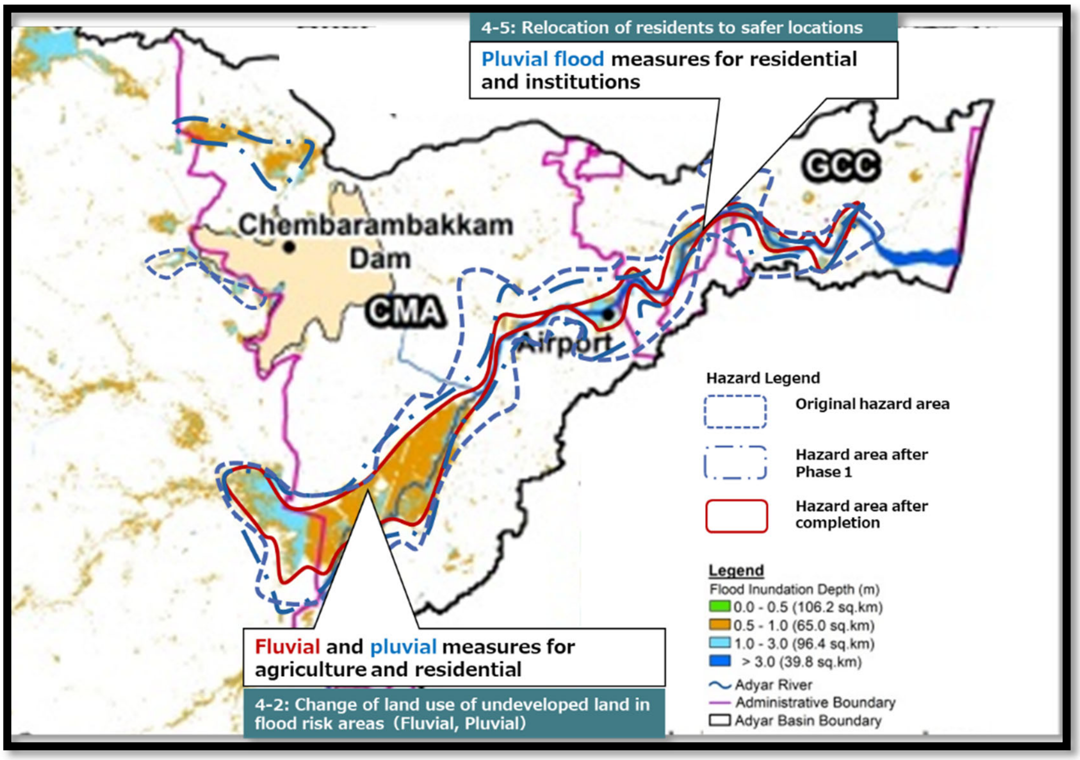
To address residual flood risk category 1 in flood-prone areas of Adyar Basin following the implementation of Phase 1 of the JICA Flood Control Master Plan, components 4-1 focus on implementing land use and building regulations, while components 4-3 involve relocating critical facilities to safer locations. These measures aim to mitigate flood risks and enhance safety in affected areas. The spatial distribution of these strategies across the Adyar Basin is depicted in the following figure.




*Source: JICA Expert Team*

**Figure 4-9: Residual Risk Management Strategies after Phase 1 in Adyar Basin**

For flood hazard areas after the completion of the Master Plan, Strategy 4-2 proposes changing the land use of undeveloped areas in flood-prone regions, particularly in the upstream areas of the Chennai Metropolitan Area (CMA), to prevent further risk. Additionally, Strategy 4-5 focuses on relocating residents from vulnerable locations to safer areas within the Greater Chennai Corporation (GCC) to enhance community safety and resilience. The spatial application of these strategies across the Adyar Basin is illustrated in the following figure.



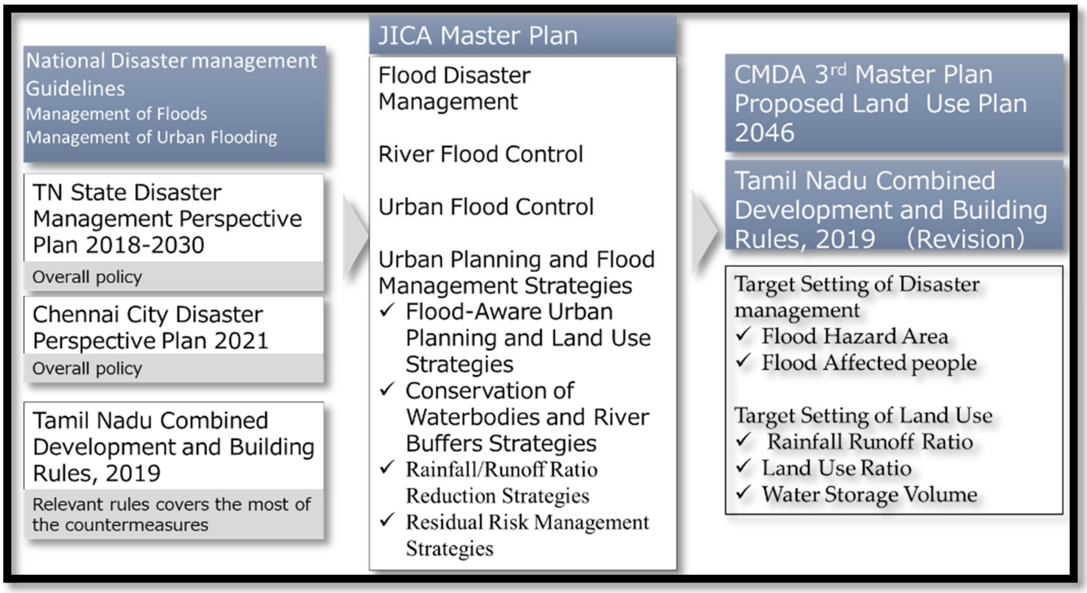

*Source: JICA Expert Team*

**Figure 4-10: Residual Risk Management Strategies after full implementation of MP**

### 4.10 Recommendations for Updating Local Guidelines and Regulations

The following section outlines recommendations for updating the local development and building regulations in Chennai to align with the flood management strategies and guidelines proposed by the JICA Flood Control Master Plan to be considered in the 3rd CMA Urban Development Master Plan. These updates aim to ensure that urban planning and development are resilient to flood risks, enhancing disaster risk reduction. The revisions will be integrated into existing frameworks, including the Tamil Nadu Comprehensive Building and Development Regulations (TNCBDR), and will address the evolving needs of urban growth while mitigating flood-related hazards. The following figure shows the process for the consideration of the JICA Flood Control Master plan in the relevant documents and guidelines.

The proposed changes focus on incorporating strategies for flood-prone areas, ensuring the safe relocation of critical facilities, and adjusting land use to better manage flood risks. These recommendations are aimed at improving both current and future urban development practices, providing a more comprehensive approach to managing flood risks in Chennai.




*Source: JICA Expert Team*

**Figure 4-11: Framework for the Application of Existing Land Use and Building Regulations in Chennai**

4.10.1 Development and Building Regulations in Chennai

The strategies and guidelines will be applied as part of the 3rd CMA Urban Development Master Plan and future disaster prevention initiatives by the Chennai Metropolitan Development Authority (CMDA). These will be enforced through government regulations and recommendations. The development regulations outlined in the Second Master Plan are already integrated into the Tamil Nadu Comprehensive Building and Development Regulations (TNCBDR). As a result, any necessary changes to these regulations, addressing future development and improvements to existing buildings, will be made either by amending the TNCBDR or through its annexes. The following Figure shows the framework for the application of Existing Land Use and Building Regulations in Chennai

4.10.2 Recommendations for the Comprehensive Building and Development Regulations

The table below compares the four flood management strategies for urban planning with the relevant sections of the current Tamil Nadu Comprehensive Building and Development Regulations (TNCBDR). Proposed amendments, which align with the suggested strategies, are highlighted in red as examples.

**Table 4-8: Adaptation of the Proposed Strategies to the Provisions of the TNCBDR**

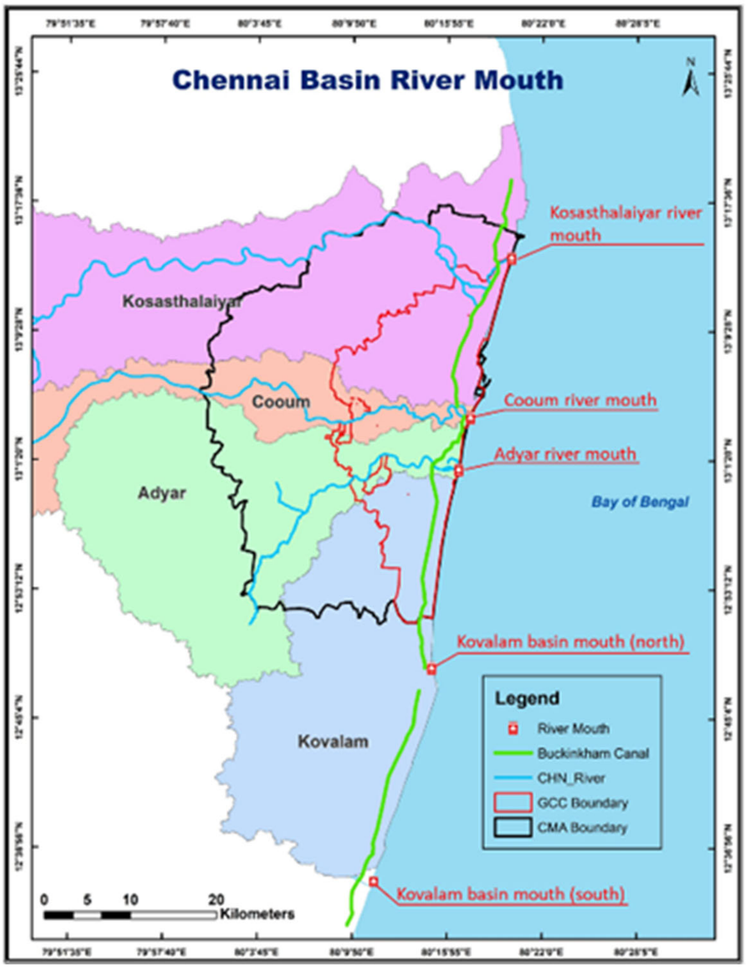
| JICA Expert Team Urban Planning Strategies | Tamil Nadu Development and Building Regulations (TNCBDR) |
|---|---|
| **Strategy 1: Flood-Aware Urban Planning and Land Use**<br><br>Components 1-1: Identification of Flood Hazard Areas<br><br>Component 1-2: Critical Facilities to be Away from the Flood Hazard Areas | **9. Inspection, Appendix XVII: Development Prohibited or Restricted Areas:**<br>(11) Aquifer Recharge Area<br>(12) Catchment Area (Only for CMA)<br>(13) Pallikaranai Wetland Area (Only for CMA)<br>✓ the JICA Flood Control Master Plan Proposal: 100-year return period flood or the largest flood in the past within the new CMA. Areas where flooding water depth is likely to be 0.5m or greater will be designated as flood hazard areas, and hazard maps will be published.<br>✓ the JICA Flood Control Master Plan Proposal: Target area: flood hazard areas for 100-year return period flood within the new CMA.<br>Not to establish key public facilities (e.g., military forces, industrial facilities, hospitals, lifelines, stations, commercial facilities, etc.) wherever possible. |
| **Strategy 2: Conservation of Waterbodies and River Preservation Framework**<br><br>Component 2-1: Conservation of Tanks and Rivers | **27. Requirement for site approval**<br>**(1) Location of Buildings**<br>Every person who constructs, reconstructs, or alters or add a building shall, whenever the site is within 15 meters of any tank, reservoir, watercourse, river, freshwater channel, or well, carry such measure as may be necessary or as the executive authority may direct, to prevent any contamination of or any risk of the drainage of building passing into such tank, reservoir, water-course, river, freshwater channel or well such other rules in force.<br>✓ the JICA Flood Control Master Plan Proposal:<br>1. For rivers, a 15-30-meter preserved zone will be established on both sides of the current riverbank and indicated on the land use map.<br>2. For canals, as separately indicated, a preserved zone of 1 to 15 meters will be established on both sides of the canal embankment based on the flow rate and shown on the land use map.<br>3. For lakes and ponds, the boundaries of the preserved zone will be clearly defined by the topography, access roads, and embankments. |

*Source: JICA Expert Team*

# Chapter 5. River Mouth and Coastal Flood Management

## 5.1 Existing Situation and Ongoing Activities

Chennai is a coastal city located on the Bay of Bengal, and all four major basins considered for the formulation of a comprehensive flood control master plan in urbanized basins of Chennai have outlets in the Bay of Bengal as in the Figure 5-1. As such, it is crucial to study their current conditions, and ongoing plans by the concerned authorities, and propose necessary supplementary countermeasures to ensure the proper functioning of river mouth openings during flood events and prevent blockages due to river or coastal sedimentation. The current conditions of these basins, along with ongoing plans by the relevant authorities, were studied to identify necessary supplementary countermeasures. This chapter reviews the existing Coastal Management Plan, analyses changes in river mouths and shorelines, and evaluates shoreline dynamics along the estuaries of the four rivers and the Chennai Metropolitan Area coastline. This analysis is crucial for the development of a comprehensive flood control master plan.

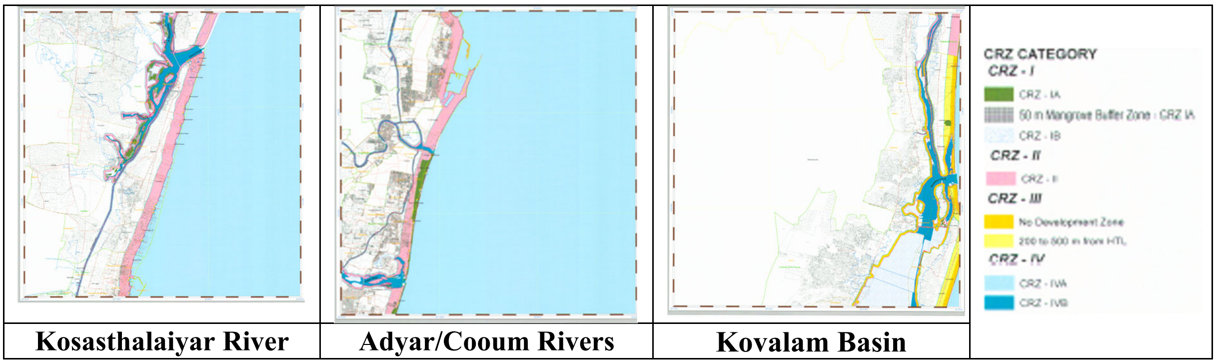



*Source: JICA Expert Team*

**Figure 5-1: Target River/Basin Mouths and Surrounding Beaches**

### 5.1.1 Coastal Zone Management Plan (CZMP) in Chennai

The Government of India has issued the Coastal Regulation Zone (CRZ) Notification (2019) to protect the coastal environment and regulate development activities in coastal areas. Under this notification, coastal areas are categorized into four zones (CRZ-I, CRZ-II, CRZ-III, CRZ-IV), which are defined to promote sustainable development. CZMPs based on CRZ notification (2011) have been published, and draft CZMPs based on CRZ notification (2019) have been published.




Note: CRZ-I (ecologically sensitive), CRZ-II (built-up area), CRZ-III (Rural area), CRZ-IV (water area which includes the water areas up to 12 Nautical miles (Nm) of the territorial waters and the tidal influenced water bodies.)

*Source: COASTAL ZONE MANAGEMENT PLAN MAPS 2011, NCSCM*

**Figure 5-2: CZMP MAP**

### 5.1.2 Projects for Beach Erosion Prevention

#### 5.1.2.1. Situation of Beach Erosion and Sedimentation

The Chennai City coastal region (Thiruvallur, Chennai, and Kancheepuram) boasts vast stretches of sandy terrain, including the popular Marina Beach, which serves as a hub for both fishing and recreational activities. Although the coastline remains generally stable, the north side of Chennai Port has experienced some erosion, while a slight erosion trend can be observed south of the Adyar River.

#### 5.1.2.2. Current Coastal Erosion Prevention Measures

The shoreline stretching from the south of the Kosasthalaiyar River Mouth to the north of Chennai Harbor is experiencing erosion, which leads to wave overtopping and further damage during high waves. To address this issue, rubble mound stone walls were constructed along this section between 1991 and 2003, covering approximately 10 km. In addition, between 2004 and 2019, the Tamil Nadu Water Resources Department (TNWRD) and Tamil Nadu Road Development Corporation (TNRDC) built around 30 jetties. The Fisheries Department also constructed about 15 groynes from 2016 to 2019 along the section from the mouth of the Kovalam Basin to Sulerikattu Kuppam. Due to severe erosion at Mamallapuram, a new plan combining groynes and beach nourishment using geo-synthetic tubes was developed.

While these measures, such as groynes and beach nourishment, are intended to mitigate coastal erosion, new structures like training walls, particularly at the Kosasthalaiyar and Cooum estuaries, are also being constructed. These structures can disrupt the natural longshore sediment transport, potentially leading to further erosion. Therefore, it is essential to monitor changes in the sand beaches over time to evaluate the impacts of these new structures. If new erosion is observed, countermeasures such as sand bypassing should be considered to restore the longshore sediment balance over a wider area.

### 5.1.3 Current River Mouth Blockage Prevention Measures and Flood Control Master Plan

All four target river Mouths have river mouth clogging caused by sandbars. The clogging causes deterioration of water quality in river mouths during the dry season and may cause a reduction in flood discharge capacity during the monsoon season. In three basins other than the Adyar, training walls have been constructed as a measure to prevent river mouth clogging, and new training walls are currently under construction on the Kosasthalaiyar and Cooum rivers. In terms of the project's objective of the JICA Flood Control Master Plan, measures to prevent river mouth clogging are the most important as studied in this chapter.

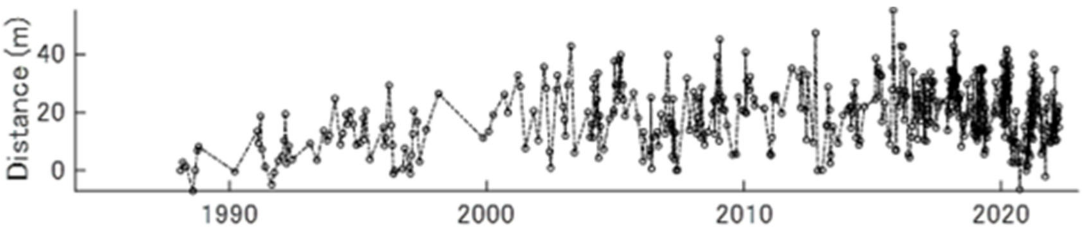
## 5.2 Analysis of changes in river mouths and shorelines

Recent shoreline changes have not yet been captured in the National Centre for Coastal Research (NCCR) study. It is recommended that monitoring continue to assess the most current conditions of the shoreline and estuaries, which is essential for the effective management of these areas in the future. Additionally, while shoreline and estuary monitoring has traditionally relied on digitizing shorelines from aerial and satellite imagery, there is an opportunity to enhance this process by utilizing more advanced digital technologies for greater efficiency.

5.2.1 Analysis of Changes in Shorelines Using Satellite Images

For the JICA Flood Control Master Plan, 42 transects in four regions were selected to analyze a time series of shoreline changes using satellite images spanning over 30 years. These regions include areas in the Kosasthalaiyar Basin (10 Transects), Adyar and Cooum Basins (10 Transects), north of the Kovalam Basin (11 Transects), and south of the Kovalam Basin (11 Transects). The results of the shoreline changes are presented as graphs, with each transect showing whether the shoreline is moving landward (toward the land) or seaward (toward the sea) over time.

An example of this study is provided for one of the transects in the Kosasthalaiyar Basin, located in the coastal area near Ramjan Mahal. The shoreline change data for each transect is plotted as a line graph to visualize the trends. In the graph, the upside shows moving seaward, while the downside shows moving landward.

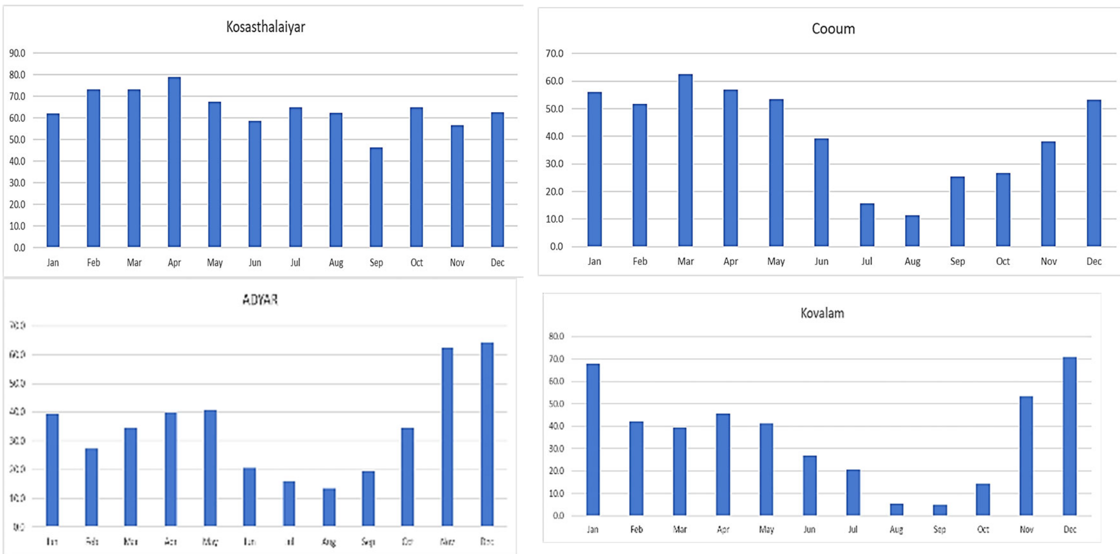



*Source: JICA Expert Team*

**Figure 5-3: Example of Analysis of Changes in Shorelines Using Satellite Images**

5.2.2 Analysis of Changes in River Mouths Using Satellite Images

Shorelines near estuaries were identified using the same methodology applied in the shoreline change analysis, with the narrowest river mouth widths calculated through AI-based analysis. The "river mouth width" refers to the width of the narrowest section of the estuary. Seasonal patterns emerged when the analysis results were categorized by month. River mouth widths typically widen after November due to the influence of the monsoon climate and narrow around August during the dry season as shown in Figure 5-4.

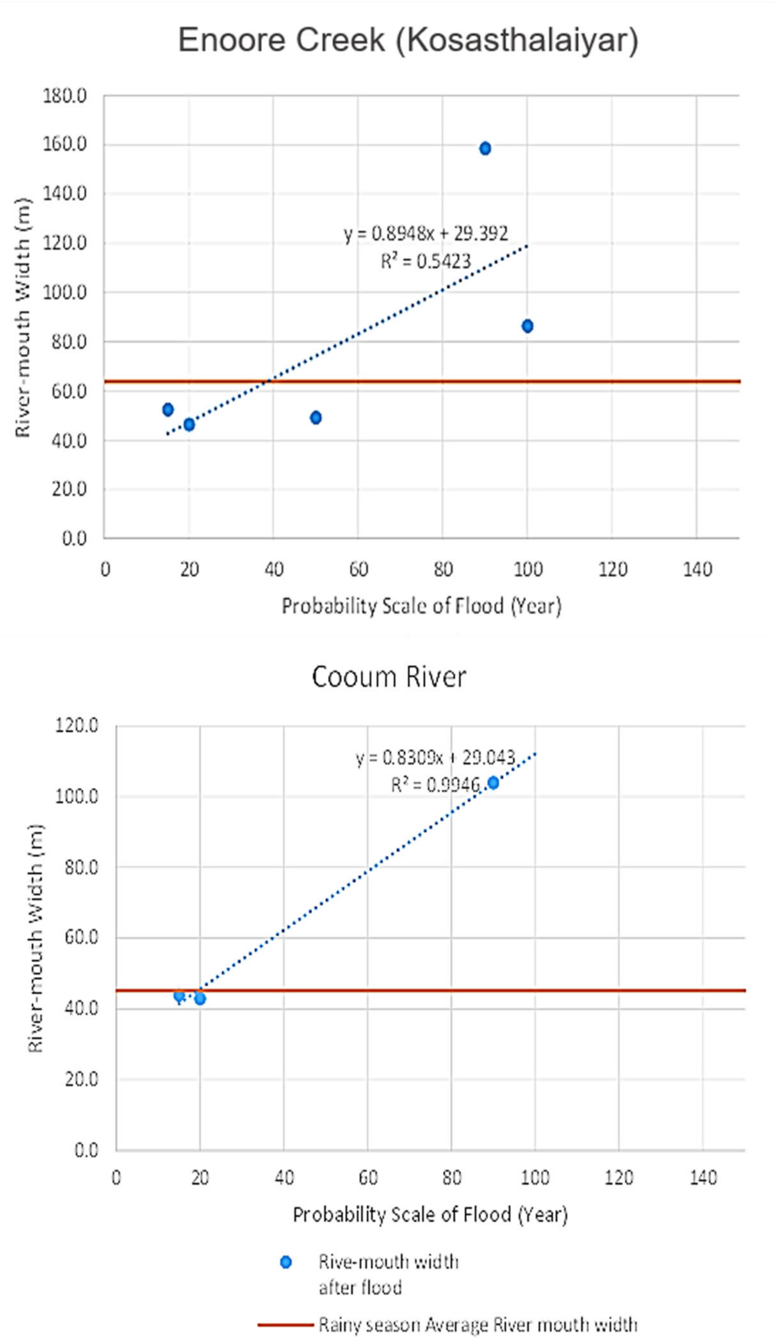



*Source: JICA Expert Team*

**Figure 5-4: Analysis of Average River Moth Width in Four Basins for 12 Months**

5.2.3 Analysis of the Relationship Between Flood Probability and Estuary Width

The relationship between estuary width and flood magnitude has been analyzed, revealing that larger floods tend to naturally flush and widen the river mouth bar. Notably, significant widening of the river mouth typically occurs during floods with a recurrence interval exceeding 50 years.



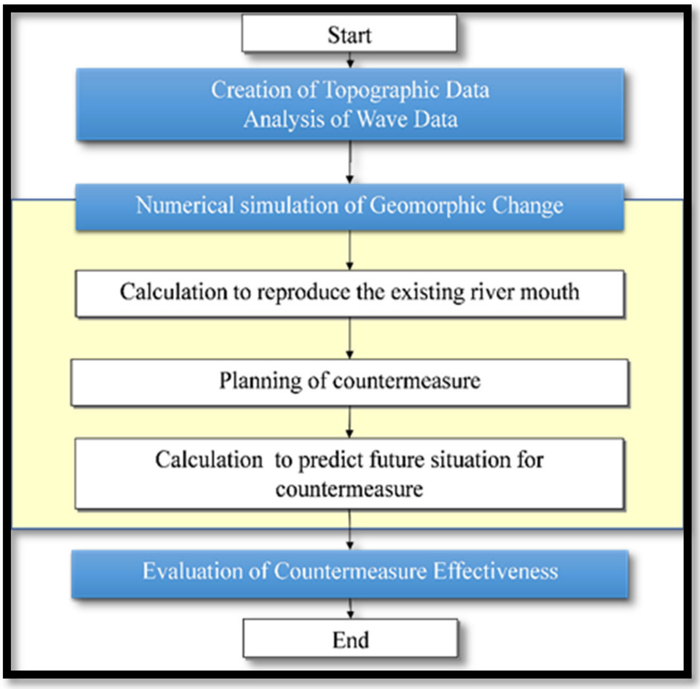

*Source: JICA Expert Team*

**Figure 5-5: Analysis of Estuary Width and Flood RPs (Kosasthalaiyar & Cooum)**

## 5.3 Proposed Measures to Prevent River Mouth Blockage

### 5.3.1 Analysis Method and Workflow

Figure 5-6 shows the workflow for addressing river mouth blockage. Initially, topographic data of the estuary for the target river is gathered to develop detailed river mouth topographic models. Next, wave transformation calculations are conducted to determine the external forces acting on the river mouth. These results are then incorporated as inputs into a three-dimensional beach deformation model to simulate the formation of sandbars at the river mouth. Using the numerical model refined through these simulations, predictive calculations are carried out to assess scenarios where proposed countermeasures are applied. Finally, the proposed measures are evaluated, and the most effective solutions are selected based on their performance in preventing river mouth blockage.




*Source: JICA Expert Team*

**Figure 5-6: Workflow of River Mouth Blockage Countermeasures**

### 5.3.2 Basic Policy and Proposed Measures for River Mouth Blockage Prevention

At present, various countermeasures, including the construction of training walls and jetties, as well as pre-monsoon dredging, have been implemented at the river mouths to prevent estuary blockages. Based on the river mouth characteristics and the causes of blockage outlined in the previous section, additional measures are proposed. Drawing from examples of river mouth blockage mitigation in Japan, three main approaches are considered: training walls (including jetties), dredging, and offshore facilities. The policies guiding countermeasure selection for each target river are outlined below:

#### 5.3.2.1. Kosasthalaiyar River Mouth

The Government of India has recently (2024) completed construction of the training walls at the river mouth, which is expected to address existing blockage concerns effectively.

#### 5.3.2.2. Cooum River Mouth

Similar to the Kosasthalaiyar River, the Government of India is undertaking the construction of training walls at the mouth of the Cooum River as a primary measure against estuary blockages.

#### 5.3.2.3. Adyar River Mouth

Investigations conducted by the Indian government have recommended maintenance dredging as the preferred approach for the Adyar River estuary. Unlike the Kosasthalaiyar and Cooum Rivers, the policy prioritizes preserving the estuary without employing hard structures like training walls.

#### 5.3.2.4. Muttukadu (North Kovalam)

While training walls are already in place at Muttukadu, the southern shoreline is progressively encroaching towards the base of the right bank training wall, undermining its effectiveness in controlling sediment movement and maintaining estuary stability. Currently, there are no plans for additional large-scale training walls in this area. A comparative study is proposed to evaluate two options: extending the training wall or continuing estuary maintenance through dredging. The objective is to develop a robust countermeasure plan that addresses shoreline advancement while preserving the function of the existing training wall.

### 5.3.3 Prediction of River Mouth Blockage and Mitigation Measures Evaluation

Using the basic policy and proposed countermeasures outlined in the previous section, predictive calculations were conducted through a numerical analysis model based on reproduced historical conditions. These forecasts assessed both the current government plans, such as training wall construction, and alternative measures (additional countermeasures) for all river mouths and estuaries. This synthesis report presents the case study of Muttukadu as an example.

#### 5.3.3.1. Muttukadu (North Kovalam)

Although a training wall exists at Muttukadu, the advancing southern shoreline is nearing the toe of the structure, compromising its effectiveness in managing sediment movement and maintaining estuary stability. Unlike the Kosasthalaiyar and Cooum Rivers, where large-scale training walls are being implemented, no such plans currently exist for Muttukadu. Therefore, a comparative study is planned to evaluate two scenarios: extending the existing training walls or maintaining the estuary through dredging. Based on this analysis, a countermeasure plan will be developed.

Figure 5-7 illustrates the proposed countermeasures under study. Different lengths of training wall extensions were examined, and sediment deposition within the light blue hatched area shown in the figure was evaluated for each scenario.


*Source: JICA Expert Team*

**Figure 5-7: Layout of Proposed Blockage Prevention Measures in Muttukadu**

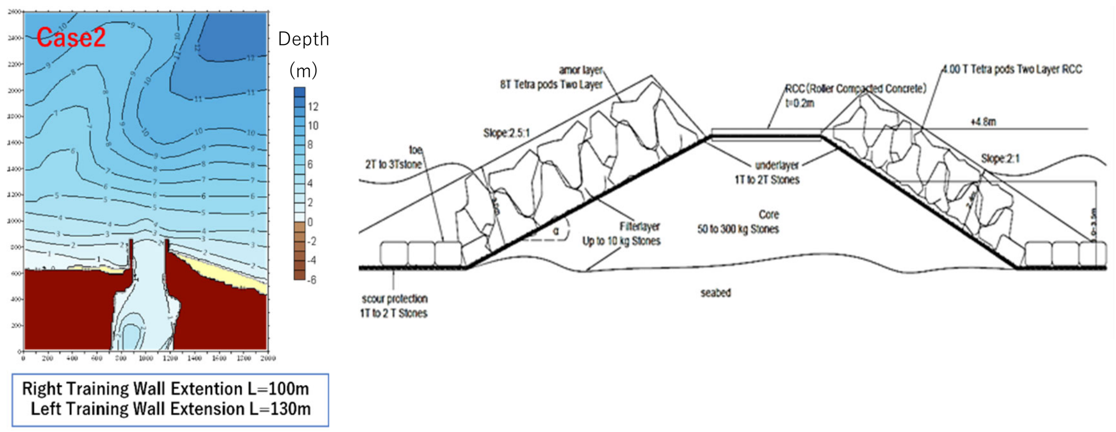
The sediment deposition at the river mouth is proposed to be managed through maintenance dredging. A cost comparison between constructing training walls and the maintenance dredging required for each proposed scenario is provided in Table 5-1. The analysis includes life cycle costs over 50 years, accounting for both dredging and the maintenance of the structures. The results indicate that Case 2 incurs the lowest overall expenditure among the options considered. Consequently, Case 2 has been selected as the most viable solution.

**Table 5-1: Comparison of the Cost of Each Proposed Countermeasure**

| Item | Notes | Present | Case1 | Case2 | Case3 | Case4 | Case5 |
|---|---|---|---|---|---|---|---|
| Extention of training wall(m) | Right bank | 0 | 100 | **100** | 150 | 200 | 350 |
| Length of training wall(m) | Right bank | 200 | 300 | **300** | 350 | 400 | 550 |
| Extention of training wall(m) | Left bank | 0 | 0 | **130** | 180 | 230 | 380 |
| Length of training wall(m) | Left bank | 200 | 200 | **330** | 380 | 430 | 580 |
| Deposition($m^3$/y) | | 16600 | 8100 | **4700** | 4600 | 4400 | 4300 |
| Erosin($m^3$/y) | | -1000 | -800 | **-800** | -700 | -500 | -400 |
| Net ($m^3$/y) | | 15600 | 7300 | **3900** | 3900 | 3900 | 3900 |
| **Cost** | | | | | | | |
| Construction Costs(IND) | | 0 | 61,993,600 | **142,585,300** | 204,578,900 | 266,572,500 | 452,553,300 |
| Maintenance fee for Structure(IND) | 50years | 0 | 15,498,400 | **35,646,400** | 51,144,800 | 66,643,200 | 113,138,400 |
| Dredging Costs(IND) | 50years | 378,300,000 | 177,025,000 | **94,575,000** | 94,575,000 | 94,575,000 | 94,575,000 |
| Shipping Costs(IND) | 50years | 176,292,000 | 86,022,000 | **49,914,000** | 48,852,000 | 46,728,000 | 45,666,000 |
| Disposition Costs(IND) | 50years | 0 | 0 | **0** | 0 | 0 | 0 |
| Total Costs(IND) | | 554,592,000 | 340,539,000 | **322,720,700** | 399,150,700 | 474,518,700 | 705,932,700 |
| Evaluation Result | | | 2nd | **1st** | 3rd | | |

*Source: JICA Expert Team*

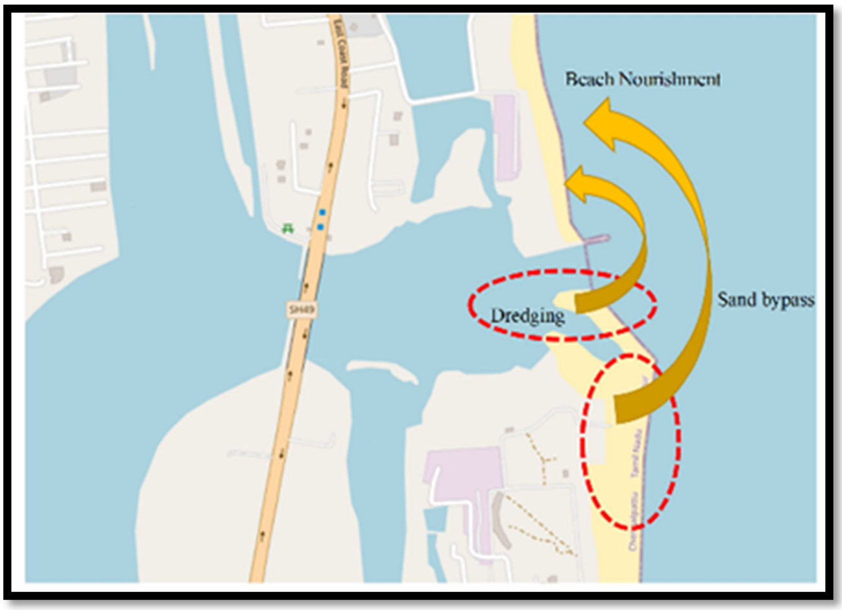
It should be noted that the unit construction cost estimates were derived from the expenses associated with the construction of training walls at the Cooum River. The standard cross-section of the proposed training walls is illustrated in Figure 5-8: Layout and Cross-Section of the Proposed Countermeasure in Muttukadu.




*Source: JICA Expert Team*

**Figure 5-8: Layout and Cross-Section of the Proposed Countermeasure in Muttukadu**

If the training walls are extended, erosion is anticipated on the northern side of the beach, located downstream of the sand drift. To mitigate this, it is recommended that all sediment dredged during maintenance be utilized to replenish the sandy beach on the northern side. Additionally, when significant sand accumulation occurs on the southern beach, implementing a sand bypass is advised. This process would involve transferring the sediment from the southern side to the northern beach to support beach nourishment. Figure 5-9 illustrates the maintenance process for dredged material transport and sand bypass operations.




*Source: JICA Expert Team*

**Figure 5-9: Beach Nourishment Strategy**

# Chapter 6. Flood Disaster Management (Before, During and After)

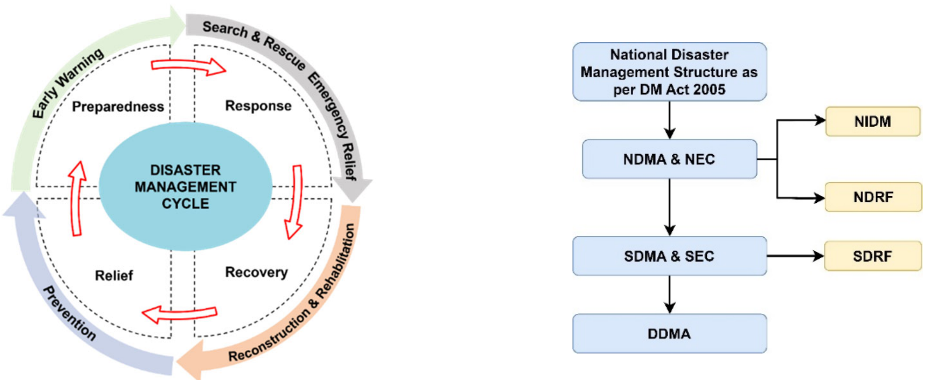
## 6.1 Introduction

Effective flood disaster management requires a comprehensive approach before, during, and after flood events. Before a flood, it is crucial to implement mitigation and preparedness strategies. During a flood, the focus shifts to response actions to ensure safety and minimize damage. After a flood, recovery efforts are paramount. This involves assessing and repairing infrastructure, supporting affected individuals, and implementing measures to prevent future flooding. This chapter examines Chennai's existing flood disaster management framework, highlighting institutional arrangements, policy gaps, and the challenges that have contributed to significant damage during past events. Drawing on best practices from Japan, it proposes tailored recommendations to enhance flood management before, during, and after floods. Importantly, the suggested measures aim to complement and build upon the ongoing efforts of local authorities, fostering a more resilient and effective system for mitigating flood risks in Chennai.

## 6.2 Overview of Existing Policies, Plans, and Institutional Arrangements

### 6.2.1 Disaster Management for National Level

The Disaster Management Act, of 2005 led to the creation of the National Disaster Management Authority (NDMA) at the national level to oversee disaster management in India. At the state level, the State Disaster Management Authority (SDMA), chaired by the Chief Minister, is responsible for policy formulation, planning, and coordination. The Tamil Nadu State Disaster Management Authority (TNSDMA) operates similarly in Tamil Nadu, with the Chief Secretary serving as the Chief Executive Officer. District Disaster Management Authorities (DDMAs), led by District Collectors, play a crucial role at the local level. The following figure shows the shows disaster management structure based on the DM Act, of 2005 institutional and coordination mechanisms at the National, State, District, and local levels.




*Source: JICA Expert team using - TNDRRA data and NDMA Act 2005*

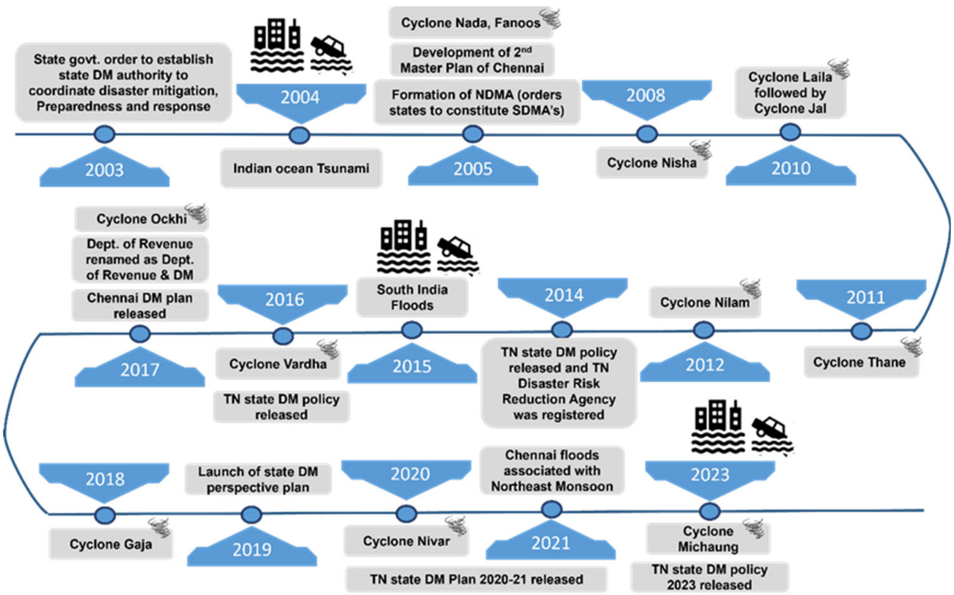
**Figure 6-1: Practice and Structure of Disaster Management System**

### 6.2.2 Disaster Management for Tamil Nadu State and Chennai District

Figure 6-2 shows the timeline of flood witnessed and strategies and policies implemented in the due time and Figure 6-3 shows the Tamil Nadu State Disaster Management Agency (TNSDMA) structure that is responsible for policy formulation, approval of state disaster management plan, and monitoring all functions of Disaster Management. The following is a list of the available policy frameworks and other related documents on disaster management for Tamil Nadu State and Chennai District reviewed in this study:

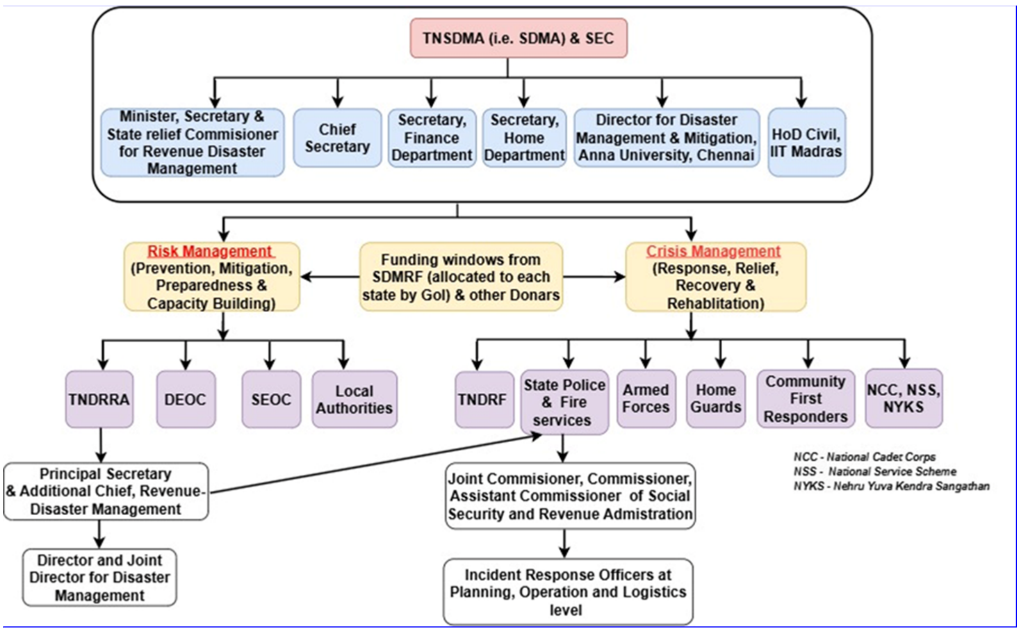
- Tamil Nadu State Disaster Management Policy (2023)
- Tamil Nadu State Disaster Management Plan
- Tamil Nadu State Disaster Management Perspective Plan (2018-30)
- District Disaster Management Plan
- Chennai City Disaster Management Perspective Plan (2019-2030)

- Advisory Committee Report on Flood Risk (March 2023)
- Vision Tamil Nadu 2023




*Source: JICA Expert Team*

**Figure 6-2: Timeline of Tamil Nadu's Key Hazard Events and Disaster Management Policies**




*Source: JICA Expert Team based on NDMA Act 2005*

**Figure 6-3: Disaster Management Structure at State-Level**

### 6.2.3 Disaster Management and Emergency Operation Control Room in Chennai

The old State Emergency Operation Center (SEOC) in Tamil Nadu used to play a crucial role in emergency operations including flood disaster management by receiving and issuing warnings, coordinating emergency activities, and monitoring disaster situations. Established to provide continuous support during disasters, the SEOC operates 24/7, particularly during the monsoon season, where engineers are stationed to collect and respond to disaster management data. The newly established SEOC was inaugurated in August 2024 as part of Tamil Nadu's larger strategy for disaster management.

The Greater Chennai Corporation (GCC) has implemented the Integrated Command and Control Center (ICCC) to centralize the management of city-wide data, including weather, waterways, and pollution. This center aims to enhance flood management by integrating a real-time flood forecasting system under development using the World Bank fund by TNUIFSL. With an array of flood sensors and cameras, the ICCC can monitor key city areas and provide early warnings about potential floods. However, the system is still being expanded to improve its forecasting capabilities, including rainfall prediction at the district level and the monitoring of critical lakes and rivers.

## 6.3 Past Major Floods and Current Flood Disaster Management Plans

### 6.3.1 Past Major Flood Events

Chennai experiences two main monsoon seasons: The southwest monsoon (June to September) and the northeast monsoon (October to December). The rainfall during the Northeast Monsoon can be intense, sometimes leading to flooding.

Notable floods occurred in 1943, 1976, 1985, 1991, 1996, 1998, 2002, 2005, 2008, 2015, 2020, 2021, and 2023. Among these, the flood in 1996 was caused by the Southwest Monsoon and occurred in mid-June. The rest of the major floods were all due to the Northeast Monsoon and took place between October and December. The table below summarizes these flood events, their dates, daily maximum rainfall, and a brief overview of the damages.

Table 6-1 (repeated from Chapter 1) summarizes significant flood events from 1976 to 2023. It has been rewritten from Chapter 1 here for easier reference and clarity.

**Table 6-1: Past Major Flood in Study Area (Repeated from Chapter 1, Table 1-5)**

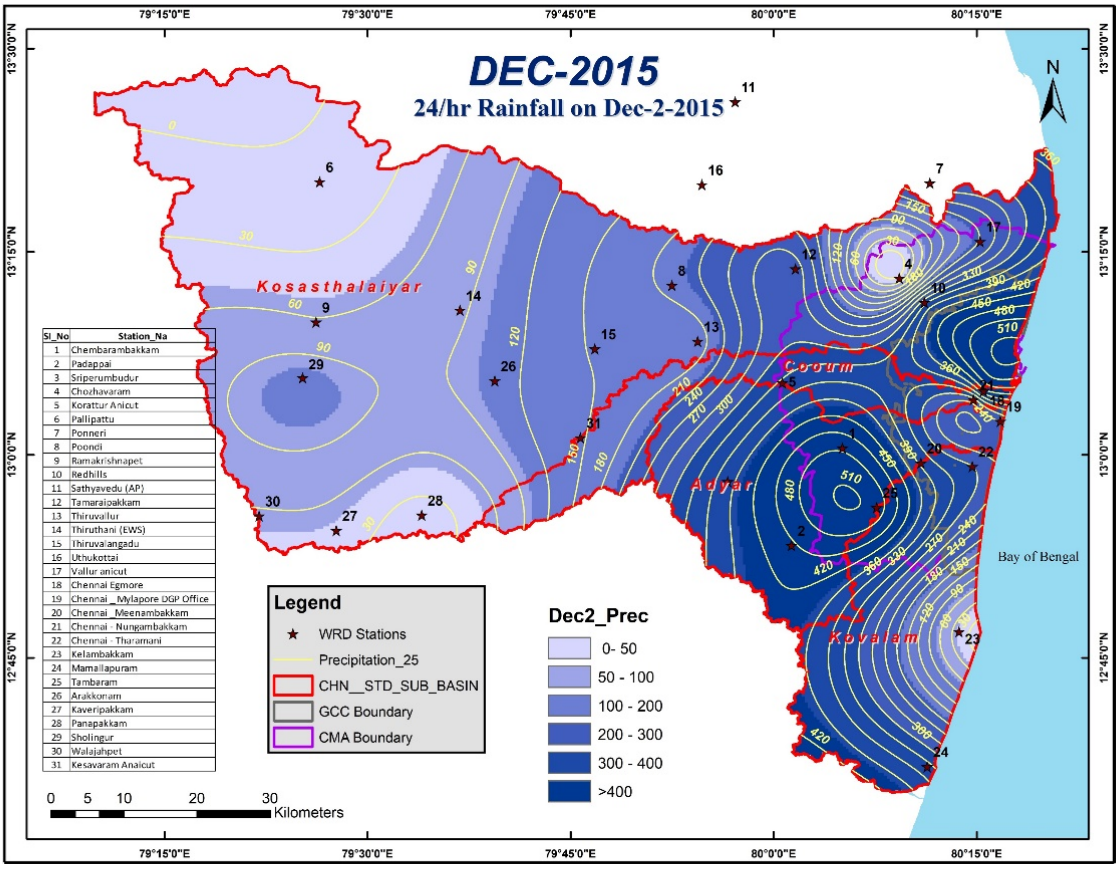
| Flood Year | Type of Flooding | Daily Max. Rainfall (mm) | Date of Daily Max Rainfall | Total Rainfall During Monsoon (mm) |
|---|---|---|---|---|
| 1976 | Primary Fluvial | 452.4<br>Nungambakkam | 11/25/1976 | 1264.5 (Meenambakkam) |
| 1985 | Fluvial & Pluvial | 329.0<br>Nungambakkam | 11/13/1985 | 1271.7 (Nungambakkam) |
| 1996 | Fluvial | 450.0<br>Cholavaram &Thamaripakkam<br>347.0<br>Nungambakkam | 6/14/1996 | 1704.6 (Nungambakkam) |
| 2005 | Fluvial & Pluvial | 312.0<br>Tambaram | 12/13/2005 | 2108.0 (Nungambakkam) |
| 2015 | Fluvial & Pluvial | 494.2<br>Tambaram<br>475.0<br>Chembarambakkam | 12/2/2015 | 2066.9 (Tambaram) |
| 2021 | Primary Pluvial | 237.1<br>Mylapore - DGP Office | 12/31/2021 | 1816.0 (Cholavaram)<br>1785.0 (Mylapore) |
| 2023 | Fluvial & Pluvial | 293.4mm<br>Nungambakkam | 12/4/2023 | 921.4 (Nungambakkam) |

*Source: Advisory Committee on Mitigation and Management of Flood Risk in Chennai Metro "Flood Risk Reduction: Final Report, "2023, originates from the work conducted by the SECON-JBA Study Team in 2021*

### 6.3.2 Details of the 2015 Flood

The 2015 Chennai floods, one of the most devastating floods in the city's history, were triggered by an exceptionally intense Northeast Monsoon, which resulted in widespread flooding across the city and its surrounding areas. The flooding began in early November 2015, with the most severe impacts being felt between November 28 and December 2, 2015. The city received continuous and heavy rainfall, with the total amount of precipitation recorded in Chennai during the monsoon season being 2,066.9 mm at Tambaram and 1,785 mm at Mylapore. This was significantly higher than the city's average annual rainfall.

Figure 6-4 illustrates 24-hour rainfall isohyets on December 2, 2015. It is evident from the figure that the Adyar basin received a substantial amount of rainfall. Following an exceptionally wet month in November 2015 with a few extreme rainfall events, the period from December 1 to 4, 2015, witnessed an unexpected rainfall that caught the city off-guard and led to significant damages.




*Source: JICA Expert Team using WRD Stations*

**Figure 6-4: 24/hr Rainfall Isohyets on 2nd December 2015**

The total estimated economic losses in the state of Tamil Nadu were approximately Rs 14,602 crore (about USD 2.2 billion in 2015), with Chennai being the hardest-hit region. The floods also led to long-term environmental consequences, as water bodies, including rivers and lakes, were heavily polluted with debris, sewage, and industrial waste.

The 2015 Chennai floods highlighted the vulnerability of the city to extreme weather events and underscored the need for better urban planning, flood control measures, and infrastructure resilience. Since then, the government and various organizations have focused on improving flood management strategies, such as better drainage systems, flood forecasting, and the strengthening of reservoirs to reduce the risks of future floods.

The key question is what contributed to the significant flood damage in 2015, making it one of the most catastrophic flood events in Chennai's history? The same question applies to the extensive flood damage in 2020, 2021, and 2023. The damage seems to be not only a result of heavy rainfall but also due to inadequate flood disaster management before, during, and after the event. It is crucial to identify what went wrong to improve future flood management strategies. It's worth noting that some of these changes have already been addressed by Tamil Nadu's Disaster Risk Reduction Authority (TNDRRA) or Chennai's District Disaster Management (Chennai DDM) authorities. However, greater emphasis on comprehensive disaster management across different phases is necessary.

### 6.4 Comprehensive Gap Analysis of Flood Disaster Management in Chennai

Chennai has faced recurrent flood disasters over the past decade, with major events occurring in 2015, 2020, 2021, and 2023. These floods have caused extensive devastation, disrupting lives, livelihoods, and critical infrastructure. Each incident has exposed systemic shortcomings in flood disaster management, including preparedness, response, and recovery efforts. This analysis identifies these gaps, drawing on specific case studies and detailed explanations, to provide actionable insights for improvement. The findings are based on a thorough review of past flood events and interviews with flood disaster managers from local authorities in Chennai as follows:

- Lack of Flood Hazard Mapping
- Inadequate Early Warning Systems (EWS)
- Lack of Evaluation and Updating Standard Operating Procedures (SOPs)
- Fragmented Command and Control and Uncoordinated Inter and Intra-Agency Efforts
- Poor Drainage Infrastructure Operation and Maintenance
- Emergency Dams and Waterbodies Operation Protocols:
- Insufficient pre-positioning of Resources, Shelter Management, and Livelihood Protection
- Improper Flood Mitigation Practices and Construction of Temporary Barriers
- Post-Flood Damage Assessment

### 6.5 Proposals to Improve Flood Disaster Management

To enhance flood preparedness, the first and most critical step is raising awareness about flood risks among residents and stakeholders. This includes educating the public on the dangers of flooding, such as the difficulty of walking in water depths of 50 cm or flow velocities of 50 cm/s, which can pose significant risks to personal safety. Drawing from domestic and international examples, it is essential to communicate these risks in a tangible and relatable manner, moving beyond abstract assumptions to create a sense of urgency and realism. By incorporating these details into flood hazard maps, public awareness campaigns, and community training programs, residents will be better equipped to understand the dangers and take appropriate actions during flood events. This approach aligns with the broader goals of improving flood risk communication and ensuring that preparedness efforts are grounded in practical, real-world scenarios.

Based on the gap analysis and examination of challenges in flood disaster management during past major floods in Chennai, this section outlines proposals to enhance flood management before, during, and after flood events. These proposals are designed to improve preparedness, response, and recovery efforts, addressing identified weaknesses and strengthening the city's resilience to future floods. Table 6-2 and Table 6-3 Provide a comparison of the current situation with the improved future situation, organized according to the disaster cycle (before, during, after) and the proposed actions to address gaps. The tables also highlight the priority levels for each action.

# Table 6-2: Current Situation and Proposed Action for the Improvement (Before Flood)

| Proposals for Improving Flood Disaster Management in the Future | | | | | | Current Situation of Flood Disaster Management and Gaps | | |
|---|---|---|---|---|---|---|---|---|
| **Disaster Cycle** | **Activities** | **Priority** | **Improved Situation** | **Main Agency** | **Operation Agency** | **Phase** | **Response details** | **The Existing Situation** |
| **Before Flood Disaster (Preparedness and Flood Disaster Prevention)** | Flood Hazard Map | High | Flood hazard maps are created and made public | TNDRRA | TNDRRA | **Before Flood Disaster (Preparedness and Flood Disaster Prevention)** | Flood Hazard Map | Flood hazard maps are not available to public and officials |
| | | | Residents will be able to understand flood hazard maps and take action | TNDRRA | TNDRRA | | | Residents lack awareness of flood hazards |
| | | | Consensus among the CPs to use unified flood hazard maps | TNDRRA | DDRRA | | | Hazard map requirements vary for each CPs |
| | | | Flood hazard maps for different probability years (e.g., 1/10 and 1/100) | TNDRRA | DDRRA | | | Inland flood maps (1/10 probability) are needed |
| | | | Disaster risk and evacuation info will be shared online | TNDRRA | DDRRA | | | Disaster risk and evacuation information are limited; digitalization lags |
| | Disaster Management Plan | Med | State plan will be revised based on situation and included in the urban master plan | TNDRRA | CMA Municipality | | Disaster Management Plan | Disaster plans lack reflection of actual situations |
| | | | Disaster prevention and evacuation follow SOPs and the actual situation | TNDRRA | CMA Municipality | | | Local disaster prevention measures at the district level are inadequate |
| | Disaster Management Center | Med | Relocate to a higher elevation to improve safety in flood and Tsunami | TNDRRA | TNDRRA | | Disaster Management Center | The old one was established after the 2015 flood and renewedg. 2024 |
| | | | Continues improvement of the command center to improve safety against fire | TNDRRA | TNDRRA | | | A command centre in the fist floor is unsafe for flood and Tsunami |
| | | | Backup communication systems for power loss (Satellite disaster digitalization) | TNDRRA | TNDRRA | | | Human damage assessments and communication rely solely on phones/Internet |
| | | | Flood disaster forecasting and warning systems will be fully digitized | TNDRRA | TNDRRA | | | Disaster warning systems are insufficient |
| | Preventive Countermeasures | Med | Improve river and drainage flow capacity | TNWRD | TNWRD | | Preventive Countermeasures | Downstream river improvements and drainage capacity are lacking |
| | | | Improve dam operation rules and dam warning systems to reduce flood damage | TNWRD | TNWRD | | | Low awareness of the emergency dam releases risk |
| | | | Developing integrated SWD | TNWRD GCC | GCC | | | Inadequet SWD and scattered drainage |
| | | | Removing blockage due to solid waste disposal and bushes, etc. | TNWRD GCC | GCC | | | Solid waste and vegetation are blocking drainage systems. |
| | | | Missing links for tanks and water bodies will be restored | TNWRD GCC | GCC | | | Missing links leading to poor drainage in several areas |
| | Business Continuity Plan | Med | Companies will develop disaster prevention plans to enhance DRR capabilities | TNDRRA TNMoI | TNDRRA TNMoI | | Business Continuity Plan | More companies are now formulating plans after 2015 floods, but still insufficient |
| | Weather Observation and Accurate Forecast | High | Weather forecasts and warning systems have been improved and integrated | TNIMD | TNIMD TNDRRA | | Weather Observation and Accurate Forecast | Prediction accuracy is low with poor coordination in warnings |
| | | | Weather radar functionality will be upgraded for better rainfall accuracy | TNIMD | TNIMD | | | S-band radar lacks sufficient rainfall forecasting capability |
| | | | Observation stations will be increased and improved based on river basin size | TNIMD | TNIMD | | | Poorly-gauged basins |
| | Risk Communication (Prevention Capacity) | Med | Public awareness and training in schools enhance preparedness | TNDRRA | CMA GCC | | Risk Communication (Flood Disaster Prevention Capacity) | Residents lack awareness of flood risks |
| | | | Informing risk areas of dam emergency discharge, proper warnings and evacuation | TNWRD | CMA GCC | | | No designated dam discharge danger zones; risk education is lacking |
| | | | Better understanding and improvement in action for flood risk | TNDRRA | TNDRRA | | | Flood risks are poorly understood, with weak cooperation between states and cities |
| | | | Evacuation facility shortages will be addressed, and hygiene improved | TNDRRA | TNDRRA | | | Evacuation facilities face operational and quality issues |
| | | | Digital flood risk information will be accessible | TNDRRA | TNDRRA | | | Insufficient risk information during floods |
| | Risk Communication (Training for | High | Enhanced technical training for disaster management and more skilled experts | TNDRRA TNDRF | DDRRA DDRF | | Risk Communication (Training for | Insufficient disaster management training for engineers |
| | | | DDRF teams will gain flood response expertise for local activities | TNDRRA TNDRF | DDRRA DDRF | | | Lack of flood response training for engineers |
| | Risk Communication (Public Training) | High | DRRA will collaborate with DRF-led training to improve effectiveness | TNDRF | DDRF | | Risk Communication (Public Training) | Few evacuation drills with resident participation |
| | | | Disaster leadership will ensure gender-neutral relief, prioritizing vulnerable groups | several | several | | | Rescue plan excludes gender and special needs |
| | | | Better access to information through disaster prevention digitization | TNDRF | DDRF | | | Residents unaware of available information sources |

*Source: JICA Expert Team*

# Table 6-3: Current Situation and Proposed Action for the Improvement (During and After Flood)

**Proposals for Improving Flood Disaster Management in the Future**

| Disaster Cycle | Activities | Priority | Improved Situation | Main Agency | Operation Agency |
|---|---|---|---|---|---|
| During Flood Disaster (Emergency Response and Mitigation) | Flood Early Warning | Med | Reliable communication using dedicated staff and departments | TNDRRA | Municipality |
| | | | Multiple communication methods: Mass media, internet, and analog systems | TNDRRA | Municipality |
| | | | Establishment of Cell phone aert, disaster radios, and bulletin boards | TNDRRA TNWRD | GCC Municipality |
| | Evacuation Order and Coordination | Med | Clear evacuation advisory and instruction criteria | TNDRRA TNDRF | TNDRRA TNDRF |
| | | | Development of media platforms for disaster updates | TNDRRA TNMCIT | TNDRRA TNMCIT |
| | | | Training local disaster leaders and providing communication tools | TNDRRA TNDRF | GCC Municipality |
| | Rescue and Relief | Med | State-local government cooperation for rapid disaster information collection | TNDRRA TNDRF | DDRRA DDRF |
| | | | Collaboration of the public sectors for infrastructure damage reporting | TNDRRA TNWRD | GCC Municipality |
| | | | Policy prioritizing vulnerable groups during disasters | several | several |
| | | | Flood rescue and relief updates shared via various media | TNDRRA | TNDRRA |
| | | | TNDRF conducts rescue operations based on community damage reports | TNDRF | DDRF |
| After Flood Disaster (Emergency Support, Recovery, and Reconstruction) | Supporting Affected People | High | Plans for rebuilding disaster-affected homes and temporary housing quickly | MHA TNDRRA | MHA DDRRA |
| | | | Utility operators (water, gas, electricity, transport) promptly schedule recovery | TNDRRA | several |
| | | | Implement support measures prioritizing vulnerable groups | several | several |
| | | | Emergency supplies with disaster prevention warehouses and home kits | TNDRF MCAFPD | TNDRF MCAFPD |
| | | | Provide digital information on victim support, evacuation facilities, etc. | TNDRRA | TNDRRA |
| | | | Fair evacuation systems addressing disparities and supporting the poor | TNDRF CWC | TNDRF CWC |
| | Urgent Infrastructure Reconstruction | High | Collaboration for rapid emergency infrastructure repairs | TNWRD | TNWRD |
| | | | Speed up desilting operations after heavy rainfall | TNWRD | GCC Municipality |
| | | | Enhance flooded area drainage with portable pumps | TNWRD | GCC Municipality |
| | | | Accelerate restoration of damaged roads and drainage systems | CMA GCC | CMA GCC |
| | Emergency Budget | Med | Establish a fast financial support system for disaster response | MOF | MOF |
| | | | Improve risk management, introduce insurance, and create DRR benefit systems | MOF | MOF |
| | Recovery and Reconstruction Plans | Med | Develop reconstruction plans based on ground realities and flood countermeasures | TNDRRA | TNDRRA |
| | | | Upgrade disaster prevention centers and welfare facilities | MHA TNDRRA | MHA DDRRA |
| | | | Facilitate and support area reconstruction efforts | several | several |

**Current Situation of Flood Disaster Management and Gaps**

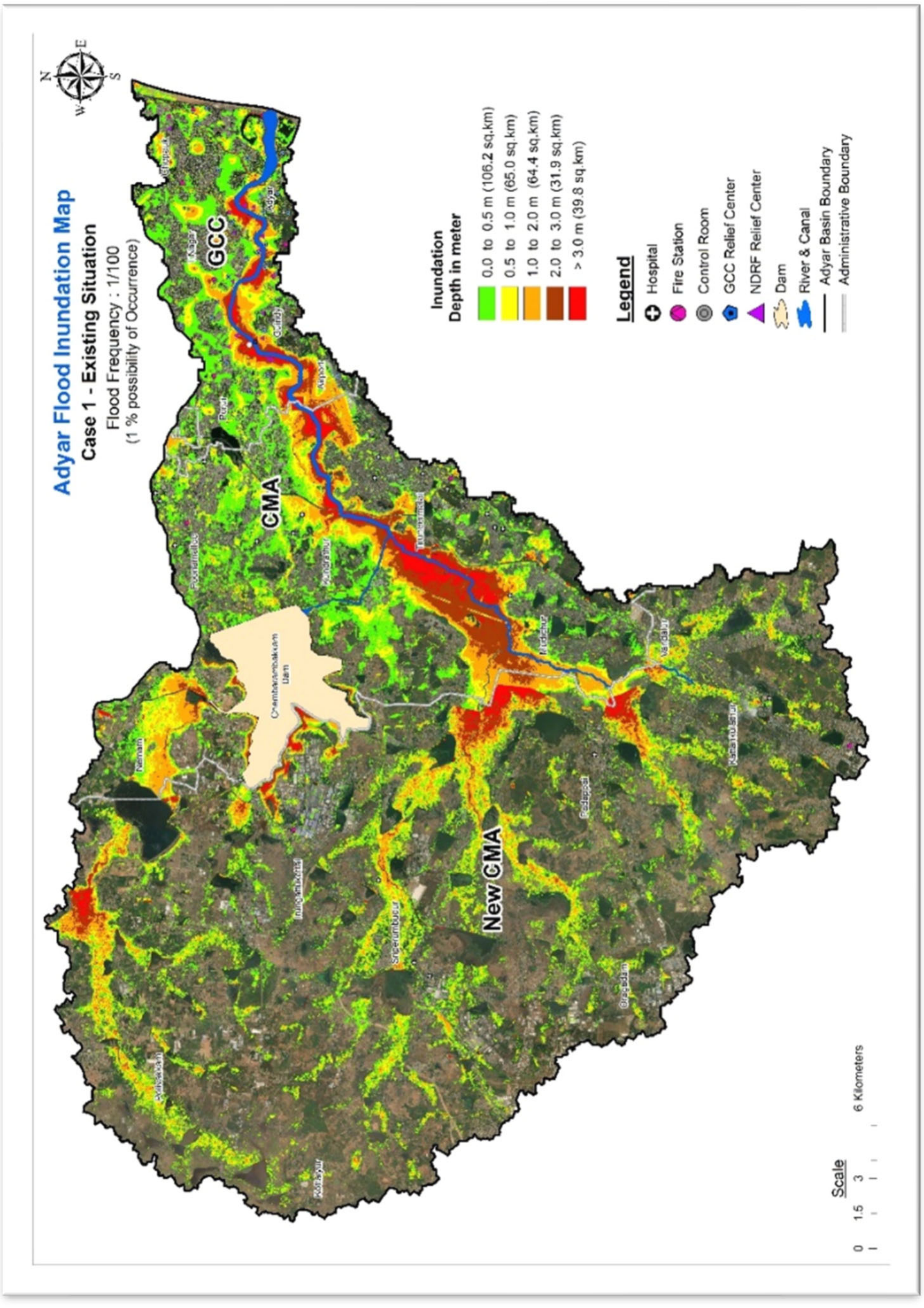
| Phase | Response details | The Existing Situation |
|---|---|---|
| During Flood Disaster (Emergency Response and Mitigation) | Flood Early Warning | Insufficient administrative judgment and communication with cities and towns |
| | | Inadequate public information dissemination methods |
| | | Underdeveloped public communication infrastructure |
| | Evacuation Order and Coordination | No established evaluation criteria for evacuation orders |
| | | Limited public notification and dissemination methods |
| | | Lack of disaster prevention capabilities in evacuation areas |
| | Rescue and Relief | Delays in sharing disaster information |
| | | Slow gathering of infrastructure damage and recovery data |
| | | Rescue plan does not consider gender or special needs |
| | | No methods to communicate rescue and relief during floods |
| | | Delays in relief and rescue operations by DRF |
| After Flood Disaster (Emergency Support, Recovery, and Reconstruction) | Supporting Affected People | Lack of support concepts for disaster-affected houses and temporary housing |
| | | Slow restoration of daily infrastructure |
| | | Insufficient support measures considering gender and special needs |
| | | Shortage of water, food, and supplies at evacuation centers and homes |
| | | Insufficient digitalization for providing support to victims and evacuation facilities |
| | | Disparity and suffering in slums along the river |
| | Urgent Infrastructure Reconstruction | Delays in restoring levees, revetments, and river channels |
| | | Limited focus on areas with sediment; slow drainage channel construction |
| | | Insufficient emergency pump drainage measures |
| | | Slow repair of damaged roads and drainage gutters |
| | Emergency Budget | Financial support delays and budget approval issues |
| | | No flood insurance and insufficient disaster relief grant systems |
| | Recovery and Reconstruction Plans | Slow and unclear recovery and reconstruction plans |
| | | Disaster prevention centers and welfare facilities at flood risk |
| | | Loss of local communities and delays in rebuilding |

*Source: JICA Expert Team*

## 6.6 Recommendations for the Creation and Publication of Flood Hazard Maps

Flood hazard maps have been developed for different return periods, including 100 and 10 years, at various spatial scales, ranging from basin-level to ward-level flood hazard maps. The following figure displays samples of the flood hazard maps for a 100-year return period flood. These maps are available in GIS layers and JPEG format and have been shared with relevant authorities, including TNDRRA, CMDA, and other local counterparts.

For better visualization, it is recommended to print these flood hazard maps at appropriate spatial scales, such as basin, CMA, or GCC level. They can also be reviewed using GIS or other applications. For zones and ward levels, it is suggested to print the maps at suitable scales, such as A1 to A3 sizes. Table 6-4 Provides suggested formats for the presentation of these flood hazard maps and recommendations for their distribution and utilization.




*Source: JICA Expert Team*

**Figure 6-5: Flood Hazard Map for Adyar Basin (100-year Return Period)**

**Table 6-4: Proposals for Using and Distribution of Flood Hazard Maps**

| Admin | Format | Potential Users | How to use/Distribute |
|---|---|---|---|
| Basin | SHP, JPEG, A0 Print | TNDRRA, TNWRD | • TN Government GIS Databases (Online and open to government agencies)<br>• TNDRRA Emergency Control Room<br>• TNWRD Basin Managers<br>• It will not be open to the public |
| CMA | SHP, JPEG, A0 Print | TNDRRA, CMDA, MAWS, HUDD, CRRT | • TN Government GIS Databases (Online and open to government agencies)<br>• TNDRRA Emergency Control Room<br>• Annex to the 3rd Urban Development Master Plan<br>• MAWS will distribute it to other major cities in TN as a pilot.<br>• It will be open to the public as an annex to the Chennai master plan |
| GCC | SHP, JPEG, A0 Print | TNDRRA, CMDA, GCC, TNUIFSL | • TN Government GIS Databases (Online and open to government agencies)<br>• TNDRRA Emergency Control Room<br>• GCC Disaster Management Control Room<br>• TNUIFSL will be used as supplementary information for the World Bank flood forecasting project.<br>• Will be shown using the website of GCC |
| GCC Zones (15) | SHP, JPEG, A1 Print | TNDRRA, GCC, TNUIFSL | • TN Government GIS Databases (Online and open to government agencies)<br>• TNDRRA Emergency Control Room<br>• GCC Disaster Management Control Room<br>• Will publicize using GCC Zones offices |
| GCC Wards (200) | SHP, JPEG, PDF Booklet (A3) | TNDRRA, GCC | • TN Government GIS Databases (Online and open to government agencies)<br>• TNDRRA Emergency Control Room<br>• GCC Disaster Management Control Room<br>• GCC ward offices will discuss it using ward community meetings. |

*Source: JICA Expert Team*

## 6.7 Conclusion

Effective flood disaster management is a dynamic process that requires continuous adaptation to address evolving challenges and incorporate lessons learned. This chapter has identified key gaps in flood disaster management across the phases of preparedness, response, and recovery. The recommendations proposed here aim to fill these gaps by ensuring that appropriate measures are in place before, during, and after a flood. Implementing these recommendations is crucial to strengthening the resilience of communities and institutions against flood disasters.

Given the changing nature of flood risks driven by factors such as climate variability, urbanization, and socio-economic changes, it is essential to periodically review and update these recommendations. This ongoing process should consider the outcomes of evaluations conducted during and after flood events, with revisions made to standard operating procedures (SOPs), disaster response timelines, and other strategic plans as necessary. Such iterative improvements will align with the overarching goals of the JICA Comprehensive Flood Control Master Plan and help ensure its relevance over time.

One critical aspect of flood disaster management is the timely coordination of actions across various levels of authority. This involves early detection of potential flood risks, proactive measures during the approach of a cyclone, and effective emergency responses during landfall and subsequent flooding. To ensure long-term success, these recommendations must be institutionalized within the disaster management framework, supported by adequate resources, capacity-building initiatives, and robust collaboration among all stakeholders. By doing so, the system will remain adaptive, responsive, and capable of protecting lives, infrastructure, and livelihoods in the face of future flood challenges.

# Chapter 7. Cost Estimation and Economic Study

## 7.1 Introduction

This chapter describes the Cost Estimation and Economic Analysis of the master plan indicated in the previous chapters. This estimate is at the master plan level and is intended to identify feasible projects based on a cost-benefit analysis. Therefore, it should be noted that these estimates do not reflect the necessary precision for F/S and D/D.

## 7.2 Preliminary Cost Estimation

This section describes the conditions and assumptions for preliminary cost estimation, the method of estimating each cost, river channelization, improvement of existing tanks, underground bypass, improvement of urban tank and drainage, gates and pumps, bypass, coastal management, operation and maintenance Cost, and project cost.

The construction cost is estimated using the construction unit cost method, referring to the manual of JICA.

The main cost items of the project cost consist of project management cost, preparation cost, construction & procurement cost, consulting service cost, contingency cost, technical training cost, and operation and maintenance cost. Unit prices for construction and procurement costs are based on unit price list data, SOR (Schedule of rate), issued by respective government agencies.

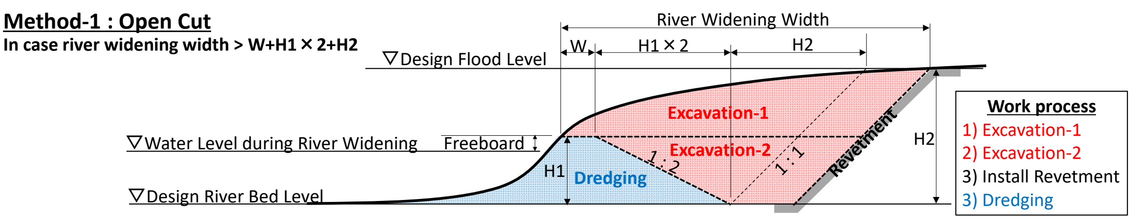
For operation and maintenance costs, annual maintenance dredging costs are set at 0.5% of construction and procurement costs, and annual maintenance dredging costs for each river are included separately. Project costs are calculated based on the construction & procurement cost of each type of work, and a project cost plan by year is also indicated.

### 7.2.1 River Channelization

#### 7.2.1.1. General

Estimated costs are calculated for the construction and procurement of the river widening measures proposed in the Master Plan. The construction types are dredging, excavation for river channel widening, and revetment.

The construction of the river channel widening is planned as land-based excavation, with 20% of the excavated soil volume to be dredged. The construction method of the river channel widening is shown below.




*Source: JICA Expert Team*

**Figure 7-1: River Widening Construction Method**

#### 7.2.1.2. Construction and Procurement Cost

The construction and procurement costs of the river widening planned for each river are shown below. The costs of the construction types indicated in Appendix, "1. Construction Unit Rate, 6) Other Types of Work" and other types of work that are unknown at the planning stage of the master plan are lumped together as other (cost). In the case of revetment work for river widening, this includes removal of existing structures, fill in front of sheet piles, gutters associated with embankments, construction of sidewalks and roadways and their pavement, and costs for communication and lighting equipment, etc. as needed. In the case of dredging, this includes the cost of a yard for temporarily laying out and drying the dredged material. The ratio is set at 20% of the major works listed so far. In addition, 6% is added to the total direct construction cost obtained from the unit cost table as expenses to be included other than direct construction in India.

**Table 7-1: Construction and Procurement Cost for River Channelization**

| | | | | Phase 1 | | Phase 2 | | Total | |
|---|---|---|---|---|---|---|---|---|---|
| River | Works | Unit Rate | Unit | Quantity | Total (INR) | Quantity | Total (INR) | Quantity | Total (INR) |
| Adyar River | Excavation | 51 | $m^3$ | 1,192,694 | 61,364,110 | 11,285,606 | 580,644,444 | 12,478,300 | 642,008,554 |
| | Dredging | 485 | $m^3$ | 4,770,776 | 2,313,826,499 | 16,722,419 | 8,110,373,000 | 21,493,195 | 10,424,199,499 |
| | Transportation | 115 | $m^3$ | 5,963,470 | 682,817,356 | 28,008,025 | 3,206,918,846 | 33,971,495 | 3,889,736,202 |
| | Embankment | 57 | $m^3$ | 3,248,656 | 183,549,064 | 8,721,138 | 492,744,308 | 11,969,794 | 676,293,372 |
| | Revetment | | $m^2$ | 324,866 | 1,168,165,200 | 872,114 | 2,751,240,934 | 1,196,979 | 3,919,406,133 |
| | Concrete block piling | 1,700 | $m^2$ | 234,293 | 398,298,100 | 685,548 | 1,165,431,634 | 919,841 | 1,563,729,733 |
| | Steel sheet piles (VL type L=12m) | 8,500 | $m^2$ | 90,573 | 769,867,100 | 186,566 | 1,585,809,300 | 277,138 | 2,355,676,400 |
| | Turf revetment | 55 | $m^2$ | 0 | 0 | 0 | 0 | 0 | 0 |
| | Check Dam | 470,074 | m | 200 | 94,014,800 | 0 | 0 | 200 | 94,014,800 |
| | Others (20% of the above total) | | | | 900,747,406 | | 3,028,384,306 | | 3,929,131,712 |
| | Civil Cost | | | | 5,404,484,434 | | 18,170,305,839 | | 23,574,790,272 |
| | Provision for GST 18% | | | | 972,807,198 | | 3,270,655,051 | | 4,243,462,249 |
| | Expense (6% of Civil Cost) | | | | 324,269,066 | | 1,090,218,350 | | 1,414,487,416 |
| | Reconstruction of bridges | 56,000 | $m^2$ | 5,000 | 280,000,000 | 13,500 | 67,500,000 | 18,500 | 347,500,000 |
| | Sub Total | | | | 6,981,560,698 | | 22,598,679,240 | | 29,580,239,937 |
| Cooum River | Excavation | 51 | $m^3$ | 6,586,101 | 338,854,902 | 10,582,423 | 544,465,639 | 17,168,524 | 883,320,541 |
| | Dredging | 485 | $m^3$ | 1,646,525 | 798,564,759 | 2,645,606 | 1,283,118,733 | 4,292,131 | 2,081,683,491 |
| | Transportation | 115 | $m^3$ | 8,232,626 | 942,635,720 | 13,228,028 | 1,514,609,226 | 21,460,655 | 2,457,244,946 |
| | Embankment | 57 | $m^3$ | 4,995,400 | 282,240,100 | 6,474,160 | 365,790,040 | 11,469,560 | 648,030,140 |
| | Revetment | 55 | $m^2$ | 499,540 | 849,218,000 | 647,416 | 1,100,607,200 | 1,146,956 | 1,949,825,200 |

| | | | | Phase 1 | | Phase 2 | | Total | |
|---|---|---|---|---|---|---|---|---|---|
| River | Works | Unit Rate | Unit | Quantity | Total (INR) | Quantity | Total (INR) | Quantity | Total (INR) |
| | Concrete block piling | 1,700 | m$^2$ | 499,540 | 849,218,000 | 647,416 | 1,100,607,200 | 1,146,956 | 1,949,825,200 |
| | Steel sheet piles (VL type, L=12m) | 8,500 | m$^2$ | 0 | 0 | 0 | 0 | 0 | 0 |
| | Turf revetment | 55 | m$^2$ | 0 | 0 | 0 | 0 | 0 | 0 |
| | Check Dam | 470,074 | m | 200 | 94,014,800 | 0 | 0 | 200 | 94,014,800 |
| | Others （20% of the above total） | | | | 661,105,656 | | 961,718,168 | | 1,622,823,824 |
| | Civil Cost | | | | 3,966,633,937 | | 5,770,309,005 | | 9,736,942,942 |
| | Provision for GST 18% | | | | 713,994,109 | | 1,038,655,621 | | 1,752,649,730 |
| | Expense（6% of Civil Cost） | | | | 237,998,036 | | 346,218,540 | | 584,216,577 |
| | Reconstruction of bridges | 56,000 | m$^2$ | 11,500 | 644,000,000 | 13,000 | 149,500,000 | 24,500 | 793,500,000 |
| | Sub Total | | | | 5,562,626,081 | | 7,304,683,166 | | 12,867,309,248 |
| Kosasthalaiyar River | Excavation | 51 | m$^3$ | 6,586,101 | 338,854,902 | 6,586,101 | 338,854,902 | 13,172,202 | 677,709,803 |
| | Dredging | 485 | m$^3$ | 1,646,525 | 798,564,759 | 1,646,525 | 798,564,759 | 3,293,051 | 1,597,129,517 |
| | Transportation | 115 | m$^3$ | 8,232,626 | 942,635,720 | 8,232,626 | 942,635,720 | 16,465,253 | 1,885,271,440 |
| | Embankment | 57 | m$^3$ | 4,995,400 | 282,240,100 | 4,995,400 | 282,240,100 | 9,990,800 | 564,480,200 |
| | Revetment | 55 | m$^2$ | 499,540 | 511,578,394 | 499,540 | 313,938,875 | 999,080 | 825,517,270 |
| | Concrete block piling | 1,700 | m$^2$ | 283,340 | 481,677,898 | 182,160 | 309,671,898 | 465,500 | 791,349,796 |
| | Steel sheet piles (VL type, L=12m) | 8,500 | m$^2$ | 0 | 0 | 0 | 0 | 0 | 0 |
| | Turf revetment | 55 | m$^2$ | 544,140 | 29,900,496 | 77,652 | 4,266,977 | 621,792 | 34,167,474 |
| | Check Dam | 470,074 | m | 170 | 79,912,580 | 0 | 0 | 170 | 79,912,580 |
| | Others（20% of above total） | | | | 590,757,291 | | 535,246,871 | | 1,126,004,162 |

| | | | | Phase 1 | | Phase 2 | | Total | |
|---|---|---|---|---|---|---|---|---|---|
| River | Works | Unit Rate | Unit | Quantity | Total (INR) | Quantity | Total (INR) | Quantity | Total (INR) |
| | Civil Cost | | | | 3,544,543,746 | | 3,211,481,227 | | 6,756,024,973 |
| | Provision for GST 18% | | | | 638,017,874 | | 578,066,621 | | 1,216,084,495 |
| | Expense（6% of Civil Cost） | | | | 212,672,625 | | 192,688,874 | | 405,361,498 |
| | Reconstruction of bridges | 56,000 | $m^2$ | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Sub Total** | | | | **4,395,234,245** | | **3,982,236,722** | | **8,377,470,967** |
| **Total** | | | | | **16,939,421,024** | | **33,885,599,128** | | **50,825,020,152** |

*Source: JICA Expert Team*

### 7.2.2 Construction and Procurement Cost for Improving Existing Tanks

**Table 7-2: Construction Cost for Tank Improvement**

(a) Adyar Basin

| Basin | Works | Unit | Quantity | Unit Rate (INR) | Total (INR) | | |
|---|---|---|---|---|---|---|---|
| Adyar Basin | Excavation | $m^3$ | 290,495 | 51.45 | 14,945,959 | | |
| | Dredging | $m^3$ | 29,049 | 485 | 14,088,999 | | |
| | Transportation | $m^3$ | 319,544 | 57.26 | 18,297,107 | | |
| | Embankment | $m^3$ | 29,049 | 56.5 | 1,641,296 | | |
| | Revetment | $m^2$ | 193,867 | 54.95 | 10,652,997 | | |
| | Discharge Channel | LS | 1 | 2,612,344,185 | 2,612,344,185 | | |
| | Gate (Type A) | LS | 39 | 3,708,925 | 144,648,061 | | |
| | Gate (Type B) | LS | 23 | 3,585,789 | 82,473,158 | | |
| | Other works（20% of above total） | | | | 579,818,352 | | |
| | Civil Cost | | | | 3,478,910,114 | | |
| | Provision for GST 18% | | | | 626,203,820 | **Breakdown (INR)** | |
| | Expenses（6 % of Civil Cost） | | | | 208,734,607 | **Phase1** | **Phase2** |
| | **Sub Total** | | | | **4,313,848,541** | **2,156,924,271** | **2,156,924,271** |

*Source: JICA Expert Team*

(b) Cooum Basin

| Basin | Works | Unit | Quantity | Unit Rate (INR) | Total (INR) | | |
|---|---|---|---|---|---|---|---|
| Cooum Basin | Excavation | $m^3$ | 246,136 | 51.45 | 12,663,721 | | |
| | Dredging | $m^3$ | 24,614 | 485 | 11,937,619 | | |
| | Transportation | $m^3$ | 270,750 | 57.26 | 15,503,152 | | |
| | Embankment | $m^3$ | 24,614 | 56.5 | 1,390,671 | | |
| | Revetment | $m^2$ | 164,622 | 54.95 | 9,045,976 | | |
| | Discharge Channel | LS | 1 | 2,094,161,122 | 2,094,161,122 | | |
| | Gate (Type A) | LS | 22 | 3,708,925 | 81,596,342 | | |
| | Gate (Type B) | LS | 18 | 3,585,789 | 64,544,211 | | |
| | Other works（20% of above total） | | | | 458,168,563 | | |
| | Civil Cost | | | | 2,749,011,377 | | |
| | Provision for GST 18% | | | | 494,822,048 | **Breakdown (INR)** | |
| | Expenses（6 % of Civil Cost） | | | | 164,940,683 | **Phase1** | **Phase2** |
| | **Sub Total** | | | | **3,408,774,107** | **1,704,387,054** | **1,704,387,054** |

*Source: JICA Expert Team*

### (c) Kosasthalaiyar Basin (Existing Tanks)

| Basin | Works | Unit | Quantity | Unit Rate (INR) | Total (INR) | | |
|---|---|---|---|---|---|---|---|
| Kosasthalaiyar Basin (Existing Tanks) | Excavation | $m^3$ | 22,250 | 51.45 | 28,660,134 | | |
| | Dredging | $m^3$ | 2,225 | 485 | 27,016,841 | | |
| | Transportation | $m^3$ | 24,475 | 57.26 | 35,086,243 | | |
| | Embankment | $m^3$ | 2,225 | 56.5 | 3,147,323 | | |
| | Revetment | $m^2$ | 14,534 | 54.95 | 20,317,086 | | |
| | Discharge Channel | LS | 30,375 | 0 | 4,324,045,427 | | |
| | Gate (Type A) | LS | 11 | 3,708,925 | 352,347,840 | | |
| | Gate (Type B) | LS | 1 | 3,585,789 | 154,188,947 | | |
| | Other works（20% of above total） | | | | 988,961,968 | | |
| | Civil Cost | | | | 5,933,771,810 | | |
| | Provision for GST 18% | | | | 1,068,078,926 | **Breakdown (INR)** | |
| | Expenses（6 % of Civil Cost） | | | | 356,026,309 | **Phase1** | **Phase2** |
| | **Sub Total** | | | | **7,357,877,044** | **3,678,938,522** | **3,678,938,522** |

*Source: JICA Expert Team*

## (d) Kosasthalaiyar Basin (New Tanks) & Total

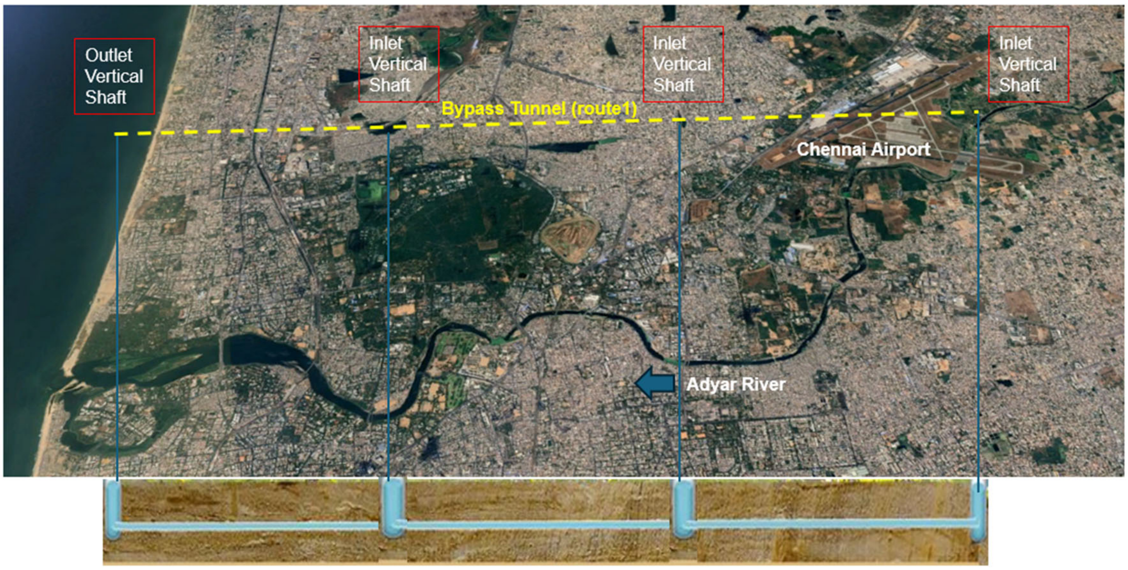
| Basin | Works | Unit | Quantity | Unit Rate (INR) | Total (INR) | | |
|---|---|---|---|---|---|---|---|
| Kosasthalaiyar Basin (New) | Excavation | $m^3$ | 22,250 | 51.45 | 1,144,763 | | |
| | Dredging | $m^3$ | 2,225 | 485 | 1,079,125 | | |
| | Transportation | $m^3$ | 24,475 | 57.26 | 1,401,439 | | |
| | Embankment | $m^3$ | 2,225 | 56.5 | 125,713 | | |
| | Revetment | $m^2$ | 14,534 | 54.95 | 798,668 | | |
| | Discharge Channel | LS | 30,375 | 0 | 0 | | |
| | Gate (Type A) | LS | 11 | 3,708,925 | 40,798,171 | | |
| | Gate (Type B) | LS | 1 | 3,585,789 | 3,585,789 | | |
| | Other works（20% of above total） | | | | 9,786,733 | | |
| | Civil Cost | | | | 58,720,400 | | |
| | Provision for GST 18% | | | | 10,569,672 | **Breakdown (INR)** | |
| | Expenses（6 % of Civil Cost） | | | | 3,523,224 | **Phase1** | **Phase2** |
| | **Sub Total** | | | | **72,813,296** | **36,406,648** | **36,406,648** |
| **Kosasthalaiyar Basin Total** | | | | | | **Breakdown (INR)** | |
| | | | | | | **Phase1** | **Phase2** |
| | | | | | **7,430,690,340** | **3,715,345,170** | **3,715,345,170** |
| **Total** | | | | | | **Breakdown (INR)** | |
| | | | | | | **Phase1** | **Phase2** |
| | | | | | **15,153,312,988** | **7,576,656,494** | **7,576,656,494** |

*Source: JICA Expert Team*

### 7.2.3 Underground Bypass

#### 7.2.3.1. General

The Underground Bypass proposed in the Master Plan has specifications of 12.3 km in length and 113.1 m2 of internal cross-sectional area. A summary is given below.




*Source: JICA Expert Team*

**Figure 7-2: Outline of Underground Bypass**

#### 7.2.3.2. Construction and procurement cost

Construction and procurement costs are shown below.

**Table 7-3: Construction and Procurement Cost for Underground Bypass**

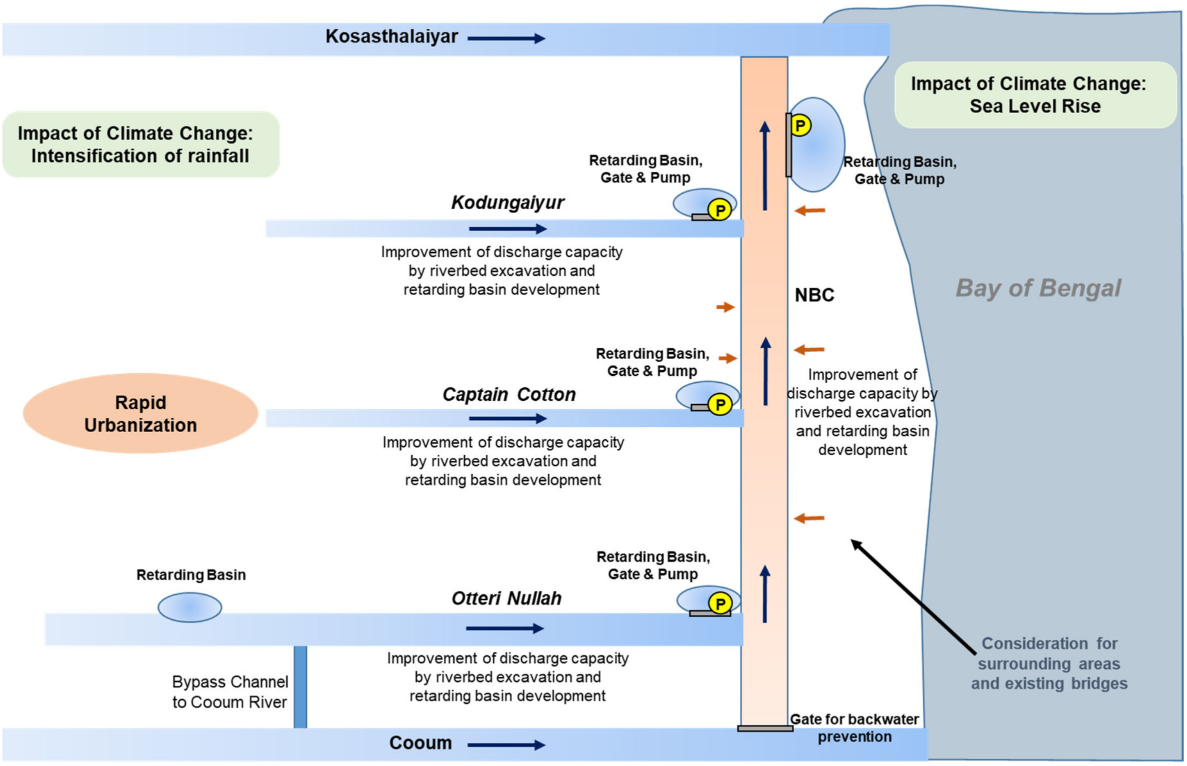
| | | |
|---|---|---|
| Extension | m | 12,300 |
| (Underground reservoir part) | m | 4,000 |
| Cross-sectional area | $m^2$ | 113 |
| Unit Rate (INR) | INR/$m^3$ | 57,315 |
| **Phase1 (INR)** | INR | **79,730,737,566** |
| **Phase2 (INR)** | INR | **0** |
| **Total (INR)** | INR | **79,730,737,566** |

*Source: JICA Expert Team*

### 7.2.4 Improvement of Existing Urban Tank

#### 7.2.4.1. General

Improvements to existing tanks are planned in the North Buckingham Canal and Adyar River Basin. The main types of work are dredging, excavation, and filling. The outline of each location is shown below.




*Source: JICA Expert Team*

**Figure 7-3: Outline of Countermeasures of North B Canal and Connecting Drainages**

7.2.4.2. Construction and procurement cost

Construction costs for the existing tank improvements are shown below.

**Table 7-4: Construction Cost of Existing Tank Improvements**

| Works | Unit | Quantity | Unit Rate (INR) | Total (INR) |
|---|---|---|---|---|
| Excavation | $m^3$ | 4,132,350 | 51 | 212,609,408 |
| Dredging | $m^3$ | 0 | 485 | 0 |
| Transportation | $m^3$ | 4,050,000 | 57 | 231,903,000 |
| Embankment | $m^3$ | 405,000 | 57 | 22,882,500 |
| Revetment | $m^2$ | 24,249 | 55 | 1,332,504 |
| Concrete placement | $m^3$ | 55,290 | 30,500 | 1,686,345,000 |
| Other works（20% of above total） | | | | 431,014,482 |
| Civil Cost | | | | 2,586,086,894 |
| Provision for GST 18% | | | | 465,495,641 |
| Expenses（6% of Civil Cost） | | | | 155,165,214 |
| **Total** | | | | **3,206,747,749** |
| | | **Breakdown** | **Phase1** | **3,206,747,749** |
| | | | **Phase2** | **0** |

*Source: JICA Expert Team*

### 7.2.5 Construction and Procurement Cost for Improvement of Urban Drainage Channel

Construction cost for the Connecting Drainage (Micro-Drainage) Improvement is shown below.

**Table 7-5: Construction and Procurement Cost for Improvement of Urban Drainage Channel**

| Works | Unit | Quantity | Unit Rate (INR) | Total (INR) |
|---|---|---|---|---|
| Excavation | $m^3$ | 6,834,215 | 51 | 351,620,361 |
| Dredging | $m^3$ | 0 | 485 | 0 |
| Transportation | $m^3$ | 5,918,122 | 212 | 1,257,009,111 |
| Embankment | $m^3$ | 3,797 | 57 | 214,511 |
| Revetment | $m^2$ | 1,770,961 | 55 | 97,314,319 |
| Concrete placement | $m^3$ | 526,727 | 30500 | 16,065,161,300 |
| Cut & Cover | m | 90 | 449,207 | 40,428,630 |
| Other works（20% of above total） | Set | 1 | | 3,562,349,646 |
| Civil Cost | | | | 21,374,097,878 |
| Provision for GST 18% | | | | 3,847,337,618 |
| Expenses（6% of Civil Cost） | Set | 1 | | 1,282,445,873 |
| **Sub Total** | | | | **26,503,881,369** |
| | | **Breakdown** | **Phase1** | **26,503,881,369** |
| | | | **Phase2** | **0** |

*Source: JICA Expert Team*

### 7.2.6 Gates and Pump

The planned gates and pumps are listed below, and a standard diagram of the storm drain pump station is shown below.

**Table 7-6: Gates and Pumps**

| Sl. No. | Canal | Gate St H m | Gate W m | Gate S m2 | Pump Q $m^3/s$ |
|---|---|---|---|---|---|
| Adyar | | | | | |
| 1 | Mambalam | 4.710 | 15.500 | 73.005 | 0.000 |
| 2 | Manapakkam | 8.450 | 10.000 | 0.000 | 0.000 |
| 3 | Kuradrathur | 4.560 | 8.000 | 36.480 | 0.000 |
| | | | | | |
| | | | | | |
| Cooum | | | | | |
| 1 | Vigrrambakkam Arunbakkam | 7.540 | 15.000 | 0.000 | 0.000 |
| | | | | | |
| | | | | | |
| B-Canal/Kovalam | | | | | |
| 1 | B-canal/Adyar | 4.000 | 20.000 | 80.000 | 0.000 |
| 2 | B-canal/Muttukadu | 2.500 | 120.000 | 300.000 | 0.000 |
| 3 | Okkiyam Maduvu Diversion | 2.000 | 120.000 | 240.000 | 0.000 |
| 4 | New Diversion/Bay of Bengal | 2.900 | 62.900 | 182.410 | 28.670 |
| | | | | | |
| | | | | | |
| Kovalam | | | | | |
| 1 | Inland water exclusion | 0.000 | 0.000 | 0.000 | 1.406 |
| | | | | | |
| NBC/CBC | | | | | |
| 1 | K1 | 1.700 | 2.000 | 3.400 | 2.000 |
| 2 | K2 | 1.700 | 2.000 | 3.400 | 1.000 |
| 3 | C1 | 1.100 | 2.000 | 2.200 | 0.500 |
| 4 | C2 | 1.100 | 2.000 | 2.200 | 0.500 |
| 5 | O1 | 2.300 | 2.000 | 4.600 | 0.000 |
| 6 | O2 | 2.300 | 2.000 | 4.600 | 0.000 |
| 7 | O3 | 1.000 | 2.000 | 2.000 | 2.000 |
| 8 | O4 | 1.000 | 2.000 | 2.000 | 2.000 |
| 9 | O5 | 1.000 | 2.000 | 2.000 | 2.000 |
| 10 | North B Canal RB | 3.600 | 2.000 | 7.200 | 2.000 |
| 11 | North B Canal | 2.400 | 9.000 | 21.600 | |
| 12 | Central B Canal | 6.000 | 6.500 | 39.000 | |

*Source: JICA Expert Team*

7.2.6.1. Construction and procurement cost

The construction cost of the gate pump is shown in below.

**Table 7-7: Construction Cost of Gate and Pump Station**

| Sl. No. | Canal | Gate St H m | Gate W m | Gate S M2 | Amount 1) Gate (INR) | Pump Q $m^3/s$ | Amount 2) Pump st. (INR) | Amount 1)+2) (INR) | Amount *Only Pump St. (INR) |
|---|---|---|---|---|---|---|---|---|---|
| Adyar | | | | | | | | | |
| 1 | Mambalam | 4.71 | 15.5 | 73 | 58,994,205 | 0 | 0 | 58,994,205 | 0 |
| 2 | Manapakkam | 8.45 | 10 | | 3,315,789 | 0 | 0 | 3,315,789 | 0 |
| 3 | Kuradrathur | 4.56 | 8 | 36 | 22,021,197 | 0 | 0 | 22,021,197 | 0 |
| | Sub Total | | | | 84,331,192 | | 0 | 84,331,192 | 0 |
| | | | | | | | | | |
| Cooum | | | | | | | | | |
| 1 | Vigrrambakkam Arunbakkam | 7.54 | 15 | | 83,625,000 | 0 | 0 | 83,625,000 | 0 |
| | Sub Total | | | | 83,625,000 | | 0 | 83,625,000 | 0 |
| | | | | | | | | | |
| B-Canal/Kovalam | | | | | | | | | |
| 1 | B-canal/Adyar | 4 | 20 | 80 | 68,157,895 | | | 68,157,895 | |
| 2 | B-canal/Muttukadu | 2.5 | 120 | 300 | 698,052,632 | | | 698,052,632 | |
| 3 | Okkiyam Maduvu Diversion | 2 | 120 | 240 | 460,578,947 | | | 460,578,947 | |
| 4 | New Diversion/Bay of Bengal | 2.9 | 62.9 | 182 | 278,978,582 | 28.67 | 886,821,790 | 1,165,800,372 | 2,721,870 |
| | Sub Total | | | | 1,505,768,055 | | 886,821,790 | 2,392,589,846 | 2,721,870 |
| | | | | | | | | | |
| Kovalam | | | | | | | | | |
| 1 | Inland water exclusion | | | | | 1.40625 | 83,748,366 | 83,748,366 | 455,508 |
| | Sub Total | | | | 0 | | 83,748,366 | 83,748,366 | 455,508 |
| NBC/CBC | | | | | | | | | |

| Sl. No. | Canal | Gate St H m | Gate W m | Gate S M2 | Amount 1) Gate (INR) | Pump Q $m^3/s$ | Amount 2) Pump st. (INR) | Amount 1)+2) (INR) | Amount *Only Pump St. (INR) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | K1 | 1.7 | 2 | 3 | 4,289,621 | 2 | 98,842,120 | 103,131,741 | 485,700 |
| 2 | K2 | 1.7 | 2 | 3 | 4,289,621 | 1 | 73,421,060 | 77,710,681 | 434,850 |
| 3 | C1 | 1.1 | 2 | 2 | 3,927,853 | 0.5 | 60,710,530 | 64,638,383 | 409,425 |
| 4 | C2 | 1.1 | 2 | 2 | 3,927,853 | 0.5 | 60,710,530 | 64,638,383 | 409,425 |
| 5 | O1 | 2.3 | 2 | 5 | 4,671,095 | | 48,000,000 | 52,671,095 | 384,000 |
| 6 | O2 | 2.3 | 2 | 5 | 4,671,095 | | 48,000,000 | 52,671,095 | 384,000 |
| 7 | O3 | 1 | 2 | 2 | 3,869,474 | 2 | 98,842,120 | 102,711,594 | 485,700 |
| 8 | O4 | 1 | 2 | 2 | 3,869,474 | 2 | 98,842,120 | 102,711,594 | 485,700 |
| 9 | O5 | 1 | 2 | 2 | 3,869,474 | 2 | 98,842,120 | 102,711,594 | 485,700 |
| 10 | North B Canal RB | 3.6 | 2 | 7 | 5,565,221 | 2 | 98,842,120 | 104,407,341 | 485,700 |
| 11 | North B Canal/Cooum | 2.4 | 9 | 22 | 12,192,253 | | | 12,192,253 | |
| 12 | Central B Canal/Cooum | 6 | 6.5 | 39 | 23,985,789 | | | 23,985,789 | |
| | Sub Total | | | | 79,128,821 | | 785,052,720 | 864,181,541 | 4,450,200 |
| | | | | | | | | | |
| | | | | | | | | | |
| | **Total** | INR | | | **1,752,853,069** | | **1,755,622,876** | **3,508,475,945** | **7,627,577** |
| | | | Breakdown | **phase1** | **1,752,853,069** | | **1,755,622,876** | **3,508,475,945** | **7,627,577** |
| | | | | **phase2** | **0** | | **0** | **0** | **0** |

*Source: JICA Expert Team*

### 7.2.7 Bypass and Diversion Canals

The list of Bypass is shown below

**Table 7-8: Quantity of Bypass**

| Location | Length | Concrete channel cross-section | Quantity of Excavation | Revetment | Bridge | Embankment |
|---|---|---|---|---|---|---|
| | m | $m^2$ | $m^3$ | $m^2$ | $m^2$ | $m^3$ |
| Buckingham Okkiyam Maduvu to Adyar River | | 256 | 0 | 10,000 | 0 | 10,000 |
| Buckingham Muttukadu to Okkiyam Maduvu | | 256 | 0 | 96,000 | 0 | 72,000 |
| Okkiyam Maduvu Short-Cut | | 256 | 474,000 | 1,000 | 0 | 5,000 |
| Otteri Nulla-Cooum Diversion Channel | 1,471 | 26 | 38,246 | 1,275 | 0 | 382 |
| Okkiyam Maduvu Bypass | 1,580 | 256 | 404,000 | 15,000 | 1,824 | 4,000 |
| **Total** | **3,051** | | **916,246** | **123,275** | **1,824** | **91,382** |

*Source: JICA Expert Team*

The calculated construction cost of the Bypass is shown below.

**Table 7-9: Construction Cost for Bypass**

| Works | Unit | Quantity | Unit Rate (INR) | Total (INR) | | | | |
|---|---|---|---|---|---|---|---|---|
| Bypass | m | 3,051 | 83,000 | 253,233,000 | | | | |
| Dredging | $m^3$ | 916,246 | 485 | 444,379,310 | | | | |
| Transportation | $m^3$ | 916,246 | 115 | 104,910,167 | | | | |
| Embankment | $m^3$ | 91,382 | 57 | 5,163,109 | | | | |
| Revetment | $m^2$ | 123,275 | 55 | 6,773,954 | | | | |
| Others (20% of Dredging, Transportation and Embankment) | | | | 112,245,308 | | | | |
| Civil Cost | | | | 926,704,848 | | | | |
| Provision for GST 18% | | | | 166,806,873 | | | | |
| Expenses (6% of Civil Cost) | | | | 55,602,291 | | | | |
| Bridge Replacement | $m^2$ | 1,824 | 56,000 | 102,144,000 | **Breakdown** | | | |
| **Total** | | | | **1,251,258,011** | **Phase1** | **1,251,258,011** | **Phase2** | **0** |

*Source: JICA Expert Team*

### 7.2.8 Coastal Management

The number of major works are listed below.

**Table 7-10: Quantity of Major Works for Coastal Management**

| Works | Unit | Quantity |
|---|---|---|
| Dredging | $m^3$ | 30,000 |
| Construction of conduit embankment | m | 230 |

*Source: JICA Expert Team*

The construction and procurement costs for coastal measures are shown below.

**Table 7-11: Construction and Procurement Costs for Coastal Management**

| Works | Unit | Quantity | Unit Rate (INR) | Total (INR) |
|---|---|---|---|---|
| Dredging | $m^3$ | 30,000 | 485 | 14,550,000 |
| Transportation (20km) | $m^3$ | 30,000 | 115 | 3,435,000 |
| Construction of conduit embankment | m | 230 | 619,936 | 142,585,280 |
| Others (Nonnude to case references) | | | | 0 |
| Civil Cost | | | | 160,570,280 |
| Provision for GST 18% | | | | 28,902,650 |
| Expenses（26% of Civil Cost） | | | | 41,748,273 |
| **Total** | | | **Phase1** | **231,221,203** |
| | | | **Phase2** | **0** |
| | | | **SUM** | **231,221,203** |

*Source: JICA Expert Team*

### 7.2.9 Preliminary Cost Estimation

Preliminary Project Cost is shown below.

**Table 7-12: Preliminary Project Cost**

| Item | | | | Phase 1 | Phase 2 | Total |
|---|---|---|---|---|---|---|
| | | | | (Unit: INR) | | |
| 1 | Project Management Cost | | | 4,636,985,983 | 1,383,678,395 | 6,020,664,378 |
| | | | **Subtotal** | 4,636,985,983 | 1,383,678,395 | 6,020,664,378 |
| 2 | Preparation Cost | | | 0 | 0 | 0 |
| | 2-1 | Land Acquisition Cost (includes 2-2) | | 93,577,157,001 | 592,713,578,940 | 686,290,735,941 |
| | | Fluvial (River) Flood Control Plan | | 82,685,402,547 | 592,713,578,940 | 675,398,981,488 |
| | | | River Channelization | 0 | 509,022,413,111 | 509,022,413,111 |
| | | | Rehabilitation of Existing Water Tank | 82,182,505,672 | 82,182,505,672 | 164,365,011,345 |
| | | | Underground Bypass | 2,011,557,031 | 0 | 2,011,557,031 |
| | | Pluvial (Urban) Flood Control Plan | | 10,891,754,453 | 0 | 10,891,754,453 |
| | | | Tank Improvement | 6,199,126,172 | 0 | 6,199,126,172 |
| | | | Connecting Drainage (Micro-Drainage) Improvement | 0 | 0 | 0 |
| | | | Bypass | 2,148,225,625 | 0 | 2,148,225,625 |
| | | | Gate and pump, Conduit flap gate installation | 2,544,402,656 | 0 | 2,544,402,656 |
| | | Coastal | Coastal Area and River Mouth | 0 | 0 | 0 |
| | 2-2 | Compensation Cost | | 0 | 0 | 0 |
| | 2-4 | Environmental Impact Assessment Cost | | 0 | 0 | 0 |
| | | | **Subtotal** | 95,085,817,157 | 591,204,918,784 | 686,290,735,941 |
| 3 | Construction & Procurement Cost | | | 0 | 0 | 0 |
| | | Fluvial (River) Flood Control Plan | | 52,497,196,086 | 99,523,076,650 | 152,020,272,737 |

| Item | | | | Phase 1 | Phase 2 | Total |
|---|---|---|---|---|---|---|
| | | | | (Unit: INR) | | |
| | | | River Channelization | 16,939,421,024 | 33,885,599,128 | 50,825,020,152 |
| | | | Rehabilitation of Existing Water Tank | 7,576,656,494 | 7,576,656,494 | 15,153,312,988 |
| | | | Underground Bypass | 79,730,737,566 | 0 | 79,730,737,566 |
| | | Pluvial (Urban) Flood Control Plan | | 34,470,363,074 | 0 | 34,470,363,074 |
| | | | Tank Improvement | 3,206,747,749 | 0 | 3,206,747,749 |
| | | | Connecting Drainage (Micro-Drainage) Improvement | 26,503,881,369 | 0 | 26,503,881,369 |
| | | | Bypass | 1,251,258,011 | 0 | 1,251,258,011 |
| | | | Gate and pump, Conduit flap gate installation | 3,508,475,945 | 0 | 3,508,475,945 |
| | | Coastal | Coastal Area and River Mouth | 231,221,203 | 0 | 231,221,203 |
| | | | **Subtotal** | 138,948,399,361 | 41,462,255,622 | 180,410,654,983 |
| 4 | Consultant Service Cost | | | 0 | 0 | 0 |
| | 4-1 | Consultant Service Cost for Civil Work | | 0 | 0 | 0 |
| | | 4-1-1 | Detail Design Cost | 6,947,419,968 | 2,073,112,781 | 9,020,532,749 |
| | | 4-1-2 | Construction Management Cost | 4,168,451,981 | 1,243,867,669 | 5,412,319,649 |
| | | | **Subtotal** | 11,115,871,949 | 3,316,980,450 | 14,432,852,399 |
| 5 | Contingency Cost | | | 0 | 0 | 0 |
| | 5-1 | Price Contingency | | 1,500,642,713 | 447,792,361 | 1,948,435,074 |
| | 5-2 | Physical Contingency | | 3,001,285,426 | 895,584,721 | 3,896,870,148 |
| | | | **Subtotal** | 4,501,928,139 | 1,343,377,082 | 5,845,305,221 |
| 6 | Technical Training Cost | | | 0 | 0 | 0 |

| Item | | | | Phase 1 | Phase 2 | Total |
|---|---|---|---|---|---|---|
| | | | | (Unit: INR) | | |
| | | | **Subtotal** | 0 | 0 | 0 |
| 7 | Operation and Maintenance Cost | | | 0 | 0 | 0 |
| | | | (1) Structural maintenance | 6,947,419,968 | 2,073,112,781 | 9,020,532,749 |
| | | | (2) Dredging (Implementation) | 13,490,506 | 13,490,506 | 13,490,506 |
| | | | **Subtotal** | 6,960,910,474 | 2,086,603,287 | 9,034,023,255 |
| **Total (Excluding OM Cost)** | | | | **254,289,002,590** | **638,711,210,332** | **893,000,212,922** |

*Source: JICA Expert Team*

## 7.3 Preliminary Economic Evaluation

The methodology for economic evaluation, construction of a GIS-based database on socioeconomics as the base information for the evaluation, conducting economic analysis, calculation of economic benefits, calculation of economic costs, and results of economic evaluation is described in this section.

The economic evaluation methodology provides a procedure for project evaluation based on the Ministry of Land, Infrastructure, Transport and Tourism's "Manual for Economic Evaluation of Flood Control Investment (Draft)". In the construction of a GIS-based database on socioeconomics, the distribution of population, GDP, land use, and infrastructure such as public facilities in the target area are organized.

In the economic analysis, identification of damaged items, estimation of the basic unit of each damaged item (damage intensity), calculation of economic benefits, and calculation of economic costs are conducted. In identifying damaged items, direct damage and indirect damage are subject to evaluation, and the intensity of damaged items is estimated. In the calculation of economic benefits, benefits are evaluated based on the difference in the amount of damage between with and without the implementation of the project.

The table below shows the unit cost for each damaged item (damage intensity) calculated based on the actual damage and damage volume during the December 2015 flooding in the target area.

**Table 7-13: Estimation of Basic Unit (Intensity) by Damage Item (Crore INR /km$^2$)**

| Flood Block | Intensity of Asset Value (Damage) (Crore INR /km$^2$ or km or unit) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Household asset (Crore INR /km$^2$) | | Industrial asset (Crore INR /km$^2$) | Commercial asset (Crore INR /km$^2$) | Agricultural asset (Crore INR/km$^2$) | Agricultural asset (Crore INR /km$^2$) | Road (Crore INR /km) | Railway (Crore INR /km) | Water Distribution line (Crore INR /km) | Electricity Infrastructure | | | | | Other public facilities (Crore INR /km$^2$) |
| | House asset | Household articles asset | | | | | | | | Substations (Crore INR /unit) | Pillar-box (Crore INR /unit) | Distribution Transformers (Crore INR /unit) | HT Line length (Crore INR /km) | LT Line length (Crore INR /km) | |
| <0.5m | 0.13 | 29.22 | 929.36 | 410.66 | 0.13 | 0.28 | 0.42 | 0.33 | 0.03 | 6.48 | 0.00 | 0.00 | 0.03 | 0.02 | 106.88 |
| 0.5< 1.0m | 0.20 | 43.38 | 1,593.19 | 583.57 | 0.28 | 0.61 | 0.66 | 0.52 | 0.05 | 10.89 | 0.01 | 0.00 | 0.05 | 0.03 | 179.56 |
| 1.0< 1.5m | 0.25 | 54.90 | 2,091.06 | 713.25 | 0.39 | 0.84 | 0.85 | 0.67 | 0.06 | 14.26 | 0.01 | 0.00 | 0.07 | 0.04 | 235.14 |
| 1.5 < 2.0m | 0.29 | 63.75 | 2,389.78 | 821.31 | 0.43 | 0.93 | 0.99 | 0.78 | 0.07 | 16.86 | 0.01 | 0.00 | 0.08 | 0.05 | 277.89 |
| 2m < | 0.35 | 77.03 | 2,854.46 | 951.00 | 0.53 | 1.14 | 1.16 | 0.92 | 0.09 | 20.75 | 0.01 | 0.00 | 0.10 | 0.06 | 342.02 |
| Total | 0.16 | 34.98 | 1,231.59 | 478.31 | 0.27 | 0.59 | 0.52 | 0.36 | 0.04 | 11.16 | 0.01 | 0.00 | 0.05 | 0.03 | 137.01 |

*Source: Based on damage figures and GIS data from various statistics and media reports.*

The table below shows the expected annual average damage reduction (economic benefits) for the four basins (Adyar, Cooum, Kovalam, and Kosasthalaiyar) that can be calculated using the simulation results of the Phase 2 project.

**Table 7-14: Calculation Table of Expected Annual Average Damage Reduction in 4 Basins (Adyar, Cooum, Kovalam, and Kosasthalaiyar) (Crore INR)**

| Scale of river flow | Annual average exceedance probability | Damage Amount | | | Average damage reduction by reach ④ | Probabilities by reach ⑤ | Annual average damage reduction ④×⑤ | Aggregated annual average damage reduction (=Expected annual average damage reduction) |
|---|---|---|---|---|---|---|---|---|
| | | Without countermeasure ① | With countermeasure ② | Amount of damage reduction ③=①−② | | | | |
| 1/1.1 | 0.909 | 0 | 0 | 0 | | | | |
| | | | | | 26,809 | 0.409 | 10,967 | 10,967 |
| 1/2 | 0.500 | 60,654 | 7,036 | 53,617 | | | | |
| | | | | | 52,890 | 0.167 | 8,815 | 19,782 |
| 1/3 | 0.333 | 66,059 | 13,897 | 52,162 | | | | |
| | | | | | 59,335 | 0.133 | 7,911 | 27,693 |
| 1/5 | 0.200 | 75,312 | 8,804 | 66,508 | | | | |
| | | | | | 71,964 | 0.100 | 7,196 | 34,890 |
| 1/10 | 0.100 | 87,658 | 10,238 | 77,420 | | | | |
| | | | | | 80,926 | 0.050 | 4,046 | 38,936 |
| 1/20 | 0.050 | 95,770 | 11,339 | 84,432 | | | | |
| | | | | | 86,126 | 0.017 | 1,435 | 40,372 |
| 1/30 | 0.033 | 99,754 | 11,934 | 87,820 | | | | |
| | | | | | 89,882 | 0.013 | 1,198 | 41,570 |
| 1/50 | 0.020 | 104,574 | 12,631 | 91,943 | | | | |
| | | | | | 94,195 | 0.008 | 706 | 42,276 |
| 1/80 | 0.013 | 109,311 | 12,865 | 96,446 | | | | |
| | | | | | 98,175 | 0.003 | 245 | 42,522 |
| 1/100 | 0.010 | 113,220 | 13,317 | 99,903 | | | | |

*Source: JICA Expert Team*

The calculation of economic costs covers project costs (construction costs of facilities, land costs, and compensation costs) and maintenance costs. In the economic evaluation, the economic efficiency of the project is evaluated using indicators such as the benefit-cost ratio (B/C ratio), Net Present Value (NPV), and economic internal rate of return (EIRR). As a result of the evaluation, the calculation results of each economic indicator are shown below.

Since the B/C ratio is 2.4 even for the remaining project evaluation, which is generally the least effective, the project can be judged to be appropriate from the standpoint of economic feasibility.

**Table 7-15: The Results of Economic Indicators for the Master Plan Projects**

| | Phase1 | Phase2 | Remaining project (Phase2-Phase1) |
|---|---|---|---|
| B/C | 13.7 | 3.5 | 2.4 |
| NPV (B-C) | 204,500 (Crore INR) | 117,500 (Crore INR) | 47,900 (Crore INR) |
| EIRR | 39% | 32% | 14% |

*Source: JICA Expert Team*

## 7.4 Conclusion

The EIRR, ENPV (=B-C), and B/C results for each phase are summarized and shown in the table below.

The high evaluation results are due to the low flow capacity of the target rivers. Project benefits are usually more pronounced in the early phases of the project, but the assessment values decrease over time as safety improves. Phase 2 assumes that Phase 1 has already ensured safety up to the 1/10 return period (RP). The assessment considers the additional protection from 1/10 RP to 1/100 RP in Phase 2 by comparing with and without Phase 1 implementation.

**Table 7-16: Economic evaluation results**

| **Items** | **Phase I** | | | **Phase II** | | | **Phase II − Phase I** |
|---|---|---|---|---|---|---|---|
| **Project Cost (Cr. INR)** | Construction | Site Preparation | Total | Construction | Site Preparation | Total | 38,500 |
| | 15,900 | 9,500 | 25,400 | 4,800 | 59,100 | 63,900 | |
| **B/C** | 13.7 | | | 3.5 | | | 2.4 |
| **NPV (B-C) (Cr. INR)** | 204,500 | | | 117,500 | | | 47,900 |
| **EIRR** | 39.1% | | | 32.3% | | | 14.1% |
| **Reference: (Underground Bypass) (Cr. INR)** | Construction | Site Preparation | Total | | | | |
| | 8,000 | 200 | 8,200 | | | | |

*Source: JICA Expert Team*

# Chapter 8. Strategic Environmental Assessment Study

## 8.1 Environmental Impact Assessment

### 8.1.1 Overview of the Physical Measures

The evaluation of the impacts on the natural and social environment for the prioritized physical measures for the JICA Comprehensive Flood Control Master Plan (CFCMP) mentioned above is summarized in the Table 8-1.

### 8.1.2 Major Negative Impacts

#### 8.1.2.1. Water pollution and other indirect potential impact

According to the water quality survey results, the quality of the surface water of the Adyar and Cooum Rivers, as well as the Buckingham Canal, is very low. This water body condition will negatively affect the aquatic ecosystem in the water bodies as well as people's living life, including odor nuisance in CMA. Additionally, the sediment soil in the projected river and canal contains high levels of heavy metals. Since these heavy metals are generally toxic to human health, careful attention must be paid if physical measures are carried out accompanied by the utilization of the excavated sediment soil or movement of the contaminated soil.

#### 8.1.2.2. Biodiversity / Ecosystem

Deterioration of the green in the CMA by cutting a large volume of wood or big trees symbolic to the regions is one of the significant negative impacts for the urbanized city since a mass of green provides the city-shaded open spaces and contributes to mitigation against heat island phenomena as well as to retaining rainwater to reduce the speed of runoff in the city in general.

The list of the prioritized physical measures that will be accompanied by the construction of a concrete structure at the coastal areas of the Bay of Bengal must be carried out based on the detailed environmental assessment of the aquatic ecosystem following the relevant local laws.

Additionally, in the Kovalam basin, the Pallikaranai Marsh Reserve Forest, where the district is determined as a flood-prone area, has been listed as a site under the Ramsar Convention. Even though there are development plans for future renovation, construction activities that may cause degradation of biodiversity-related wetland functions should be given due attention.

#### 8.1.2.3. Involuntary Resettlement and Land Acquisition

Many residential and business buildings are settled along the rivers; therefore, a large volume of involuntary resettlement and land acquisition required for river widening is expected. The following table shows the approximate relocation volume of both informal and formal settlements necessary for the implementation of the CFCMP.

**Table 8-1: Major Physical Measures of the CFCMP for EIA**

| Category | | Physical Measures | Construction Works Overview |
|---|---|---|---|
| A. Fluvial (River) Flood Control Measures | A1: Adyar River Basin | A1-①: Adyar River and Chembarambakkam Surplus Channelization-1 (Deepening Riverbed) | Dredging riverbed soil |
| | | A1-②: Adyar River and Chembarambakkam Surplus Channelization-2 (Widening Riverbank) | Earthworks for widening riverbanks, construction of raised bank |
| | | A1-③: Underground River construction from the Adyar River near the airport to the Bay of Bengal | Excavation of land by TBM (Tunnel Boring Machine), construction of concrete structures for the new tunnel structure, construction of intake and outlet vertical shaft from Adyar River to Bay of Bengal |
| | A2: Cooum River basin | A2-①: Cooum River Channelization-1 (Deepening Riverbed) | Dredging riverbed soil |
| | | A2-②: Cooum River Channelization-2 (Widening Riverbank) | Earthworks for widening riverbanks, construction of raised bank |
| | A3: Kosastha-laiyar River Basin | A3-①: Kosasthalaiyar River and Redhills Surplus Channelization-1 (Deepening Riverbed) | Dredging riverbed soil |
| | | A3-②: Kosasthalaiyar River and Redhills Surplus Channelization-2 (Widening Riverbank) | Earthworks for widening riverbanks, construction of raised bank |
| | | A3-③: Kosasthalaiyar River Looped waterway development with gate construction | Construction of raised bank, earthworks for widening riverbanks, construction of gates |
| | A4: Kovalam Basin | A4-①: Okkiyam Maduvu Surplus Channelization-1 (Deepening Riverbed) | Dredging riverbed soil |
| | | A4-②: Okkiyam maduvu Surplus Channelization-2 (Widening Riverbank) | Earthworks for widening riverbanks, construction of raised bank |
| | A5: All river basin | A5-①: Water tanks rehabilitation with gate construction (to enhance flood storage capacity) | Dredging bed soil of the existing tanks, construction of gates and drainage channels connecting tank and river |
| | | A5-②: New detention ponds (water tanks) development with gate construction (especially in Kosasthalayar Basin) | Excavation of land for the new detention ponds (tanks), construction of gates and drainage channels connecting tank and river |
| B. Pluvial (Drainage) Flood Control Measures | B1: North Buckingham Canal (NBC) | B1-①: Rehabilitation of the B. Canal | Dredging bed soil of the canal, construction of raised walls |
| | | B1-②: Retarding Pond construction adjacent to the Kodungaiyur Drain, Captain Cotton Canal, Otteri Nala Drain, and midstream of NBC | Excavation of ground soil, construction of gate, installation of pump, construction of concrete structure for bank protection |
| | | B1-③: Bypass channel (Cut &Cover) construction connecting Otteri Nala Drain and the Cooum River | Excavation of land for the new culvert drainage channel, construction of concrete structure for the channel |
| | | B1-④: Construction of gate at the junction of NBC and Cooum River to prevent backwater | Excavation of canal bed soil, construction of gates |
| | B2: Central Buckingham Canal (CBC) | B2-①: Rehabilitation of the B. Canal | Dredging bed soil of the canal, construction of raised walls |
| | | B2-②: Gate construction with side walls at the junction of the Cooum River | Excavation of canal bed soil, construction of gates |
| | B3: South Buckingham Canal (SBC) | B3-①: Rehabilitation of the B. Canal | Dredging bed soil of the canal, construction of riverbank/raised wall |
| | | B3-②: Gate construction at the north end and the area near Pallikaranai Marsh, and Pump installation at lowlands | Excavation of riverbed soil, construction of gate, installation of pump |
| | | B3-③: Construction diversion channel connecting B. Canal and the Bay of Bengal at Injambakkam area and shortcut channel from Okkiyam Maduvu to B. Canal | Excavation of land for the new open channel, construction of concrete structure for the channel and a gate near the Bay of Bengal |
| | B4: Connecting Drains to Adyar and Cooum Rivers | B4-①: Drainage rehabilitation by deepening and widening of the connecting drains to Adyar and Cooum River (MGR, Kolapakkam, Kundrathur, Pammal Drain) | Dredging drain bed soil, earthworks, and concrete works for widening drain banks, construction of raised bank |
| | | B4-②: Gate construction at the drainage outlet and reorientation of the outlet discharge to align river flow | Construction of gate, excavation of drainage bed soil, reorienting the drainage outlet using either a concrete guide wall or soil works |
| | | B4-③: Water tank rehabilitation and development with gate construction (midstream of Kundrathur Drain (Open ground near the Madha College), upstream of Palmmar Drain (Thiruneermalai Lake=Periya Eri)) | Dredging the bed soil of the existing tanks, excavation of land for the new tanks, construction of gates and drainage channels connecting tank and drainage |

*Source: JICA Expert Team*

#### 8.1.2.4. Local Resources (Groundwater and Beach)

Depending on the geological conditions, excessive excavation, and withdrawal of water from the groundwater cause the groundwater level to drop in general, which could have a significant negative impact on the natural and social environment, including water scarcity for those who rely on the water resource and subsidence of terrain in CMA. Changing the shape of the beaches, including losing or accumulating the existing beach sands to undesirable or offshore areas, has a significant negative impact on the tourism industry in Chennai.

### 8.1.3 Alternative Analysis

Table 8-2 Shows a summary of alternative analysis for the proposed countermeasures for the CFCMP. A "without project" aspect is added to the evaluation items to confirm the validity of the proposed actions. Critical evaluation criteria are selected from the items identified in the EIA, in addition to the cost of flood mitigation.

### 8.1.4 Mitigation Measures

Mitigation measures for the major negative impacts are analyzed as shown in the items below.

#### 8.1.4.1. Water pollution and other indirect potential impact

- ✓ Applying emerged and aquatic vegetation areas near the inlet of the tanks for future water purification by the vegetation. (Phytoremediation)
- ✓ Periodical monitoring of surface water quality during the construction and operation periods.
- ✓ Promoting the implementation of sewer improvement projects in the CMA.

#### 8.1.4.2. Biodiversity / Ecosystem

- ✓ Planting of additional trees shall be carried out for cutting trees. (Green Offset)
- ✓ Consideration of nature-friendly development, including the development of additional marshlands.

#### 8.1.4.3. Resettlement and Land Acquisition

- ✓ Preparation of the Resettlement Action Plan (RAP) and carrying out proper management.

#### 8.1.4.4. Local Resources (Groundwater and Beach)

- ✓ Conducting a detailed survey for geological and groundwater conditions.
- ✓ Conducting a detailed analytical study to clarify the long-term sand movement.

Periodical monitoring of groundwater and sand movement during the construction and operation period.

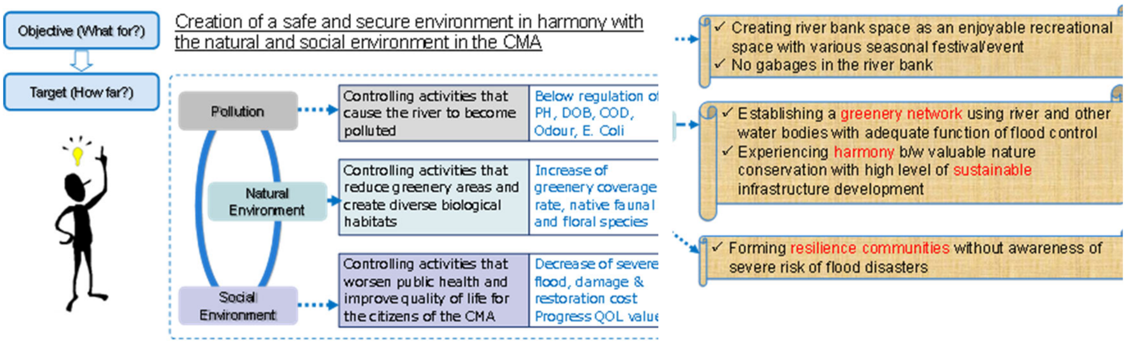
**Table 8-2: Summary of Alternative Analysis**

| # | Category of Measures and Counter Measures / Evaluation Item | Without Project Option | A: Fluvial (River) Flood Control Measures | | | | | | | | | | | | B: Pluvial (Drainage) Flood Control Measures | | | | | | | | | | | | C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | A1 Adyar | | | A2 Cooum | | A3 Kosasthalaiyar | | | A4 Kovalam | | A5 All basin | | B1 NBC | | | | B2 CBC | | B3 SBC | | | B4 Connecting Drains | | | C |
| | | | ① | ② | ③ | ① | ② | ① | ② | ③ | ① | ② | ① | ② | ① | ② | ③ | ④ | ① | ② | ① | ② | ③ | ① | ② | ③ | ① |
| | | | Adyar River and Chembarambakkam Surplus Channelization-1 (Deepening) | Adyar River and Chembarambakkam Surplus Channelization-2 (Widening) | Underground river construction | Cooum River Channelization-1 (Deepening) | Cooum River Channelization-2 (Widening | Kosasthalaiyar River and Redhills Surplus Channelization-1 (Deepening) | Kosasthalaiyar River and Redhills Surplus Channelization-2 (Widening) | Kosasthalaiyar River Looped waterway development with gate construction | Okkiyam Maduvu Surplus Chamelization-1 (Deepening Riverbed) | Okkiyam maduvu Surplus Chamelization-2 (Widening Riverbank) | Water tanks rehabilitation with gate construction | New detention ponds (water tanks) development with gate construction | Rehabilitation of the B. Canal | Retarding pond construction adjacent to the Kodungaiyur Drain, and others | Bypass channel (Cut &Cover) construction connecting Otteri Nala and the Coum R. | Construction of gate at the junction of NBC and Coum River to prevent backwater | Rehabilitation of the B. Canal | Gate construction with side walls at the junction of the Coum River | Rehabilitation of the B. Canal | Gate construction at the north end and the area near Pallikaranai Marsh, and others | Construction diversion channel connecting B. Canal and the Bay of Bengal | Drainage rehabilitation by deepening and widening of the connecting drains to the Rs. | Gate construction at the drainage and reorientation of the outlet discharge | Water tank rehabilitation and development with gate construction | Training wall construction at Muttukadu |
| 1 | Cost for flood mitigation | 1 | 3 | 3 | 1 | 2 | 2 | 3 | 3 | 2 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 2 | 4 | 2 | 2 | 4 | 4 | 4 | 3 |
| 2 | Beneficial to local economy | 1 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 4 | 5 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 4 |
| 3 | Pollution control | 1 | 2 | 4 | 2 | 2 | 4 | 2 | 4 | 4 | 2 | 4 | 2 | 3 | 3 | 3 | 3 | 4 | 3 | 4 | 3 | 4 | 2 | 3 | 4 | 2 | 2 |
| 4 | Impact on natural environment | 3 | 3 | 3 | 2 | 4 | 2 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 4 | 2 | 5 | 5 | 4 | 5 | 4 | 5 | 2 | 4 | 5 | 2 | 2 |
| 5 | Involuntary Resettlement and land acquisition | 5 | 5 | 2 | 3 | 5 | 2 | 5 | 2 | 4 | 5 | 4 | 4 | 3 | 5 | 4 | 5 | 4 | 3 | 3 | 5 | 4 | 3 | 5 | 4 | 4 | 5 |
| 6 | Impact related with living condition of the citizens | 1 | 5 | 4 | 5 | 5 | 4 | 5 | 4 | 5 | 5 | 4 | 5 | 3 | 5 | 4 | 4 | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 3 |
| 7 | Impact on local resource | 3 | 3 | 3 | 2 | 3 | 4 | 3 | 3 | 5 | 3 | 3 | 3 | 3 | 5 | 3 | 4 | 5 | 5 | 5 | 5 | 5 | 2 | 5 | 5 | 3 | 2 |
| | Total/ | 15 | 26 | 24 | 19 | 26 | 23 | 26 | 24 | 27 | 26 | 26 | 25 | 22 | 31 | 24 | 28 | 31 | 29 | 28 | 30 | 29 | 19 | 30 | 31 | 25 | 21 |
| | Average/ | | 23.00 | | | 24.50 | | 25.67 | | | 26.00 | | 23.50 | | 28.50 | | | | 28.50 | | 26.00 | | | 28.67 | | | 21 |
| | Average | | 24.53 | | | | | | | | | | | | 27.92 | | | | | | | | | | | | 21 |

*Source: JICA Expert Team*

## 8.2 Environmental Objective and Target, Vision, and Strategy

The following figure summarizes the environmental objective, target, and vision for the SEA.

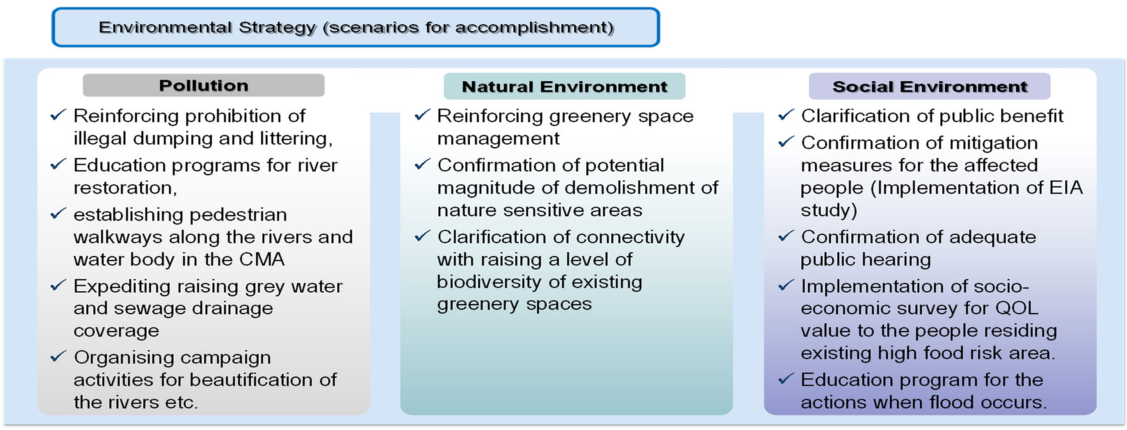



*Source: JICA Expert Team*

**Figure 8-1: Environmental Objective and Target, Vision**

## 8.3 Environmental Strategy in Chennai

Following the environmental vision, the environmental strategy accompanied by the Flood Control Master Plan is prepared as follows.




*Source: JICA Expert Team*

**Figure 8-2: Environmental Strategy**

# Chapter 9. Comprehensive Flood Control Master Plan (CFCMP)

## 9.1 Proposed Project Components of the JICA Flood Control Master Plan

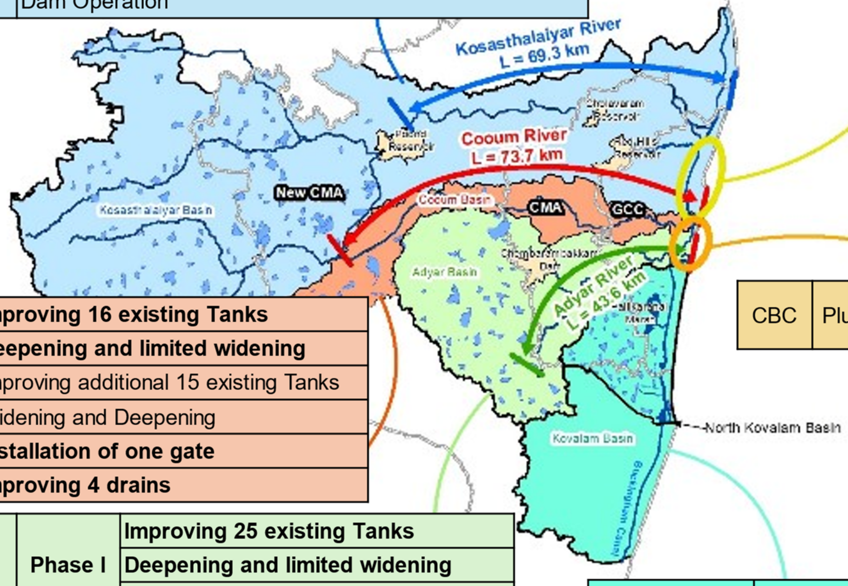
This chapter provides a comprehensive overview of the proposed countermeasures for fluvial (riverine) and pluvial (urban) flood control. These measures, previously detailed in earlier chapters, are now integrated into a cohesive framework that includes a step-by-step implementation plan and the prioritization of interventions. This chapter serves as a roadmap, offering a structured approach to addressing flood risks by summarizing and scaling the measures into actionable components.

A detailed list of the proposed components for flood control is shown in the following figure, addressing both fluvial and pluvial measures. The chapter not only consolidates the interventions but also evaluates their importance and urgency to guide resource allocation effectively. This prioritization ensures that critical areas are addressed first, aligning technical, financial, and institutional considerations with the overall goals of the Master Plan.

By providing practical insights into the sequencing of actions, this chapter enables a systematic approach to flood risk management. It highlights the importance of aligning implementation with prioritized needs, ensuring that the proposed measures lead to impactful and sustainable results in mitigating flood-related challenges.

| | | | |
|---|---|---|---|
| Kosasthaliyar Basin | Fluvial | **Phase I** | **Improving 56 existing Tanks** |
| | | | **Deepening and localized widening** |
| | | | **Redhills improvement** |
| | | Phase II | Improving additional 56 existing Tanks and 7 new tanks |
| | | | Widening and Deepening |
| | | | Dam Operation |

| | | | |
|---|---|---|---|
| NBC | Pluvial | **Phase I** | **Gates in connecting drains to NBC** |
| | | | **3 connecting drains improvement** |
| | | | **A diversion from Otteri Nula to Coour** |
| | | | **5 retarding ponds** |




| | | | |
|---|---|---|---|
| CBC | Pluvial | **Phase I** | **One Gate at the Coour side** |
| | | | **Canal improvement** |

| | | | |
|---|---|---|---|
| Cooum Basin | Fluvial | **Phase I** | **Improving 16 existing Tanks** |
| | | | **Deepening and limited widening** |
| | | Phase II | Improving additional 15 existing Tanks |
| | | | Widening and Deepening |
| | Pluvial | **Phase I** | **Installation of one gate** |
| | | | **Improving 4 drains** |

| | | | |
|---|---|---|---|
| Adyar Basin | Fluvial | **Phase I** | **Improving 25 existing Tanks** |
| | | | **Deepening and limited widening** |
| | | | **Underground bypass** |
| | | Phase II | Improving additional 25 existing Tanks |
| | | | Widening and Deepening |
| | | | Dam Operation |
| | Pluvial | **Phase I** | **Installation of 3 gates** |
| | | | **Improving 8 drains** |

| | | | |
|---|---|---|---|
| Kovalam Basin and SBC | Pluvial | **Phase I** | **Improving 61 existing Tanks** |
| | | | **Okkiyam Maduvu Improvement** |
| | | | **Installation of 3 gates in B Canal** |
| | | | **2 pumps** |
| | | | **One bypass and one short-cut** |

*Source: JICA Expert Team*

**Figure 9-1: Overview of the Master Plan Components**

## 9.2 Development Implementation Plan

Since a flood control master plan includes several components that need to be implemented over a relatively long timeframe, it is essential to prioritize these components. This involves proposing different phases and an implementation plan. In this section, the prioritization of components is outlined by basin and by type of countermeasure, taking into account technical and socio-economic considerations.

### 9.2.1 Prioritization by Basin

The JICA Flood Control Master Plan provides countermeasures across the study area, including four basins. Therefore, it is essential to prioritize the implementation of the master plan basin-wide, starting with the basins that have the highest priority. The prioritization was conducted based on factors such as potential flood damages (hazard), recent urbanization and accumulation of assets and economic activities (exposure), and the effect of controlling fluvial and pluvial flooding (coping capacity).

The total flood damage for both a 100-year and 10-year return period of flood has been summarized based on asset values in each basin. These estimates were derived using developed flood hazard maps applied across the entire basin area as well as per unit area (per km²) of the basins. Table 9-1 presents the total potential damage across the basin-wide areas, and Table 9-2 Details the potential damage per square kilometer.

**Table 9-1: Basin-wide Potential Flood Damage**

| Basin-wide Total Potential Damage (INR Cr.) | Flood RPs | Adyar (854 km²) | Cooum (435 km²) | Kosasthaliyar (4082 km²) | Kovalam (782 km²) |
|---|---|---|---|---|---|
| | 10-year | 16900 | 12600 | 28900 | 19000 |
| | 100-year | 22800 | 17600 | 39000 | 20500 |
| | **Rank** | ~2 | 4 | 1 | ~2 |

*Source: JICA Expert Team*

**Table 9-2: Potential Flood Damage per km2**

| Potential Damage per Km² (INR Cr.) | Flood RPs | Adyar (854 km²) | Cooum (435 km²) | Kosasthaliyar (4082 km²) | Kovalam (782 km²) |
|---|---|---|---|---|---|
| | 10-year | 20 | 29 | 7 | 24 |
| | 100-year | 27 | 40 | 10 | 26 |
| | **Rank** | ~2 | 1 | 4 | ~2 |

*Source: JICA Expert Team*

When considering both basin-wide and per-unit-area damage, we observe that while the Kosasthalaiyar and Cooum Basins rank higher in the basin-wide damage table, they receive lower ranks when considering damage per unit area. Conversely, the Adyar and Kovalam Basins exhibit higher scores in both assessments. Therefore, integrating both the basin-wide total damage and damage per unit area, the Adyar and Kovalam Basins emerge as the highest-priority basins (ranked 1 or 2), while the Cooum and Kosasthalaiyar Basins are assigned lower priority (ranked 3 or 4).

Flood control efforts in the Adyar River Basin will minimize the backwaters in the connecting drains and tributaries connected to Adyar, such as Mudichur, offering protection against flooding from the main river and mitigating damage from backwater effects and urban flooding. Consequently, the Adyar River Basin has been assigned the highest priority, followed by the Kovalam Basin. The following is a summary of the selected priority basins, considering the B Canal:

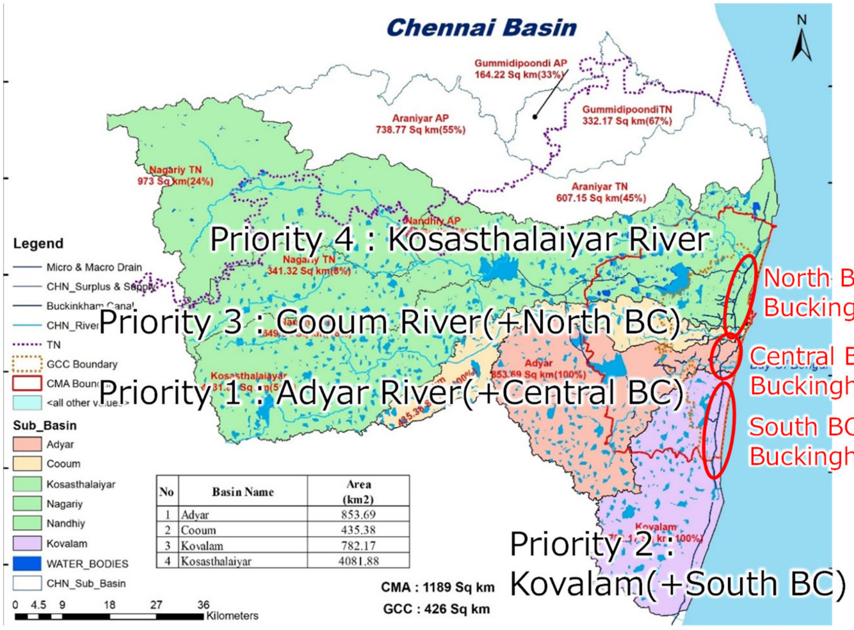
Priority 1: Adyar Basin and Central B Canal
Priority 2: Kovalam Basin and South B Canal
Priority 3: Cooum Basin and North B Canal
Priority 4: Kosasthalaiyar Basin

Table 9-3 Summarizes the prioritization results based on these factors. As shown, the Adyar Basin ranks the highest, followed by the Kovalam Basin.

**Table 9-3：Priority by river basin**

| **Priority** | Basin | Potential Damage Rank (Hazard) | Urbanization (Reduce Exposure) | Effectiveness (Improve Flood Control) |
|---|---|---|---|---|
| **1** | Adyar | 1 or 2 | 2 | 1 |
| **2** | Kovalam | 1 or 2 | 1 | 2 or 3 |
| **3** | Cooum | 3 or 4 | 3 | 4 |
| **4** | Kosasthalaiyar | 3 or 4 | 4 | 2 or 3 |

*Source: JICA Expert Team*




*Source: JICA Expert Team*

**Figure 9-2: Priority by Basin**

9.2.2 Prioritization of Countermeasures for Each Basin

9.2.2.1. Prioritization of River Flood Control Countermeasures

- **Basic Approach for River Channelization**: River channelization, which involves land acquisition for channel widening, is expected to take time due to the need for relocating residential and commercial facilities. Therefore, the project will be implemented in phases, as outlined in Figure 9-3**: Phase 1**: Deepening the existing river channel (with limited localized widening) and **Phase 2**: Widening the river channel. Phase 1 will take 10 years, and Phase 2 will start after it.


*Source: JICA Expert Team*

**Figure 9-3: River Channelization Priority and Phases**

- **Basic Approach for Enhancing Flood Storage in Tanks and Waterbodies**: The restoration of waterbodies and tanks and enhancement of flood storage are currently being initiated by TNWRD and other counterparts using internal resources and external funding supports. Considering this, the JICA Flood Control Master Plan suggests progressively improving the functionality of these tanks for flood storage through the relevant implementing agencies. Figure 9-4 Illustrates the expected number of waterbodies and tanks to be improved for flood storage in Phase 1, which will span 10 years, followed by Phase 2, which will commence after the completion of Phase 1.

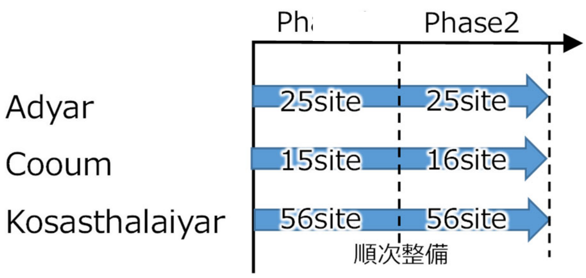



**Figure 9-4: Improving Tanks for Flood Storage and Phases**

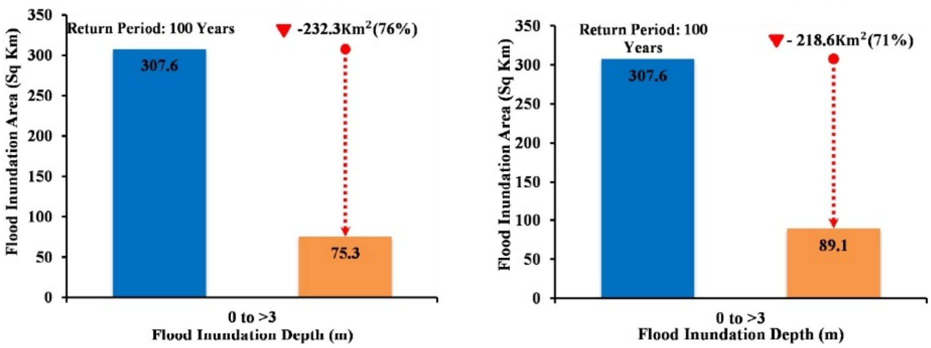
9.2.2.2. Priority Comparison between Deepening and Flood Storage in Tanks

Figure 9-5 shows the effect of river channelization through deepening and the improvement of tanks for flood storage on the reduction of inundation area at a 1/100 scale, using the Adyar River as an example.

Deepening of the Adyar River will result in a 76% reduction in riverine inundation, from 307.6 km² to 75.3 km². Similarly, improving waterbodies and tanks will reduce the inundation area by 71%, from 307.6 km² to 89.1 km². The effects of both measures are nearly identical, with river deepening showing slightly greater effectiveness.

In terms of cost, the total cost for river channel improvement through excavation alone across the three rivers is approximately 1,700 INR Crores, which is slightly higher than the total cost for tank improvement, estimated at 1,500 INR Crores. However, a tank would require additional preparation costs of approximately 1,800 INR Crores, including land acquisition, so excavation of the river channel would be cheaper for the overall project.

Given the above, excavation of the river channel is more effective at flood control than a tank and is also advantageous in terms of total cost, so it has been determined that implementing it in Phase 1 is appropriate.




*Source: JICA Expert Team*

**Figure 9-5: Effectiveness of River Deepening (left) and Flood Storage in Tanks (right)**

9.2.2.3. Prioritization of Urban Flood Control Countermeasures

Due to the high frequency of urban flooding (pluvial floods), improving urban drainage measures will be implemented in Phase 1 (~10 years). The sequence of improvements for Phase 1 at each location is as follows:

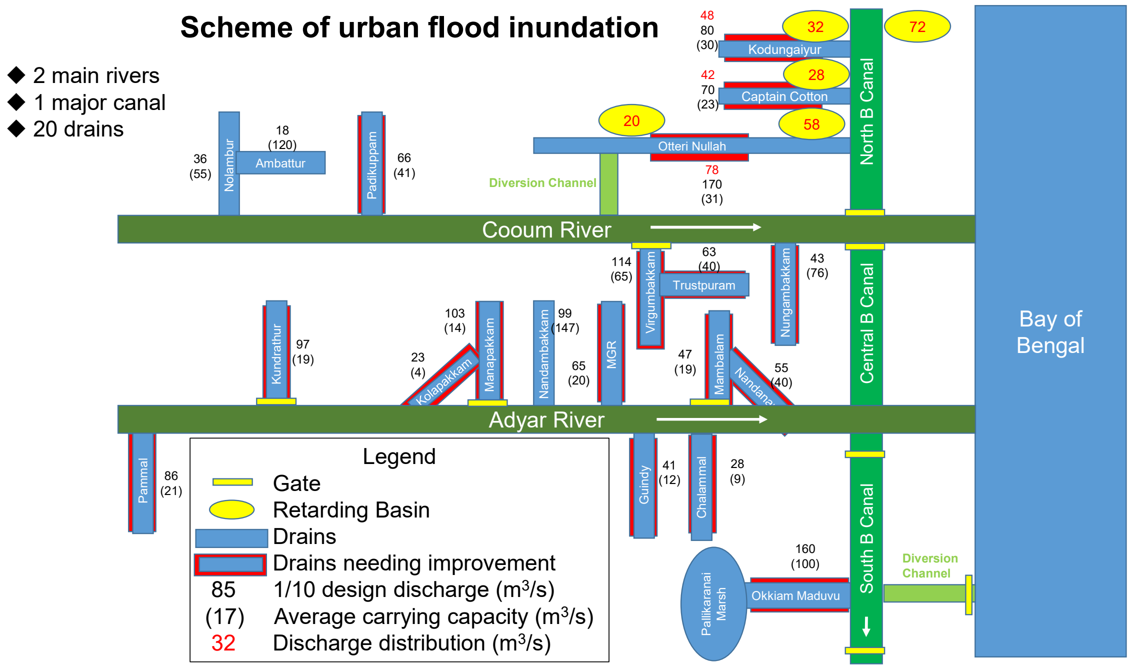
- **B Canal and its Connecting Drainages**: B Canal is located near the estuary, and

increasing its flow capacity is more critical than preventing backflow caused by rising water levels in the main river. Specifically, the northern B Canal connects to three drainage channels, two of which have insufficient flow capacity. Therefore, priority will be given to increasing the flow capacity of the B Canal.
Phase 1 (First Half): Improvement of the flow capacity of B Canal
Phase 1 (Second Half): Installation of backflow prevention gates from the main river

- **Improvement Connecting Drainages to Adyar and Cooum Rivers**: In addressing internal drainage, improvements to the flow capacity of the drainage channels and the installation of backflow prevention gates from the main river are planned.
  Until the improvement of the main river channel is completed, there is a high risk of tributary flooding due to backflow. Additionally, as coordination with surrounding areas is required for the drainage channel improvements, the installation of backflow prevention gates has been prioritized.
  Phase 1 (First Half): Installation of backflow prevention gates from the main river
  Phase 1 (Second Half): Drainage channel improvement

*Source: JICA Expert Team*

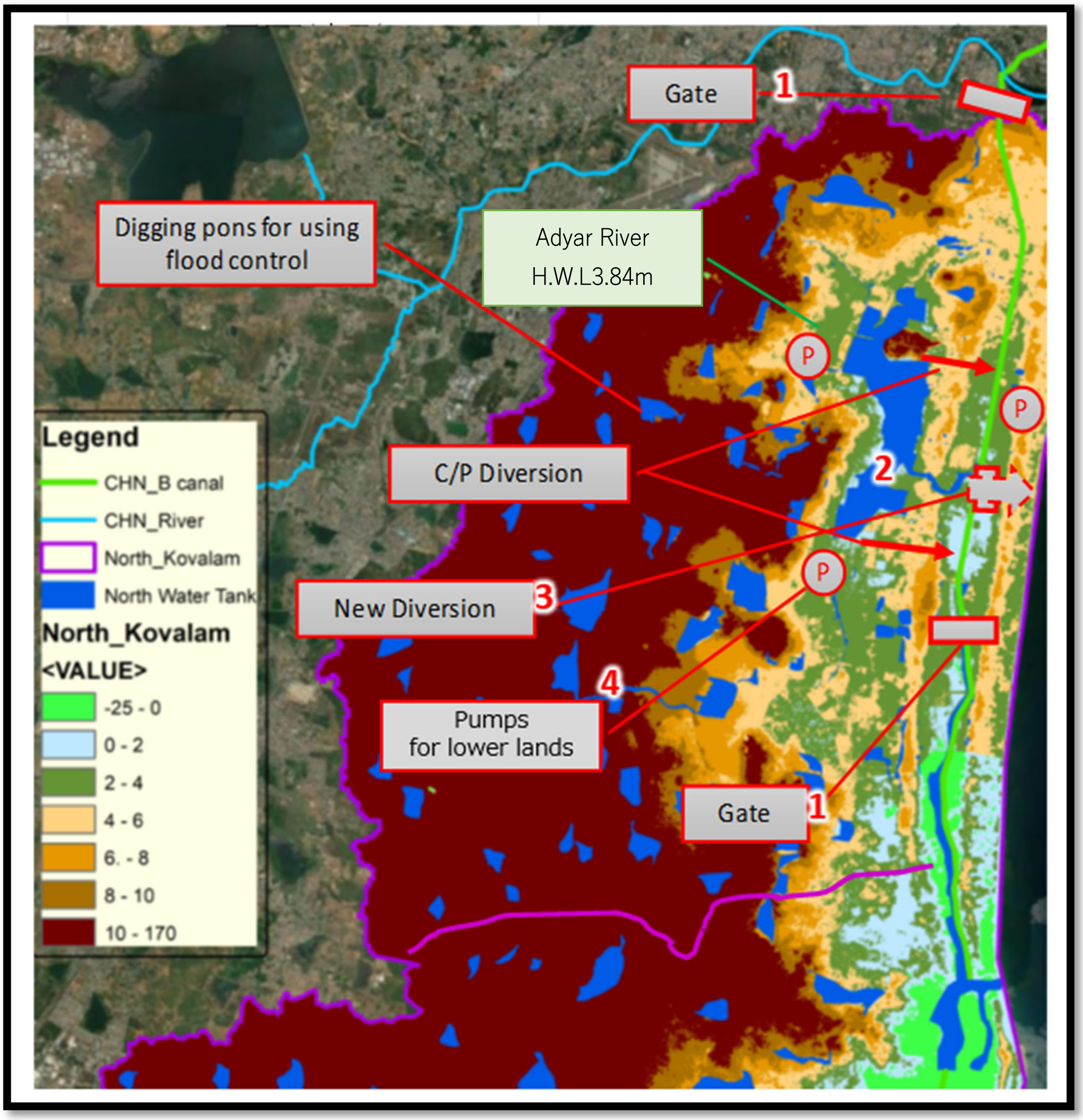
Figure 9-6 Shows the location of the several drainage systems, their current discharge capacity, the improved discharge capacity, and the location of detention ponds, etc.




*Source: JICA Expert Team*

**Figure 9-6: Overview of Urban Drainage Proposals**

- **Flood Control in Kovalam Basin (North Part of the Basin):** Urban flooding due to drainage issues is a significant concern in the north of Kovalam Basin, with the primary solution being the restoration of the drainage system and the construction of a bypass from B canal to the Bay of Bengal. Therefore, in Phase 1, the focus will be on constructing the bypass channel, improving flood storage in tanks and restoration of missing links, installing backwater prevention gates, and channelization of Okkiyam Maduvu. Following these improvements, it will also be necessary to address the flood stagnation and stormwater logging in low-lying areas, following the priority developments.




*Source: JICA Expert Team*

**Figure 9-7: Target Areas for Countermeasures in the Kovalam Basin**

### 9.2.3 Implementation Schedule

The project schedule is outlined in Table 9-4, based on the sequence discussed above. The implementation schedule is divided into two phases: the immediate phase (Phase 1) and the future phase (Phase 2), as described in Chapter 2. The approach for each improvement is detailed below, with the schedule presented. Although the processes in the table were initiated simultaneously across each basin, due to the project's large scale, the start of improvements in the Adyar River Basin, Kovalam Basin, Cooum River Basin, and Kosasthalaiyar River Basin may be adjusted in that sequence.

## Table 9-4: Tentative Implementation Schedule

| Proposed Countermeasure | | | | Phase 1 | | Phase 2 and beyond | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 5 | 10 | 15 | 20 | beyond |
| Adyar River | Flood control | Using Existing Waterbodies | 50 Tanks | 12 tanks | 13 tanks | 12 tanks | 13 tanks | Extended (depend on circumstances) |
| | | Dam Operation Improvement | Under verification | Verification | | Operation | | |
| | | Channelization | Deepening and local widening | 0.0～25.0k | | upper 25.0k | | |
| | | | Widening | | | 0.0～43.6k | | |
| | | Underground River | | | | Extended (depend on circumstances) | | |
| | Strom Water | Gates in Connecting Drains to River | 3 Gates | | | | | |
| | | Drain Channelization | 8 Drains | | | | | |
| Centrl B Canal | Strom Water | Gates in Junction to River | 1 Gates | | | | | |
| | | Channelization | Centrl B Canal | | | | | |
| Cooum River | Flood control | Using Existing Waterbodies | 31 Tanks | 7 tanks | 8 tanks | 8 tanks | 8 tanks | Extended (depend on circumstances) |
| | | Channelization | Deepening and local widening | 0.0～25.0k | | upper 25.0k | | |
| | | | Widening | | | 0.0～34.2k | | |
| | Strom Water | Gates in Connecting Drainages to River | Gates（One Drain） | | | Extended (depend on circumstances) | | |
| | | Channelization | 4 Drains | | | | | |
| North B Canal | Strom Water | Gates in Connecting Drainages to NBC | 1 Gates | | | | | |
| | | Channelization | NBC , 3 Connecting Drains | | | | | |
| | | Diversion Canal | One from Otteri to Cooum | | | | | |
| | | New retarding pond | 5 locations | | | | | |
| Kosasthala iyar River | Flood Control | Using Existing Waterbodies | 112 Tanks | 28 tanks | 28 tanks | 28 tanks | 28 tanks | Extended (depend on circumstances) |
| | | Dam Operation Improvement | Under verification | Verification | | Operation | | |
| | | Channelization | Deepening and local widening | 0.0～31.7k | | upper 31.7k | | |
| | | | Widening and Deepening | | | 0.0～69.3k | | |
| Kovalam | Strom Water | Using Existing Waterbodies | 61 Tanks | 15 | 16 | Extended (depend on circumstances) | | |
| | | River Channelization | Okkiyama Maduvu | | 0.0~1.8k | | | |
| | | Gates in B Canal | 3 Gates | | | | | |
| | | Pumps | 2 Pumps | | | | | |
| | | Bypass and Shortcut | One Bypass and One Short cut | | | | | |

*Source: JICA Expert Team*

Note: Adyar Basin and central B Canal are the top priority, while Kovalam Basin and south B Canal are the second priority.

## 9.3 Overview of the Priority Countermeasures for River Flood Control

This section provides a brief implementation plan for each component of river flood control and urban flood control, based on the results and procedures discussed in the previous sections.

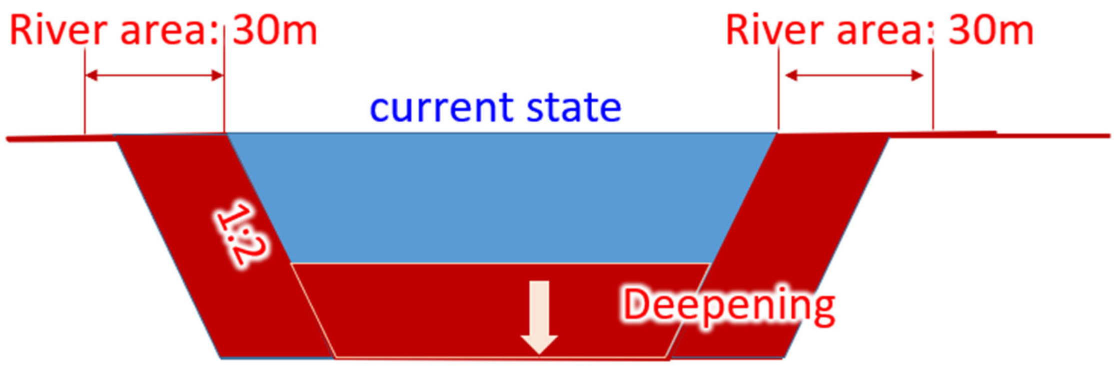
### 9.3.1 Adyar River

Figure 9-8 shows the standard cross-section for the river channelization of the Adyar River. Figure 9-9 provides an aerial view of the implementation phases and the locations of the proposed river channelization countermeasures. Figure 9-11 shows the longitudinal profile and design riverbed for deepening the river.

Regarding the standard cross-section: In Phase 1, widening is not primarily implemented; instead, excavation is carried out. Additionally, the excavation slope is generally set at 1:2.

Regarding the longitudinal profile and design riverbed, the river will be excavated from the mouth (0.0 km) to the confluence with the Chembarambakkam River (25.2 km). Deepening from the river mouth to 10.0 km will reach a depth of -2.0 meters, as needed to maintain the river mouth condition.

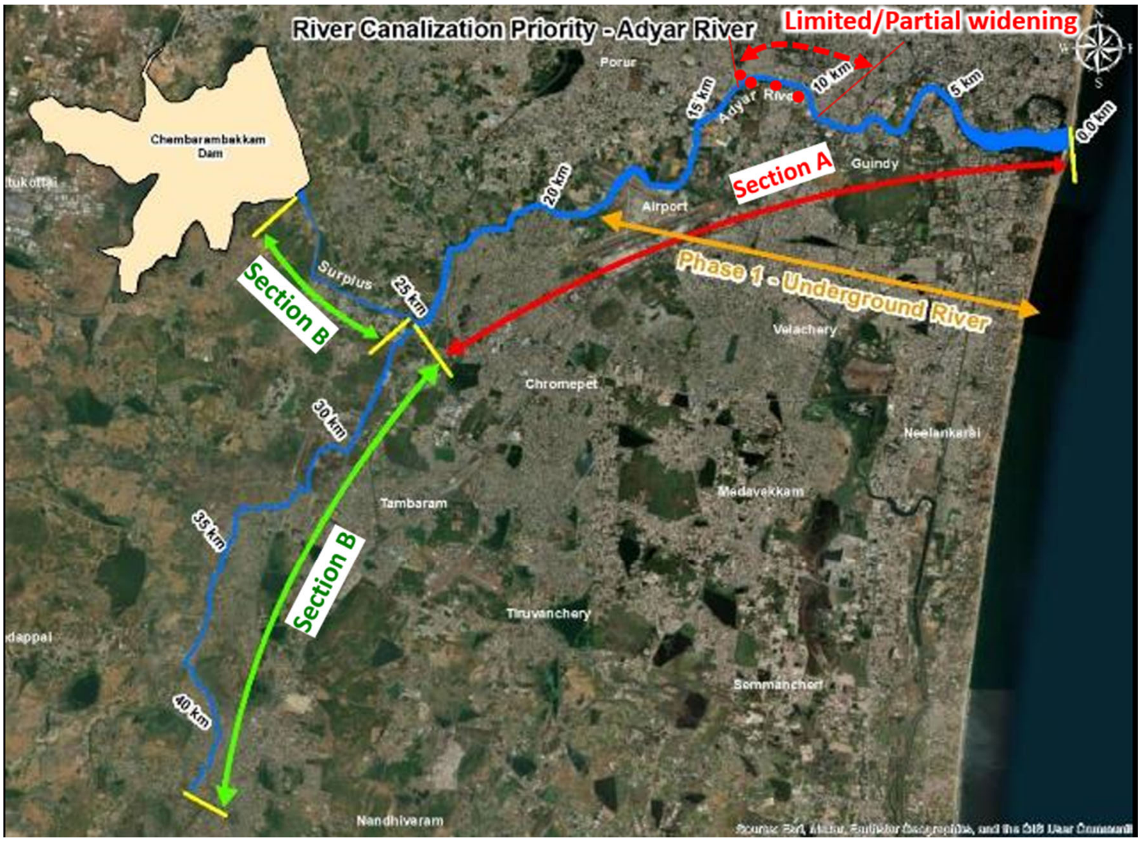
Phase 2 includes the continuation of the river deepening upstream (from 25.0 km to 43.7 km), as well as river widening along the entire river and improvements to the flood storage capacity in the remaining tanks, as outlined in Table 9-4.




*Source: JICA ExpertTeam*

**Figure 9-8: Standard Cross-section for River Channelization**

Based on the effects discussed in the previous section, the overviews of each project are as follows.



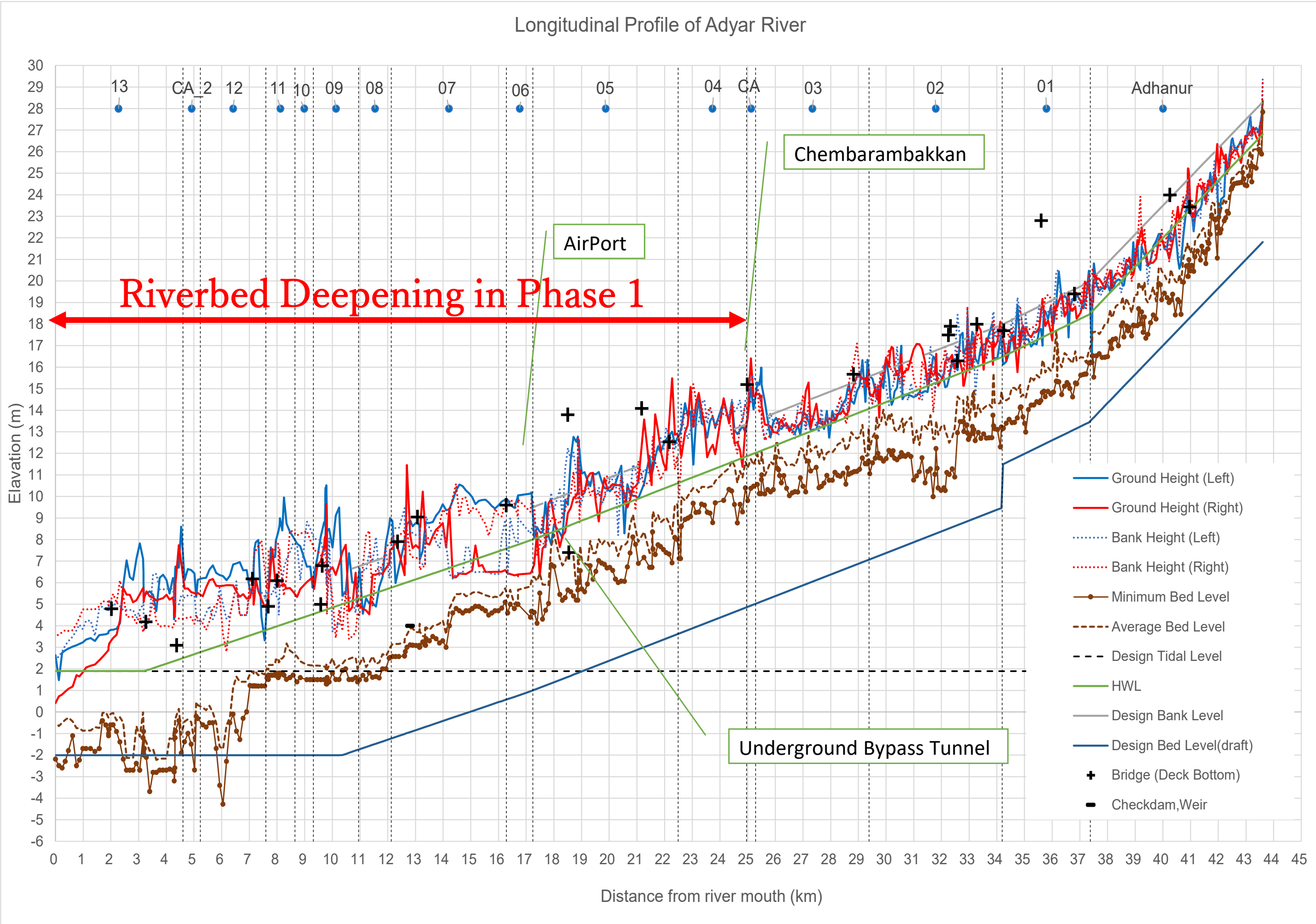

*Source: JICA ExpertTeam*

**Figure 9-9: Aerial View of Phases and Countermeasures in Adyar River**

The sections that require partial widening are Adyar 8 and Adyar 9 in Figure 9-10. These sections will be partially widened mainly on the right bank because the right bank is not urbanized.


*Source: JICA ExpertTeam*

**Figure 9-10: Plan View of Areas Requiring Limited/Partial Widening**




*Source: JICA Expert Team*

**Figure 9-11: Adyar River Longitudinal Profile and Designed Riverbed**

### 9.3.2 Underground Bypass

The underground river channels water from the Adyar River to the underground tunnel via an intake facility and inlet shaft. Drainage from the tunnel relies on natural siphons leading to Bengal Bay. The longitudinal gradient of the underground river is i = 1/2000, and the inner diameter is 11 m.

Since the route passes through the Kovalam area, the underground river is designed to provide flood protection for the Adyar River and also address internal water issues in Kovalam. To achieve this, water intake facilities will be installed at Kallu Kuttai Lake and Adambakkam Lake along the route.

**Table 9-5: Bypass tunnel schematic specification table**

| | | Unit | Route1 |
|---|---|---|---|
| Bypass Tunnel Length | | km | 12.5 |
| Inlet | Adyar River Kilopost | k | 18.009 |
| | Adyar River HWL | DL.+m | 8.38 |
| Outlet | Bengal Bay HHWL | DL.+m | 1.90 |
| WL Difference(Inlet-Outlet) ΔH | | m | 6.483 |
| WL Gradient(1/n) | | - | 1,928 |

*Source: JICA Expert Team*

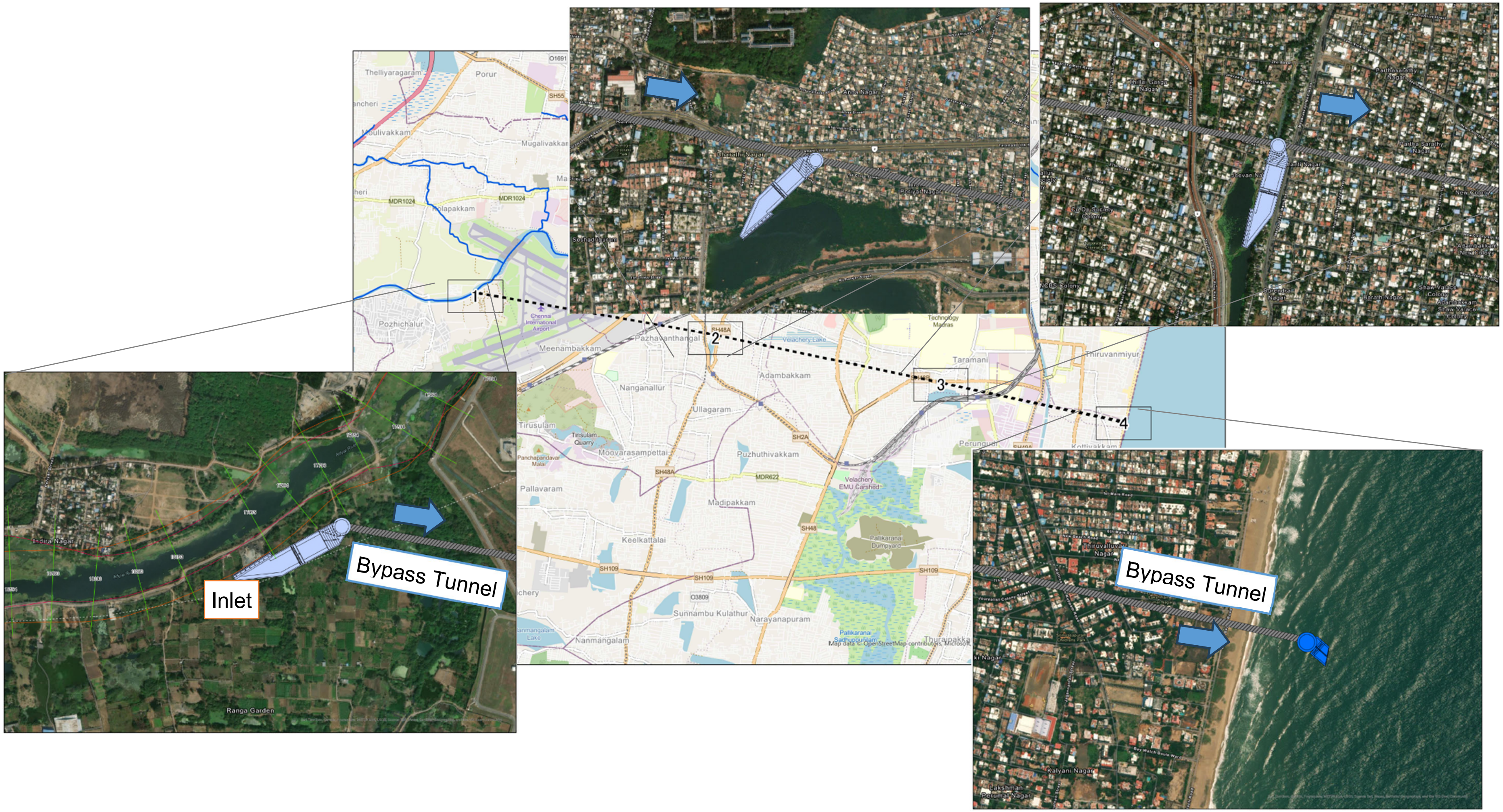
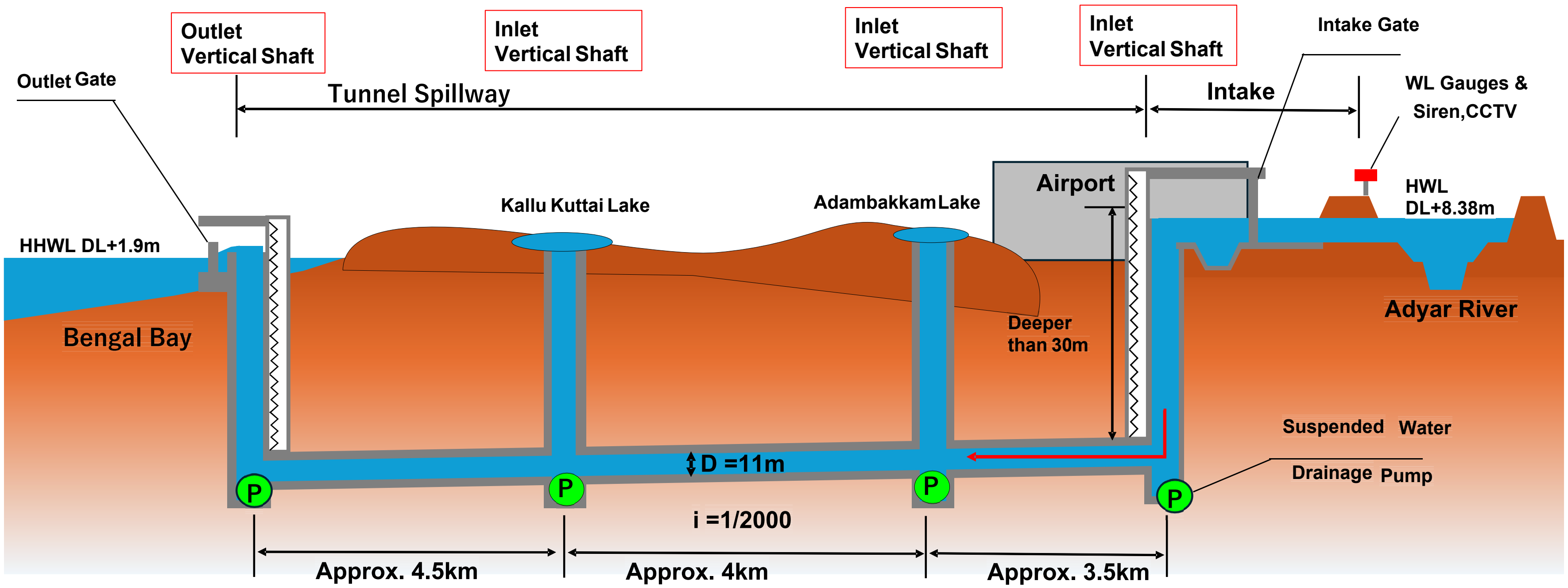



**Figure 9-12：Plan View of the Underground Bypass**




*Source: JICA Expert Team*

**Figure 9-13: Underground Bypass**

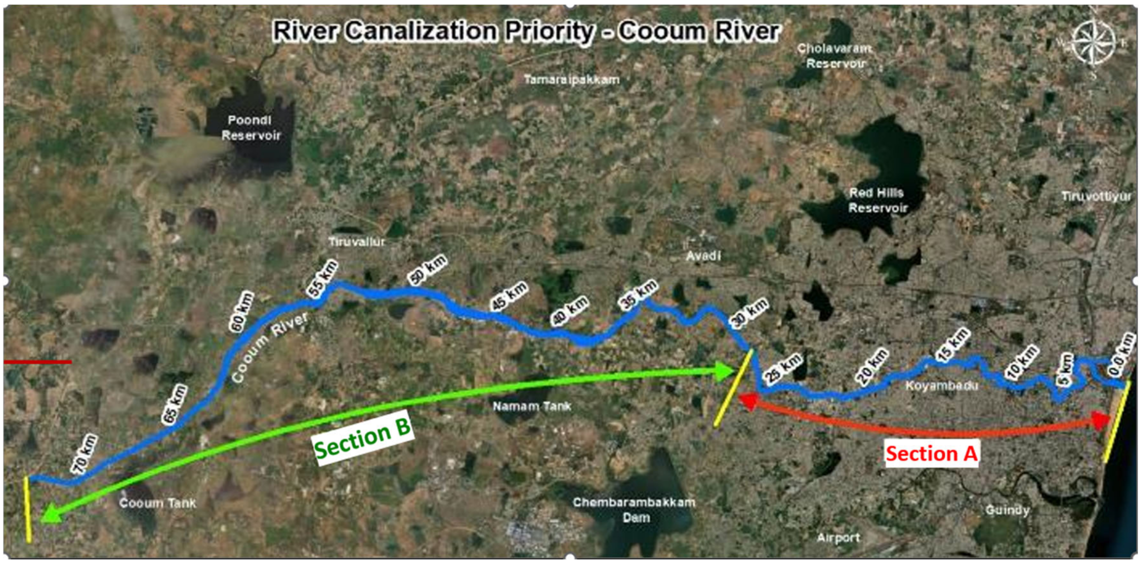
### 9.3.3 Cooum River

The standard cross-section of the Cooum River is the same as Figure 9-8. Figure 9-14 provides an aerial view of the implementation phases and the locations of the proposed river channelization countermeasures. Figure 9-15 shows the longitudinal profile and design riverbed for deepening the river.

Regarding the standard cross-section: In Phase 1, widening is not primarily implemented; instead, excavation is carried out. Additionally, the excavation slope is generally set at 1:2.

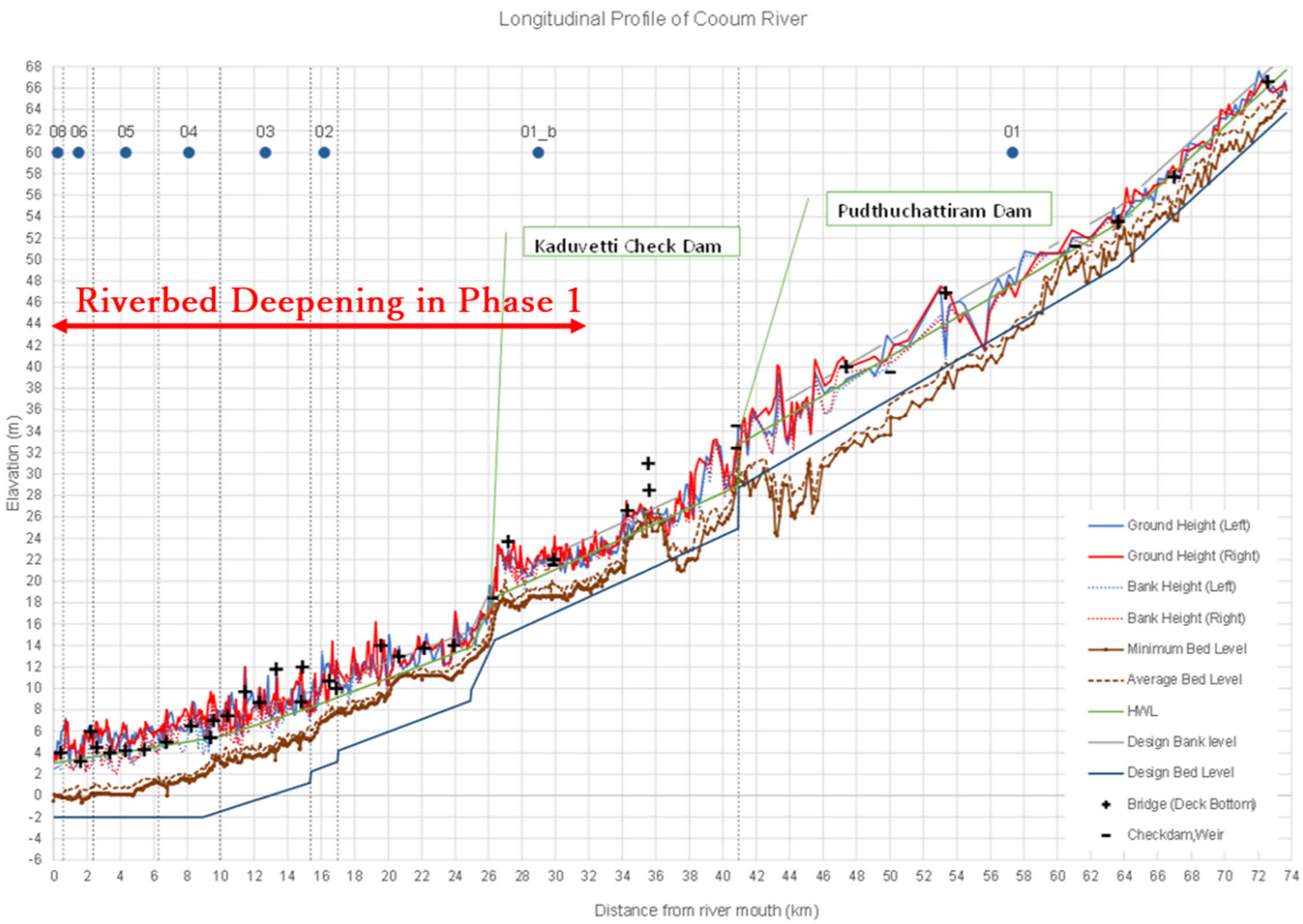
Regarding the longitudinal profile and design riverbed, the river will be excavated from the mouth (0.0 km) to 25. km. Deepening from the river mouth to 9.0 km will reach a depth of -2.0 meters, as needed to maintain the river mouth condition.

Phase 2 includes the continuation of the river deepening upstream (from 25.0 ~), as well as river widening along the entire river and improvements to the flood storage capacity in the remaining tanks, as outlined in Table 9-4.




*Source: JICA Expert Team*

**Figure 9-14: Aerial View of Phases and Countermeasures in Cooum River**




*Source: JICA Expert Team*

**Figure 9-15: Cooum River Longitudinal Profile and Designed Riverbed**

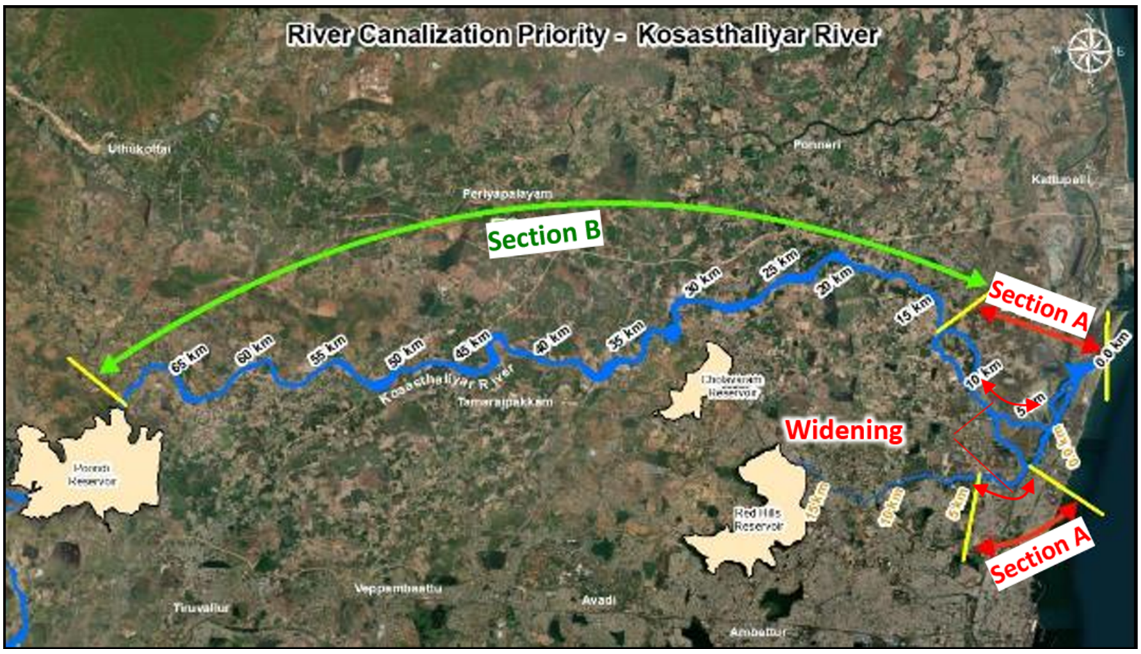
### 9.3.4 Kosasthalaiyar River

The standard cross-section for the river channelization of the Kosasthalaiyar River is the same as Figure 9-8. Figure 9-16 provides an aerial view of the implementation phases and the locations of the proposed river channelization countermeasures. Regarding the standard cross-section: In Phase 1, widening is not primarily implemented; instead, excavation is carried out. Additionally, the excavation slope is generally set at 1:2.

Figure 9-17 shows the target area downstream of the Kosasthalaiyar River for river channelization, where an embankment will be constructed to divert the Kosasthalaiyar discharge to the left side (north arm) of the loop. This helps discharge from the Redhills during the flood time by preventing the backwater effect. Figure 9-18 shows proposed widening in Redhills. In the Redhill River, widening is required in the section from 3.0 km to 6.0 km, where the flow capacity is low, and excavation will be carried out to a depth corresponding to the current maximum riverbed elevation.

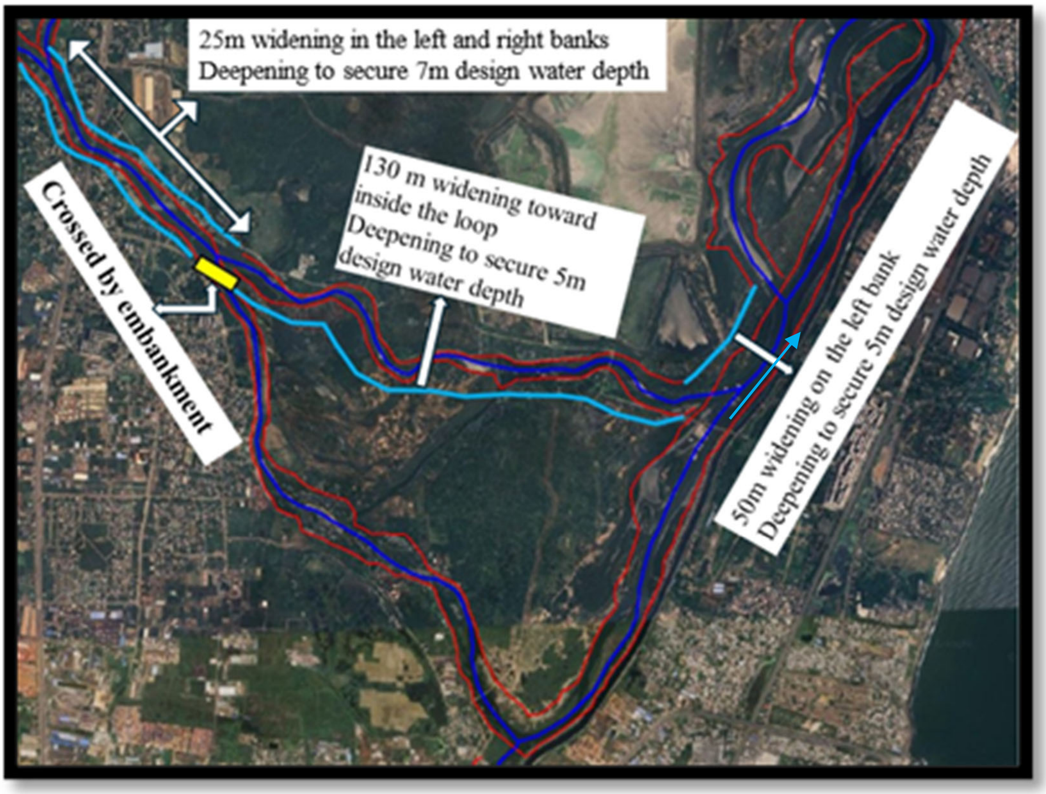
Figure 9-19 and Figure 9-20 shows the longitudinal profile and design riverbed for deepening the Kosasthalaiyar River. Regarding the longitudinal profile and design riverbed, the river will be excavated from the mouth with a depth of -2.0 meters, as needed to maintain the river mouth condition.

Phase 2 includes the continuation of the river deepening upstream (from 31.7 km ~), as well as river widening along the entire river and improvements to the flood storage capacity in the remaining tanks, as outlined in Table 9-4.



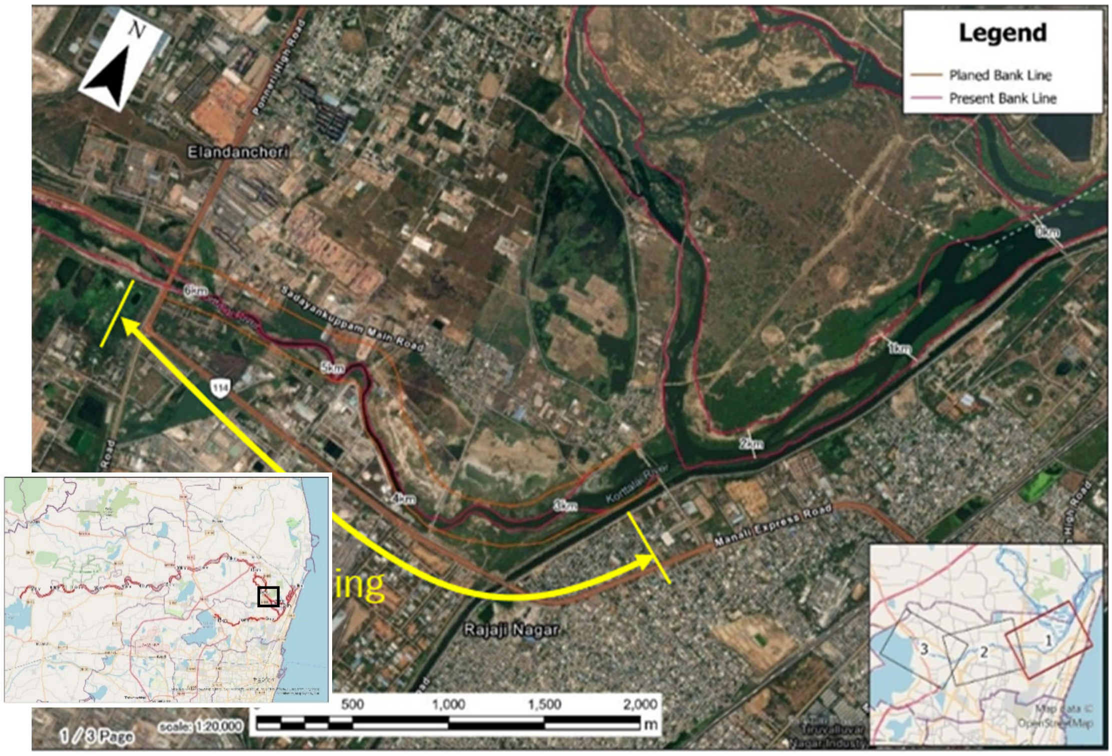

*Source: JICA Expert Team*

**Figure 9-16: Aerial View of Phases and Countermeasures in Kosasthalaiyar River**



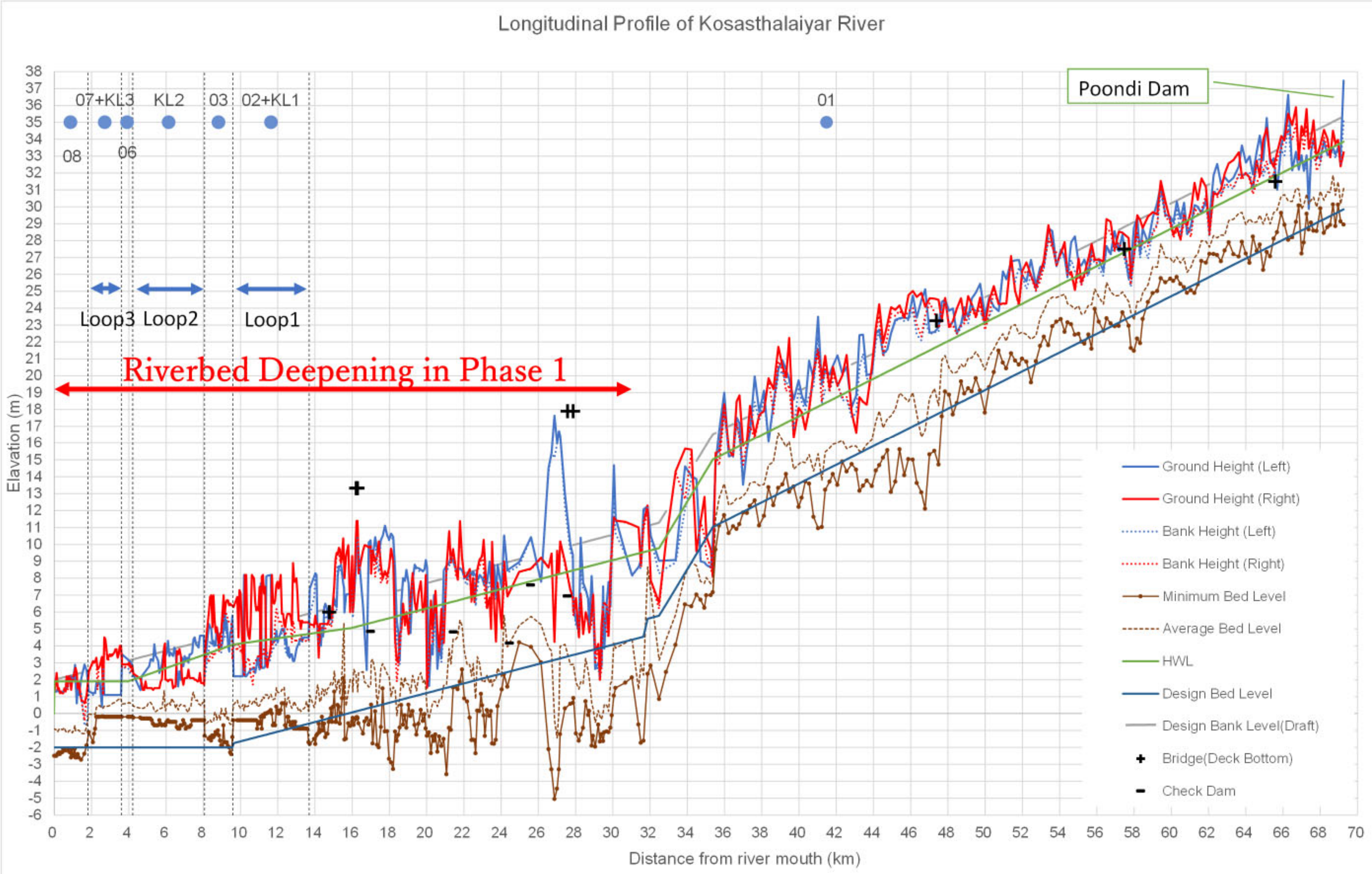

*Source: JICA Expert Team*

**Figure 9-17：Countermeasures in the Loop (about 5.0 km) of Kosasthalaiyar River**



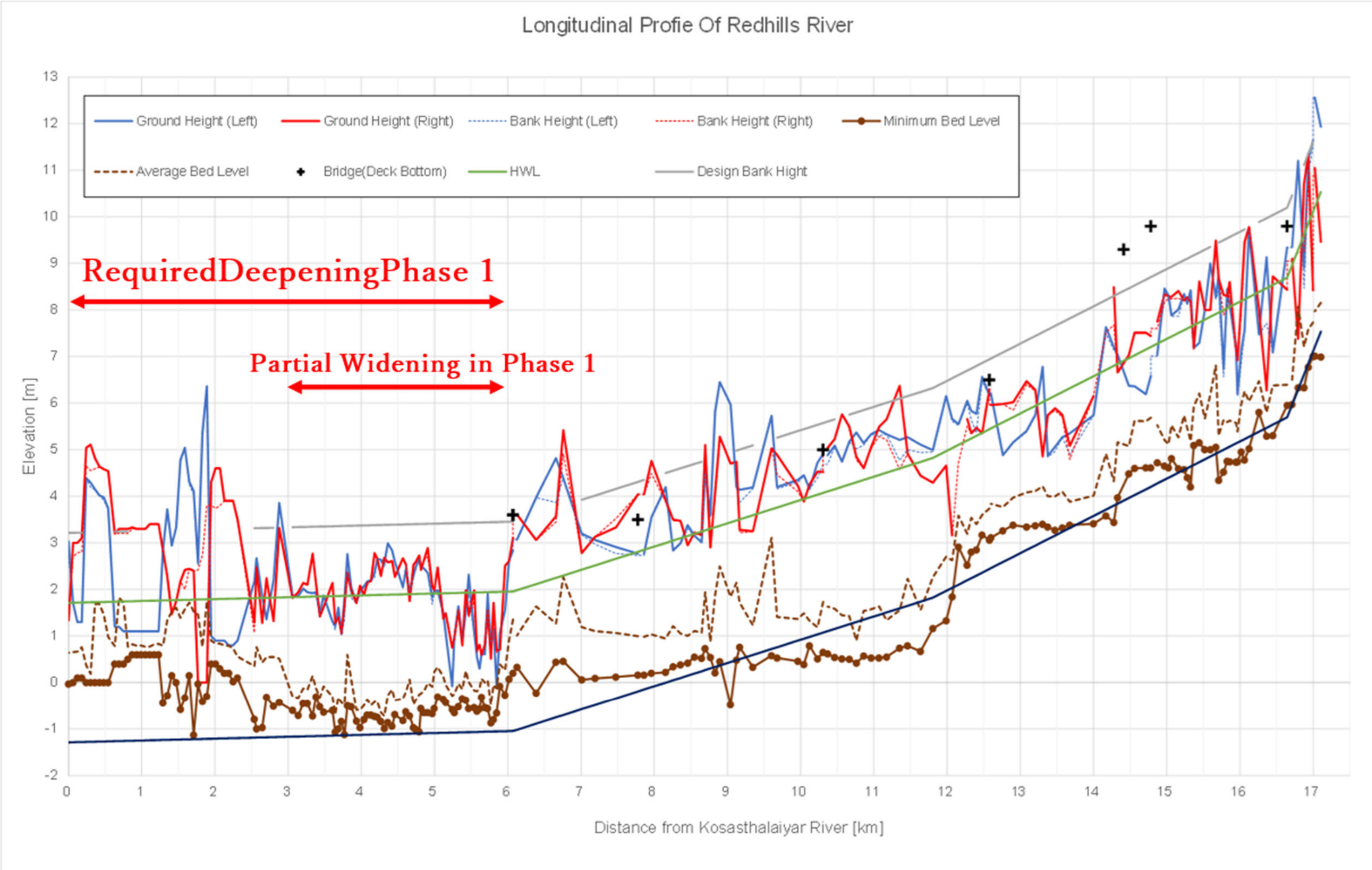

*Source: JICA Expert Team*

**Figure 9-18：Proposed Widening Reach of Redhills**




*Source: JICA Expert Team*

**Figure 9-19: Kosasthalaiyar River Longitudinal Profile and Designed Riverbed**

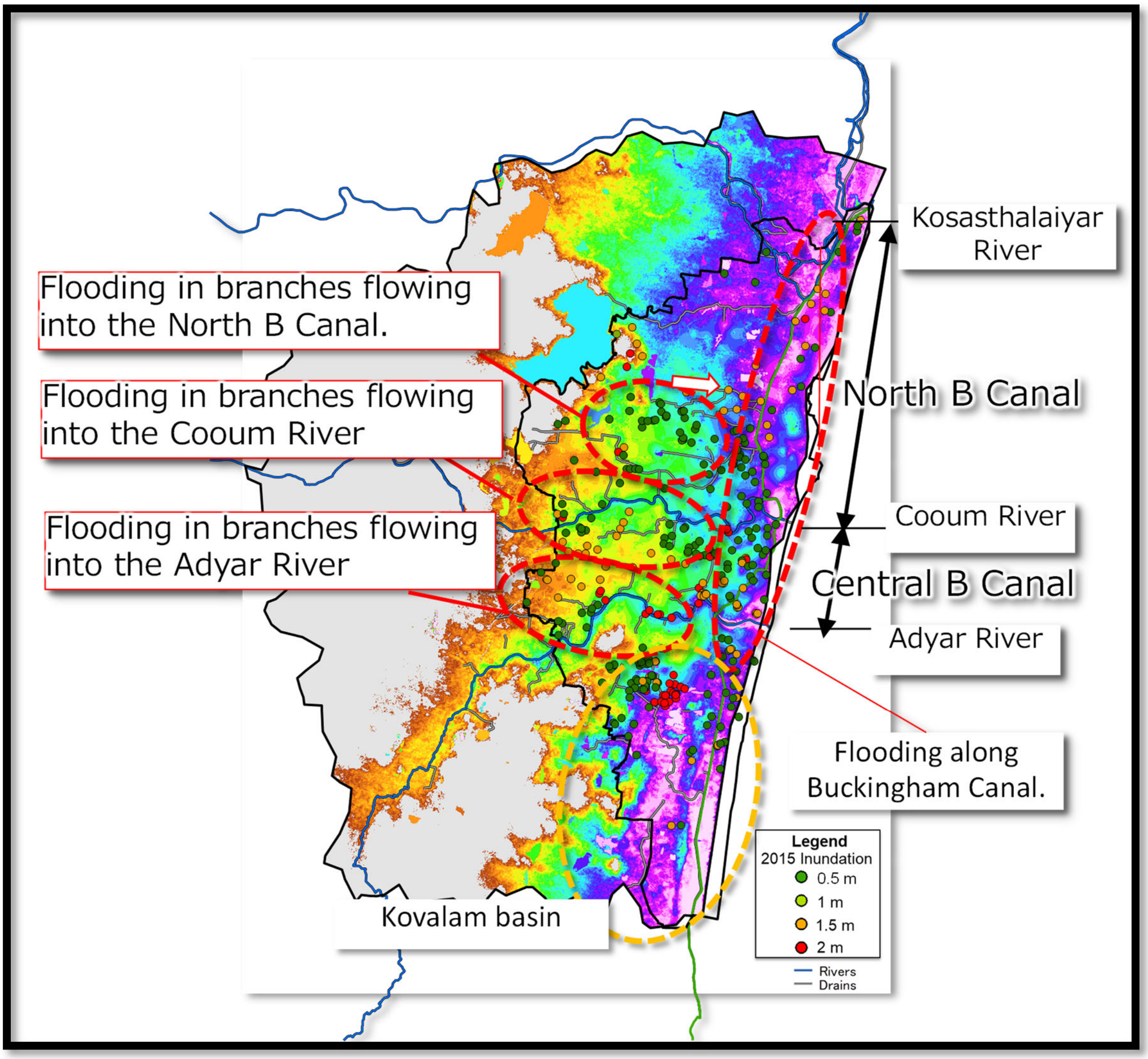



*Source: JICA Expert Team*

**Figure 9-20: Redhills Surplus Longitudinal Profile and Designed Riverbed**

### 9.4 Overview of Countermeasures for Urban Flood Control

Urban flood control in Chennai can be classified into four distinct categories, as shown in Figure 9-21. These categories include the North B Canal and its tributaries, the Central B Canal, which has no major tributaries, drains connected to the Adyar and Cooum Rivers, and the Kovalam Basin (north).




*Source: JICA Expert Team*

**Figure 9-21: Urban Flooding in Chennai: 2015 Flood and Key Elements**

### 9.4.1 North B Canal and Connected Drains

The North B Canal currently lacks sufficient flow capacity, which also reduces the capacity of its connected drainages. Phase 1 prioritizes improving the canal through channel excavation, followed by similar enhancements in three major connected drainages. However, even with excavation, the North B Canal's flow capacity will reach only 60%, equivalent to 1/10th of the current riverbank height standard.

To address this gap as in the Figure 9-22, new detention ponds will be installed in the three connected drainages, and the existing Cooum River diversion channel will be reinforced in the Otteri Nullah tributary. This will achieve a 1/10th scale improvement. Additionally, gates will be installed at the North B Canal and Cooum River junction to prevent backwater flow.

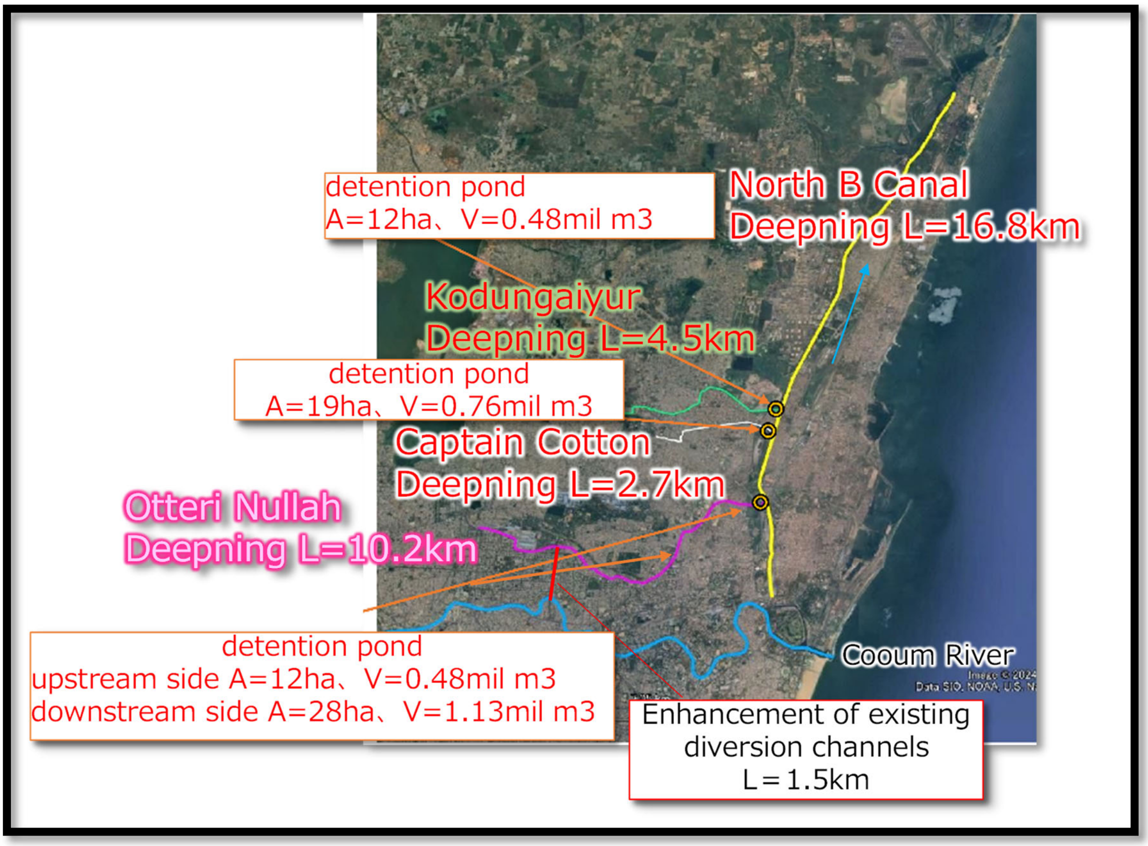


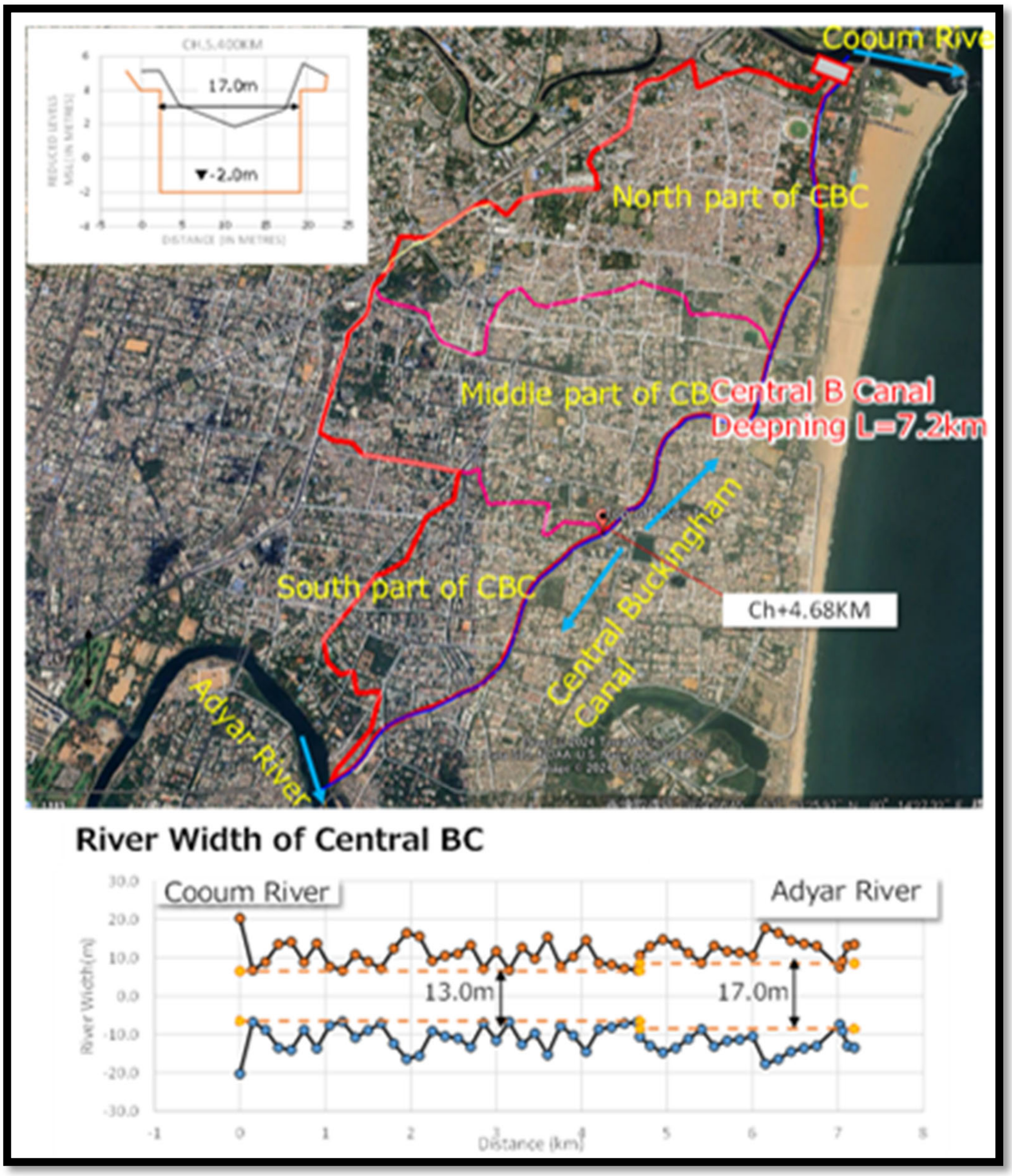

**Figure 9-22: Phase 1 Measures for the North B Canal and Connected Drainages**

### 9.4.2 Central B Canal

The Central B Canal has a relatively small catchment area and no major tributaries, unlike the North B Canal. However, it is located in a densely populated area at the heart of Chennai's business, residential, and administrative zones. To enhance the drainage capacity of the Central B Canal, Phase 1 will commence with channel excavation.

The excavation depth is set at -2 m, consistent with the excavation parameters in Phase 1 of the Adyar and Cooum Rivers. As shown in the figure below, the excavation width is either 13.0 m or 17.0 m without widening. In some sections, only excavation and dredging are necessary, while in others, both deepening and widening will be required, as illustrated in the figure.

Additionally, since the Cooum River's high-water level (HWL) exceeds the height of its riverbanks, a gate will be installed on the Cooum side of the river after channelization to prevent backflow.



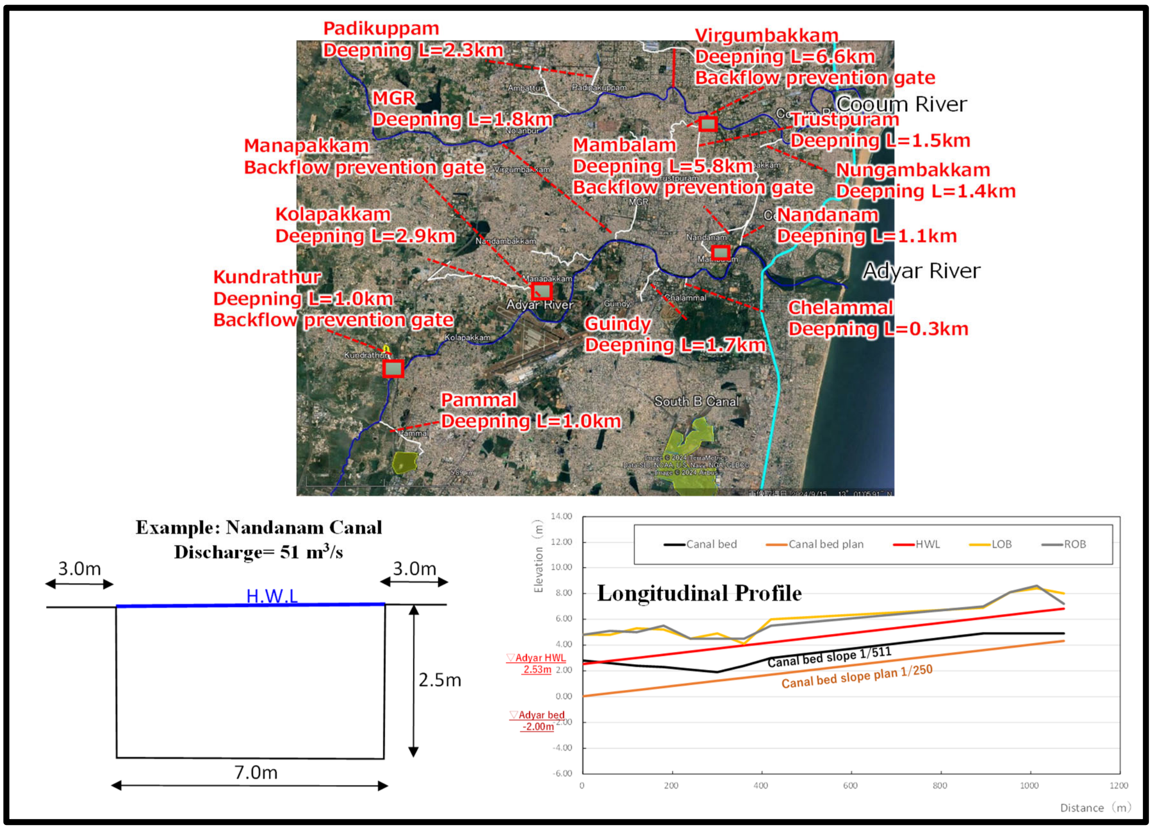

*Source: JICA Expert Team*

**Figure 9-23: Phase 1 measures in the Central B Canal**

### 9.4.3 Major Connecting Drains to the Adyar and Cooum Rivers

River channelization (primarily deepening) of the Adyar and Cooum Rivers in Phase 1 will reduce the backwater impact on the connecting drains. As a result, channelization and improvement, mainly through excavation, will be carried out for the connecting drains with insufficient flow capacity to handle a 10-year return period flood in urban areas. A total of 8 drains in the Adyar River and 1 drain in the Cooum River are targeted for improvement.

However, in drains where the high-water level (HWL) exceeds the height of the drain banks, the backwater impact remains significant. Since channelizing (deepening) the Adyar and Cooum Rivers may take time, backflow prevention gates will be installed first at four locations on the connecting drains to mitigate the backwater effect.




*Source: JICA Expert Team*

**Figure 9-24: Proposed Countermeasures for Connecting Drains to Adyar and Cooum**

### 9.4.4 Kovalam Basin

Poor drainage is a significant issue in the urbanized areas of the Kovalam Basin (northern part) due to flat topography, low-lying areas, rapid urbanization, and the shrinking of Pallikaranai marshland, waterbodies, and tanks as well as missing links. To address urban flooding in the Kovalam Basin effectively, a comprehensive approach is required, prioritizing both immediate and long-term measures as in Figure 9-25.

#### 9.4.4.1. Phase 1: (~10 years)

The primary focus will be on the construction of a bypass canal from the B Canal to the Bay of Bengal at the VGP Amusement Park or nearby. This bypass aims to enhance the basin's drainage capacity and alleviate urban flooding. However, due to the anticipated time required for land acquisition, site preparation, and other procedural steps, additional countermeasures will be implemented concurrently to mitigate flood risks including:

Backwater prevention gates in B canal: Install backflow prevention gates to reduce the risk of backwater flooding during high tides or storm surges.

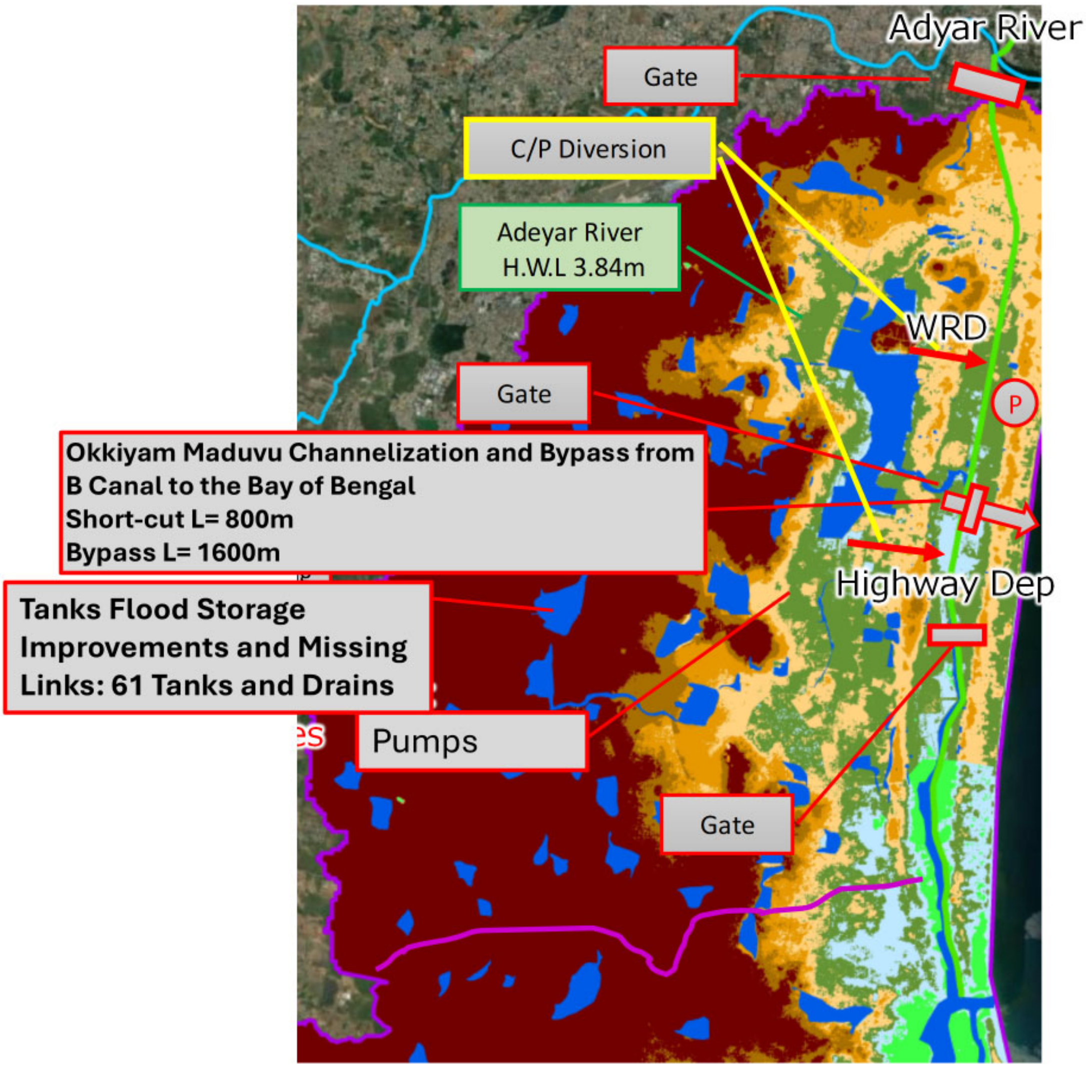
Channelization of Okkiyam Maduvu and other Drains: Increase flow capacity by widening, straightening, and deepening Okkiyam Maduvu and other drainages.

Pumping Systems: Deploy pumps to facilitate the discharge of excess water from urban areas.

Flood Storage in Existing Tanks: Improve flood storage capacity of existing tanks and waterbodies (61 tanks) for flood storage.

9.4.4.2. Phase 2: Complementary Measures (After the Phase 1)

Once the bypass canal is operational and preliminary flood risks are reduced, Phase 2 will focus on resolving residual flooding issues in depressions and low-lying areas by installing additional pumps to remove stagnant water and improve drainage in localized urban floodings.




*Source: JICA Expert Team*

**Figure 9-25: Proposed Countermeasures for Urban Flood Control in Kovalam Basin**

## 9.5 Conclusion and Recommendations

The implementation of a comprehensive flood control master plan is a challenging and multifaceted endeavor, particularly in urban environments such as Chennai. Factors such as rapid urbanization, land-use conflicts, and institutional barriers have often hindered the seamless execution of flood control measures. A robust master plan requires meticulous coordination, long-term commitment, institutional capacity building, continuous monitoring, and social-environmental integration. The following key aspects are essential for the successful implementation of the flood control master plan:

**Coordination among Authorities at the Highest Level:** The success of the flood control plan hinges on effective coordination among stakeholders, including government authorities, technical experts, and local communities. Establishing a robust framework for decision-making and collaboration is crucial. Regular briefings and consensus-building sessions among high-level authorities can eliminate bureaucratic delays and ensure that all entities work toward a common goal.

**Financial Mechanism:** Securing adequate funding is vital for the execution of proposed countermeasures in different phases. Both internal resources and external financial arrangements, such as loans and grants from international agencies, must be leveraged. A phased funding approach ensures that resources are allocated efficiently without overwhelming fiscal capacities.

**Capacity Building and Development:** Strengthening the technical and institutional capacities of involved agencies is indispensable for sustaining the implementation of the master plan. Targeted training programs, resource allocation, and knowledge-sharing initiatives enhance the capabilities of personnel and institutions, enabling them to address emerging challenges effectively.

**Regular Monitoring and Evaluation:** Systematic monitoring of progress and periodic reviews of achievements ensure that the master plan remains on track. Continuous evaluation not only identifies areas of improvement but also builds accountability among stakeholders. Regular reporting mechanisms further enhance transparency and foster trust among the public and decision-makers.

**Socio-Environmental Considerations:** The integration of social and environmental factors into all planning and implementation stages is critical to minimizing adverse impacts. Engaging local communities, addressing social concerns, and safeguarding environmental integrity foster inclusive development. This approach ensures long-term sustainability and resilience to future flood risks.

By focusing on these critical aspects, the flood control master plan can overcome implementation challenges and deliver measurable outcomes that enhance urban resilience and safeguard communities against the threat of flooding.