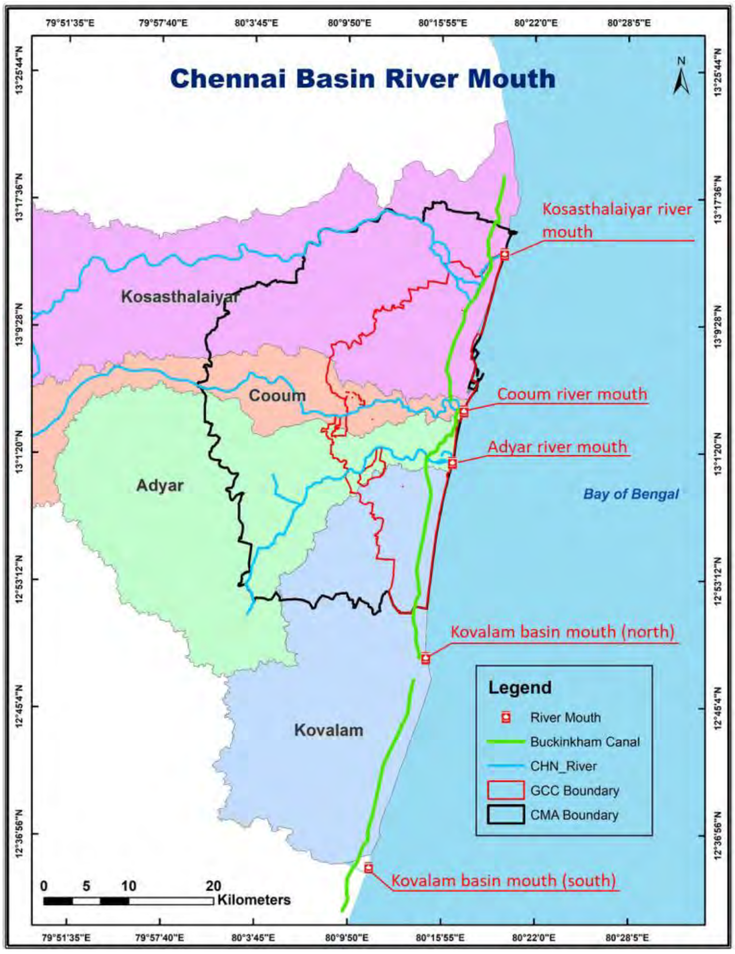
Chapter 5. Study on Coastal Area and River Mouth

5.1 Introduction

The coastal area of Chennai, or target coasts, consists of long sandy beaches facing the Indian Ocean to the east. The direction of the coastline is generally from north to south; the Kosasthalaiyar estuary is located in the northernmost part, the Cooum and the Adyar River estuary is located south of that, with the mouth of the Buckingham Canal at Muttukadu in the southernmost part. The dominant direction of littoral drift in the coastal area is northward, and river mouth bars have developed in the estuaries, often causing estuarine blockage problems. As there are no sea cliffs near the coast of Chennai, it is thought that the source of the littoral drift is sediment supplied by rivers. Coastal structures are built to mitigate the movement of sediments. In this chapter, the current status of the Chennai coastal area and estuaries is analyzed, and estuary blockage countermeasures that contribute to flood control are studied. Figure 5-1 shows the location of the target coasts and rivers.



Source: JICA Expert Team

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

5.2 Review of Existing Coastal Management

This section reviews the management status of the River/Basin Mouths and the beaches surrounding each River/Basin Mouth that significantly impact river flood control in the City of Chennai.

5.2.1 Coastal Zone Management Plan (CZMP)

The Government of India has issued the Coastal Regulation Zone (CRZ) Notification (2019) to manage and protect coastal environments while promoting sustainable development. Coastal Zone Management Plans (CZMPs), which outline the permitted activities and conservation measures in these zones, were originally based on the CRZ Notification (2011). The draft CZMPs under the updated CRZ Notification (2019) have been published as part of ongoing efforts to incorporate new guidelines and adapt to recent environmental and developmental changes. Under this notification, coastal areas are categorized into four zones (CRZ-I, CRZ-II, CRZ-III, CRZ-IV).

- 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.)

Soft measures, like beach nourishment or dune restoration, are less disruptive to the natural sediment transport and for coastal protection. While hard measure-like Groins, built perpendicular to the shoreline prevent erosion in the area where they are built and tend to cause erosion on the down-drift side of the structure by interrupting the natural flow of sand along the coast. Thus, the Department of Environment (DoE) recommends prioritizing groins as a last resort when softer, less invasive methods are not feasible. The CZMP Maps for the target river are shown in Figures 5-2 through Figure 5-4.

Within the CRZ classification, CRZ-III is a non-development zone where development activities such as hard measures are restricted. The Chennai coast, from the mouth of the Kosasthalaiyar River to the area between the mouth of the Adyar River and the mouth of the Kovalam Basin, is highly developed with many houses built behind the coast, and almost the entire area is classified as CRZ-II (built-up area), with the exception of some areas. The southern area, including the mouth of the Kovalam Basin (Muttukadu), is classified as CRZ-III because it is not highly developed, although there are houses scattered behind the coast. CR Z-I includes the mudflats in the brackish waters of the Kosasthalaiyar River, the right bank of the Cooum River estuary, and some of the dunes on the right bank of the Adyar River.

5.2.1.1. CRZ-I

CRZ-I is considered the most environmentally sensitive zone and is further classified into two subcategories:

- CRZ-I A: This includes Ecologically Sensitive Areas (ESAs) and the geomorphological features which play a role in maintaining the integrity of the coast viz. Mangroves, Corals and coral reefs, Dunes, Biologically active mudflats, National parks, marine parks, sanctuaries, reserve forests, wildlife habitats and other protected areas, Salt marshes, Turtle nesting grounds, Horseshoe crabs' habitats, Seagrass beds, Nesting grounds of birds, areas or structures of archaeological importance and heritage sites.
- CRZ-I B: This refers to the intertidal zone, the area between the Low Tide Line (LTL) and the High Tide Line (HTL).

5.2.1.2. CRZ-II

CRZ-II refers to the developed land areas up to or near the shoreline, within the existing municipal limits or in other existing legally designated urban areas, that are substantially built-up with a ratio of built-up plots to that of total plots being more than 50% and have been provided with drainage and approach roads and other infrastructural facilities, such as water supply and sewerage mains.

5.2.1.3. CRZ-III

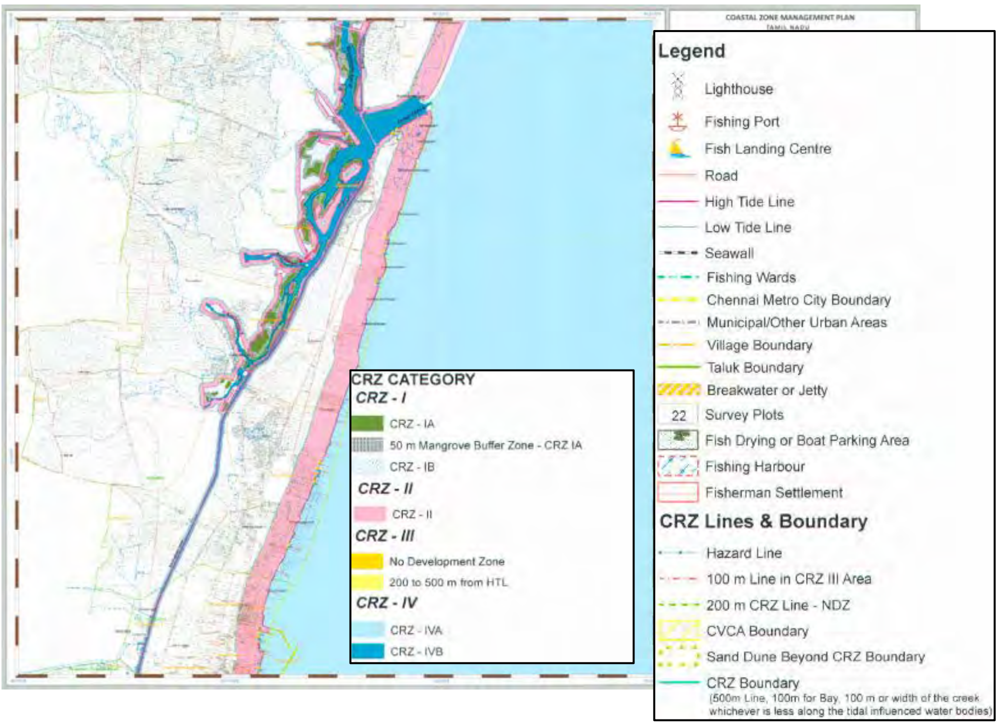
CRZ-III shall consist of relatively undisturbed land areas (e.g., rural areas), as well as those that do not fall under CRZ-II. CRZ-III areas are categorized based on population density, and the extent of the "No Development Zone" (NDZ) in these regions is regulated accordingly:

- CRZ-III A: It designates densely populated CRZ-III areas with a population density exceeding 2161/km^2 (as per the 2011 census). In CRZ-III A, the landward side of the area up to 50 m from the HTL on the landward side shall be earmarked as NDZ, only if the CZMP has been approved. If the CZMP remains unapproved, the 200 m NDZ remains in effect.
- CRZ-III B: All other CRZ-III areas with a population density of less than 2161/km^2 (as per the 2011 census) shall be designated as CRZ-III B. CRZ-III B designates the landward side of the area up to 200 m from the HTL as NDZ.

5.2.1.4. CRZ-IV

The CRZ- IV shall constitute the water area and shall be further classified as CRZ- IVA and CRZ-IV B.

- CRZ- IV A: It covers coastal waters and the seabed extending seaward. It refers to the water area and the seabed area between the LTL up to 12 nautical miles on the seaward side shall constitute CRZ-IV A.
- CRZ-IV B: It includes the water area and the bed area between LTL on the banks of the tidal-influenced water bodies, extending from the mouth of the water body inland up to the point where tidal influence can be observed. The influence of the tide is determined by the salinity level, specifically where the salinity is 5 parts per thousand (ppt) during the driest season of the year.

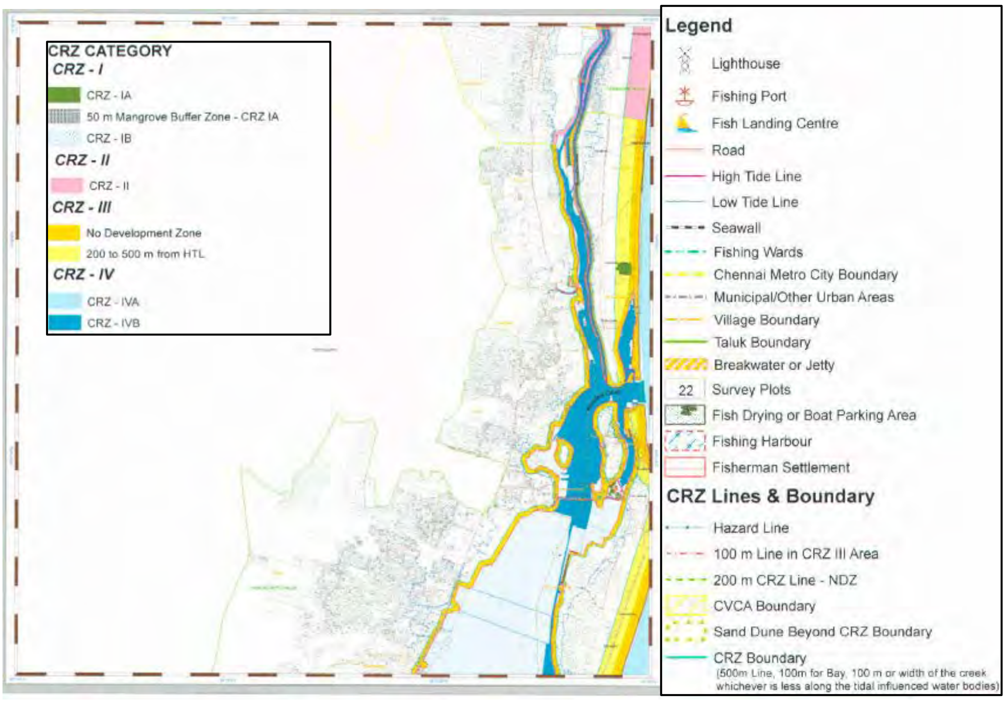


Source: Coastal Zone Management Plan Maps 2011, NCSCM.

Figure 5-2: CZMP Map (Kosasthalaiyar River)

Source: Coastal Zone Management Plan Maps 2011, NCSCM.

Figure 5-3: CZMP Map (Adyar and Cooum Rivers)



Source: Coastal Zone Management Plan Maps 2011, NCSCM.

Figure 5-4: CZMP Map (Kovalam Basin)

5.2.2 Projects for beach erosion prevention

5.2.2.1. Situation of beach erosion and sedimentation

Tables 5-1 and 5-2 and Figures 5-5 and 5-6 show the results of the analysis of the erosion and sedimentation trends of the coastal areas around Chennai by the NCCR. The analysis of the erosion and sedimentation trends was based on satellite images and field surveys. According to this, the Chennai coast is divided into three districts: Tiruvallur, Chennai, and Kancheepuram, and it has a wide sandy beach topography, such as Long Beach, and is used for fishing and recreation. Based on Table 5-2 and Figure 5-5, the coastline of the target coast is generally stable, with the longest section being Stable, followed by Low Erosion. Figure 5-6 shows the changes in the erosion and sedimentation trends in the three areas mentioned above, enlarged. From this, it can be seen that erosion is occurring on the coast north of the Chennai Port, and there is also a slight erosion trend in the Adyar River estuary and the coast to the south of it.

Table 5-1: Definition of the trend of coastal erosion and sedimentation

Classification	Rate(m/year)	Color Schemes
High Erosion	<-5.0	
Moderate Erosion	-5.0 to -3	
Low Erosion	-3.0 to -0.5	
Stable	-0.5 to 0.5	
Low Accretion	0.5 to 3.0	
Moderate Accretion	3.0 to 5.0	
High Accretion	>5.0	

Source: National Assessment of Shoreline Changes along Indian Coast, NCCR, 2018.

Table 5-2: Shoreline Erosion and Sedimentation Trends (1990-2016)

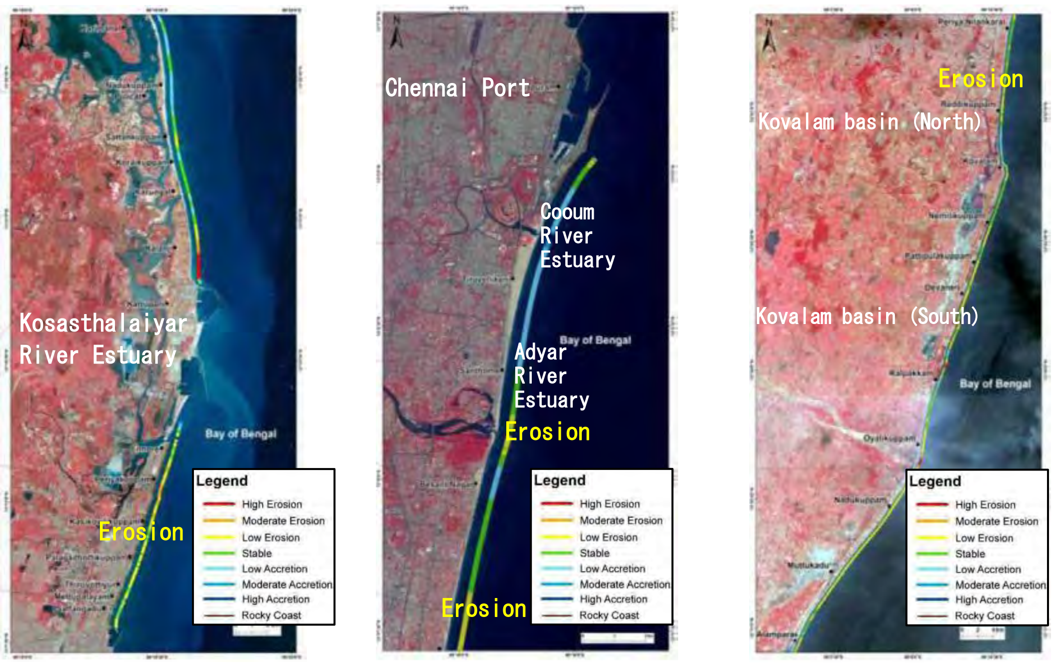
SL No	District	Coast Length (in km)	Coast length (in km)						
			High Erosion	Moderate Erosion	Low Erosion	Stable	Low Accretion	Moderate Accretion	High Accretion
1	Thiruvallur	40.97	1.66	3.12	9.22	17.22	6.54	0.61	2.60
2	Chennai	24.87	0.00	0.00	3.08	14.31	7.13	0.35	0.00
3	Kancheepuram	84.41	1.30	3.54	44.56	27.74	7.27	0.00	0.00

Source: National Assessment of Shoreline Changes along Indian Coast, NCCR, 2018.

Source: National Assessment of Shoreline Changes along Indian Coast, NCCR, 2018.

Figure 5-5: Shoreline Erosion and Sedimentation Trends (1990-2016: Wide Area)

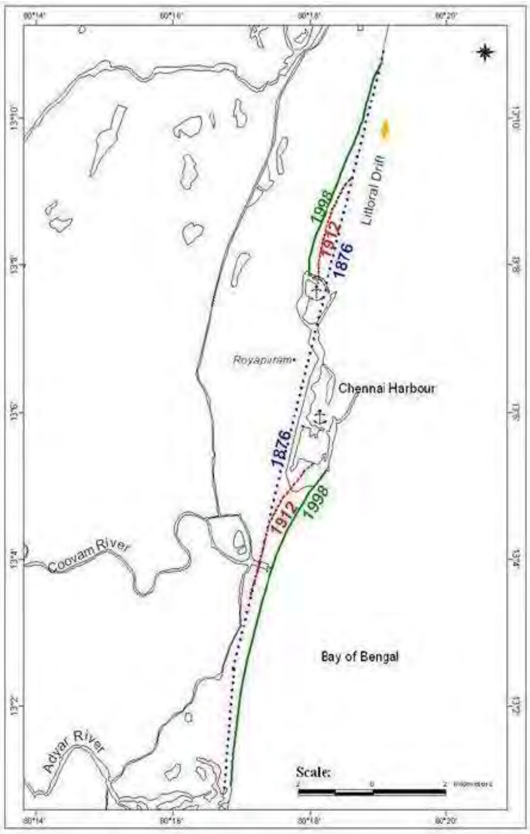
Thiruvallur | Chennai | Kancheepuram



Source: National Assessment of Shoreline Changes along Indian Coast, NCCR, 2018.

Figure 5-6: Shoreline Erosion and Sedimentation Trends (1990-2016: Expanded Coverage)

Figure 5-7 illustrates that erosion to the north of Chennai Port has intensified since the construction of the Port in the 1900s. It is believed that the breakwater at Chennai Port has impeded the longshore drift of sand. The direction of longshore drift varies between the dry and rainy seasons, but northward drift remains dominant throughout the year. If new structures are built, especially around river mouths, to prevent sediment blocking, there is a risk that erosion trends could worsen along the northern coast. This is because such structures may further impede the natural sand movement, leading to more severe erosion. According to the "Shoreline Management Plan for Ennore Coast (Tamil Nadu), Ministry of Earth Science, 2006," the annual amount of coastal sand drift in a northerly direction is approximately 0.3×10^6 m^3.



Source: Shoreline management plan for Ennore coast (Tamil Nadu), Ministry of Earth Science, 2006.

Figure 5-7: Shoreline Changes with the Construction of the Port of Chennai (1876-1998)

5.2.2.2. Existing projects for coastal erosion prevention measures

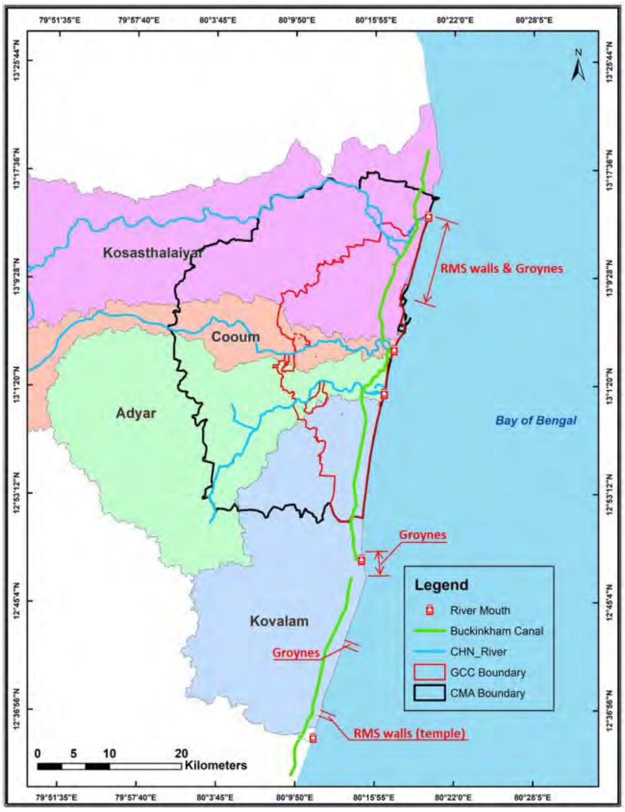
The shoreline in the section stretching from the south of the Kosasthalaiyar River Mouth to the north of Chennai Harbour tends to retreat, resulting in wave overtopping and erosion damage during high waves. To counter this, rubble mound stone walls were erected along the shoreline between 1991 and 2003, covering a distance of approximately 10 km. Additionally, TNWRD and TNRDC constructed around 30 jetties between 2004 and 2019 (Figure 5-8). Furthermore, the Fisheries Department built about 15 groynes from 2016 to 2019 for the section spanning from the mouth of the Kovalam Basin to Sulerikattu Kuppam (Figure 5-9). Due to severe erosion in Mamallapuram, a new plan involving a combination of groynes and beach nourishment (using Geo-synthetic tubes) has been devised (Figure 5-10). Given the above measures, it can be inferred that appropriate steps are being taken to prevent coastal erosion and plans for constructing groynes and beach nourishment are in progress for coasts susceptible to erosion. The effectiveness of these measures will need to be evaluated based on the results of long-term monitoring in the future.

Source: JICA Expert Team

Figure 5-8: Rubble Mound Stone Walls and Groynes (Beasant Nagar Beach)

Source: JICA Expert Team

Figure 5-9: Groynes (Kovalam Beach)



Source(location): Comp.Shore line Mgt Plan - 19.04.2022 - Annex-I&II, TNWRD

Figure 5-10: Location of RMS (Rubble Mound Stone) Walls and Groynes

5.2.3 Existing projects for river mouth clogging prevention

All four target river mouths are experiencing clogging due to the formation of sandbars. This clogging worsens during the dry season, leading to the deterioration of water quality in the river mouth areas. During the monsoon season, clogged river mouths can restrict the river's capacity to discharge floodwaters into the sea. Construction of training walls and dredging are among the commonly employed initiatives to manage and prevent blockages at the river mouths. The details of existing projects for the prevention of river mouth clogging at each river mouth are summarized below.

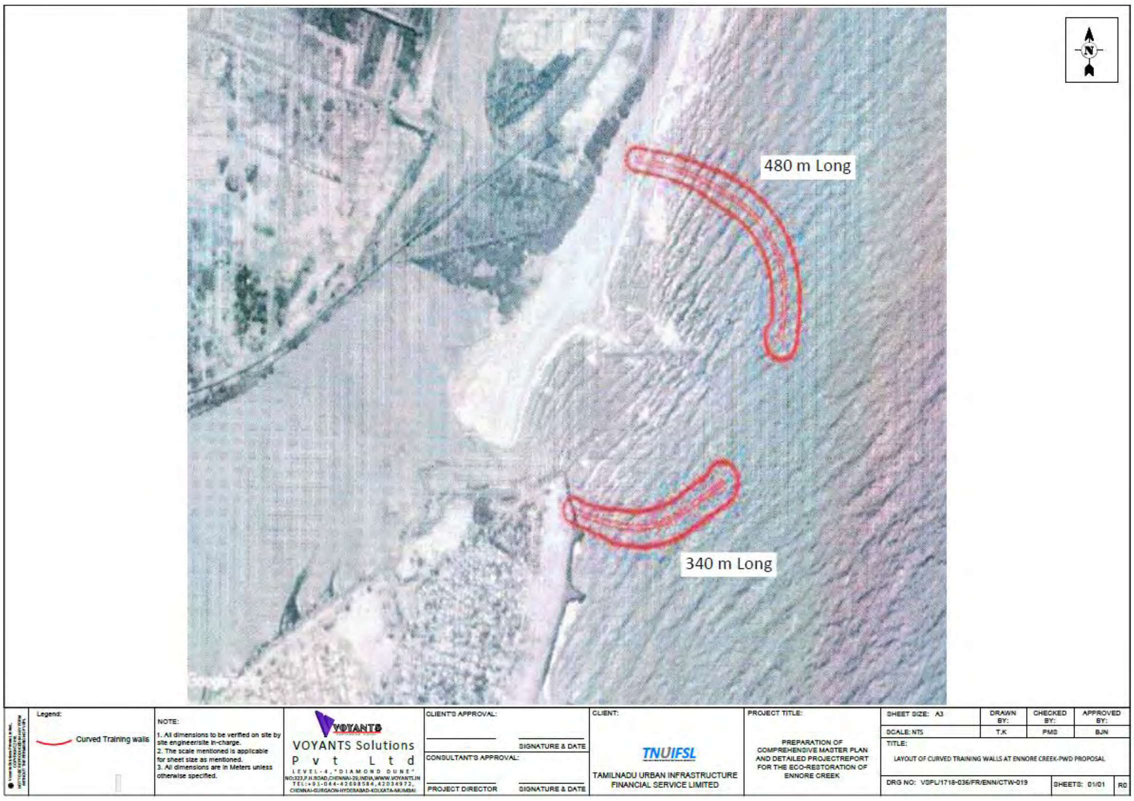
5.2.3.1. Existing river mouth clogging prevention projects (Kosasthalaiyar River mouth)

At the Kosasthalaiyar River Mouth, no groynes were constructed. Rather, until November 2016, Ennore Thermal Power Plant carried out regular dredging activities to prevent blockages caused by sandbars. Following the ending of dredging operations in 2016 due to the shutdown of its water intake system, the river mouth became obstructed, thereby disrupting the ecological balance of the river and affecting water flow, sediment movement, and local water quality.

Source: JICA Expert Team

Figure 5-11: Sandbar Conditions (Kosasthalaiyar River)

Consequently, a comprehensive plan and detailed project report for the eco-restoration of Ennore Creek was formulated by TNUIFSL/CRRT in 2020. This report points out that, after the Ennore Thermal Power Station stopped operating in 2016, the dredging operations to secure the cooling water intake were also stopped, and the estuary subsequently silted up, disrupting the balance of the ecosystem. The report recommended a synergistic approach of constructing curved training walls and continuing dredging (as seen in Figure 5-12 and Table 5-4 of the report). The curved training walls proposed in the plan are now under construction in 2023-2024 to mitigate river mouth blockage and help restore the region's ecological and hydrological balance. On the other hand, since the training walls restricts the movement of littoral drift, erosion occurs on the coast downstream of the drift (mainly the northern coast in the Chennai area), while deposition occurs on the upstream side, which may affect the future maintenance function of the training walls at the mouth of the river. Therefore, monitoring of the coastline and continuous countermeasures are recommended.



Source: Preparation of Comprehensive Master Plan and Detailed Project Report for Eco restoration of Ennore Creek, TNUIFSL/CRRT, 2020.

Figure 5-12: Plan for River Mouth Clogging Prevention; Curved River Training Walls （Kosasthalaiyar River）

Table 5-3: Estimated Cost of Countermeasures for River Clogging (Kosasthalaiyar River)

Description of works	Amount Cost (INR)
Sustainable River Mouth Opening - Training walls, Dredging (in crores)	119.0

Source: Preparation of Comprehensive Master Plan and Detailed Project Report for Eco restoration of Ennore Creek, TNUIFSL/CRRT, 2020.

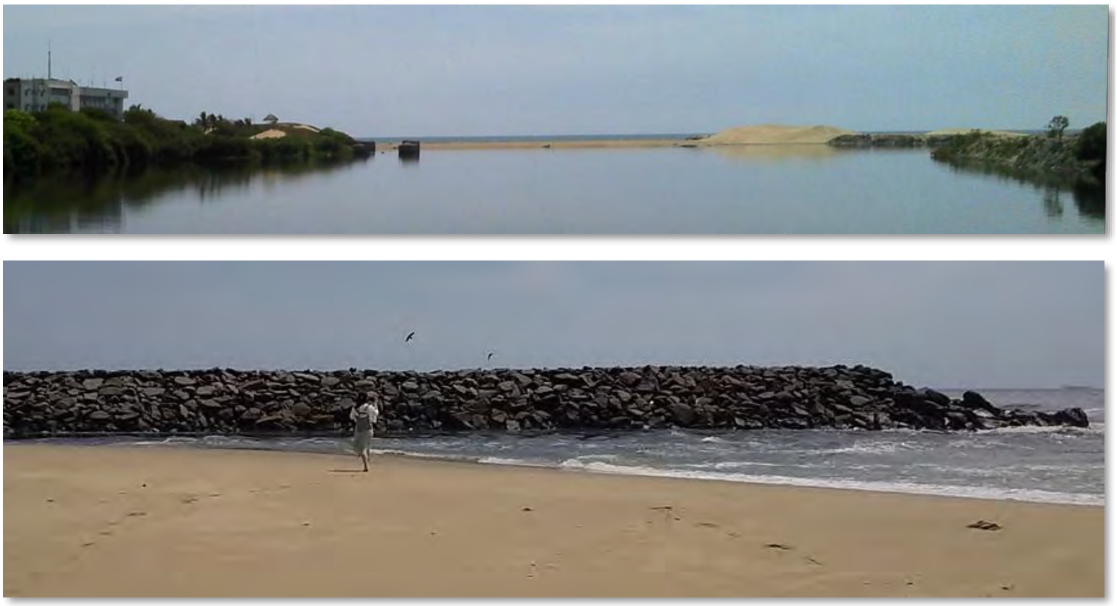
5.2.3.2. Existing river mouth clogging prevention projects (Cooum River mouth)

In 2011, TNWRD erected training walls (150 m on the northern side, 200 m on the southern side) at the mouth of the Cooum River to mitigate estuary obstruction. Interviews with TNWRD revealed that regular dredging was still necessary to maintain the estuary's clogging despite the construction of training walls. A closer look at the situation revealed some critical insights. During a JICA interview, Dr. V. Sundar, an expert from IIT Madras, brought up a crucial point. He noted that one of the reasons the walls weren't enough was because of their insufficient height. Hence, this flaw allowed the river mouth to remain vulnerable to clogging.

Table 5-4: Existing Training Walls at River Mouth (Cooum)

Location	Type	Length	Year of Construction	Carried out by
Northern Training Wall	Training Wall	150 m	2011	TNWRD
Southern Training Wall	Training Wall	200 m	2011	TNWRD

Source: Comp.Shore line Mgt Plan - 19.04.2022 - Annex-I&II, TNWRD

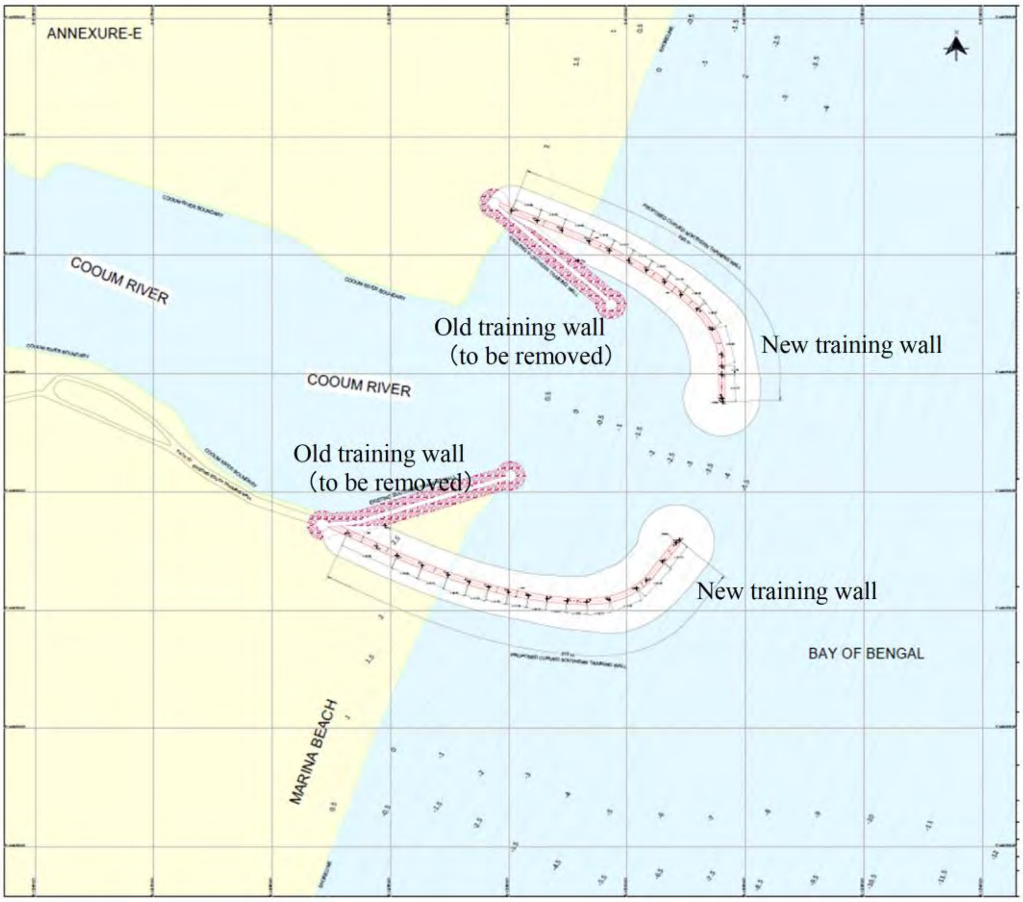


Source: JICA Expert Team

Figure 5-13: Sandbar and Training Walls (Cooum River)

In 2019, National Institute of Ocean Technology (NIOT) and TNUIFSL prepared a report on "Study on a sustainable solution for Cooum river mouth opening" to prevent river mouth clogging. The report pointed out that river mouth clogging causes water quality deterioration in the estuary by blocking drainage from the river when it is not the monsoon season, and also causes ocean pollution when the monsoon seasons, which is caused by a discharge of large amounts of untreated sewage from the river to the ocean.

The report presented several countermeasures, such as extending existing training walls, examined the effectiveness of each countermeasure in preventing river mouth clogging using Delft 3D sand drift analysis, and recommended: "Curved River training walls" (Figure 5-14). River mouth dredging was also presented as a comparison with constructing training walls, and a sand bypass to the erosion area on the north side of Chennai Port was also discussed (Figure 5-15, Table 5-5). As in the case of Kosasthalaiyar, the training walls based on these plans are being constructed in the Cooum estuary in 2023-2024.



Source: Study on sustainable solution for Cooum River mouth opening-Final Report, NIOT/TNUIFSL, 2019.

Figure 5-14: Plan for River Mouth Clogging Prevention; Curved River Training Walls (Cooum River)

Table 5-5: Estimated Cost of Countermeasures for River Clogging (Cooum River)

Scheme	Curved River Training Walls	Dredging and Bypassing
Capital Cost (in Cr. INR)	70*	31.28
Annual Maintenance cost (in Cr. INR)	2.25	13.2

*Includes initial capital dredging of 3.05 lakh m^3 of sediments.

Source: Study on sustainable solution for Cooum River mouth opening-Final Report, NIOT/TNUIFSL, 2019.

Source: Study on sustainable solution for Cooum River mouth opening-Final Report, NIOT/TNUIFSL, 2019.

Figure 5-15: Plan for River Mouth Clogging Prevention; Dredging and Bypassing （Cooum River）

5.2.3.3. Existing river mouth clogging prevention projects (Adyar river mouth)

According to TNWRD, at the mouth of the Adyar River, structures such as training walls have not been developed to prevent clogging, however, regular dredging was being carried out. Therefore, it is considered that additional measures can improve clogging (Figure 5-16).

In 2022, NIOT and TNUIFSL prepared a report on "Scientific Studies for Sustainable opening of the Adyar River mouth" to prevent river mouth clogging. The report pointed out that river mouth clogging causes water quality deterioration in the estuary by blocking drainage from the river when it is not in the monsoon season.

In the report, new training walls (Straight River training walls, Curved River training walls) and river mouth dredging were presented, and the effectiveness of each countermeasure in preventing river mouth clogging is examined using Delft 3D sand drift analysis. As a result, river mouth dredging is recommended considering the construction of the training wall hinders coastal sediment transport (Figure 5-17).

Source: JICA Expert Team

Figure 5-16: Sandbar and training walls (Adyar River)

Source: Scientific Studies for Sustainable Opening of the Adyar River Mouth (Draft Detailed Project Report), NIOT/TNWRD, 2022

Figure 5-17: Dredging and Sand Bypass Plan (Adyar River Mouth)

5.2.3.4. Existing river mouth clogging prevention projects (Kovalam Basin mouth)

At the mouth of the Kovalam Basin in Muttu Kadu (north side), the Fisheries Department constructed training walls (200m on the north side, 200m on the south side) in 2016 (Table 5-7, Figure 5-18). After the construction of the training walls, the shoreline on the upstream side of the training walls (the right coast of the river mouth) has advanced to the tip of the training wall, and the river mouth control function of the training walls are gradually being lost. At present, dredging is being carried out to deal with this, but it is thought that further study will be needed in the future regarding the improvement of the existing training walls and effective maintenance dredging. According to the interview with TNWRD, no additional estuary blockage measures are planned.

Similarly, regarding the mouth of the Kovalam Basin in Kokilamedu (south side), there is no implementation or plan for estuary blockage measures such as training walls or dredging.

Table 5-6: Existing Training Walls at River Mouth (Kovalam Basin)

Location	Type	Length	Year of Construction	Carried out by
Northern Training Wall	Groin	200 m	2016	Fisheries Department
Southern Training Wall	Groin	200 m	2016	Fisheries Department

Source:" Comp.Shoreline Mgt Plan - 19.04.2022 - Annex-I&II, TNWRD"

Source: JICA Expert Team

Figure 5-18: Dredging and Training Walls (Kovalam Basin)

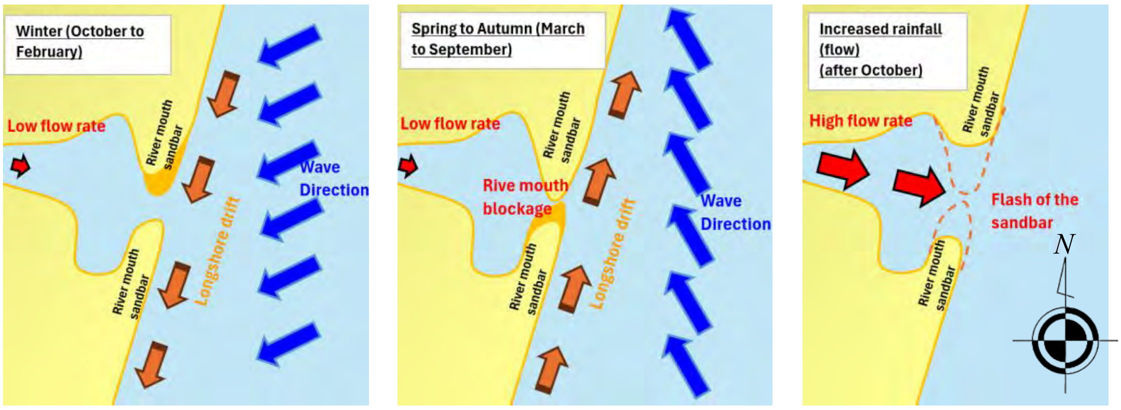
5.3 Analysis of Changes in River Mouths and Shorelines

The review of existing coastal management in Chapter 5.2 confirms that coastal and river mouth monitoring has been conducted for coastal zone management planning, erosion control, and estuary closure control (maintenance dredging is carried out every year). However, the monitoring period is from 1990 to 2016 in the NCCR study, recent shoreline changes have not been identified. The monitoring should be continued to determine the latest shoreline and estuary conditions to properly implement future shoreline and estuary management. In addition, monitoring of shorelines and estuaries is conducted conventionally by digitizing shorelines from aerial and satellite photographs, but this should be made more efficient by taking advantage of the latest digital technology.

In this section, AI analysis has been done by Professor Wu of the Tokyo University of Marine Science and Technology to analyze the past deformation of coastlines and river mouths. Satellite imageries from the 1980s to the present are collected from Landsat 5, Landsat 7, Landsat 8, Landsat 9, and Sentinel-2.

Regarding sea conditions, the previous documents show that the 50-year probability wave is estimated to be relatively high at 9.0 m, and the 50-year probability tide level is about 1.4 m, which is not very large.

The basic mechanism of sedimentation is caused by flooding and waves associated with a monsoon climate. In a monsoon climate, the sand drift from the north tends to move southward, affected by the waves from the north with the wind from the northeast. On the other hand, the drifting sand tends to move northward in summer because the southward wave dominates thanks to the wind blowing from the southwest. The flash effect clears sedimentation in the river mouth when floods of a certain scale occur. However, the river mouth will be often blocked by wave-induced sediment drifts if there are only relatively small floods (Figure 5-19).

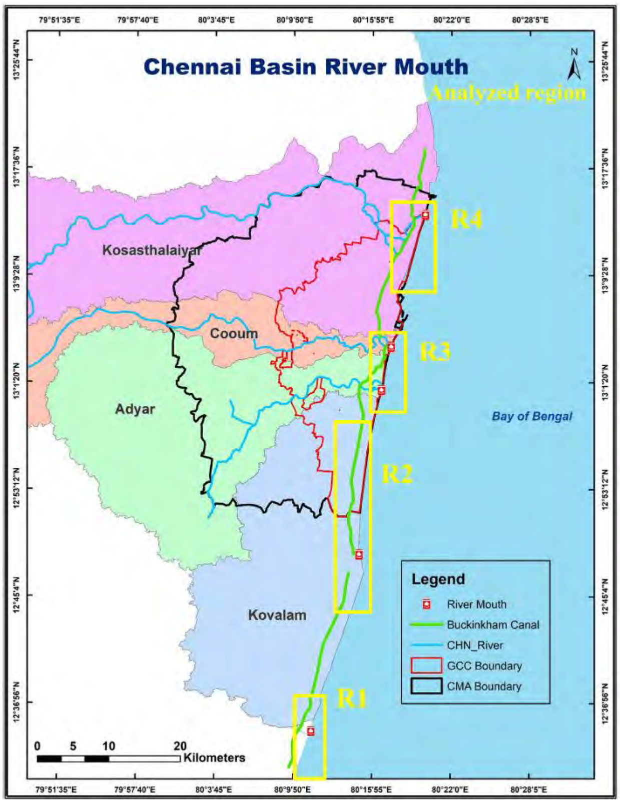


Source: JICA Expert Team

Figure 5-19: Basic mechanisms of longshore drift on the target beach

5.3.1 Analysis of changes in shorelines using satellite imageries

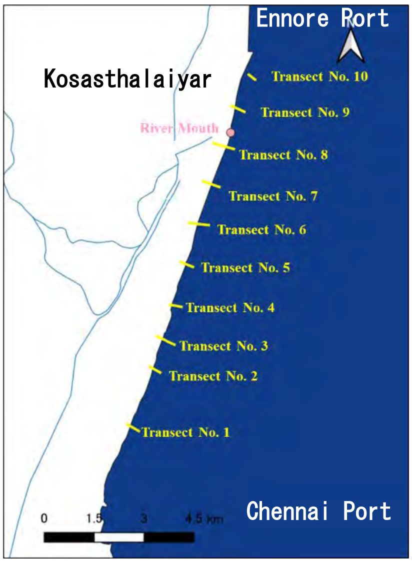
As shown in Figure 5-20, Four regions were selected for detailed analysis of shoreline change. These regions are analysed by obtaining time-series data of the shoreline using shore-normal transects. The results of the shoreline change analysis are plotted as a line graph for each transect line in Figure 4-22, Figure 5-24, Figure 5-25, and Figure 5-28. The vertical axis represents the degree to which the shoreline has moved forward or backward in the direction of the transect line due to erosion, sediment transport, or human interventions such as construction of coastal structures or dredging activities. The shoreline position of the earliest date was set as the reference value.



Source: JICA Expert Team

Figure 5-20: Target Areas for Shoreline Change Analysis

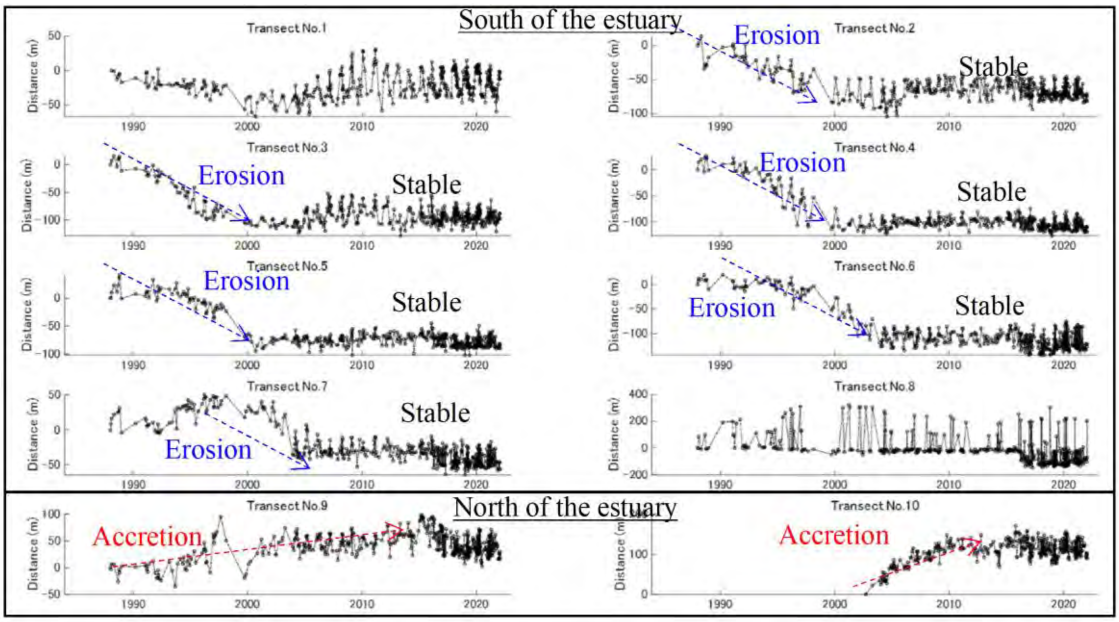
5.1.1.1. R4: Kosasthalaiyar



Source: JICA Expert Team

Figure 5-21: Location of transect lines around Kosasthalaiyar

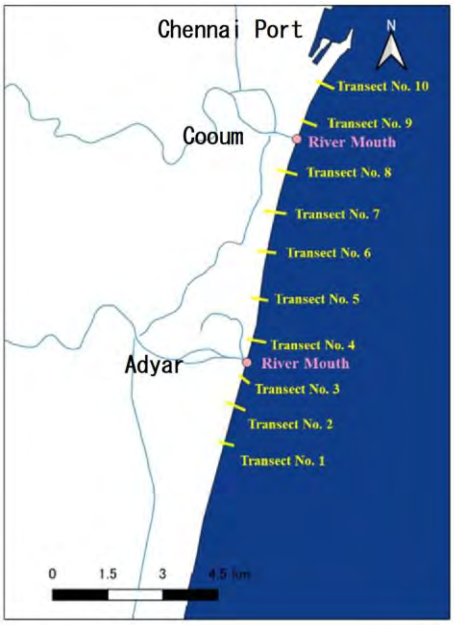
Transect lines were set as shown in Figure 5-21. Noted the figure of transect No.8 contains unreliable data affected by the movement of the sandbar at the mouth. Due to the severe erosion, a variety of coastal protection structures were constructed at the right bank after 2000. The shoreline has to stable since then (transect No. 1~8). At the left bank, advancement seaward of the coastline was observed due to the construction of the Ennore port (Transect No. 10).



Source: JICA Expert Team

Figure 5-22: Shoreline Change Analysis Results around Kosasthalaiyar

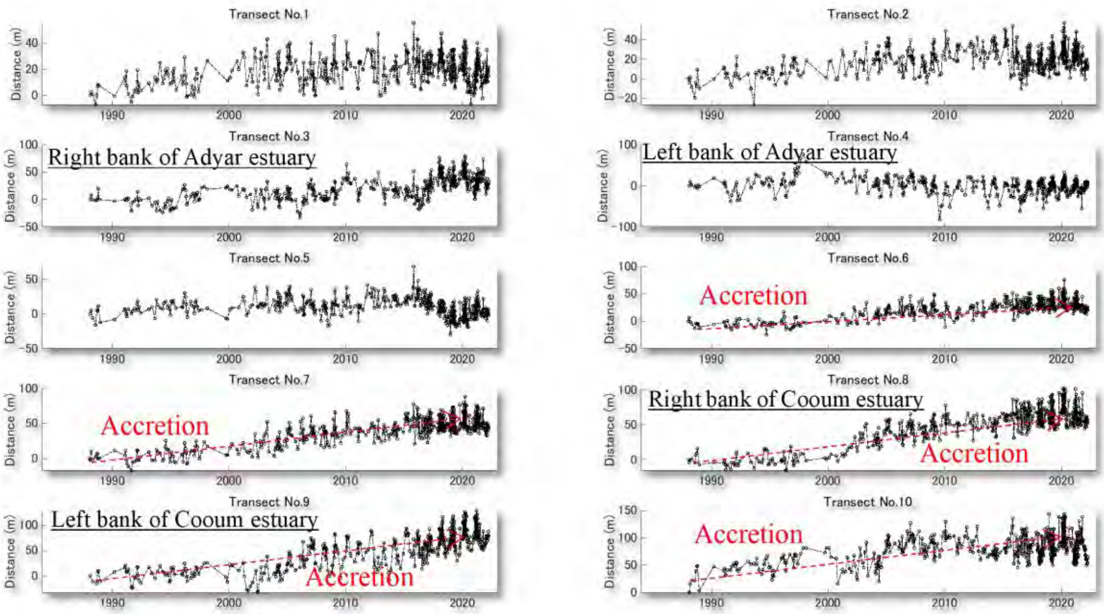
5.1.1.2. R3: Cooum and Adyar



Source: JICA Expert Team

Figure 5-23: Location of Transect Line around Cooum and Adyar

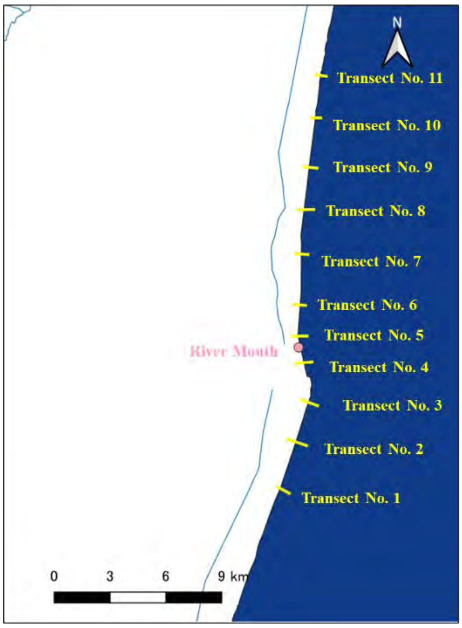
Transect lines were set as shown in Figure 5-23. Generally, the sandy beach in this region has an accretion tendency due to the existence of the Chennai Port on the north side.



Source: JICA Expert Team

Figure 5-24: Shoreline Change Analysis Results around Cooum and Adyar

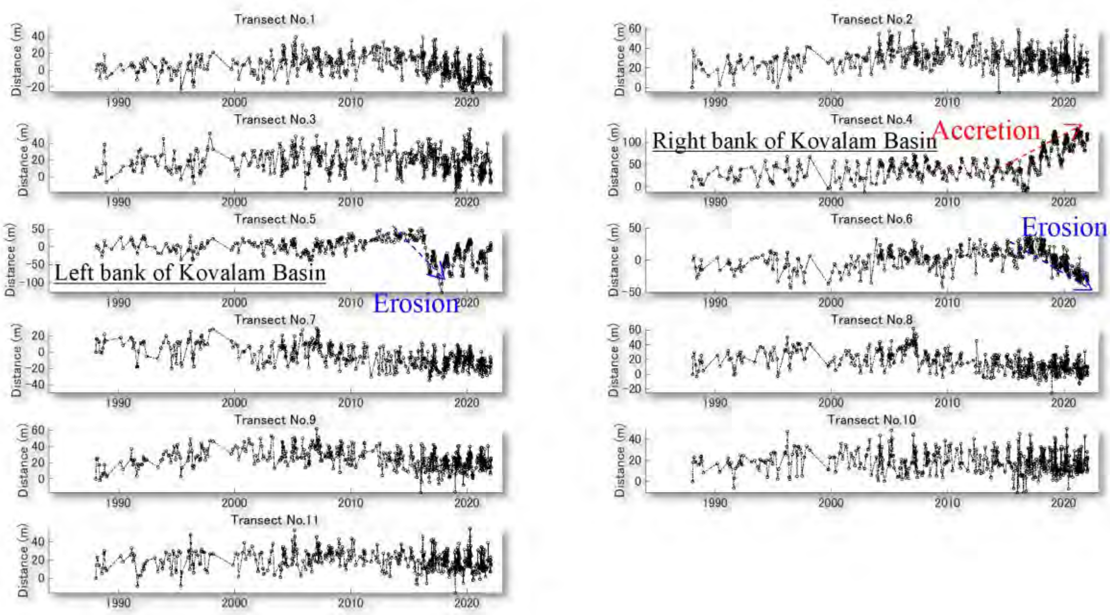
5.1.1.3. R2: Kovalam



Source: JICA Expert Team

Figure 5-25: Location of Transect Line around Kovalam

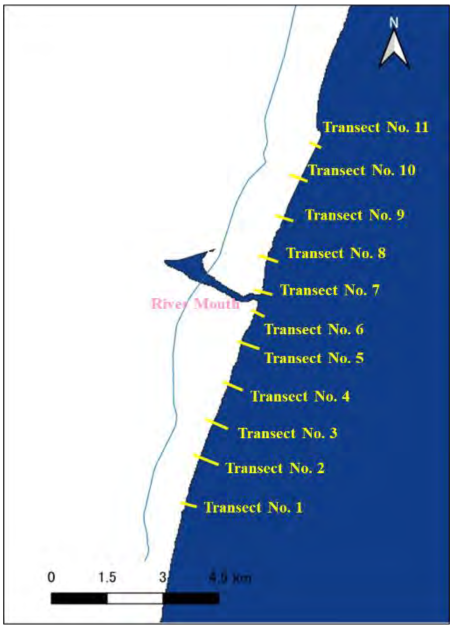
Transect lines were set as shown in Figure 5-25. Due to the construction of jetty structures at the river mouth, erosion occurred at the left bank (Transects No. 5~6) and accretion occurred at the right bank (Transects No. 4). As for the other locations, sandy beach is generally stable.



Source: JICA Expert Team

Figure 5-26: Shoreline Change Analysis Results around Kovalam

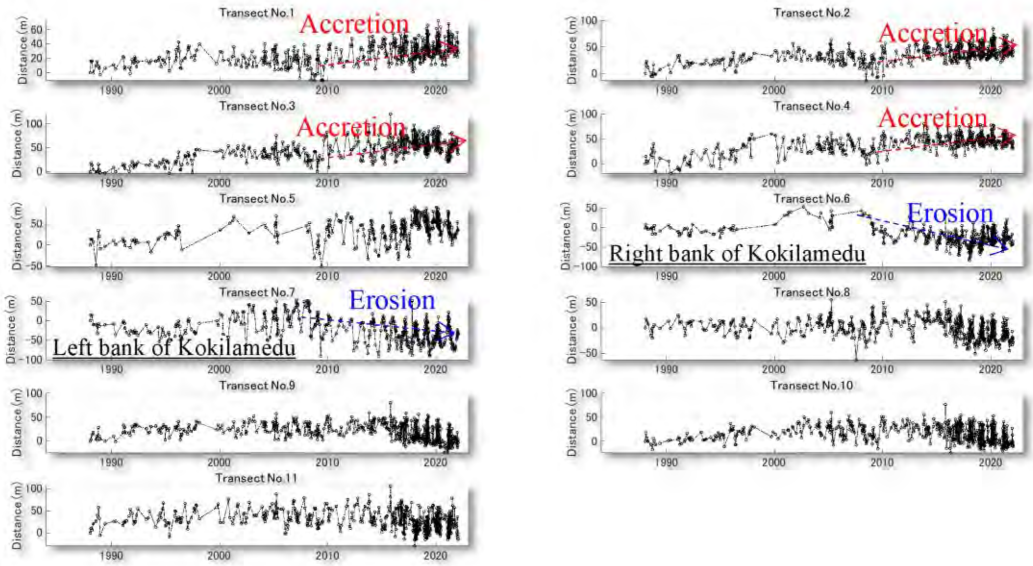
5.1.1.4. R1: Kokilamedu



Source: JICA Expert Team

Figure 5-27: Location of Transect Line around Kokilamedu

The transect line (Transect Line) was set as shown in Figure 5-27. In transect line Nos. 1-4, shoreline advance was observed due to a rubble dike placed near the shoreline. The estuary topography is significantly altered (Transects No. 6-7). The shoreline on the left bank of the river is generally stable (Transects No. 8~11).



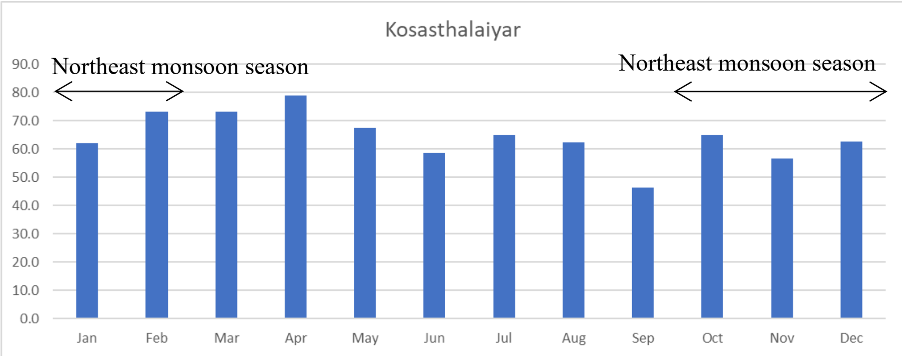
Source: JICA Expert Team

Figure 5-28: Shoreline Change Analysis Results around Kokilamedu

5.3.2 Analysis of changes in river mouths using satellite imageries

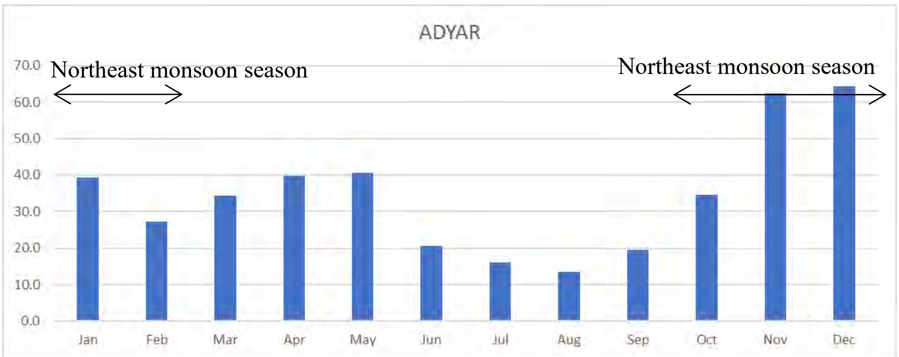
Shorelines around estuaries were detected using the same method as shoreline change analysis, then the narrowest part of the river mouth width was calculated by AI. River Mouth widths were averaged by month in Figure 5-29 to Figure 5-33. An example of reading from a satellite image is shown in Figure 5-34.

Seasonal trends are evident when the analysis results are arranged by month, except Kosasthalaiyar. River mouths are typically wider after November due to the monsoon climate, and they become narrower around August, which is the dry season.



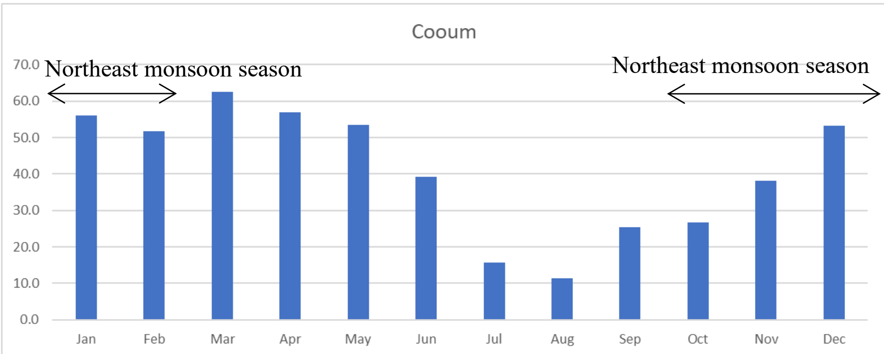
Source: JICA Expert Team

Figure 5-29: Average River Mouth Widths/Month (Kosasthalaiyar)



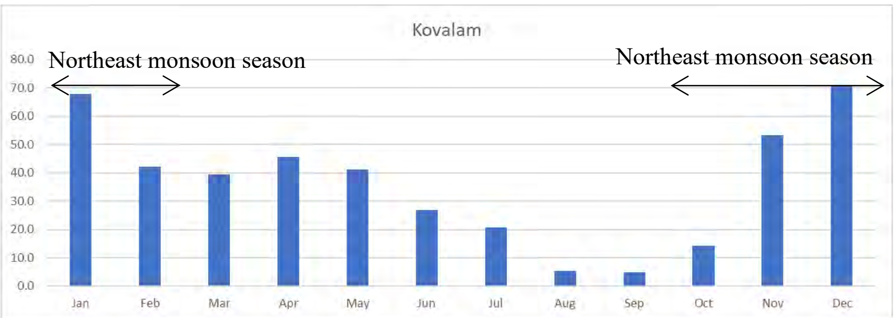
Source: JICA Expert Team

Figure 5-30: Average River Mouth Widths/Month (Adyar)



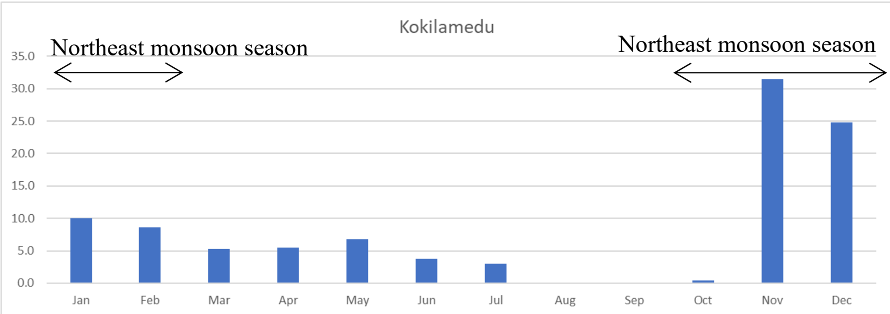
Source: JICA Expert Team

Figure 5-31: Average River Mouth Widths/Month (Cooum)



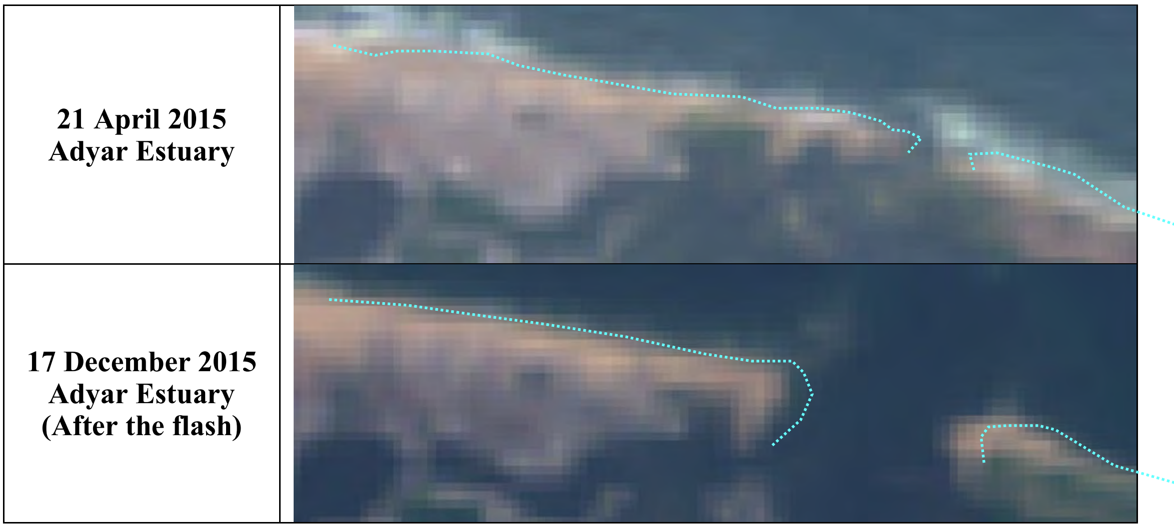
Source: JICA Expert Team

Figure 5-32: Average River Mouth Widths/Month (Kovalam)



Source: JICA Expert Team

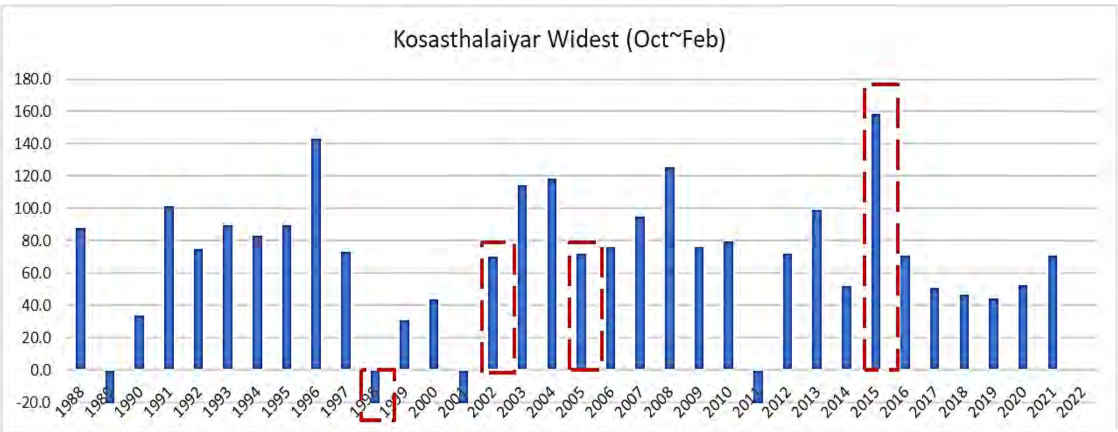
Figure 5-33: Average River Mouth Widths/Month (Kokilamedu))



Source: JICA Expert Team

Figure 5-34: Example of reading the width of a river mouth in a satellite image (Adyar)

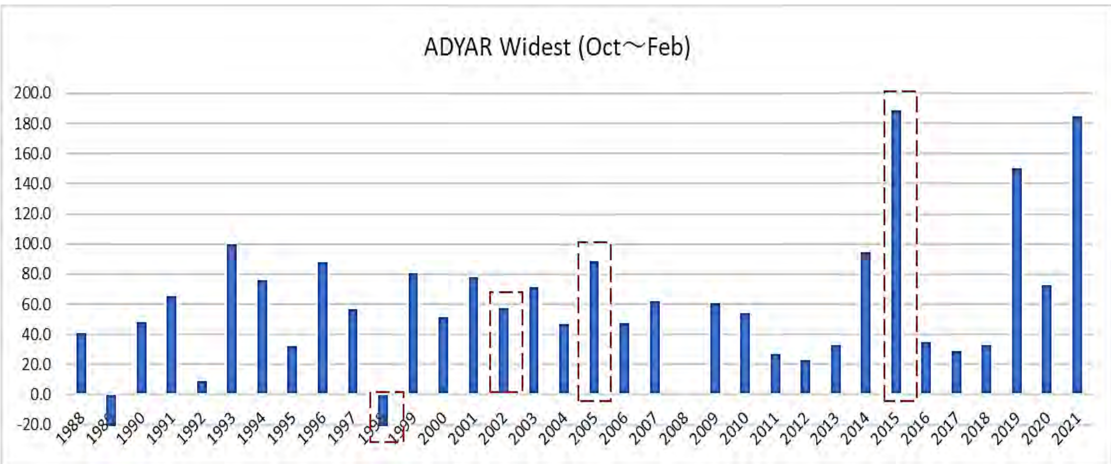
The maximum River Mouth widths around the monsoon season (October to February) are extracted for each year in Figure 5-35 to Figure 5-39. A flush of a sandbar is a rare phenomenon observed only at the Adyar River mouth and Kosasthalaiyar River mouth in 2015(below 100-year probability) in this study. Though it is difficult to analyse the conditions of the rainy season before 2003 using satellite imagery as there are few suitable satellite images of the Chennai River Mouth region before 2003, there was no significant widening of the estuary (flash flooding) in the Kosasthalaiyar estuary during the 2005 floods (below 50-year probability).



*Negative values indicate absence of data. Red boxes indicate the year the flood occurred.

Source: JICA Expert Team

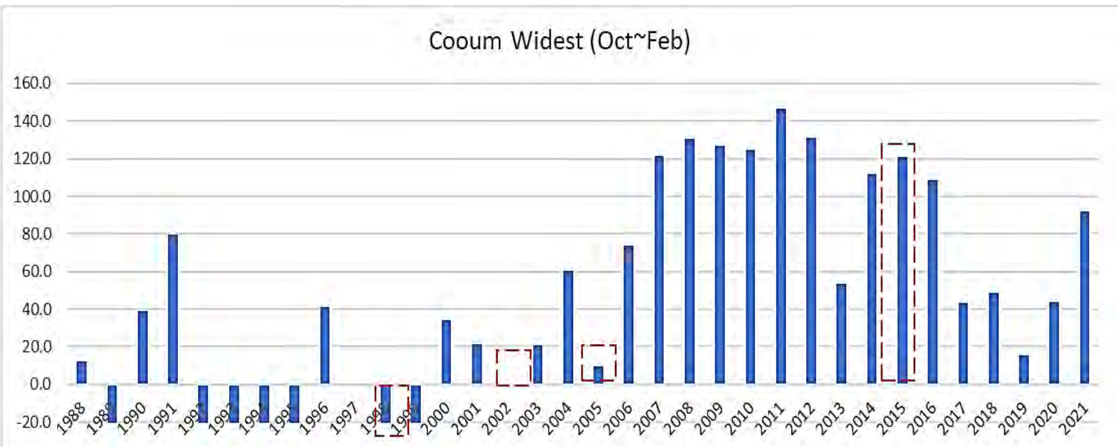
Figure 5-35: The maximum River Mouth Widths during the Monsoon (Kosasthalaiyar)



*Negative values indicate the absence of data. Red boxes indicate the year the flood occurred.

Source: JICA Expert Team

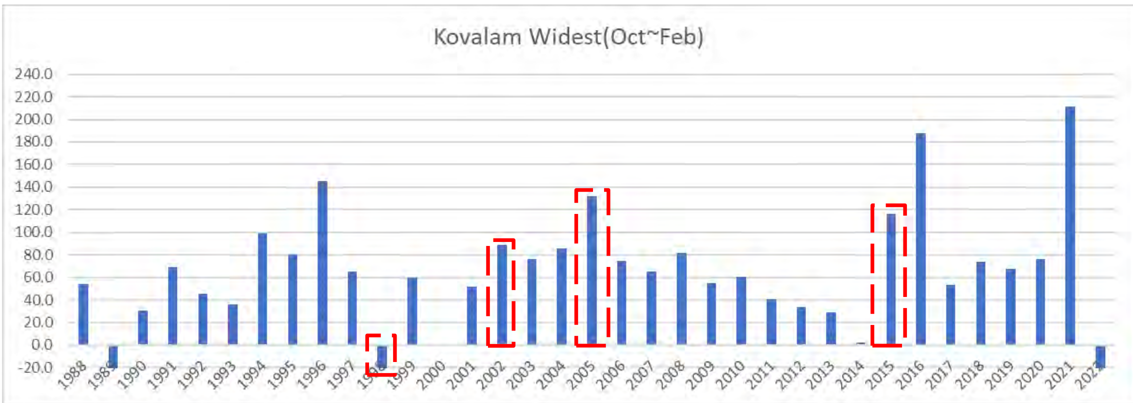
Figure 5-36: **The maximum River Mouth Widths during the Monsoon (Adyar)**



*Negative values indicate the absence of data. Red boxes indicate the year the flood occurred.

Source: JICA Expert Team

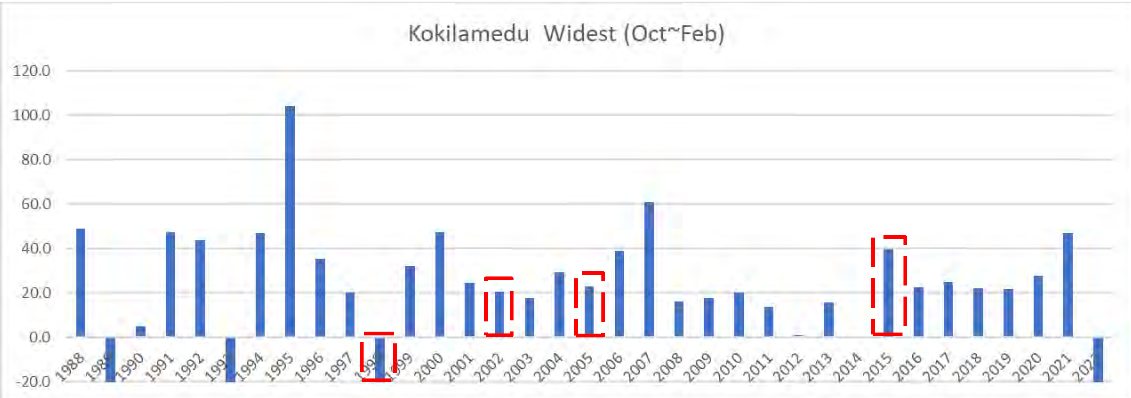
Figure 5-37: The maximum River Mouth Widths during the Monsoon (Cooum)



*Negative values indicate the absence of data. Red boxes indicate the year the flood occurred.

Source: JICA Expert Team

Figure 5-38: The maximum River Mouth Widths during the Monsoon (Kovalam)



*Negative values indicate the absence of data. Red boxes indicate the year the flood occurred.

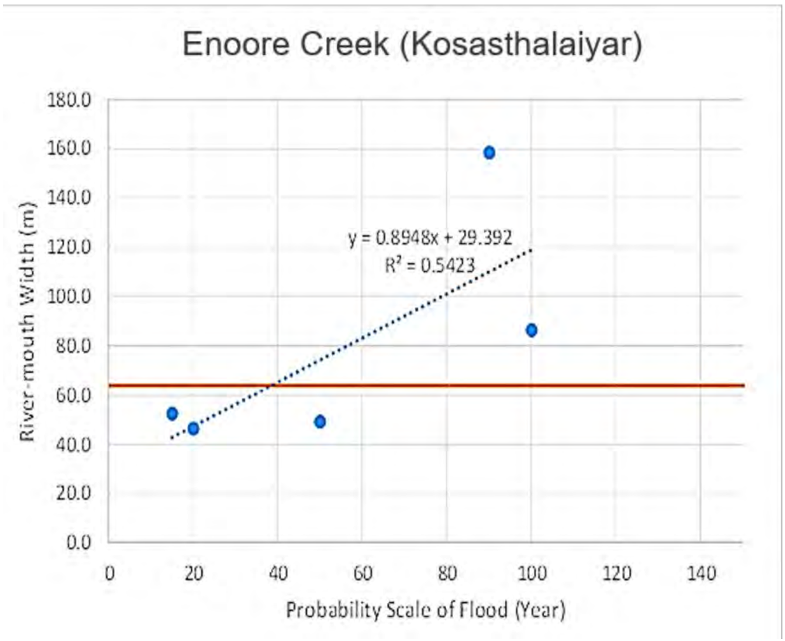
Source: JICA Expert Team

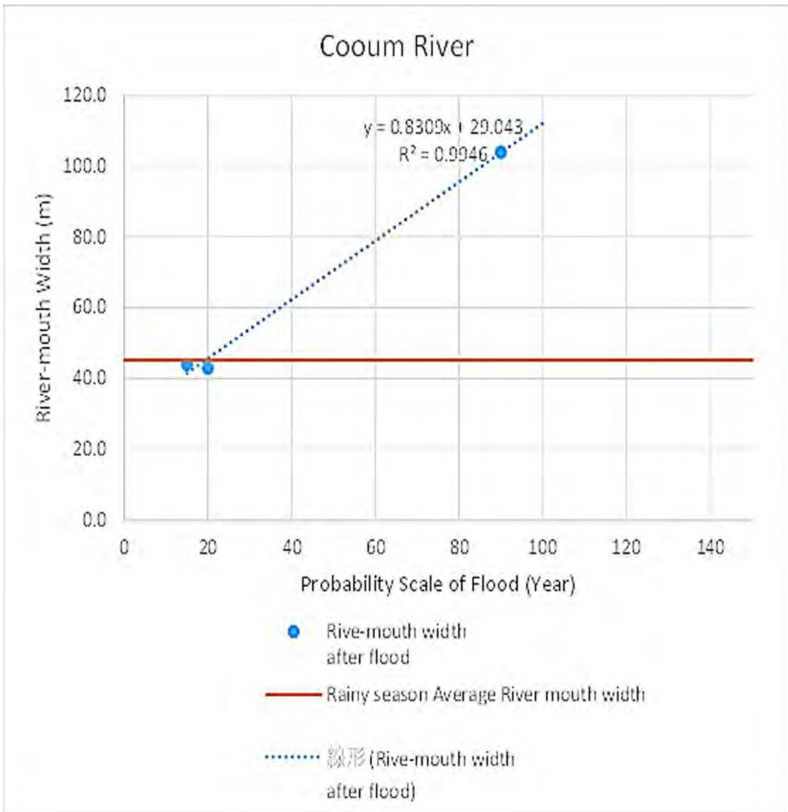
Figure 5-39: **The maximum River Mouth Widths during the Monsoon (Kokilamedu)**

5.3.3 Relationship between flood probability magnitude and estuary width

If the estuary's width is narrow during a flood event, the water level at the mouth of the estuary may be raised, which may be one of the causes of flooding. Therefore, the relationship between the estuary width and the size of existing floods, as summarized in the previous section, is summarized. The resulting figure is shown in Figure 5-40 to Figure 5-41.

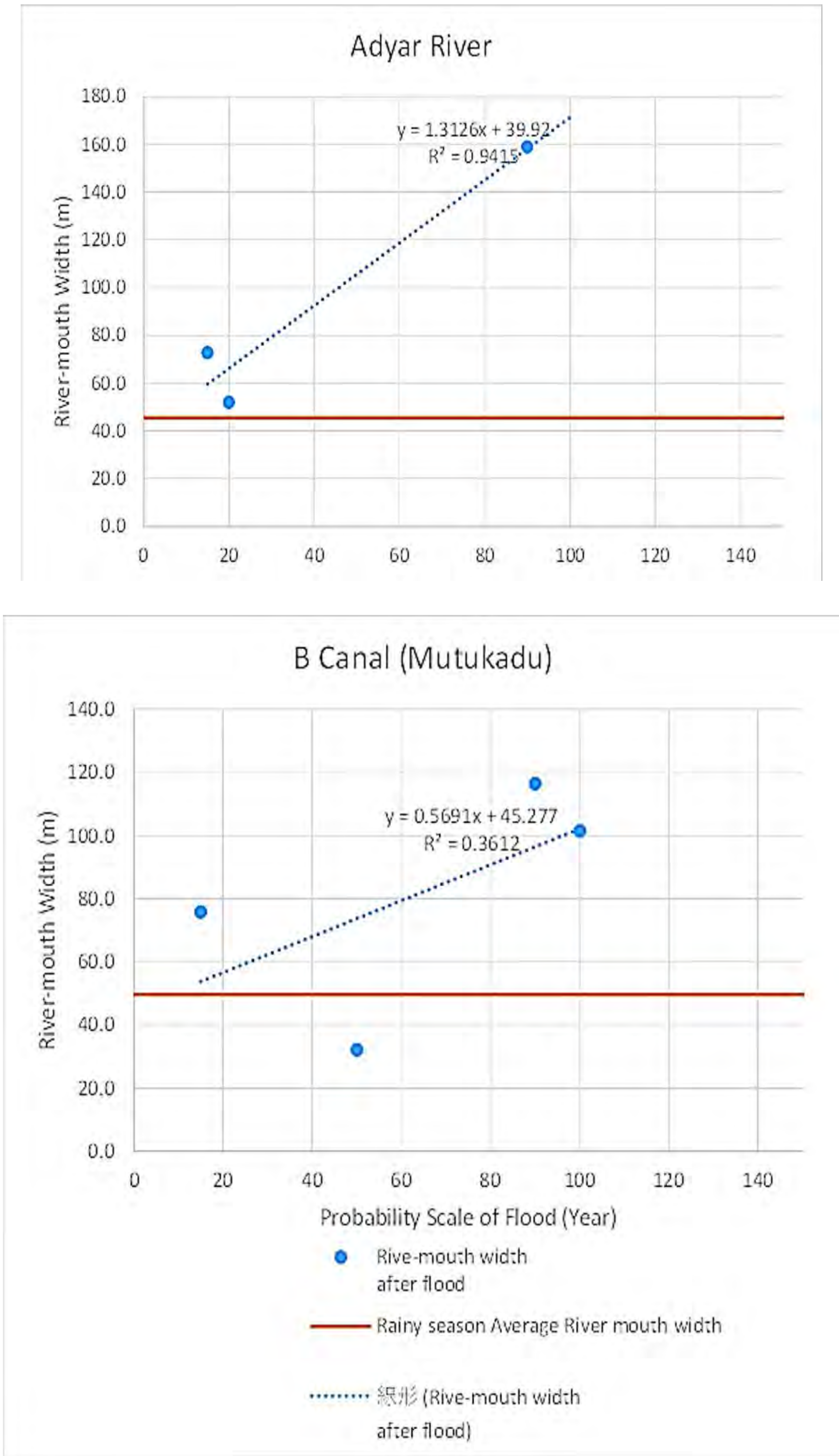
From this figure, it can be seen that as the flood magnitude increases, the river mouth bar naturally flushes and widens. The standard for the rapid widening of a river mouth by river mouth flushing is generally a flood with a probability greater than 50-year probability. However, it should be noted that the sample size is small, and the correlation coefficient is small for the Kosasthalaiyar and Kovalam basin (Muttukadu) due to the sampling of flood events.





Source: JICA Expert Team

Figure 5-40: Relationship between Estuary Width and Flood Magnitude (Kosasthalaiyar and Cooum)



Source: JICA Expert Team

Figure 5-41: Relationship between Estuary Width and Flood Magnitude (Adyar, Muttukadu B Canal North)

5.4 Tidal Levels and Waves in Estuaries

Tidal levels and waves along the Chennai coast and at various estuaries were organized as the basic conditions for examining coastal issues.

5.4.1 TideLevel

5.4.1.1. Basic condition

Tidal conditions are crucial for port operations, shipping, coastal management, and even river mouth management, as they influence sediment transport and water flow dynamics. The basic tidal conditions for Chennai Port are summarized in the Indian Tide Table. The tidal conditions are as follows:

- Mean High Water Spring: C.D.L. + 1.15m
- Mean High Water Neap: C.D.L. + 0. 84m
- Mean Low Water Spring: C.D.L. + 0.14m
- Mean Low Water Neap: C.D.L. + 0.43m
- Mean Sea Level: C.D.L. + 0.65m

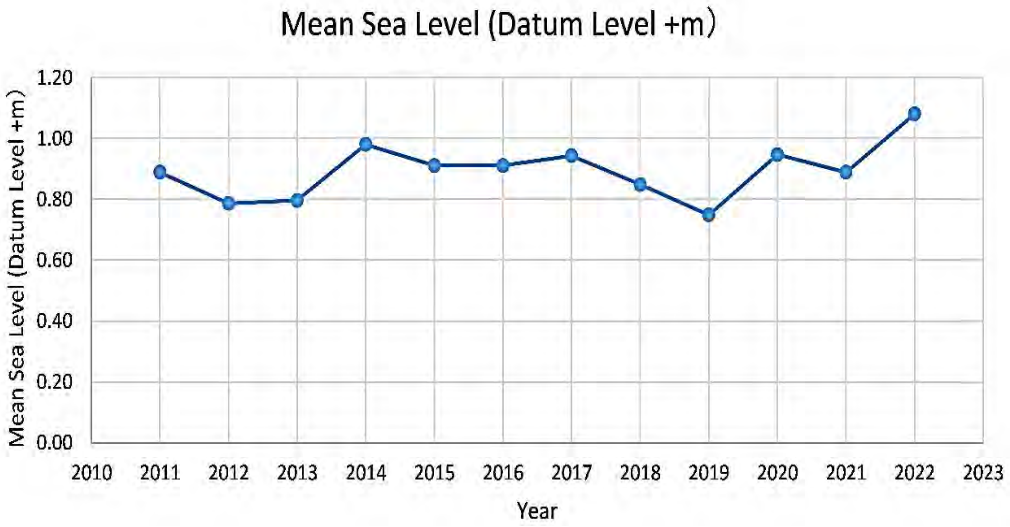
Were, C.D.L.: Chart Datum Level.

Since topographic elevation and land survey results are based on the Mean Sea Level standard, the main values will be converted to Mean Sea Level for this study.

- Mean High Water Spring: M.S.L. + 0.50m
- Mean Sea Level: M.S.L. + 0.00m
- Mean Low Water Spring: M.S.L. - 0.51m

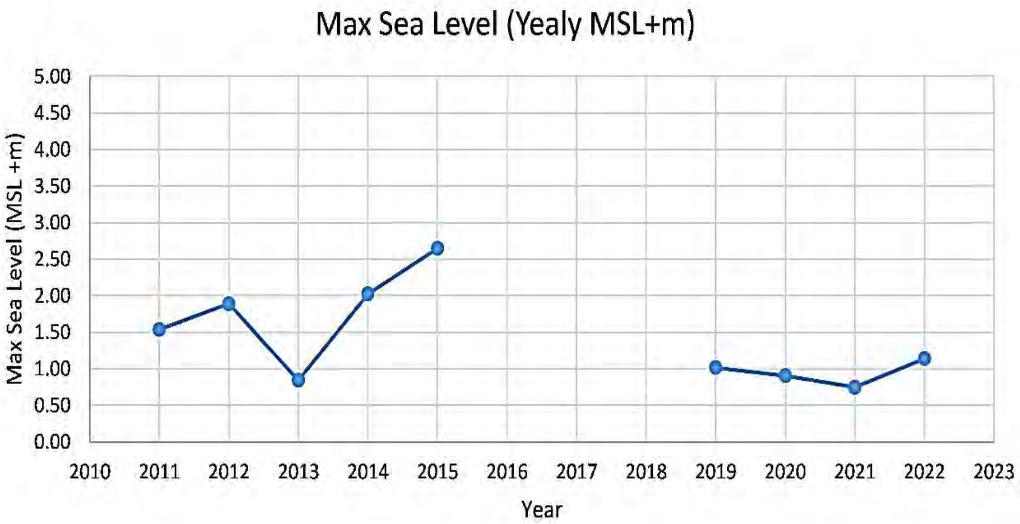
5.4.1.2. Tide level observation

In Chennai, the coastal area has been affected by cyclones in the past and often experiences high tides. Therefore, the maximum tide levels were compiled from the data of the Chennai Tide Level Observatory. The period covered was 12 years from 2011 to 2022. The results are shown in Figure 5-43 and Figure 5-43. Since the definite height of the Datum Level at the Chennai tide station is unknown, the annual mean tide level was calculated from year to year and converted to mean tide level. The Chennai tide station has a very large number of missing measurements, and the mean tide level fluctuates. Therefore, maximum tides that were clearly anomalous were dismissed (Maximum tides M.S.L.+3 m or higher were dismissed). From this analysis, the annual maximum tides were determined to be between M.S.L.+1 and 2.5 m.



Source: JICA Expert Team

Figure 5-42: Average Tide Level (Tide Level Observation Standard)



Source: JICA Expert Team

Figure 5-43: Maximum Tide Level (based on Annual Mean Tide Level)

5.4.1.3. Stochastic tidal deviation

Stochastic tides were studied at the Central Water and Power Research Station (CWPRS). Numerical calculations were performed for past historical cyclones, etc., and probability tide level anomalies were calculated from extreme value statistical analysis. The calculated probability tide level anomalies are shown below.

Table 5-7: Probability Tidal Deviation

Return Period in years	Storm Surge in m
10	1.0
25	1.2
50	1.4
100	1.6

Source: "Design Wave Prediction & Storm Surge Analysis" by M. D. Kudale, Joint Directo, CWPRS, Pune

5.4.1.4. Design high tide level

Based on these studies up to the previous section, the design high tide level or Highest High-Water Level (H.H.W.L.) for coastal structures such as seawalls can be calculated as follows. Here, the return period (reproduction probability year) of extreme tide events is set at 50 years, which is equivalent to the maximum tide level (M.S.L. + 1 to 2.5 m) for about 10 years in the past, as summarized in 8.4.1.2, and is generally considered a reasonable choice because it accounts for significant tide events. Accordingly,

H.H.W.L. = M.S.L. + 1.90 m

Here,

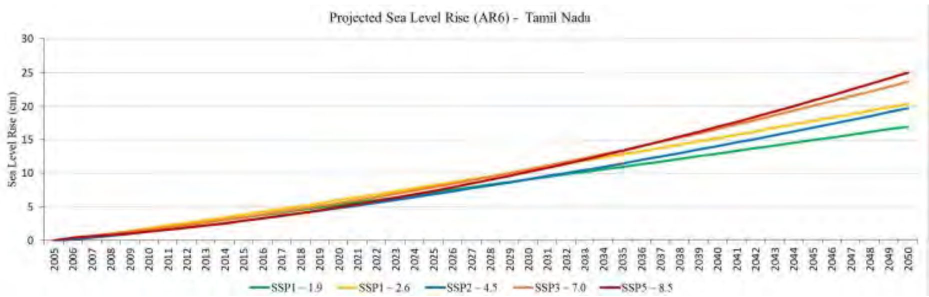
H.H.W.L. = H.W.L. + Probability tidal deviation (50-years return-period)

H.H.W.L. = M.S.L. + 0.50 m + 1.40 m

= M.S.L. + 1.90 m

5.4.1.5. Impact of climate change on tidal levels

Particularly for coastal regions, the potential consequences of climate change and the rise in sea level are a critical concern. The amount of sea level rise in Tamil Nadu by 2050 is expected to be about 20 cm under the medium scenario (SSP1-2.6: a scenario in which global warming is limited to less than 2°C and CO2 emissions are reduced to net zero in the second half of this century). In addition, the low-end scenario (SSP1-1.9) predicts a rise of about 17 cm, while the high-end scenario (SSP5-8.5) predicts a rise of 25 cm, so the range of predictions is about 7 cm, as per the draft report titled "Climate Risk Assessment and Adaptation Plan of Tamil Nadu — Coastal Ecosystem" by the Centre for Climate Change and Disaster Management (CCCDM), Anna University.



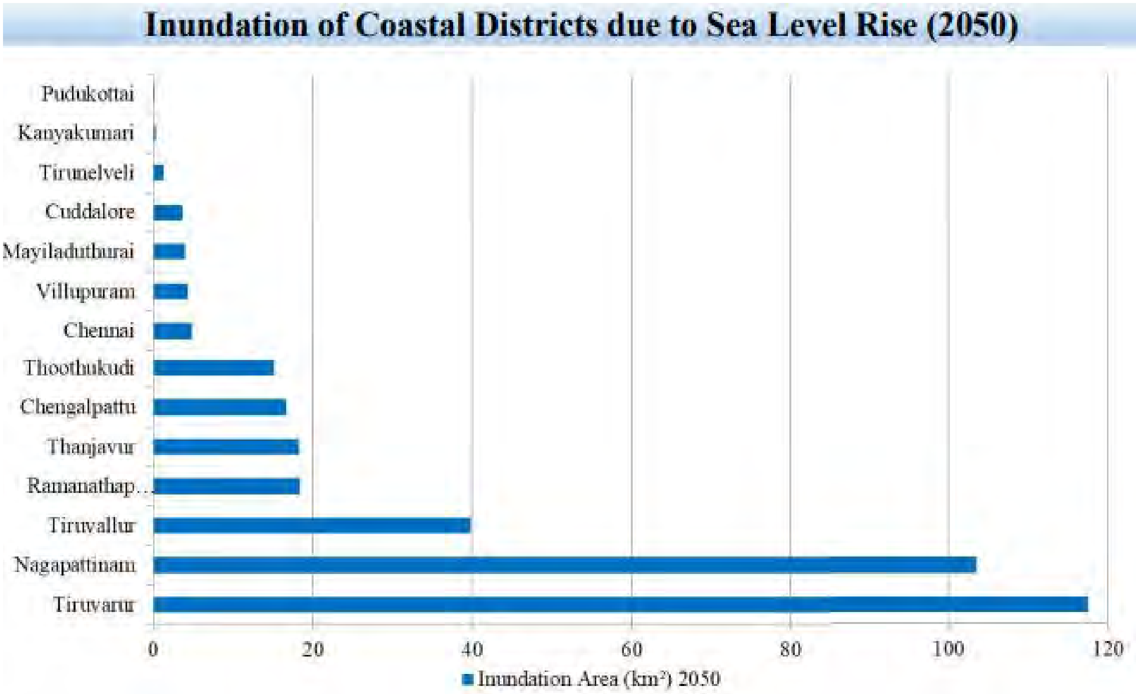
Source: CCCDM, Anna University

Figure 5-44: Amount of sea level rise in Tamil Nadu

In addition, according to NIOT, the rate of change in relative sea level along the coast of India is between -3.36 mm/year and +5.16 mm/year (positive and negative values indicate sea level rise and fall, respectively). In Chennai, sea levels are rising (0.33 mm/yr), but Nagapatnam (-1.95

mm/yr) and Tuticorin (-2.70 mm/yr) are also showing a downward trend, so it is not uniform. In another report by the Center for Study of Science, Technology and Policy (CSTEP) in India, it was found that between 1987 and 2021, the sea level in Chennai rose by a total of 0.679 cm, with an average annual rise of 0.066 cm (approximately 0.66 mm). In addition, according to a report by the Centre for Climate Change and Coastal Ecosystems (CCCDM) on "Climate Risk Assessment and Adaptation Planning for Tamil Nadu - Coastal Ecosystems", the relative sea level rise along the Chennai coast over the past 100 years (1916-2015) has been 5.5 cm.

As for the impact of rising sea levels, it is thought that the areas most affected in terms of the area inundated will be districts such as Tiruvarur, Nagapattinam and Thanjavur, which are located 300 to 350 km south of Chennai, and the impact on Chennai itself is thought to be relatively small. Based on the above research, the risk of sea level rise in Chennai is thought to be relatively low.



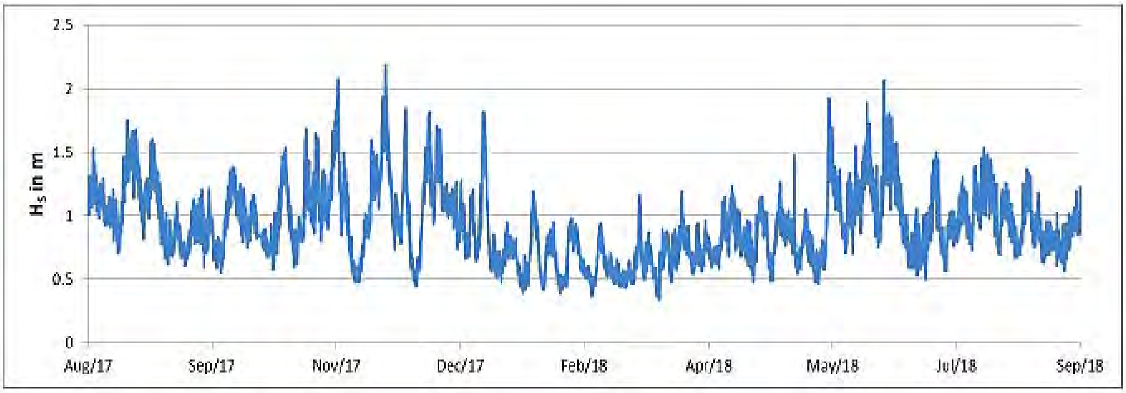
Source: CCCDM, Anna University

Figure 5-45: Inundated coastal areas due to sea level rise in 2050

5.4.2 Waves

5.4.2.1. Wave observation

There are no permanently established wave monitoring facilities in the Chennai area. Moreover, there are no long-term wave observation data. However, there are records of one-year observations at Chennai Port. Figure 5-46 illustrates an example of an observation record. It is observed that the wave heights vary from 0.5 to 2 m.

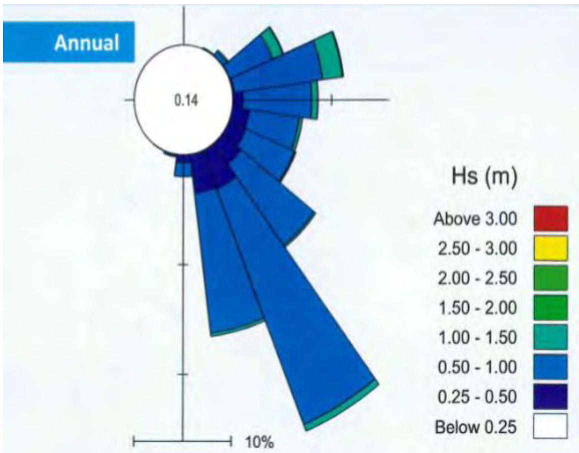


Source: Scientific studies for sustainable opening of the Adyar River mouth

Figure 5-46: Wave Observation Data

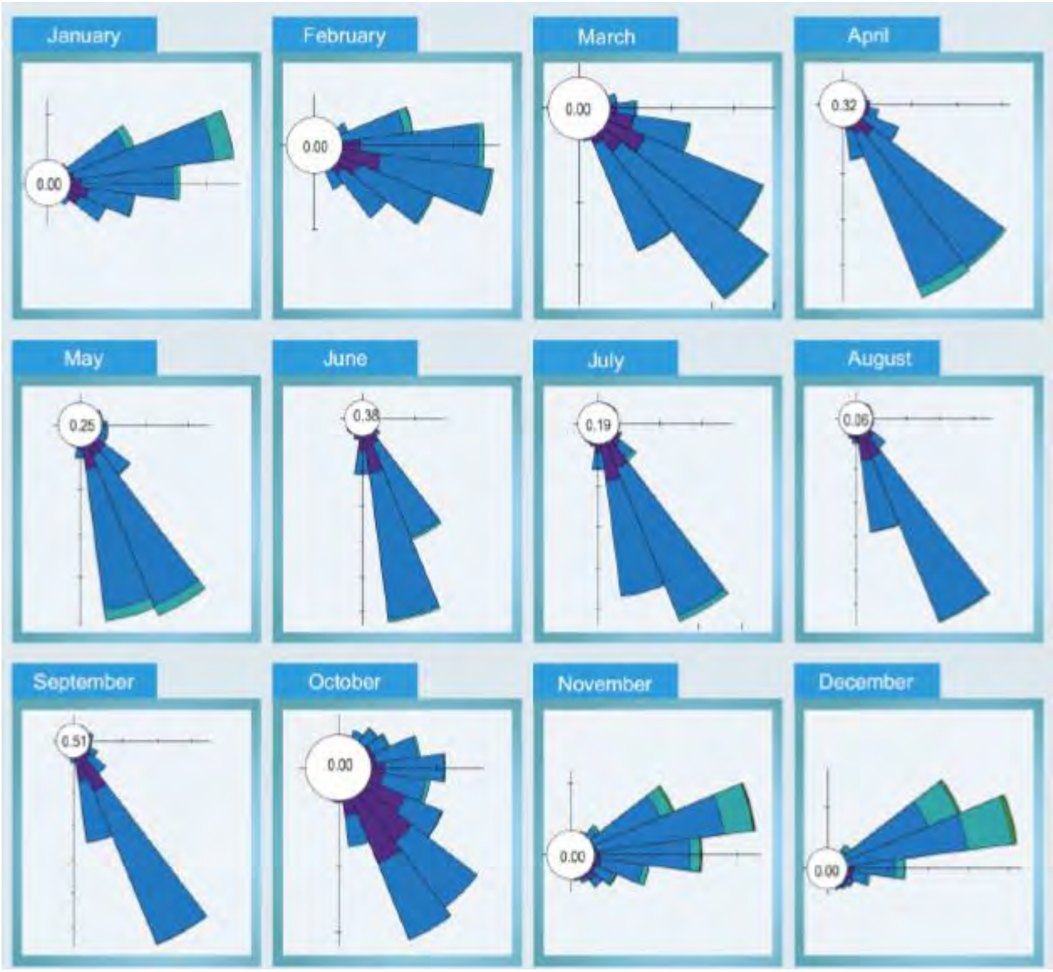
5.4.2.2. Estimated Wave

As mentioned above, despite the unavailability of wave data, NIOT had performed wave estimation utilizing MIKE21-SW over the entire Indian coast. The wave estimation outcomes for the Chennai region are presented here (Figure 5-47, Figure5-48). The predominant wave height category is from 0.5 to 1.0 m, and high waves beyond 2 m originate from the ENE direction.



Source: Wave Atlas of Indian Coast, NIOT

Figure 5-47: Annual Wave Estimates for Chennai



Source: Wave Atlas of Indian Coast, NIOT

Figure 5-48: Estimated Monthly Waves in Chennai

5.4.2.3. Stochastic Waves

Stochastic waves were studied at the Central Water and Power Research Station in the same way as probability tides. Numerical calculations were performed for historical cyclones, etc., and probability waves were calculated from extreme value statistical analysis. The calculated probability waves are shown below.

Table 5-8: Wave probability (40 m depth)

Return Period in years	Hs in meters
10	8.1
25	8.7
50	9.0
100	9.3

Source: "Design Wave Prediction & Storm Surge Analysis" by M. D. Kudale, Joint Directo, CWPRS, Pune

5.4.2.4. Design Wave

The probability year for the design waves for coastal structures is set at a 50-year return period for the Cooum River training wall at the river mouth, which is a reasonable choice for such structures. Thus, the design waves will be as follows:

- Offshore Design Wave Height: Hs = 9.0 m (at water depth = 40 m)

In addition, the following values were used in the design of the conduit embankment at the mouth of the Cooum River:

- Significant wave height of incident waves at toe of the structure (Hs) = 3.5 m
- Mean Wave Period (Tm) = 5.37 s (this Tm corresponds to Hs = 3.5 m, sourced from Wave Atlas)

The following values were used as the run-up height of the conduit embankment.

- Design Crest Elevation =D.W.L. + Run-up Height +FB

= C.D.L. +2.5 m +2.37 m + 0.75 m
= C.D.L. + 5.62 m
= M.S.L. + 4.97 m

Here,

Design Crest Elevation:	Design crest height of training walls (m)
Run-up Height:	Wave run-up height (m)
FB (Free Board):	Safety margin (m)

The design high tide level (C.D.L. +2.5m) used above is almost the same as the value set in the previous section (MSL +1.90m = C.D.L. +2.55m).

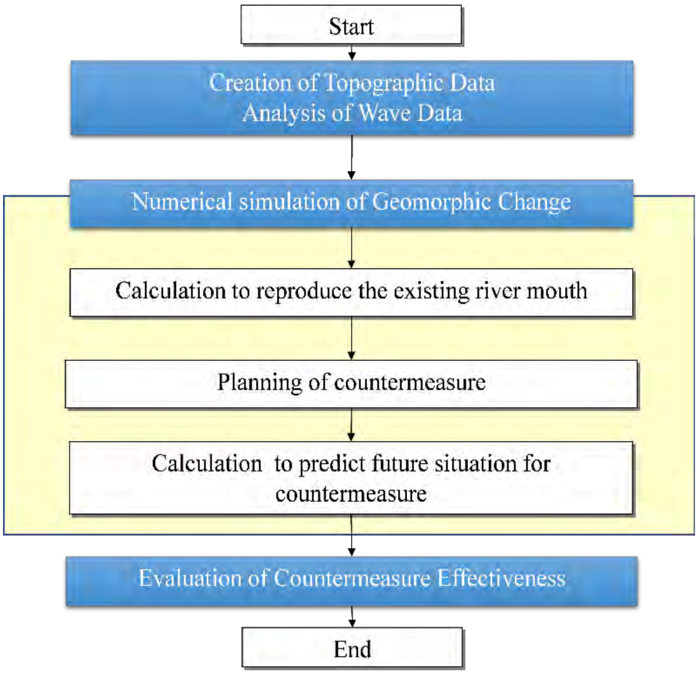
5.5 Study on Measures to Prevent River Mouth Blockage

5.5.1 Objective

As mentioned in the previous sections, river mouths along the Chennai coast often experience blockages. Although measures such as the construction of training walls and regular dredging are being taken at each estuary, it is thought that problems such as sedimentation and erosion due to the blocking of littoral drift will occur in the future at estuaries where new training walls have been constructed. Therefore, it is thought that additional measures and dredging will be necessary in the future. The purpose of this study is to examine measures to prevent the closure of estuaries (additional measures, alternative plans, etc.) for the target four estuaries.

5.5.2 Analysis Method and Workflow

Figure 5-49 shows the workflow of river mouth blockage countermeasures. First, topographic data of the estuary of the target river is collected and river mouth topographic models are created. Then, Wave transformation calculations are performed to gain external forces on the river mouth. The results of the Wave transformation calculations are used as external forces in a three-dimensional beach deformation calculation to reproduce the formation of sandbars at the river mouth. By using a numerical analysis model developed from the reproduction calculations, predictive calculations are performed for the case in which the proposed river mouth blockage countermeasures are implemented. Finally, the studied river mouth blockage countermeasures are evaluated, and the most effective countermeasures are selected.



Source: JICA Expert Team

Figure 5-49: Workflow of River Mouth Blockage Countermeasures

5.5.3 Creation of Topographical Data

To construct the numerical model, topographic data for the estuary were collected and integrated to create the estuary topographic data. The estuary topographic model was created by using bathymetric data for the sea and AW3D[1] data for the upland area. For areas where estuary topographic data was not sufficient, we supplemented the data from aerial photographs and other sources as appropriate. The results are shown below (Figure 5-50 – 5-53).

[1] AW3D is 3D map data developed and sold jointly by the Remote Sensing Technology Center of Japan (RESTEC), which has many years of experience in satellite image processing technology, and NTT Data, which has high-speed, high-precision data processing technology. The data used as the basis for the maps is derived from the Advanced Land Observing Satellite (ALOS), also known as Daichi, operated by the Japan Aerospace Exploration Agency (JAXA), which has excellent wide-area coverage, and high-resolution satellite images provided by Maxar, a US company that operates the world's most advanced satellites. These are 3D maps of the entire world that combine wide-area coverage and high resolution.

Source: JICA Expert Team

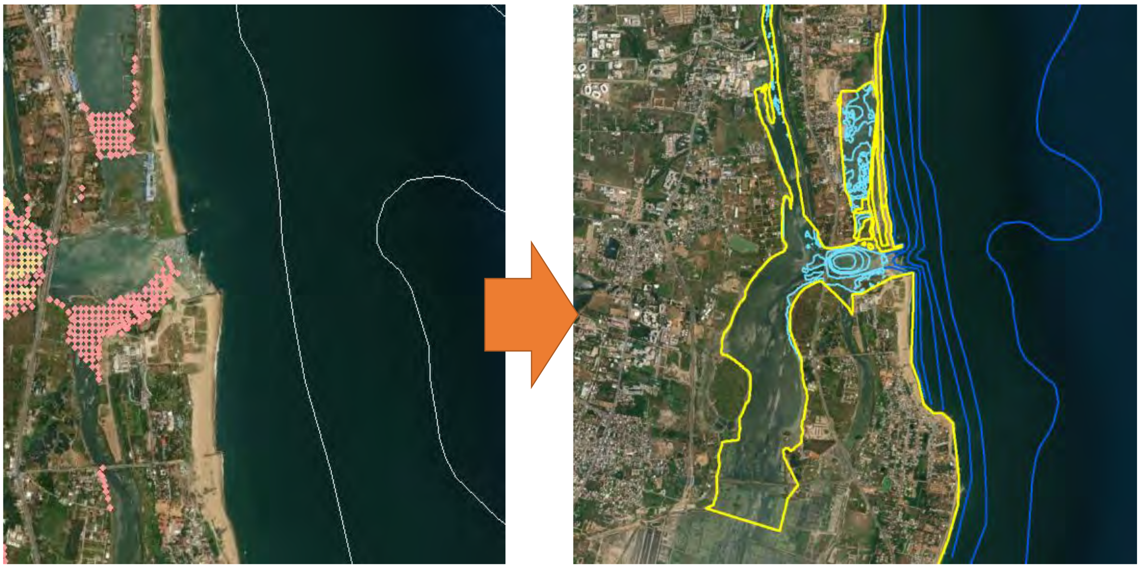
Figure 5-50: Estuary Topography Model (Kosasthalaiyar)

Source: JICA Expert Team

Figure 5-51: Estuary Topography Model (Cooum)

Source: JICA Expert Team

Figure 5-52: Estuary Topography Model (Adyar)



Source: JICA Expert Team

Figure 5-53: Estuary Topography Model (B Canal North)

5.5.4 Wave Transformation Calculation

Wave transformation calculations were performed using the energy equilibrium equation method to establish the wave conditions that would be set as the external forces for the three-dimensional beach deformation calculations. For offshore wave conditions, monthly energy-averaged waves were calculated from ERA5[2] data and fed as input into the Wave transformation calculation model. From the Wave transformation calculation results, the wave conditions at each river mouth of the target rivers were extracted and used as input conditions for the three-dimensional coastal deformation model.

5.5.4.1. Analysis Method

The method used to calculate wave deformation was the energy equilibrium equation method. The energy equilibrium equation method was used to calculate wave deformation from offshore to coastal areas, as the model can account for offshore refraction and shallow water deformation. Table 5-9 presents a comparison of each analysis method. In this table, the Karlsson equation corresponds to the energy equilibrium equation method.

[2] ERA5 is the fifth generation of atmospheric reanalysis data sets produced by the European Center for Medium-Range Weather Forecasts (ECMWF). ERA5 is a data set that reproduces past weather conditions by assimilating past observational data into the latest forecast models, and wave data is also included in this reanalysis data.

Table 5-9: Theoretically Applicable Ranges of Various Model Equations for Wave Transformation

model equation	shoaling	refraction	diffraction	Reflection	breaking model	arbitrary depth	current	irregularity	nonlinearity	calculation region			remarks
										large	middle	small	
Wave ray equation	◎	◎	×			◎	○	○	△	○	○	○	1)
Karlsson equation	◎	◎	▽	△	○	◎	○	◎	×	○	○	○	
Helmholtz equation	○	○	◎	◎	×	◎	×	○	×			○	2)
Takayama's method			◎	◎	×	◎	×	◎	×		○	○	3)
Mild slope equation	◎	◎	◎	◎	○	◎	○	○	△			○	
Time-dependent mild slope equation	◎	◎	◎	◎	○	◎	○		×			○	4)
Numerical wave analysis equation	○	◎	◎	◎		◎			×			○	
Mild slope equation for irregular waves	◎	◎	◎	◎	○	◎		◎	×			○	
Parabolic equation	◎	◎	◎	△	○	◎	○	○	△		○	○	
Nonlinear shallow water equations	◎	◎	◎	◎	○	×		◎	◎			○	5)
Boussinesq equations	◎	◎	◎	◎	○	○	○	◎	◎			○	6)
Fully nonlinear and dispersive equations	◎	◎	◎	◎	○	◎		◎	◎			○	

◎ : applicable in original form, ○ : applicable in modified form, △ : partially applicable in modified form,
▽ : practically applicable but not theoretically, blank : possibility in the future study, × : not applicable.

calculation region =
large: like a region from deep to shallow water, middle: like a shallow water region, small: like a region within a harbor

1) Nonlinear wave celerity can be used.
2) Piece wise uniform water depth is assumed.
3) Uniform water depth is assumed.
4) Breaking model and arbitrary reflection coefficient can be introduced easily.
5) The set of equations is applicable only to very shallow water.
6) Original set of equations is applicable only to shallow water.

Source: Coastal Facility Plan & Design Handbook 2000 Edition, Japan Society of Civil Engineers (JSCE)

5.5.4.2. Offshore Wave

For offshore waves, the ERA5 which is GPV data provided by ECMWF (European Centre for Medium Term Forecasting) was used because long-term wave observation records are not available on the Chennai coast. Energy-averaged waves were also calculated as they are used in numerical calculations of topographic changes. The results of the calculations are presented in Table 5-10. The locations of the estimated points for the offshore wave are shown in Figure 5-54. The ERA5 estimated values have been compared with the observed values from wave observation buoys around the world, and although there are not many observation buoys in the Indian Ocean, they have also been verified[3].

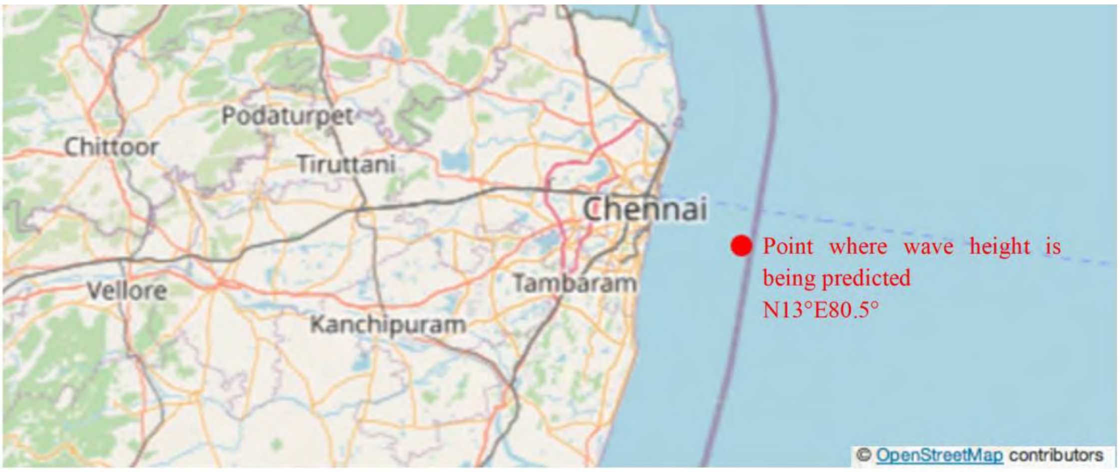
Table 5-10: Offshore Waves (Monthly Energy Mean Waves)

Input data		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Item	Ho(m)	0.94	0.82	0.72	0.85	1.11	1.09	1.03	1.04	0.97	0.94	1.22	1.30
	To(s)	7.0	7.1	7.1	7.1	7.5	7.8	8.2	8.3	8.2	8.1	7.3	7.3
	Dir(° N)	87	102	137	153	158	171	167	167	164	126	83	76
	Smax	75	75	75	75	75	75	75	75	75	75	75	25

Ho: offshore wave height, To: offshore wave period, Dir: wave direction, Smax: wave direction concentration

Source: JICA Expert Team

[3] Verification results for significant wave height and peak period in ERA5:
Significant wave height: https://confluence.ecmwf.int/display/WLW/Significant+wave+height
Peak period: https://confluence.ecmwf.int/display/WLW/Wave+peak+period



Source: JICA Expert Team, Map: OpenStreetMap Contributors

Figure 5-54: Wave Height Predicted Point (ERA5)

5.5.4.3. Wave Transformation Calculation

Wave transformation calculations were performed with the above values as input waves. An example of the input Wave transformation calculation conditions and an example of the output diagram of the energy equilibrium equation model are illustrated in Table 5-11, Figure 5-55 and Figure 5-56. The wave conditions at each estuary extracted from these Wave transformation calculations are also shown in Table 5-12.

Table 5-11: Input Conditions for Wave Transformation Calculation

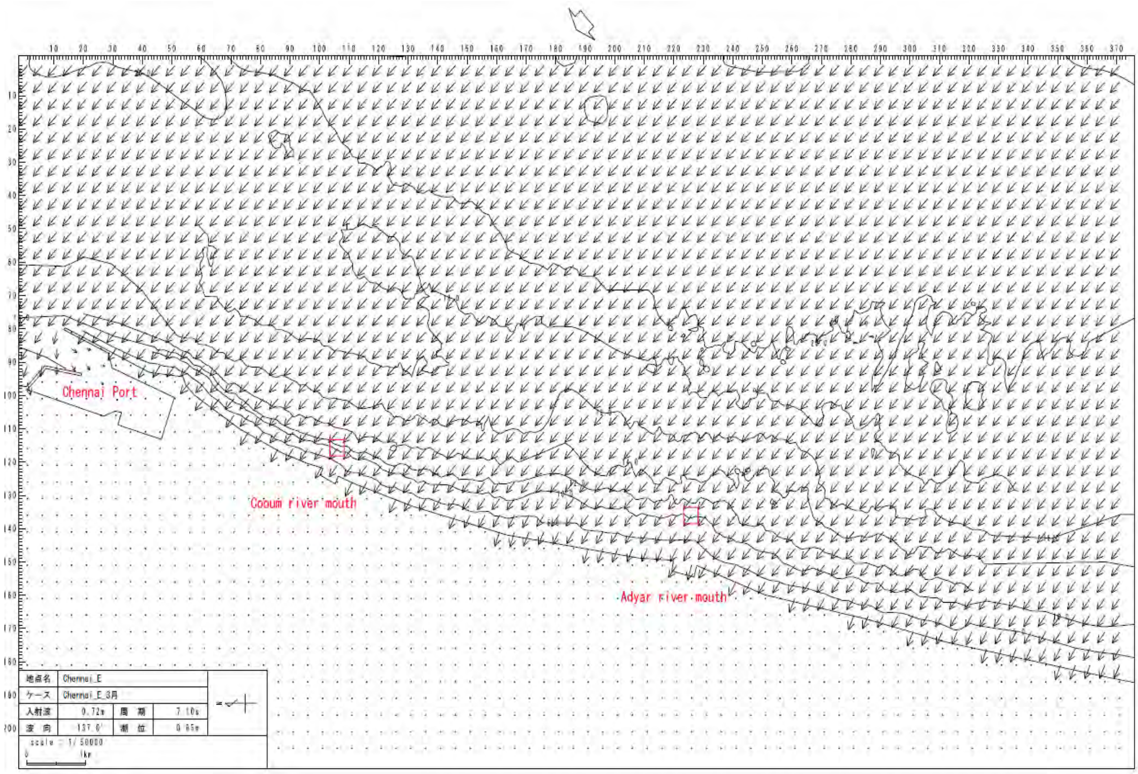
Input data		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Item	Ho(m)	0.94	0.82	0.72	0.85	1.11	1.09	1.03	1.04	0.97	0.94	1.22	1.30
	To(s)	7.0	7.1	7.1	7.1	7.5	7.8	8.2	8.3	8.2	8.1	7.3	7.3
	Dir(° N)	87	102	137	153	158	171	167	167	164	126	83	76
	Smax	75	75	75	75	75	75	75	75	75	75	75	25
	Tide Level	CDL+0.65m(MSL+0.0m)											
	Number of direction splits	36											
	Frequency Division Number	10											

Source: JICA Expert Team

Table 5-12: Calculation Results (Waves at the Mouth of Each River)

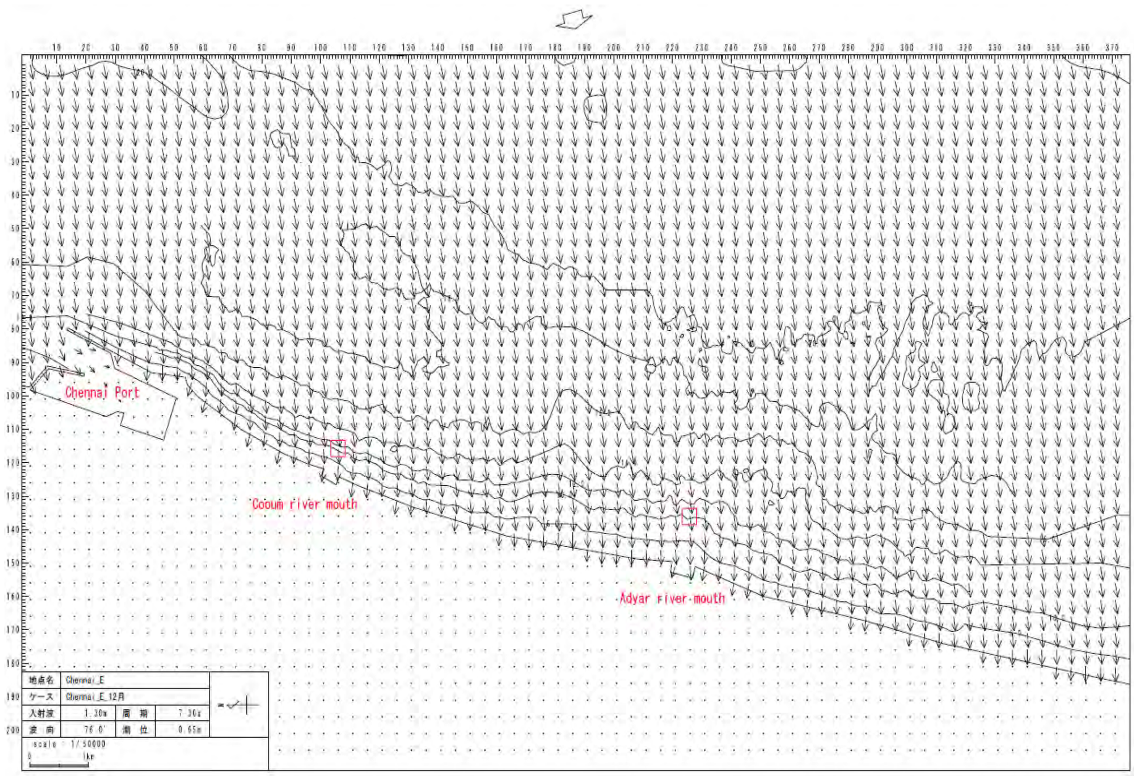
River Mouth		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ennore	Hs(m)	0.86	0.76	0.64	0.72	0.91	0.79	0.77	0.78	0.75	0.85	1.10	1.13
	Ts(s)	7.0	7.1	7.1	7.1	7.5	7.8	8.2	8.3	8.2	8.1	7.3	7.3
	Dir(° N)	92	104	131	142	144	149	145	145	144	121	89	87
Cooum	Hs(m)	0.87	0.77	0.66	0.70	0.86	0.69	0.69	0.69	0.68	0.89	1.13	1.16
	Ts(s)	7.0	7.1	7.1	7.1	7.5	7.8	8.2	8.3	8.2	8.1	7.3	7.3
	Dir(° N)	90	103	131	142	143	149	146	145	144	121	88	85
Adyar	Hs(m)	0.87	0.78	0.66	0.74	0.93	0.78	0.79	0.80	0.77	0.85	1.12	1.18
	Ts(s)	7.0	7.1	7.1	7.1	7.5	7.8	8.2	8.3	8.2	8.1	7.3	7.3
	Dir(° N)	90	101	130	141	142	148	144	144	143	119	87	82
Kovalam	Hs(m)	0.85	0.74	0.59	0.63	0.78	0.66	0.65	0.65	0.63	0.79	1.11	1.18
	Ts(s)	7.0	7.1	7.1	7.1	7.5	7.8	8.2	8.3	8.2	8.1	7.3	7.3
	Dir(° N)	90	102	127	136	137	141	138	137	137	118	87	82
Kokilamedu	Hs(m)	0.86	0.76	0.66	0.75	0.95	0.85	0.84	0.85	0.81	0.87	1.12	1.15
	Ts(s)	7.0	7.1	7.1	7.1	7.5	7.8	8.2	8.3	8.2	8.1	7.3	7.3
	Dir(° N)	88	103	131	143	144	151	147	147	145	121	88	86

Source: JICA Expert Team



Source: JICA Expert Team

Figure 5-55: Wave Direction Vector Diagram (March)



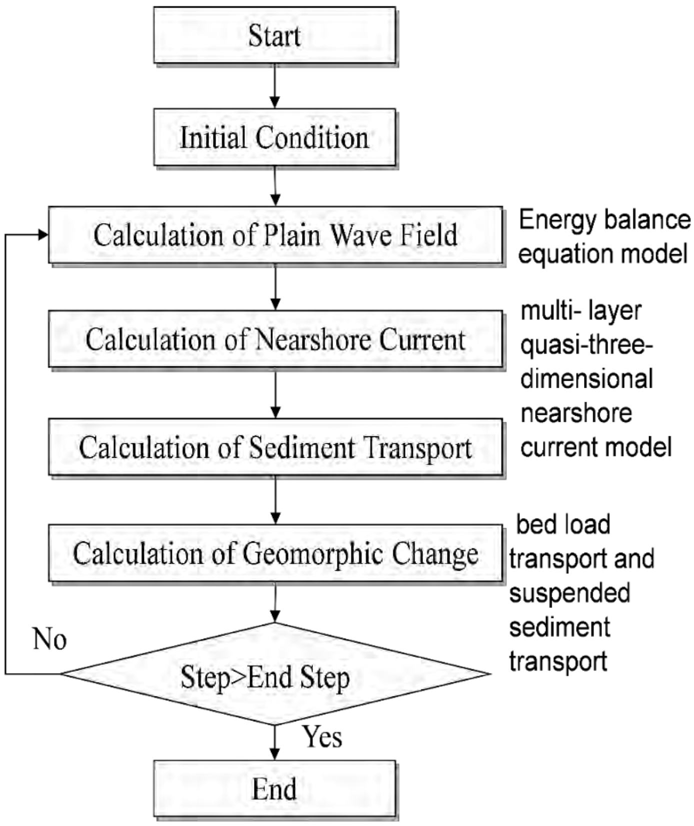
Source: JICA Expert Team

Figure 5-56: Wave Direction Vector Diagram (December)

5.5.5 Geomorphic Change Analysis

5.5.5.1. Analysis Model

The three-dimensional beach deformation prediction model consists of four sub-models: (1) Plain wave field calculation, (2) Nearshore current calculation, (3) Sediment transport calculation, and (4) Geomorphic change calculation. For the calculation of the wave field, the energy balance equation for multi-directional random waves by Mase et al. (2001)[4] was used, and for the calculation of the nearshore current field, a multi-layer quasi-3D beach current model[5] using sigma coordinate transformation was used, and the amount of sediment transport was considered to be due to both suspended and bedload sediment. In this model, a quasi-3D beach current model was used for the calculation of the beach current field, and the Watanabe model (1984) was used for the calculation of the amount of sand drift.



Source: JICA Expert Team

Figure 5-57: Computational Flow of the Three-Dimensional Beach Deformation Model

[4] Hajime Mase, Tomotsuka Takayama, Shoji Kunitomi, and Toyoaki Mishima: Multi-Directional Spectral Wave Transformation Model Including Diffraction Effect, JSCE Journal, No. 628, II-48, pp.177-187, 1999.

[5] Kuroiwa, M., Noda, H., and Yoshiji, Y. (1997): A study on numerical simulation of quasi-3-dimensional nearshore flow fields, Proceedings of the Coastal Engineering, Vol. 44, pp. 151-155.

5.1.1.5. Analysis Conditions

(1) Tidal Condition

The tidal condition was set to mean tide level (M.S.L. + 0.0 m).

(2) Wave Condition

The wave conditions assigned to each river are shown below. They were set based on the results of wave transformation calculations.

Table 5-13: Calculation Results (Waves at the Mouth of Each River)

River Mouth		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Ennore	Hs(m)	0.86	0.76	0.64	0.72	0.91	0.79	0.77	0.78	0.75
	Ts(s)	7.0	7.1	7.1	7.1	7.5	7.8	8.2	8.3	8.2
	Dir(° N)	92	104	131	142	144	149	145	145	144
	Cal.	23	11.0	−16.0	−27.0	−29.0	−34.0	−30.0	−30.0	−29.0
Cooum	Hs(m)	0.87	0.77	0.66	0.70	0.86	0.69	0.69	0.69	0.68
	Ts(s)	7.0	7.1	7.1	7.1	7.5	7.8	8.2	8.3	8.2
	Dir(° N)	90	103	131	142	143	149	146	145	144
	Cal.	48	33	−2	−18	−23	−36	−32	−32	−29
Adyar	Hs(m)	0.87	0.78	0.66	0.74	0.93	0.78	0.79	0.80	0.77
	Ts(s)	7.0	7.1	7.1	7.1	7.5	7.8	8.2	8.3	8.2
	Dir(° N)	90	101	130	141	142	148	144	144	143
	Cal.	48	33	−2	−18	−23	−36	−32	−32	−29
Kovalam	Hs(m)	0.85	0.74	0.59	0.63	0.78	0.66	0.65	0.65	0.63
	Ts(s)	7.0	7.1	7.1	7.1	7.5	7.8	8.2	8.3	8.2
	Dir(° N)	90.0	102.0	127.0	136.0	137.0	141.0	138.0	137.0	137.0
	Cal.	20	8	−17.0	−26.0	−27.0	−31.0	−28.0	−27.0	−27.0
Kokilamedu	Hs(m)	0.86	0.76	0.66	0.75	0.95	0.85	0.84	0.85	0.81
	Ts(s)	7.0	7.1	7.1	7.1	7.5	7.8	8.2	8.3	8.2
	Dir(° N)	88	103	131	143	144	151	147	147	145
	Cal.	−13	−28	−56	−68	−69	−76	−72	−72	−70

Source: JICA Expert Team.

(3) Grain Diameters

D50 grain size was set based on the findings of the grain size survey conducted for each river. Specifically, the grain size was set at the mouths of the Cooum and Adyar rivers where grain size survey results were available, whereas for the other rivers, the grain size was set based on the nearest river.

(4) River Discharge

The three-dimensional beach deformation model is a model that calculates geomorphic changes (such as the development of estuarine sandbars) mainly due to waves. Therefore, the calculation period covered 9 months of the dry season, and the rainy season with flood was excluded. Therefore, the discharge from the river was assumed to be zero.

(5) Computational Domain and Grid

The wave transformation calculations were carried out over a wide area as shown in "5.5.4.3 Wave Transformation Calculations", but the topographical change calculations were carried out focusing on the area around each estuary. The size of the calculation area and the calculation grid interval are shown in Table 5-14. The calculation grid is a 10m square grid. The Cooum River, however, has a narrow estuary width, so the grid was set at 5m.

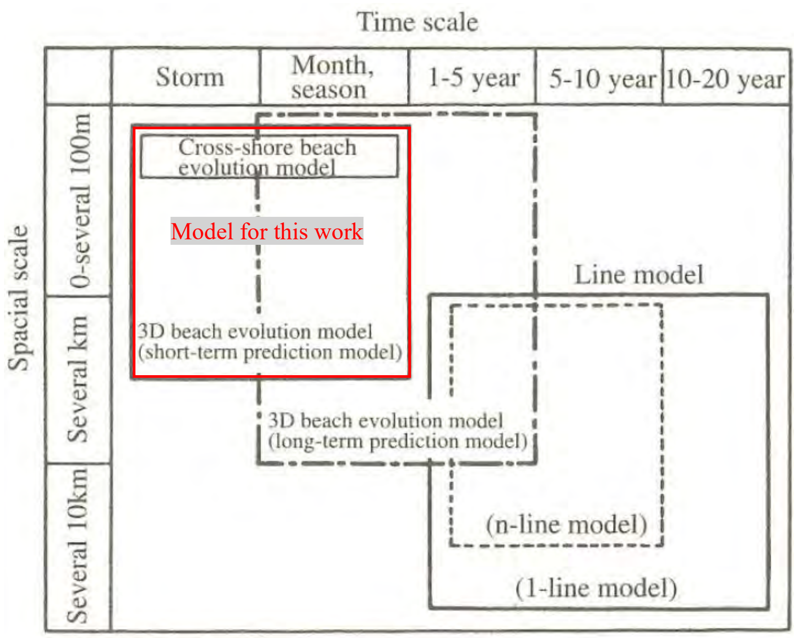
Table 5-14: Computational Domain and Grid Size

River Mouth	Area		Mesh size	
	Alongshore	Cross-shore	dx	dy
Ennore	2000m	2000m	10m	10m
Cooum	1000m	1000m	5m	5m
Adyar	2500m	1000m	10m	10m
Kovalam	2500m	2500m	10m	10m
Kokilamedu	2500m	2500m	10m	10m

Source: JICA Expert Team

(6) Calculation Period

The application range of the beach deformation model is shown in Figure. The three-dimensional beach deformation model used in this work is classified as a three-dimensional beach deformation model (short-term prediction model) that can also handle return flows within the surf zone. As mentioned above, this model handles topographical changes over spatial scales of several kilometers and time scales of up to one year. Therefore, the calculation period for this project was set at one year, and since it is difficult to handle the river flow in a strictly accurate way by providing a time series flow rate, and it is also difficult to make assumptions, the period when the influence of the river flow is large (October to December) was not included, and the target for study was the estuary sandbar topography that develops mainly due to waves during the period when the influence of the river flow is small (January to September).



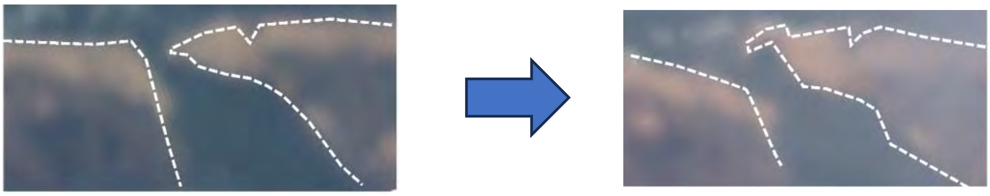
Source: Design Manual for Coastal Facilities, JSCE

Figure 5-58: Classification of beach morphology models

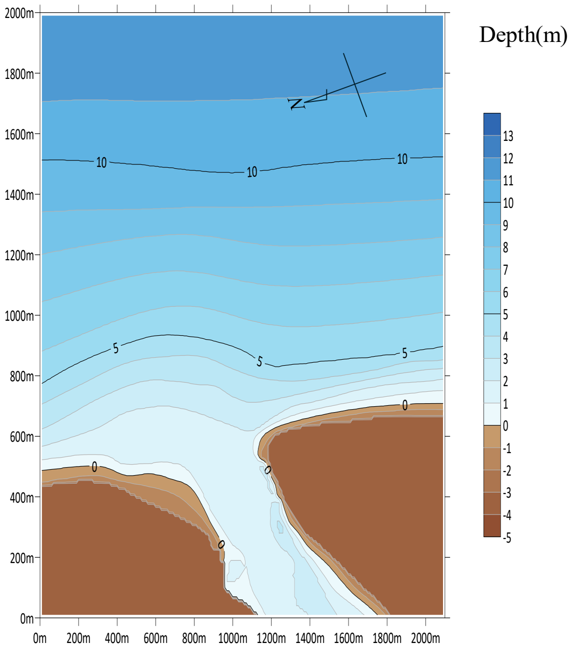
5.1.1.6. Reproduction Calculations

Based on the conditions that were set in the previous section, a reproduction calculation using a three-dimensional beach deformation model was conducted. The results of the reproduction calculations are shown in Figure 5-59 to Figure 5-62. The period of the numerical simulation was set to nine months, excluding the rainy season (the flood season), because the model mainly analyses the deformation of beaches, including river mouth sandbars, and dredging of river mouths is also carried out before the monsoon season. The numerical calculations reproduced the situation where the sandbars at the mouths of rivers develop from the right bank towards the left bank due to northward drift (the expansion of each sandbar is shown in the satellite images at the top of each figure), and it can be said that the numerical calculations reproduced the development of sandbars at the mouths of rivers in reality.

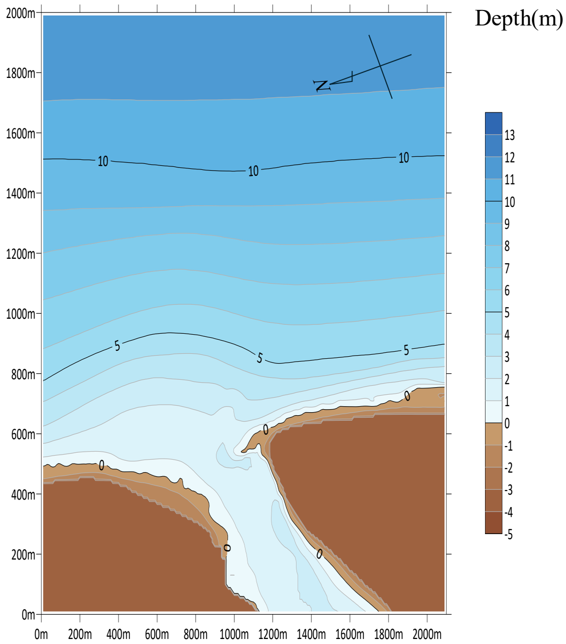
Example of changes when the river mouth sandbar extends (Satellite image)



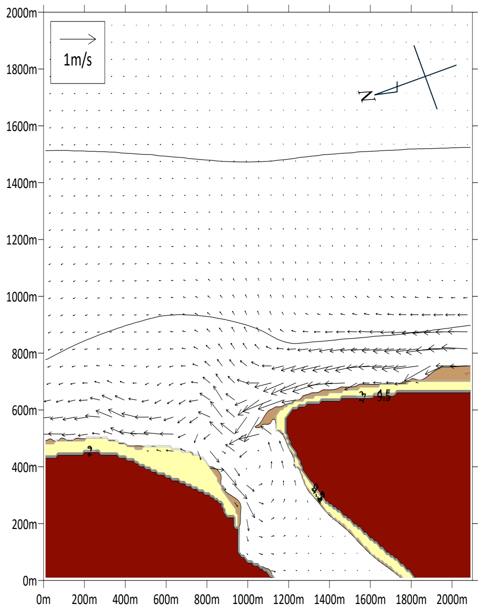
January 2007 estuary May 2007 estuary



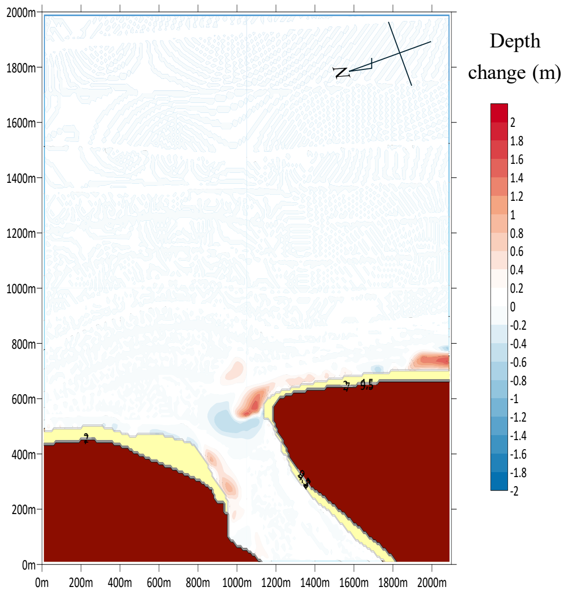
Initial Topography



Calculated Topography after 9 months



Flow Fields

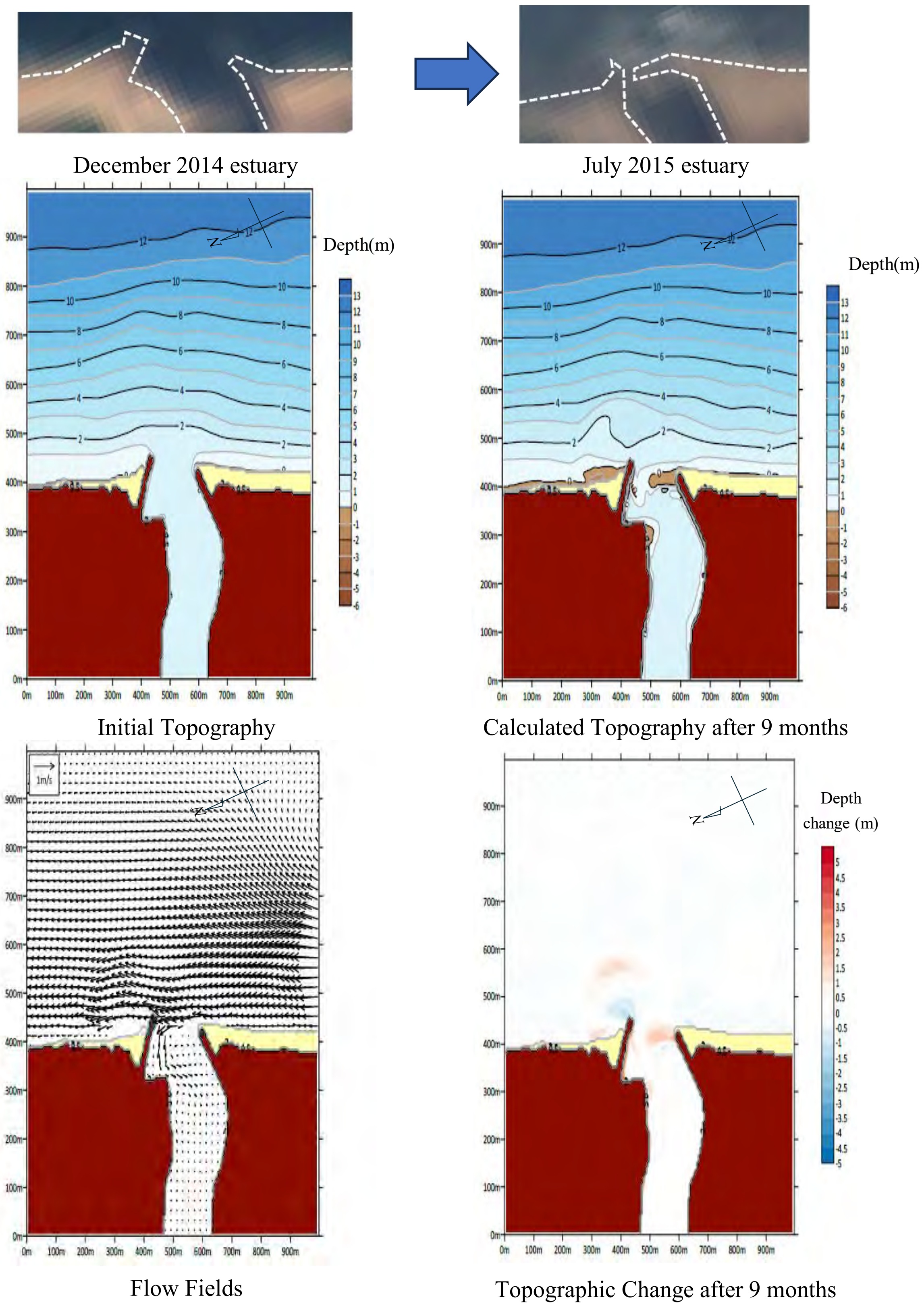


Topographic Change after 9 months

Source: JICA Expert Team

Figure 5-59: Results of Reproduction Calculation (Kosasthalaiyar)

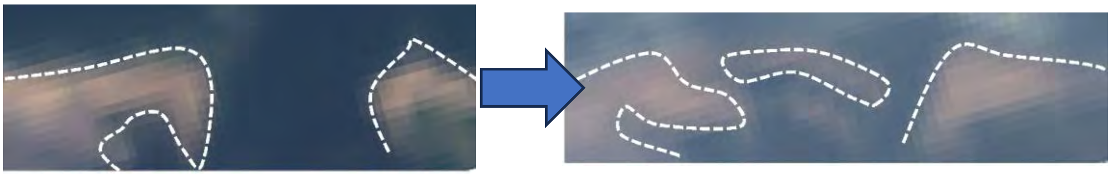
Example of changes when the river mouth sandbar extends (Satellite image)



Source: JICA Expert Team

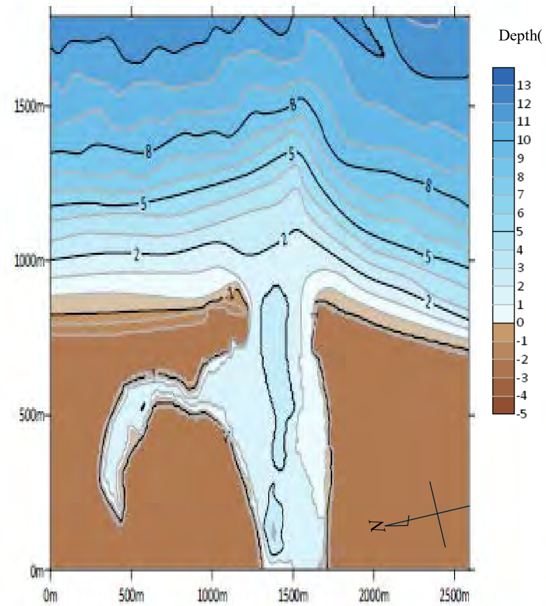
Figure 5-60: Results of Reproduction Calculation (Cooum)

Example of changes when the river mouth sandbar extends (Satellite image)

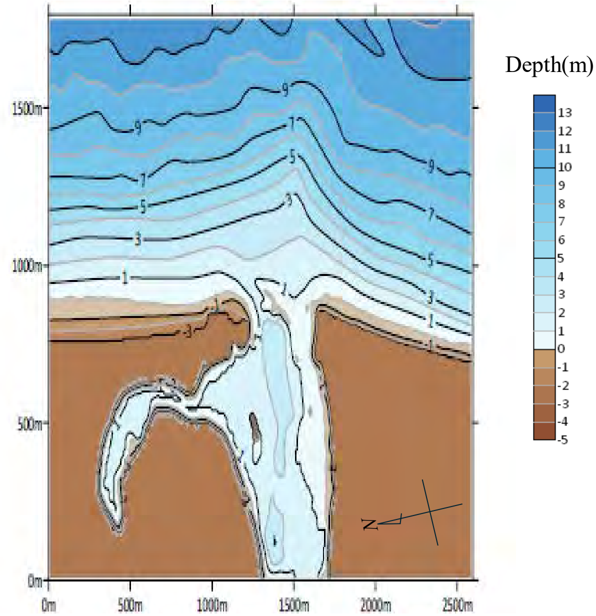


December 2015 estuary

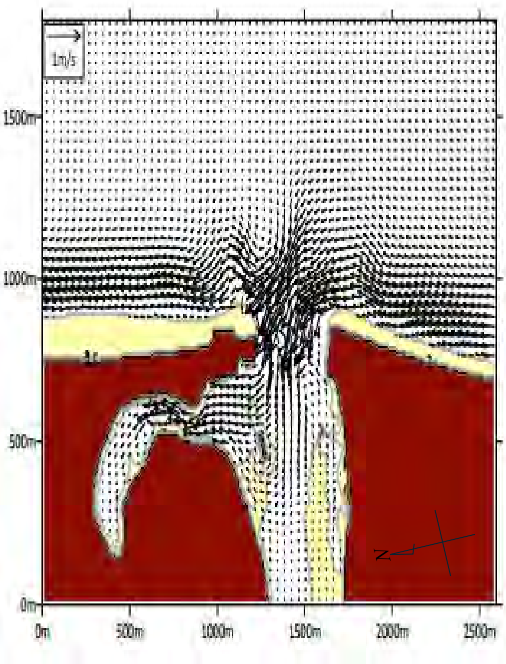
July 2016 estuary



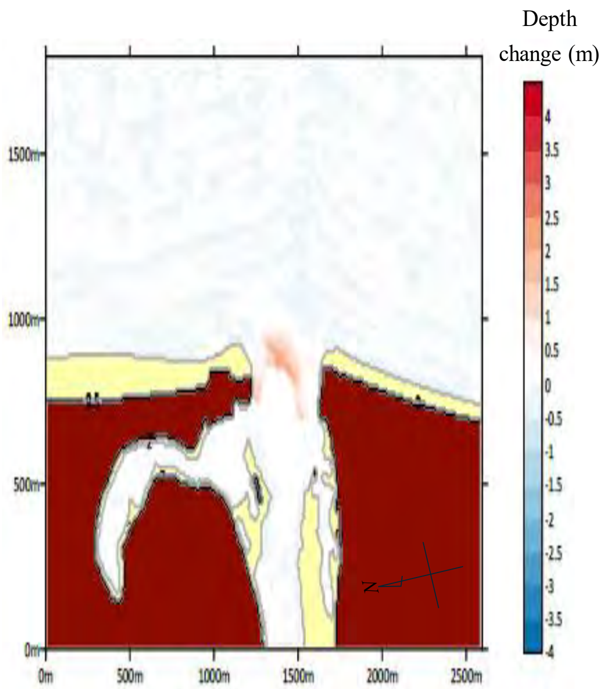
Initial Topography



Calculated Topography after 9 months



Flow Fields

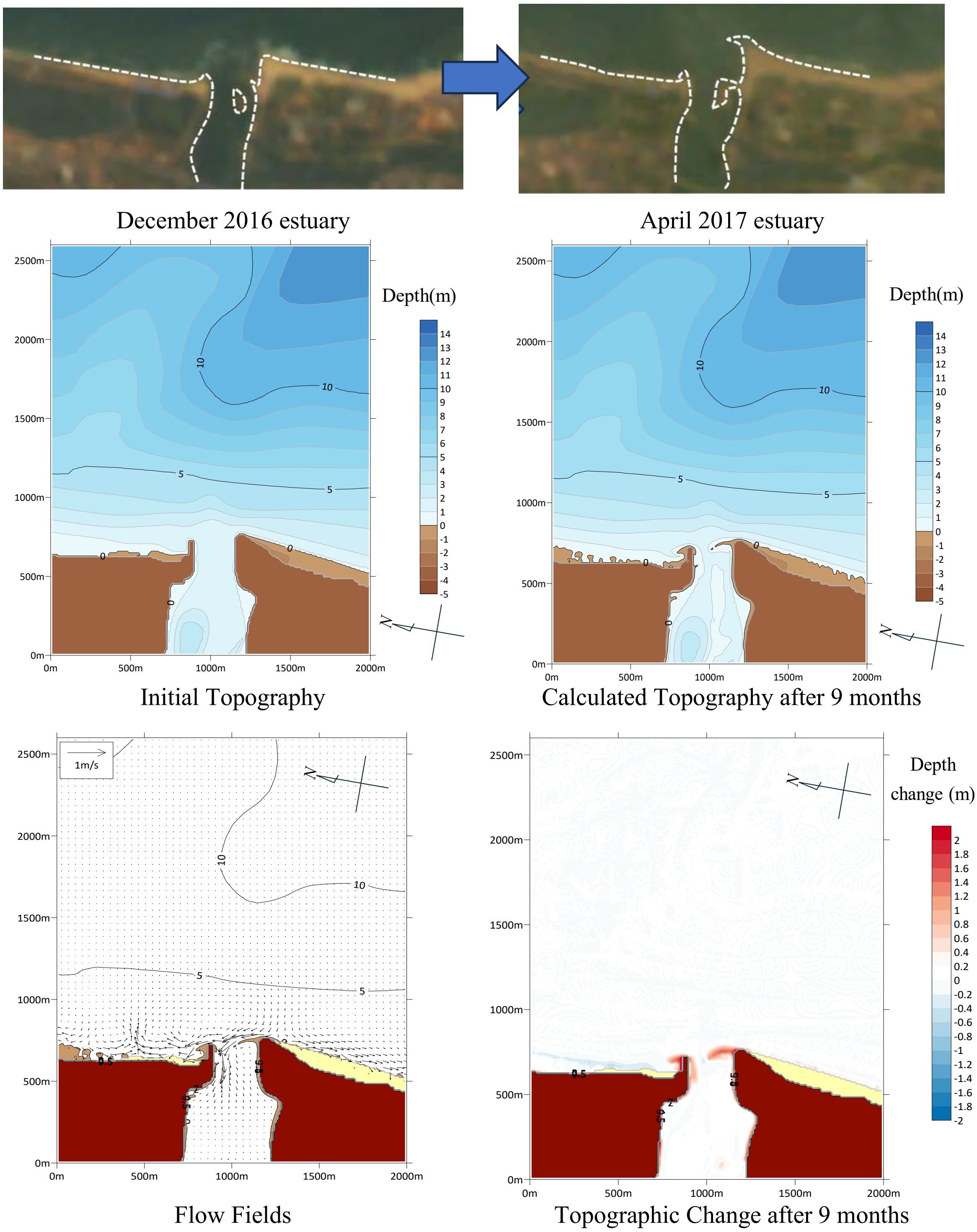


Topographic Change after 9 months

Source: JICA Expert Team

Figure 5-61: Results of Reproduction Calculation (Adyar)

Example of changes when the river mouth sandbar extends (Satellite image)



Source: JICA Expert Team

Figure 5-62: Results of Reproduction Calculation (B Canal North)

5.1.1.7. Study on Proposed Countermeasures

(1) Policy of Setting Countermeasures

Currently, at each river mouth, training walls and jetties have already been installed as measures to prevent estuary blockage and pre-monsoon dredging is being conducted. Based on the river mouth characteristics and causes of river mouth blockage described in the previous section, several countermeasures will be considered. As for measures to prevent river mouth blockage, examples of river mouth blockage countermeasures in Japan (Figure 5-57), three options will be considered. The characteristics of each measure are listed below.

- Training wall (including Jetty): Prevent the movement of littoral drift into estuary
- Dredging: By dredging the sediment that has accumulated in the estuary, blockage of the estuary is directly prevented
- Offshore facilities (offshore breakwaters, artificial reefs, etc.): By piling up sediment behind the offshore facility, the movement of littoral drift from coast to estuary is prevented

The policy for assessing countermeasure works for each of the target rivers is as follows.

Source: JICA Expert Team

Figure 5-63: Examples of River Mouth Blockage Countermeasures in Japan (Training Walls, Dredging, and Offshore Facilities)

(2) Kosasthalaiyar River

For the mouth of the Kosasthalaiyar River, WRD has been carrying out a Training walls construction project and measures have been taken. Therefore, predictive calculations based on the countermeasures proposed by WRD will be performed, and alternatives will be studied as well. Figure 5-64 illustrates photographs of the river mouth training barriers that are almost completed.

Left bank Training Wall

Right bank Training Wall

Source: JICA Expert Team

Figure 5-64: Training Walls Constructed at Kosasthalaiyar River Mouth (taken on 2/14/2024)

(3) Cooum River

The Government of India is also in the process of constructing the training walls at the mouth of the Cooum River. Consequently, predictive calculations and alternative studies will be conducted in a manner similar to that of Kosasthalaiyar, in accordance with the proposed measures recommended by the Indian government. Figure 5-65 illustrates photographs of the nearly completed training walls.

Left bank Training Wall

Right bank Training Wall

Source: JICA Expert Team

Figure 5-65: Training Walls Constructed at Cooum River Mouth (taken on 2/13/2024)

(4) Adyar River

According to investigation carried out by the Indian government, the policy for the Adyar River estuary is to preserve it through maintenance dredging rather than employing hard measures like training walls, which are seen as alternatives to be evaluated in specific cases.

(5) Muttukadu (Buckingham Canal North)

In Muttukadu, although there are already training walls in place, the southern shoreline is advancing towards the toe of the right bank training wall, diminishing its ability to control sediment movement and maintain the estuary’s navigability or stability. However, unlike in the cases of the Kosasthalaiyar and Cooum River, there are no current plans for similar large-scale training wall in Muttukadu. A comparative study between extending the training wall and maintaining the estuary through dredging is planned, with the goal of developing an effective countermeasure plan to manage the advancing shoreline and preserve the function of the training wall in Muttukadu. Since measures (construction) are underway on the Indian government side for the three rivers of Kosasthalaiyar, Cooum and Adyar, and no measures (construction) are underway for Muttukadu, a more detailed study was conducted, including the structure of the diversion embankment and economic efficiency, compared to the estuaries of other rivers.

5.1.1.8. Prediction Calculations and Evaluation of Proposed Countermeasures

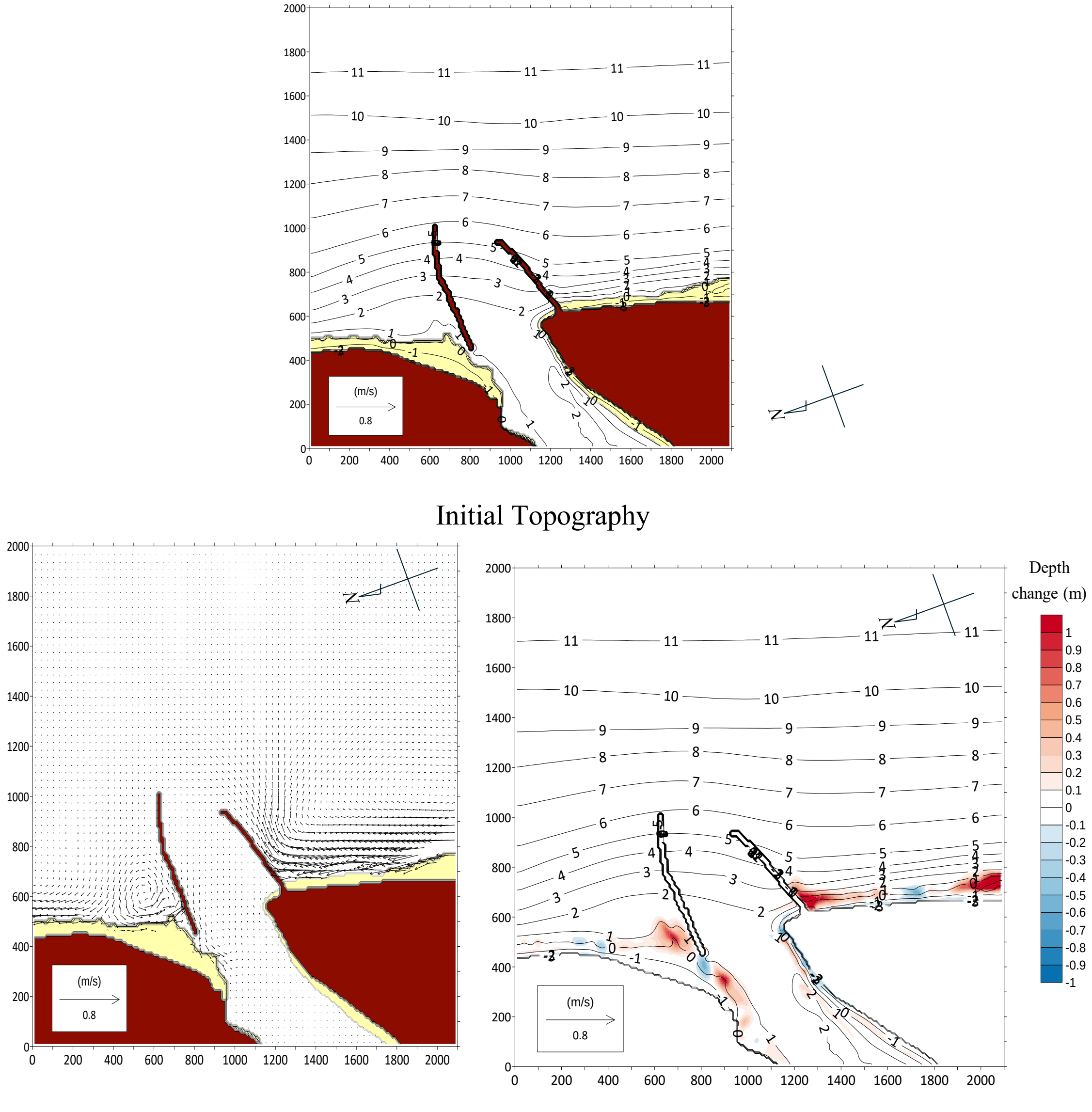
Based on the countermeasure policy described in the previous section, predictive calculations were obtained using the numerical analysis model constructed by the reproduction calculations. The targets of the forecasting calculations show the current Indian government plan for the construction of training walls and alternative plans (additional countermeasures). Calculations were performed for four target rivers. The calculation results are shown below. The calculation results were compared with respect to the amount of sedimentation in the river channel and the effectiveness of each proposed measure.

(1) Kosasthalaiyar River

The Kosasthalaiyar River estuary is undergoing training walls construction project by the Government of India, and measures are being taken. Therefore, the forecast calculation based on the countermeasure plan promoted by the Government of India and the alternative plan were examined. First, the results of the calculations for the Indian government's proposal are shown in Figure 5-66. The offshore depth of the training walls reaches -5m to -6m, and it almost completely blocks the littoral drift. A beach current can be seen on the right bank of the river mouth, flowing north (right side of the figure) towards the beach, but the training walls blocks the inflow into the river mouth, and the current flows out to sea. The flow velocity decreases at the training wall, resulting in significant sedimentation at the base of the training walls on the right bank of the estuary. On the other hand, the beach current also forms a circle at the base of the training wall on the left bank, resulting in sedimentation at the base of the left bank training wall. The beach on the left bank is slightly eroding. There is no sedimentation in the estuary between the training walls, and it is thought that the training walls are able to prevent sedimentation from entering the estuary.

The Indian government's proposed training walls has a tip that reaches around -6m offshore, and it is thought to be highly effective as a measure to prevent river mouth blockage, as it almost completely prevents the movement of littoral drift into the river channel. However, at the same time, it would almost completely cut off the supply of sediment to the northern coast, which is on the downstream side of the littoral drift, so there is a high possibility of coastal erosion occurring. Therefore, as an alternative to the Indian government's proposed training walls, we considered an alternative plan that would combine the placement of a small-scale training walls and offshore facilities (offshore breakwaters) and would not completely block the movement of littoral drift. The results of the study are shown in Figures 5-67 to 5-68. The difference between Alternative 1 and Alternative 2 is the configuration of the detached breakwater. Alternative 1 has detached breakwaters parallel to the shoreline, whereas Alternative 2 has detached breakwaters perpendicular to the training wall, with the scale of the detached breakwater on the left bank reduced. Both Alternative 1 and Alternative 2 reduce the beach current flowing from south to north, and store sediment on the right bank side, reducing the amount of sediment flowing into the estuary, but the effect of these is weaker than the Indian government's proposal. As a result, a circulating current occurs in the estuary and sediment accumulates. On the other hand, the trend of erosion on the left bank side of the beach is also reduced compared to the Indian government's proposal.

Indian Government's Training Wall Project



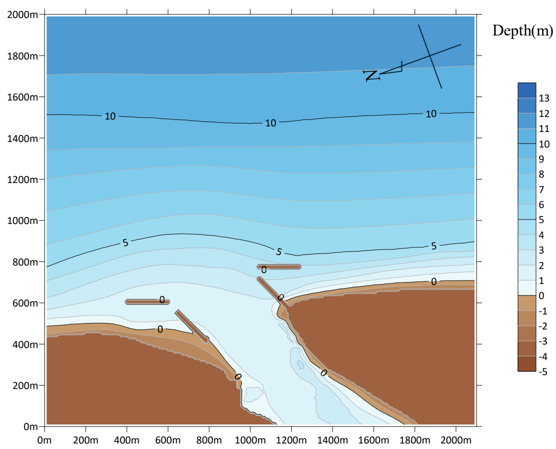
Flow Field

Topographic change after 9 months

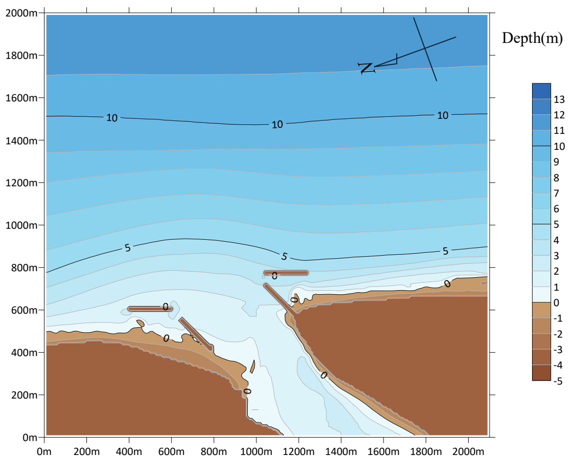
Source: JICA Expert Team

Figure 5-66: Kosasthalaiyar Prediction Calculation Results (Indian Government Plan)

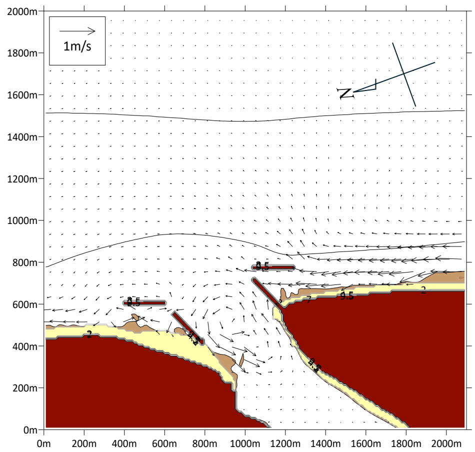
Alternative 1



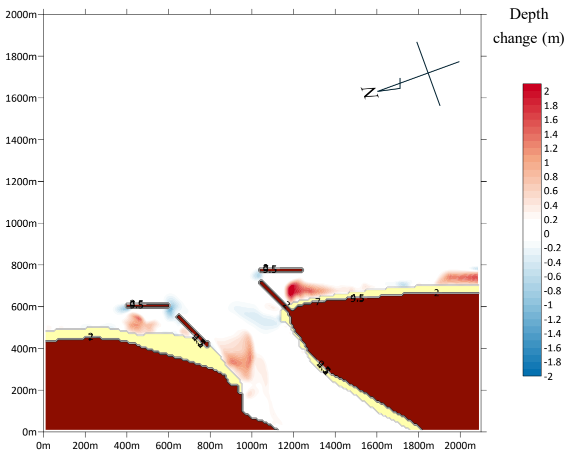
Initial Topography



Calculated Topograpy after 9 months



Flow Field

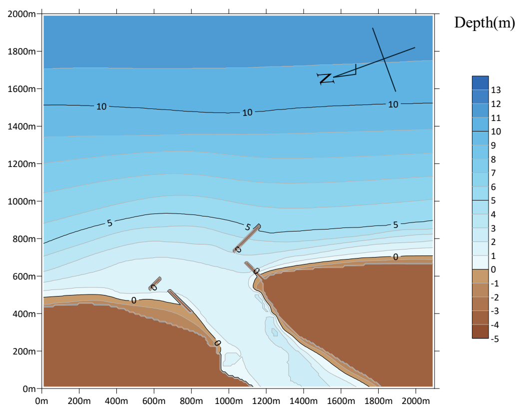


Topographic change after 9 months

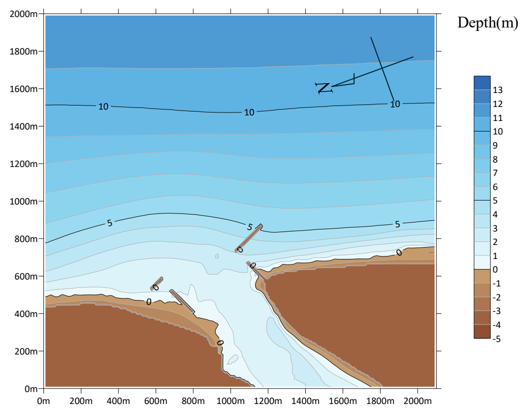
Source: JICA Expert Team

Figure 5-67: Kosasthalaiyar Prediction Calculation Results (Alternatives1)

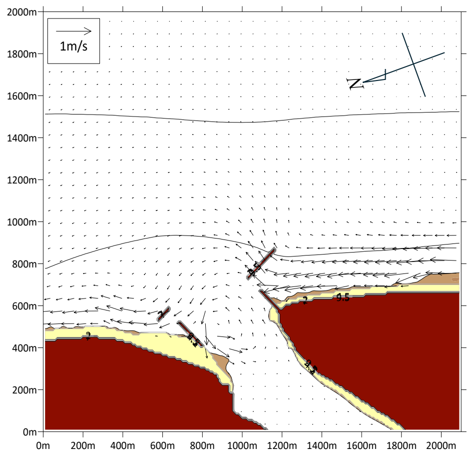
Alternative 2



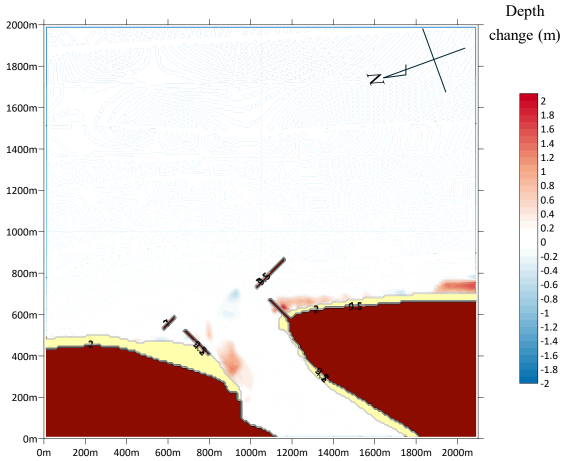
Initial Topography



Calculated Topograpy after 9 months



Flow Field



Topographic change after 9 months

Source: JICA Expert Team

Figure 5-68: Kosasthalaiyar Prediction Calculation Results (Alternatives2)

A comparison of sedimentation in the estuary is shown in Table 5-15. From this table, it can be seen that the Indian government's planned training wall would reduce sedimentation at the estuary the most. On the other hand, both Alternative 1 and Alternative 2 were found to be effective in controlling sedimentation in the estuary, and Alternative 2 was found to be more effective in controlling sedimentation than Alternative 1. Alternative 2 can be said to be a more efficient measure because the facility scale is smaller than Alternative 1.

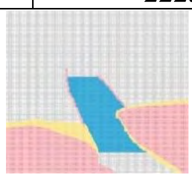
As mentioned above, while the training walls plan proposed by the Indian government is highly effective, it blocks littoral drift and there are concerns about the impact on the northern coast. In addition, if sedimentation on the right bank side progresses in the future, the water depth at the tip the training walls will become shallower, and sediment will flow back into the estuary, reducing the effectiveness of the training walls. In that case, the simplest additional measure would be to extend the training walls plan further out to sea, but another option would be to add offshore facilities like Alternative 2 (Figure 5-69). Offshore facilities like Alternative 2 (offshore breakwaters) slow down the movement of littoral drift, but do not completely block it. Therefore, the impact on the downstream side of the drift is thought to be smaller than with long groins.

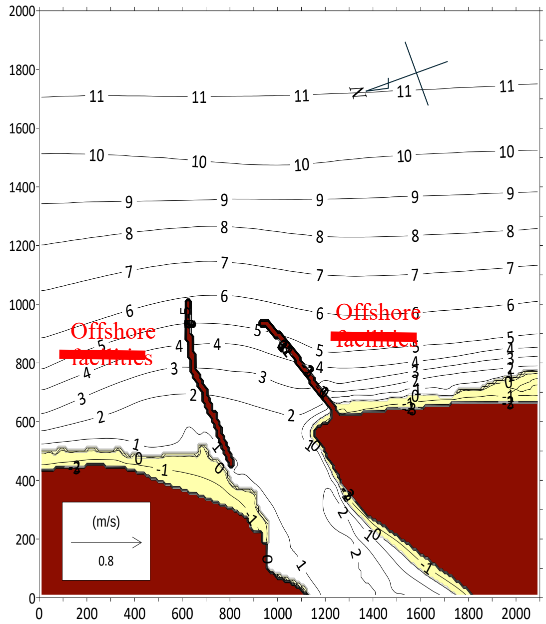
Table 5-15: Comparison of the Amount of Sedimentation for Each Proposed Measure

Plan	Deposition (m^3/y)	Erosion (m^3/y)	Total (m^3/y)
Present Condition	30519	-10881	19638
Training wall planed by Government of India	9440	-1732	7707
Alternative 1	30003	-7195	22808
Alternative 2	20442	-2225	18217

Source: JICA Expert Team

Sediment measurement range in the table
(Blue area in the diagram on the right)





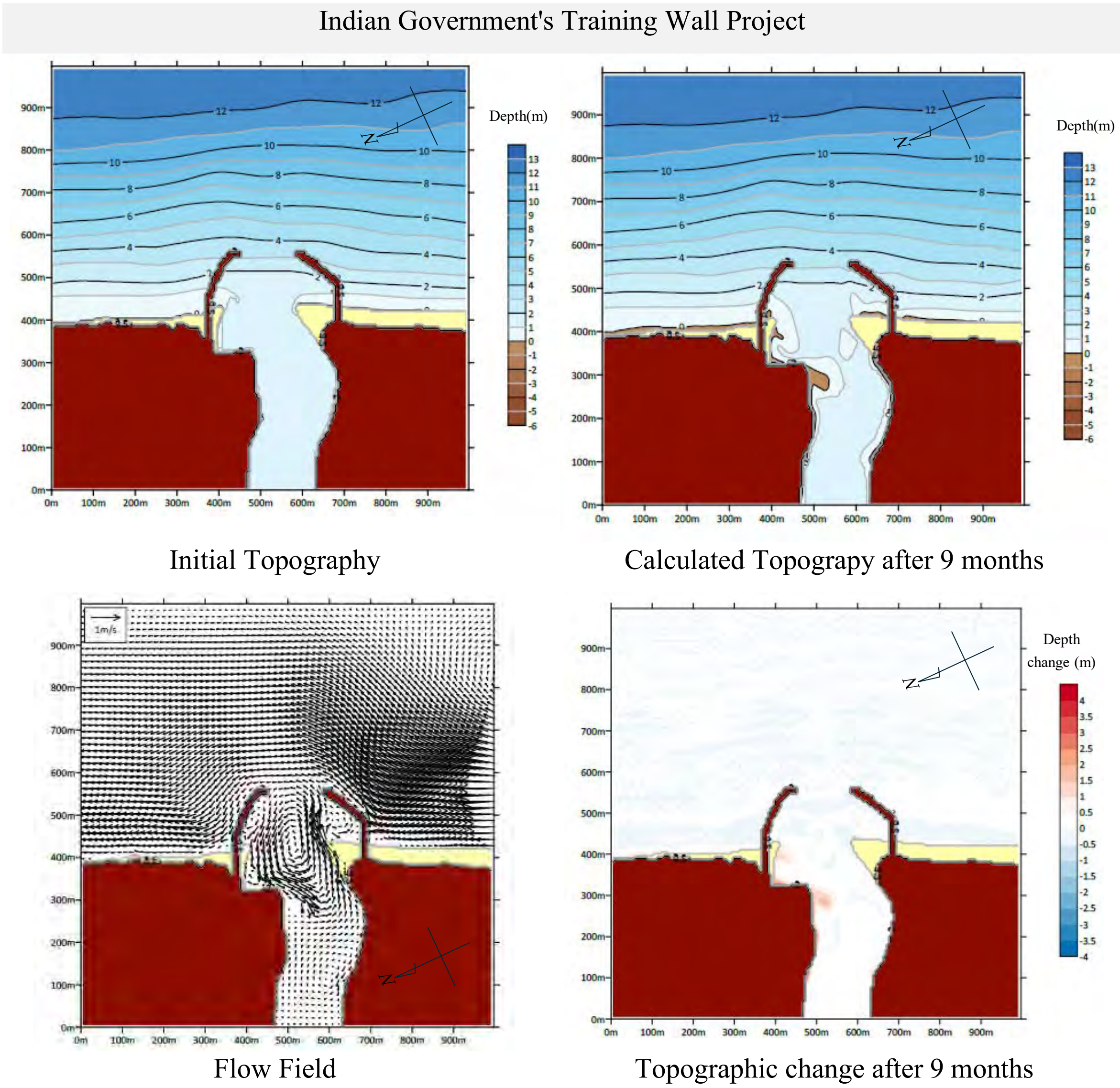
Source: JICA Expert Team

Figure 5-69: Image of Additional Facilities

(2) Cooum River

The mouth of the Cooum River is also under construction by the Government of India. Therefore, similar to Kosasthalaiyar, the forecasting calculations are based on the proposed countermeasures promoted by the Indian government and alternatives.

The Indian government's training walls plan, and alternative plan were examined. First, the results of the examination of the Indian government's training walls plan are shown in Figure 5-70. The training walls suppress the northward beach currents, and by blocking the northward littoral drift, they suppress the deposition within the estuary. On the other hand, a circulating current is generated between the training walls, and as a result, deposition is observed on the left bank of the estuary.



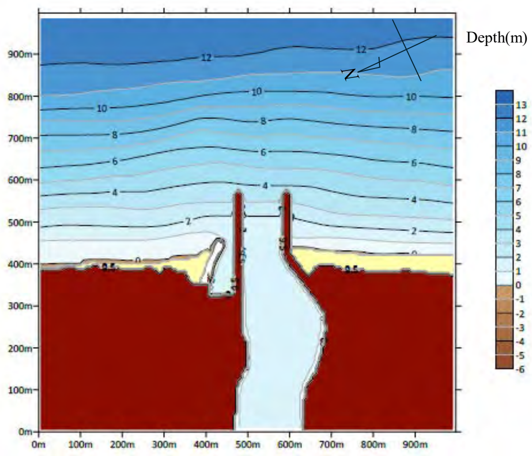
Source: JICA Expert Team

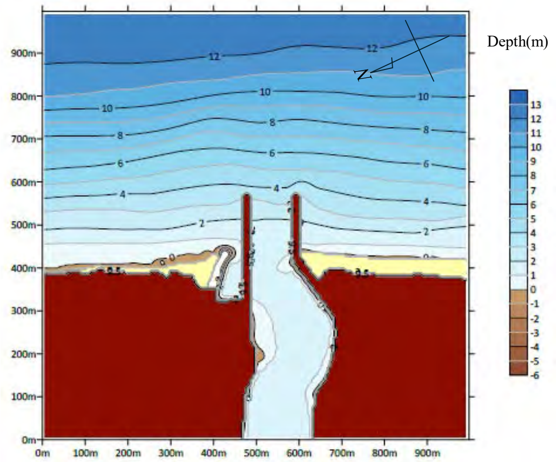
Figure 5-70: Cooum Prediction Calculation Results (Indian Government Plan)

he results of the examination of Alternative 1, which aims to reduce the circulation current in the estuary by narrowing the space between the training walls (at the mouth of the river), and Alternative 2, which aims to reduce the movement of sediment into the estuary by extending the existing training walls and placing detached breakwaters offshore, are shown in Figures 5-71 to 5-72.

In Alternative 1, the circulation currents between the training walls seen in the Indian government's plan are also seen, but they are relatively small-scale and, although there is sedimentation in the estuary, the sedimentation is smaller than in the Indian government's plan. The sedimentation and erosion of the surrounding coast are about the same, as the water depth at the tip of the offshore training walls is about the same.

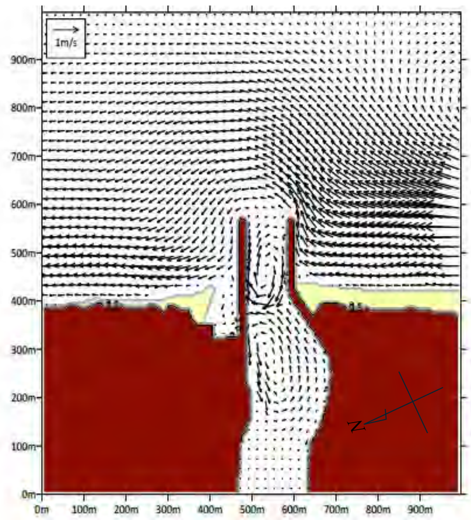
Alternative 1

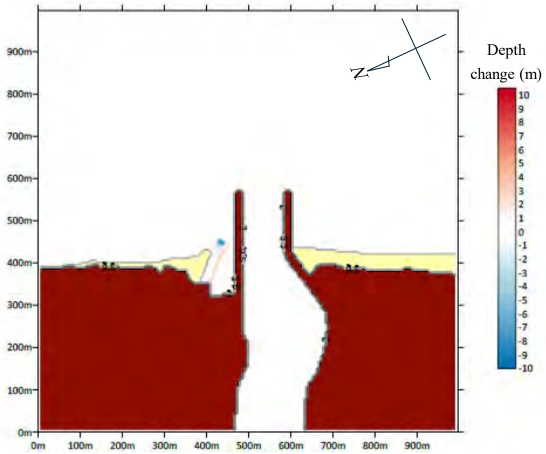




Initial Topography

Calculated Topograpy after 9 months





Flow Field

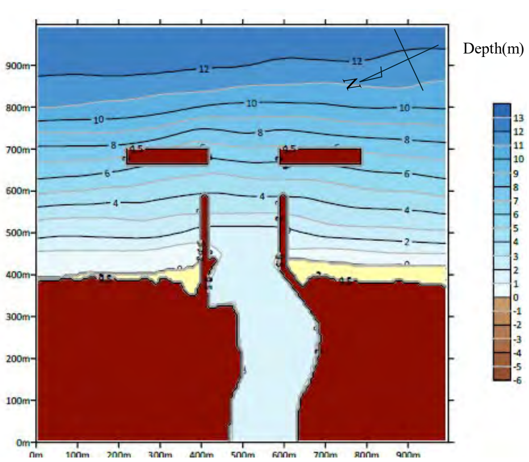
Topographic change after 9 months

Source: JICA Expert Team

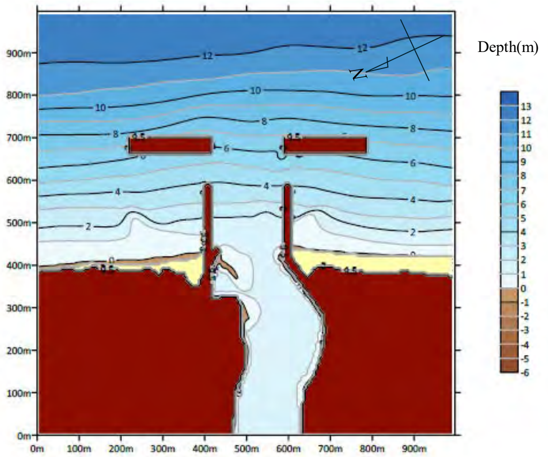
Figure 5-71: Cooum Prediction Calculation Results (Alternative1)

In Alternative 2, although no significant circulation currents occurred between the training walls, sedimentation occurred between the training walls due to the large width of the estuary. Although the detached breakwater on the left and right banks has the effect of restraining littoral drift by accumulating sediment behind them, the distance between the breakwater and the shoreline is large, so there is no significant circulation current behind the breakwater, and the sedimentation effect is small. The impact of the training walls on the surrounding coast is similar to the Indian government's plan and Alternative 1, so it is also about the same.

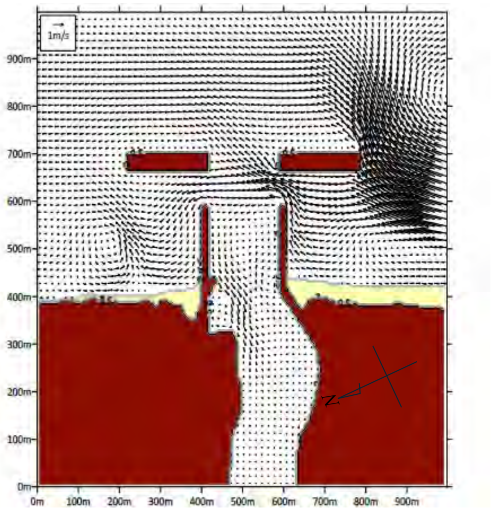
Alternative 2



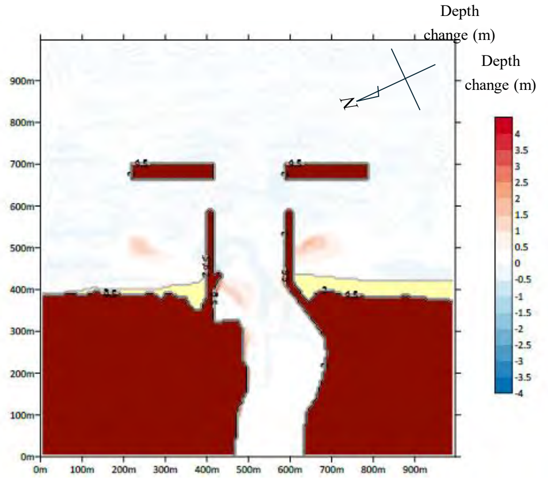
Initial Topography



Calculated Topogray after 9 months



Flow Field



Topographic change after 9 months

Source: JICA Expert Team

Figure 5-72: Cooum Prediction Calculation Results (Alternative2)

A comparison of sedimentation in the estuary is shown in Table 5-16. From this table, it can be seen that the Government of India’s plan of constructing training walls can significantly reduce the amount of sediment deposited.

Alternative 1 can reduce the amount of sediment in the estuary even further than the Indian government's plan. Therefore, if there is significant sediment accumulation in the estuary after the construction of the Indian government's plan for the training walls, it may be possible to improve the situation as in Alternative 1. However, Alternative 1 has a narrower estuary width than the old training walls and the Indian government's plan, so it is necessary to consider ways to make the structure of the training walls base, etc. so that the estuary width can be widened during times of high water.

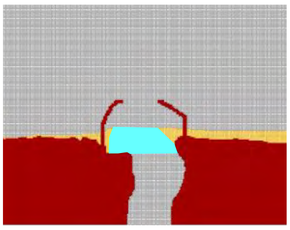
Alternative 2, with a wider estuary and additional offshore facilities, would also reduce sedimentation compared to the current conditions but would result in greater estuary sedimentation than the Indian Government Plan and Alternative 1.

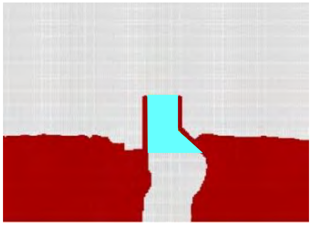
Table 5-16: Comparison of the Amount of Sedimentation for Each Proposed Measure

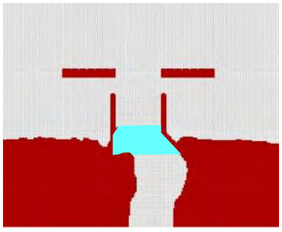
Plan	Deposition (m^3/y)	Erosion (m^3/y)	Total (m^3/y)
Present Condition	10819	-519	10301
Training wall planned by the Government of India	3865	-247	3617
Alternative 1	1606	-1421	185
Alternative 2	6177	-325	5852

Source: JICA Expert Team

Sediment measurement range in the table
(Blue area in the diagram below)


Indian government plan


Alternative 1

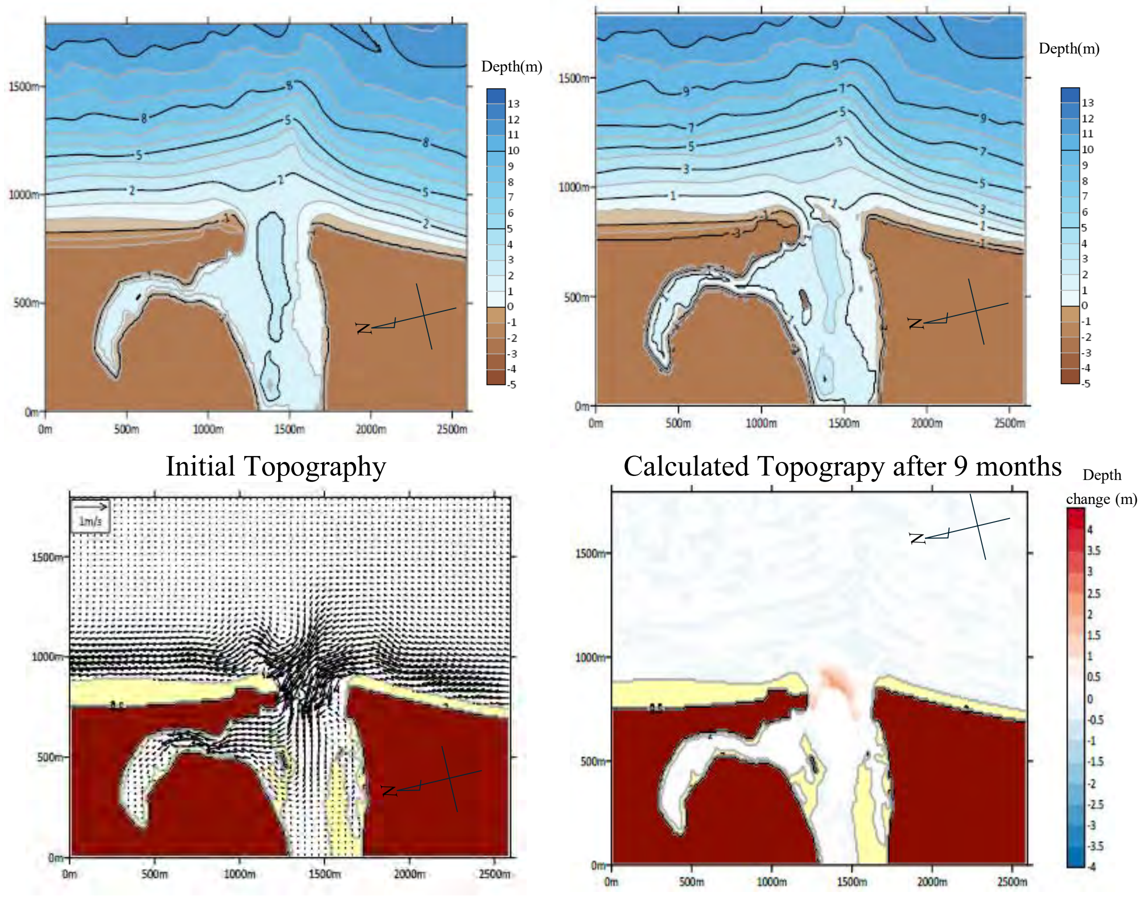

Alternative 2

(3) Adyar River

The Indian government's scrutiny at the Adyar River mouth indicates that the policy is to preserve the river mouth through maintenance dredging rather than employing hard measures like training walls. Consequently, alternative studies were undertaken to investigate scenarios including the implementation of hard measures.

Figure 5-73 shows the results of calculations without maintenance dredging measures taken by the Indian government. In the Adyar River, a shallow area (estuary terrace) has formed offshore, and this area is eroded by waves and longshore currents, causing sediment to accumulate in the estuary and form an island-like sandbar, which significantly reduces the width of the estuary. If this sandbar develops, it is thought that it will result in the blockage of the river mouth, but in reality, the river mouth is maintained through maintenance dredging carried out by the Indian government (maintenance dredging is not taken into account in the numerical calculations).

Local Counterpart's Plan (Without Hard Measures)



Initial Topography

Calculated Topogray after 9 months

Flow Field

Topographic change after 9 months

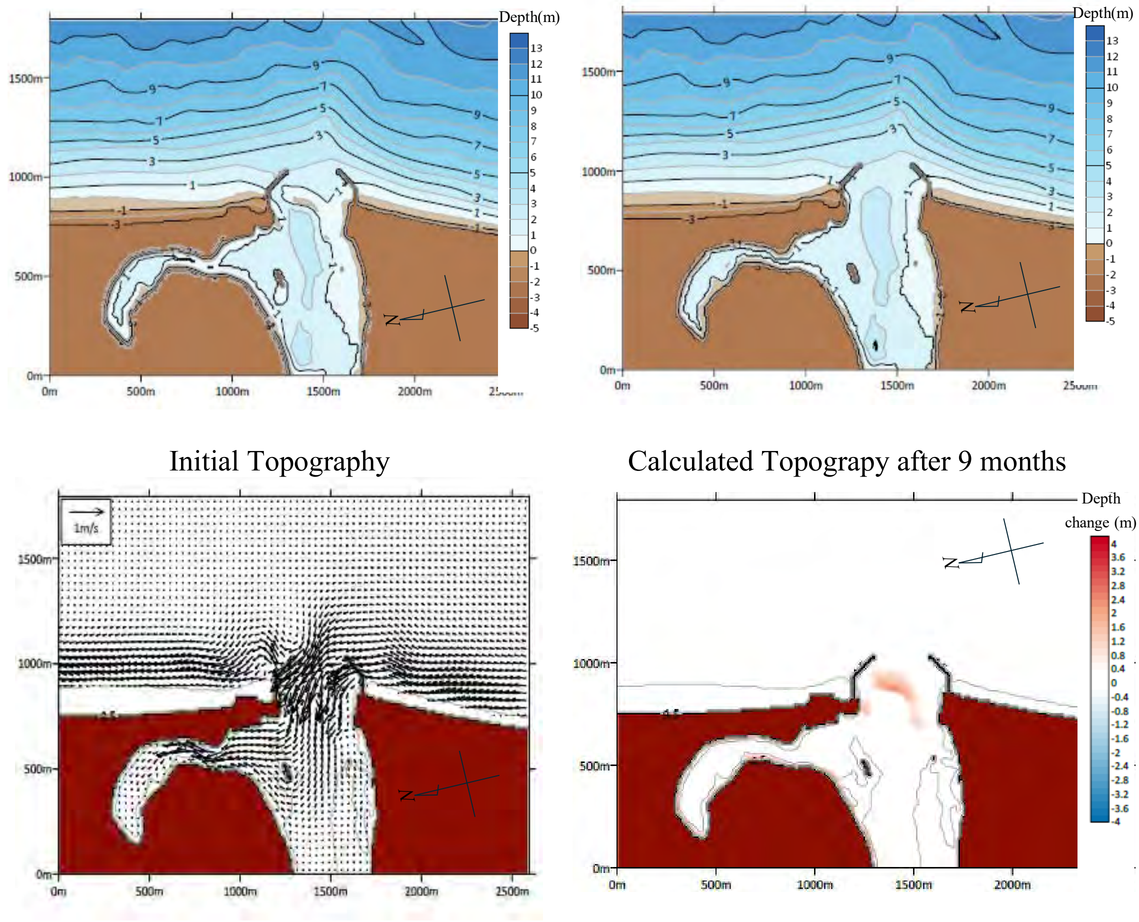
Source: JICA Expert Team

Figure 5-73: Cooum Prediction Calculation Results (Indian Government Plan)

The results of examining the alternative plans for the Indian government's estuary project, which involved the placement of training walls and offshore facilities, are shown in Figures 5-74 and 5-75. Alternatives 1 and 2 are those in which littoral drift, which causes estuary blockage, is controlled by training walls. The difference between the two is whether the training walls are curved or straight, but as the water depth at the tip of the training walls (2m) is the same, they are equally effective in preventing littoral drift. Alternative 3 is a plan in which the size of the training walls is smaller than in Alternatives 1 and 2 (water depth at the tip: 1-1.5m), and instead, detached breakwaters are placed on the left and right banks as offshore facilities. As the water depth at the tip of the training walls is shallow in all of the plans, they do not completely block littoral drift, and they are not facilities that have a significant impact on the surrounding coast. The aim is to make it easier to maintain the river mouth and reduce the number of dredging operations.

First, regarding the results of Alternative 1 and 2, the training walls blocked the northward beach currents, but did not block the beach currents flowing upstream to the river mouth, resulting in the accumulation of sediment in the river mouth. This is thought to be because the Adyar River has an estuary terrace, and the wave erosion of the estuary terrace topography causes sediment to be deposited in the river channel due to the movement of sediment in the onshore and offshore directions, and the training walls are unable to sufficiently prevent this movement. Alternative 3 also resulted in the movement of longshore currents and littoral drift being suppressed by the training walls and detached breakwaters, but direct sediment movement from offshore to the estuary could not be stopped.

Alternative 1



Initial Topography

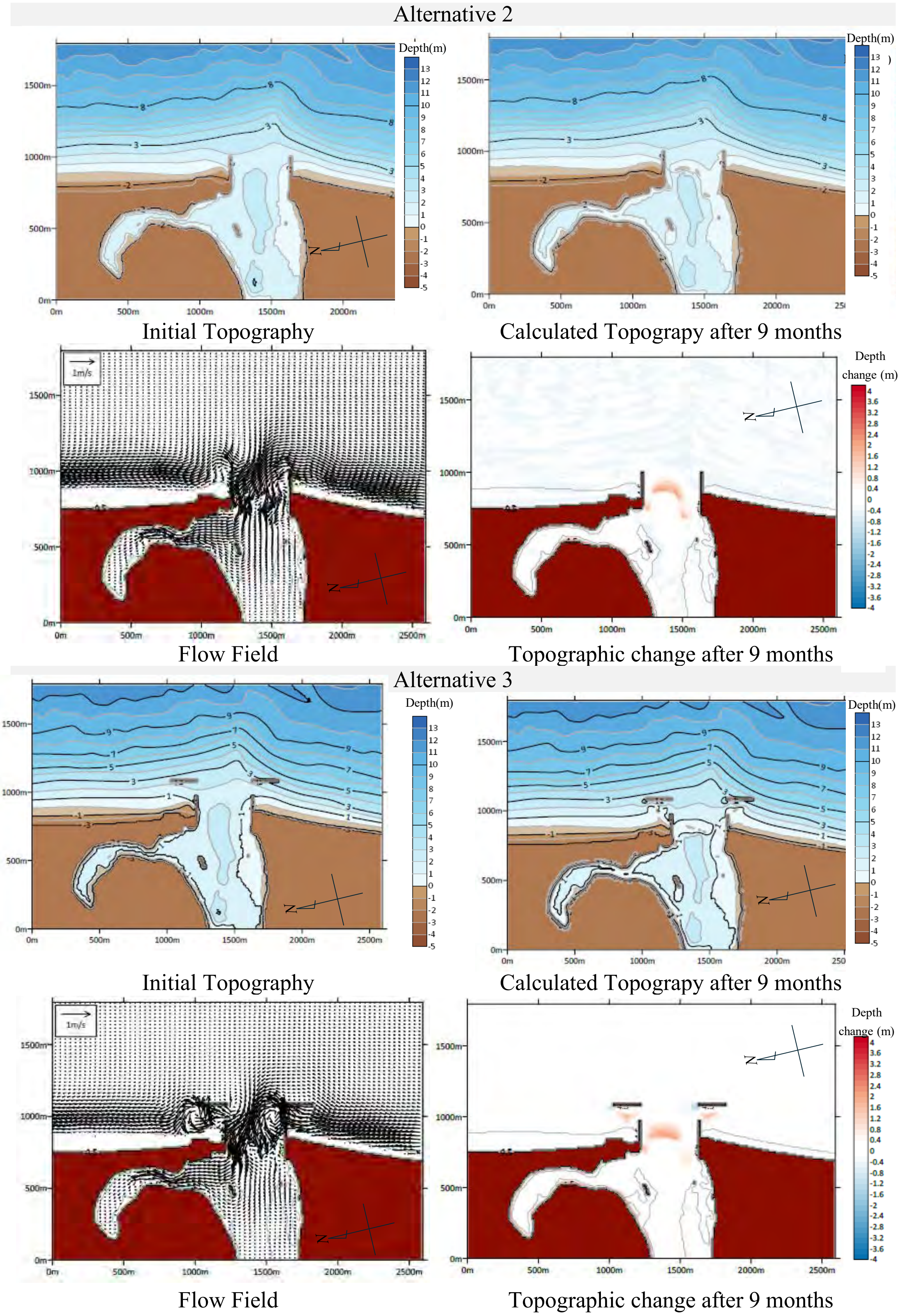
Calculated Topograpy after 9 months

Flow Field

Topographic change after 9 months

Source: JICA Expert Team

Figure 5-74: Adyar Prediction Calculation Results (Alternative 1)



Source: JICA Expert Team

Figure 5-75: Adyar Prediction Calculation Results (Alternative2,3)

A comparison of sedimentation in the estuary is shown in Table 5-17. It can be seen that maintenance dredging is necessary because significant sedimentation occurs under the current conditions. If maintenance dredging alone becomes difficult in the future, structural measures could be implemented. Among the alternatives considered, Alternative 2 and Alternative 3 were relatively effective but did not result in a significant reduction of sediment deposition at the river mouth. The reason is thought to be that the formation of the sandbar at the mouth of the Adyar River is not only due to littoral drift, which can be prevented by training walls, etc. but also due to the direct sediment movement from the estuary terrace, which is formed in front of the mouth (offshore) due to the abundant sediment supply, to the estuary and sandbar. Therefore, it is thought that maintaining the estuary through dredging, controlling sediment transport by narrowing the width of the estuary and changing the location of the estuary, is effective because it is not possible to maintain the estuary using only conventional measures such as training walls. In order to control littoral drift, which is one of the factors in the formation of an estuary sandbar, it is also possible to extend the training wall further offshore than the training wall proposed in this study. However, due to the factors that cause the formation of river mouth sandbars as mentioned above, it may not be an effective measure. In addition, if the littoral drift around the Adyar River mouth, which is thought to be a source of sediment supply to the surrounding coast, is prevented, the impact of coastal erosion is expected to be significant. So, it is important to fully predict the impact in advance and implement it in combination with impact mitigation measures such as sand bypasses if it is to be implemented.

Table 5-17 shows the results of an examination of the economic feasibility of each plan. The unit cost of the countermeasures was calculated based on the actual cost of the Cooum River countermeasures (as there were no actual costs for detached breakwaters, the same unit cost as for training walls was used). In this plan, Alternative 2 (Case 2) was the most economical, but the difference between the Indian government's plan and Alternative 2 was very small, and a decision needed to be made based on the impact on the surrounding coast as well.

Table 5-17: Comparison of the Amount of Sedimentation for Each Proposed Measure

Plan	Deposition (m^3/y)	Erosion (m^3/y)	Total (m^3/y)
Present Condition	59620	-793	58826
Alternative 1	52268	-1839	50408
Alternative 2	49614	-663	48951
Alternative 3	49716	-1895	47821

Source: JICA Expert Team

Sediment measurement range in the table (Blue area in the diagram below)

Alternative 1　　Alternative 2　　Alternative 3

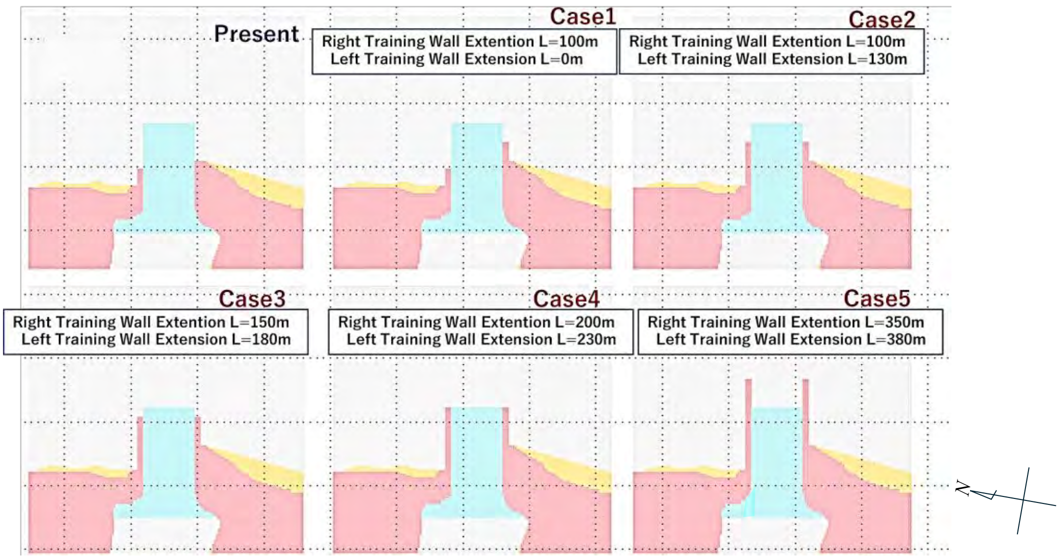
Table 5-18: Comparison of the cost of each countermeasure (for reference)

Item	Notes	Present	Case1	Case2	Case3
Length of training wall(m)	Right bank	0	200	170	300
Length of training wall(m)	Left bank	0	200	170	300
Deposition(m^3/y)		59620	52270	49610	49720
Erosin(m^3/y)		-790	-1840	-660	-1900
Net (m^3/y)		58830	50430	48950	47820
Cost					
Construction Costs(IND)		0	247,974,400	210,778,300	371,961,600
Maintenance fee for Structure(IND)	50years	0	61,993,600	52,694,600	92,990,400
Dredging Costs(IND)	50years	1,426,627,500	1,222,927,500	1,187,037,500	1,159,635,000
Shipping Costs(IND)	50years	633,164,400	555,107,400	526,858,200	528,026,400
Disposition Costs(IND)	50years	0	0	0	0
Total Costs(IND)		2,059,791,900	2,088,002,900	1,977,368,600	2,152,613,400
Evaluation Result		2nd	3rd	1st	

Source: JICA Expert Team

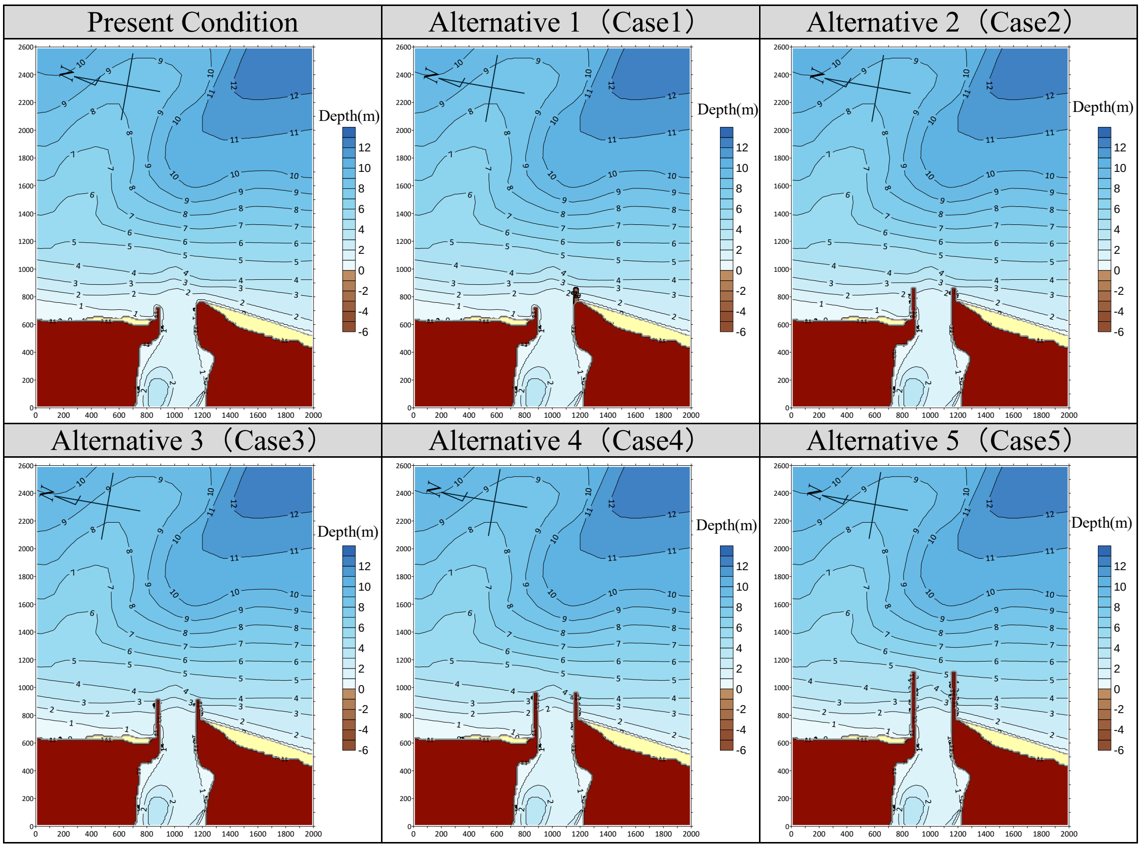
(4) Muttukadu (Buckingham Canal North)

In Muttukadu, although there is an existing training wall already in place, the southern shoreline is advancing to near the toe of the training wall, causing the function of the training wall to be lost. Since there are no current plans to construct a large-scale training wall as in Kosasthalaiyar and Cooum River, in Muttukadu, a comparative study between the case of extending the existing training walls and the case of maintenance dredging will be conducted, and a countermeasure plan will be proposed. The proposed countermeasures studied are shown in Figure 5-76. The lengths of the training walls were evaluated in stages, and the sediment deposition in the area indicated by the light blue hatch in the figure was compared. The initial topography of each proposal is shown in Figure 5-77, and the calculation results are shown in Figures 5-78 to 5-81.



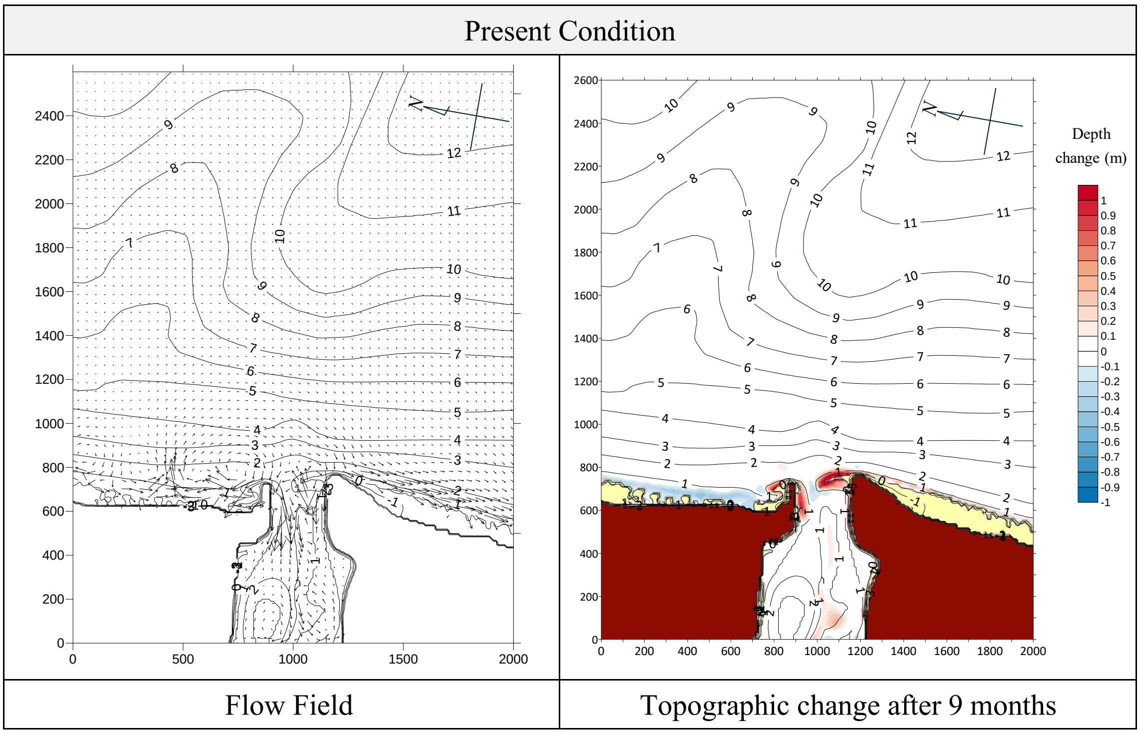
Source: JICA Expert Team

Figure 5-76: Layout of Proposed Measures in Muttukadu



Source: JICA Expert Team

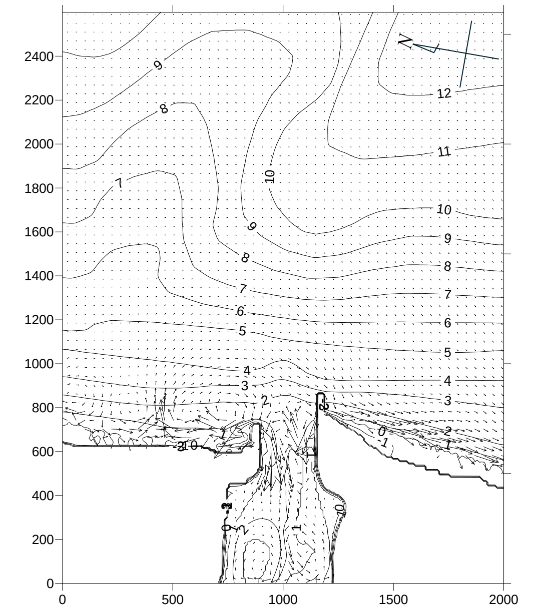
Figure 5-77: Initial Topography in Muttukadu



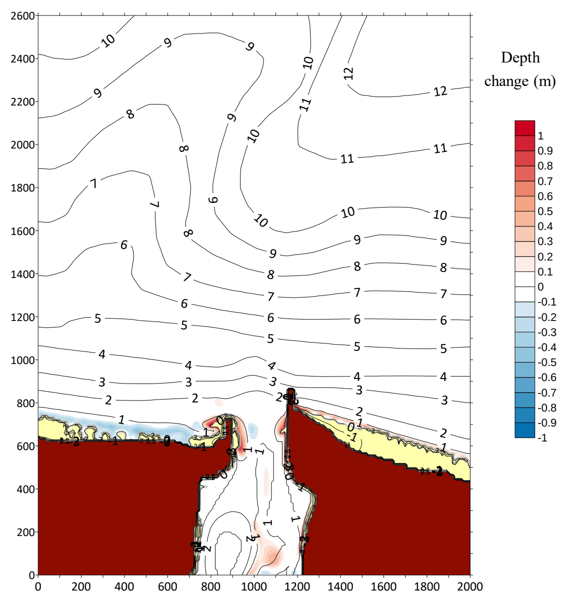
Source: JICA Expert Team

Figure 5-78: Muttukadu Prediction Calculation Results (Present Condition)

Alternative 1 (Case1)

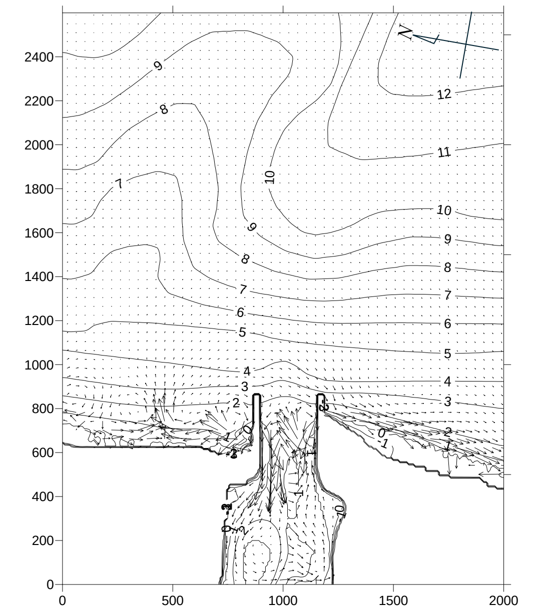


Flow Field



Topographic change after 9 months

Alternative 2 (Case2)



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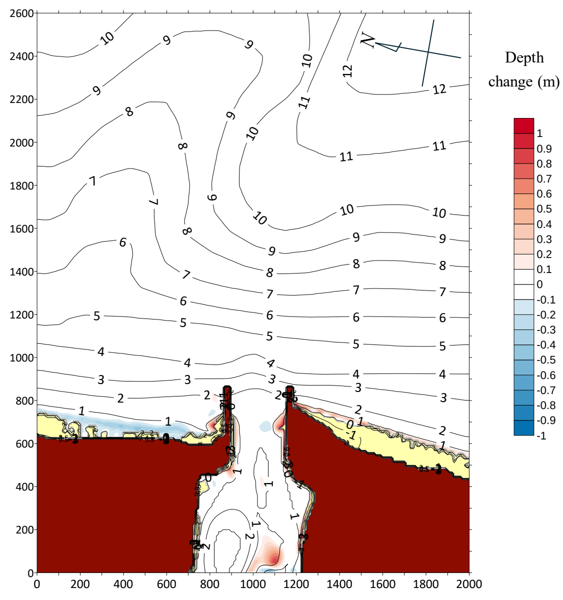
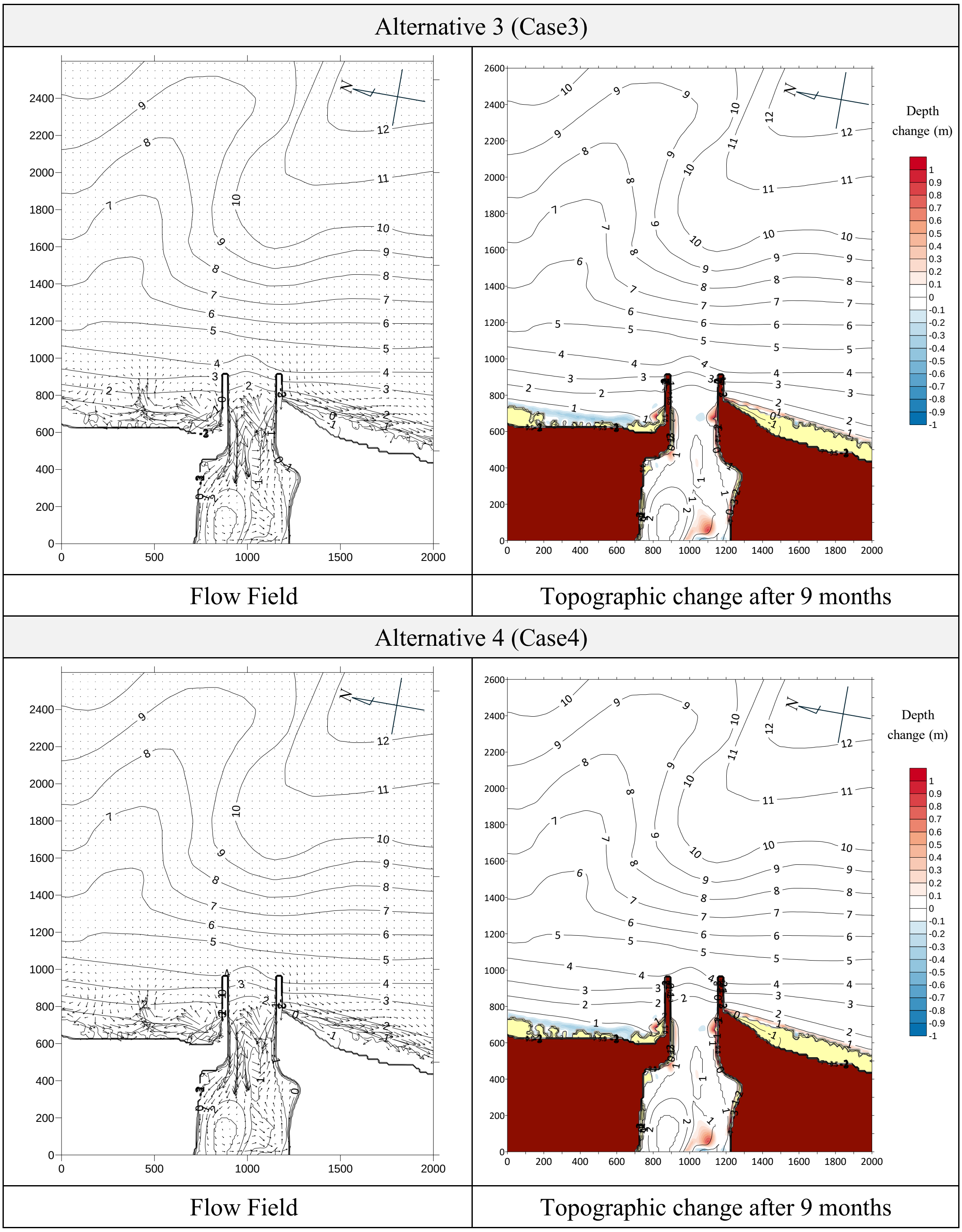


Topographic change after 9 months

Source: JICA Expert Team

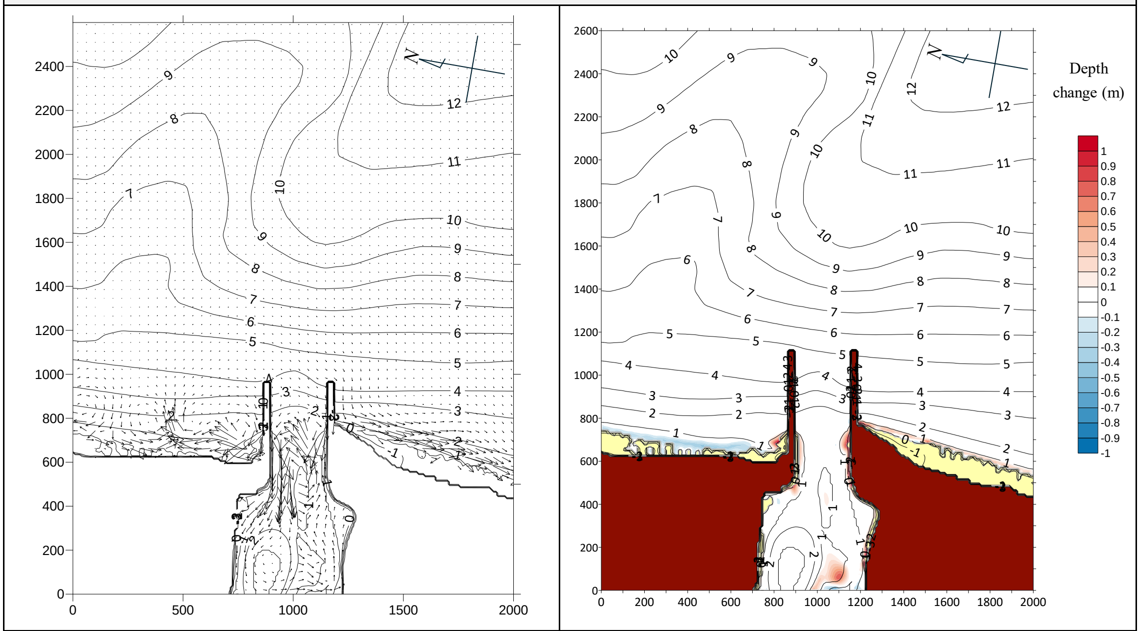
Figure 5-79: Muttukadu Prediction Calculation Results (Alternative 1, 2)



Source: JICA Expert Team

Figure 5-80: Muttukadu Prediction Calculation Results (Alternative 3, 4)

Alternative 5 (Case5)



Flow Field | Topographic change after 9 months

Source: JICA Expert Team

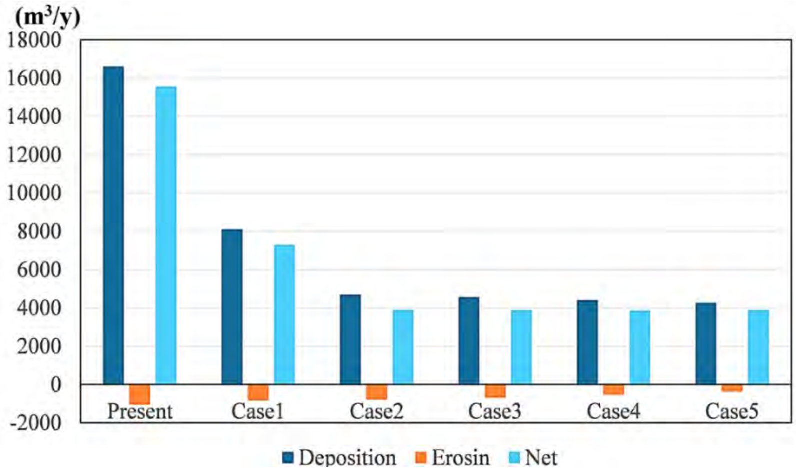
Figure 5-81: Muttukadu Prediction Calculation Results (Alternative 5)

A comparison of sedimentation in the estuary is shown in Table 5-19. Significant sedimentation occurs in the existing conditions, but as the training walls are extended offshore (Cases 1-5), the amount of sediment deposited in the estuary decreases. The greatest reduction in sediment deposition at the river mouth occurs in Case 5. This means that the amount of maintenance dredging will decrease as the training walls are extended. A bar graph of the amount of sediment deposited at the river mouth for each proposal is shown in Figure 5-82. It can be seen that the decrease in sediment deposition for each proposal is not uniform, but decreases rapidly up to Case 2, while for Cases 2-5, the sediment deposition at the estuary is almost the same.

Table 5-19: Comparison of the Amount of Sedimentation for Each Proposed Measure

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

Source: JICA Expert Team



Source: JICA Expert Team

Figure 5-82: Comparison of Predictive Calculations in Muttukadu

The sediment deposition at the river mouth is to be handled by maintenance dredging, and a comparison of the construction cost of the training walls and the maintenance dredging cost for each proposal is shown in Table 5-20. The maintenance dredging and maintenance fee for structures were compared for 50 years as life cycle costs. Consequently, Case 2 incurred the lowest expenditure for the countermeasures. Therefore, Case 2 was selected as the preferred solution. It is noted that the unit cost of construction was determined based on the expenses associated in building the Cooum River training walls.

Table 5-20: 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

The total project cost of the selected Case 2 is shown in Table 5-21. In addition, the standard cross-section of the assumed training walls is shown in Figure 5-83. The cross-sectional drawings were revised based on the technical standards and guidelines for coastal protection facilities in Japan, as well as the specifications in the block catalogue, with reference to the cross-section of the Cooum River.

Table 5-21: Project Cost (Case2)

Project Cost (Training Wall, Case2)

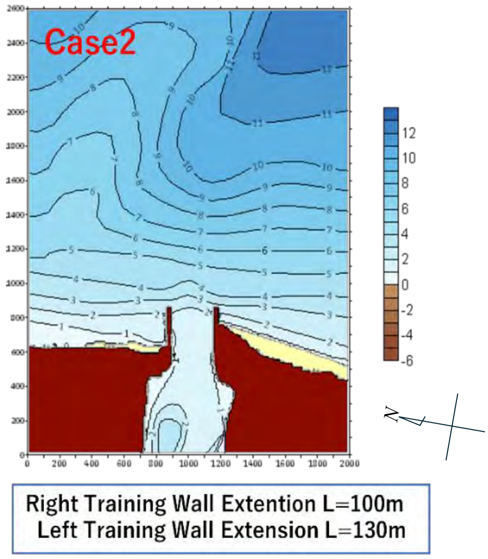
Item	Specification	Unit Price		Quantity		INR
Construction Costs	=130m(Left), L=100m(Righ	619,936	INR/m	230	m	142,585,275
Dredging Costs		485	INR/m3	30,000	m3	14,550,000
Shipping Costs	20km	212.4	INR/m3	30,000	m3	6,372,000
Base Cost						**163,507,275**
GST	18%					29,431,310
Subtotal						**192,938,585**
Provision	Base Cost x 26%*					42,511,892
Total						**235,450,477**

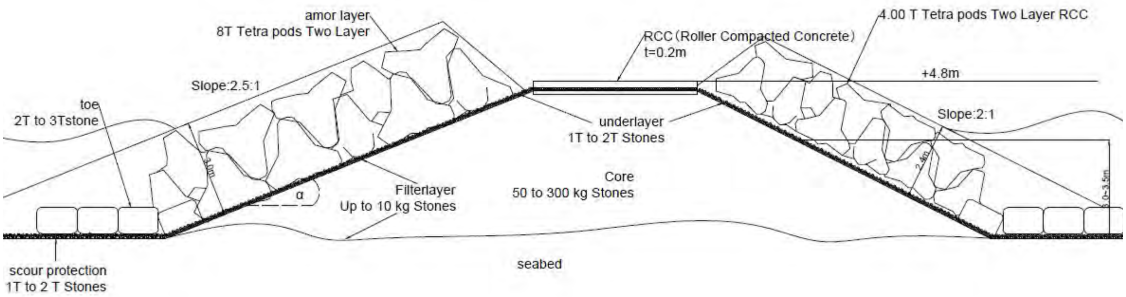
*Provisin rate was estimated from training wall construction cost in Cooum River.

Maintenance Cost

Item	Specification	Unit Price		Remark
Maintenance fee for Structure	0.5% x Project Cost	1,177,252	INR/year	
Dredging for Maintenance	4,000m3/year (Case2)	2,789,600	INR/year	The dredge volume was rounded to the nearest numerically calculated volume.
Total		**3,966,852**	**INR/year**	

Source: JICA Expert Team





Source: JICA Expert Team

Figure 5-83: Training Walls Layout and Standard Cross-Section of the Proposed Countermeasure in Muttukadu (Case 2)

If the training walls are extended, erosion is expected to occur on the north side of the beach, which is downstream of the sand drift. Therefore, it is recommended that all sediment dredged for maintenance be supplied to the sandy beach on the north side. In addition, when a large amount of sand is deposited on the beach on the south side, it is hoped that a sand bypass will be performed, and the sediment deposited on the south side will be supplied to the north side of the sandy beach for beach nourishment. Figure 5-84 depicts the maintenance of dredged material transport and sand bypass.

Source: JICA Expert Team, Map: OpenStreetMap Contributors

Figure 5-84: Beach Nourishment Strategy by Maintenance Dredging and Sediment Redistribution via Sand Bypassing

5.6 Future Issues and Solutions

5.6.1 Future Issues

In this chapter, the coastal zone and estuaries were analysed, with a particular focus on river mouth blockage measures that contribute to flood control. Regarding river mouth blockage measures, the Government of India has just installed two new training walls at the estuaries of the Kosasthalaiyar and Cooum Rivers. Although the training walls are expected to contribute to the maintenance of the estuary, the newly constructed training walls will likely block longshore sand drift and affect the shoreline around the embankments in the future. Additional measures will be needed to address this issue after monitoring the estuary.

5.6.2 Solutions

5.6.2.1. Estuary and coastline monitoring

In the Government of India, monitoring has been conducted so far at the mouth of the river and the surrounding beaches, and it is recommended to continue monitoring on a regular basis on an ongoing basis. In particular, the topographic survey and aerial photo measurement (including satellite image measurement) should be conducted at least once a year for the newly constructed training walls to confirm and evaluate their function and impact on the surrounding area.

5.6.2.2. Maintenance dredging and supply to surrounding beaches (sand bypass)

The amount of sediment deposited in the estuary per year is thought to decrease as a result of the installation of the training wall. On the other hand, the installation of the training wall has increased the length of time during which the width of the estuary is open during the year, and the scouring force during this period is smaller than before the installation, so there is a possibility that sediment will continue to accumulate in the estuary and upstream. Therefore, it is thought that sediment will not completely disappear from the estuary, so maintenance dredging should continue in order to ensure the necessary and reliable width of the estuary. In addition, it is desirable to use the dredged sand to nourish the eroding coast. Furthermore, if a large amount of sediment accumulates on the south side of the training wall and the coastline on the north side of the training wall recedes inland, this is evidence that the continuity of the sand drift is being disrupted by the training wall, so it is necessary to take measures to maintain the continuity of the sand drift by constructing a sand bypass.

5.6.2.3. Responding to climate change

As described in Chapter 5.4, although the estimated rise in sea level due to climate change is not so large, the effects of sea level rise may occur depending on future conditions. Since beaches and estuaries facing the sea are directly affected, it is desirable to respond by explicitly factoring the effects of sea level rise due to climate change into design conditions, etc., when the effects of sea level rise due to climate change become clear.

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

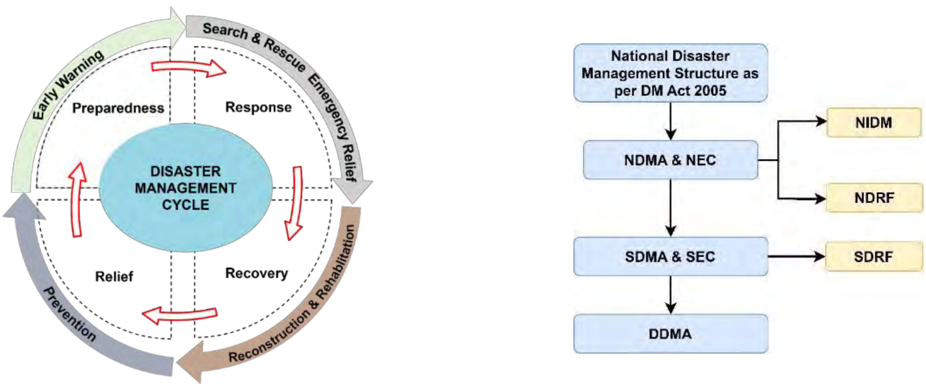
Effective flood disaster management requires a comprehensive approach before, during, and after flood events. Before a flood, it is crucial to implement mitigation and preparedness strategies. During a flood, the focus shifts to response actions to ensure safety and minimize damage. After a flood, recovery efforts are paramount. This involves assessing and repairing infrastructure, supporting affected individuals, and implementing measures to prevent future flooding. By adhering to these comprehensive strategies, communities can enhance their resilience to floods, minimizing both human and material losses.

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.

6.1 Overview of Existing Policies, Plans, and Institutional Arrangements

6.1.1 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. **Figure 6-1** 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

The following is a list of other strategies and plans related to flood management at the national level: National Disaster Management Policy (2009), National Disaster Management Plan (2016), Prime Minister's Ten-Point Agenda on DRR (2016) and National Disaster Management Guidelines, Templates and Standard Operating Procedures (SoPs).

The National Disaster Management Policy (2009) serves as a comprehensive framework for disaster risk reduction, preparedness, response, and recovery in India. It emphasizes key aspects such as risk assessment and mitigation, institutional strengthening at all levels, and capacity building through training and innovation. Overall, the policy provides a strategic roadmap for effective and inclusive disaster management across India.

The National Disaster Management Plan 2016 (NDMP) complements the National Disaster Management Policy by detailing operational measures for all phases of disaster management. It emphasizes risk assessment, hazard mapping, and mitigation strategies while defining the roles and coordination mechanisms of various stakeholders. Additionally, it highlights recovery strategies that address immediate needs and sustainable rehabilitation.

The Prime Minister's Ten Point Agenda on Disaster Risk Reduction (DRR) in 2016 outlines priorities to enhance India's disaster resilience. It emphasizes risk assessments, increased investments in DRR infrastructure, and the adoption of innovative technologies. The agenda promotes resilient infrastructure, robust governance, and effective early warning systems, along with risk financing and insurance. It underscores the importance of public awareness, education, and integrating climate change adaptation into DRR strategies.

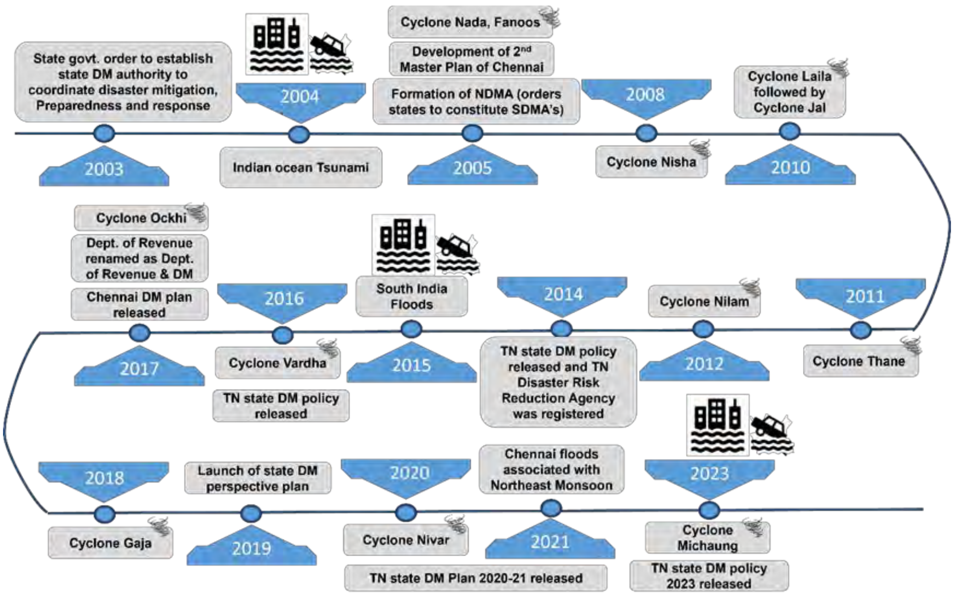
The National Disaster Management Authority (NDMA) of India has developed comprehensive guidelines, templates, and SoPs to ensure standardized and effective disaster management practices. The guidelines provide frameworks for risk assessment, disaster response, early warning systems, and sector-specific strategies, supporting disaster preparedness at all levels. Templates for disaster management plans assist authorities in formulating systematic and consistent plans at national, state, and district levels. The SoPs streamline disaster management actions, defining roles, coordination mechanisms, and response protocols. These resources, available on the NDMA website, reflect India's commitment to structured and efficient disaster risk reduction.

6.1.2 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:

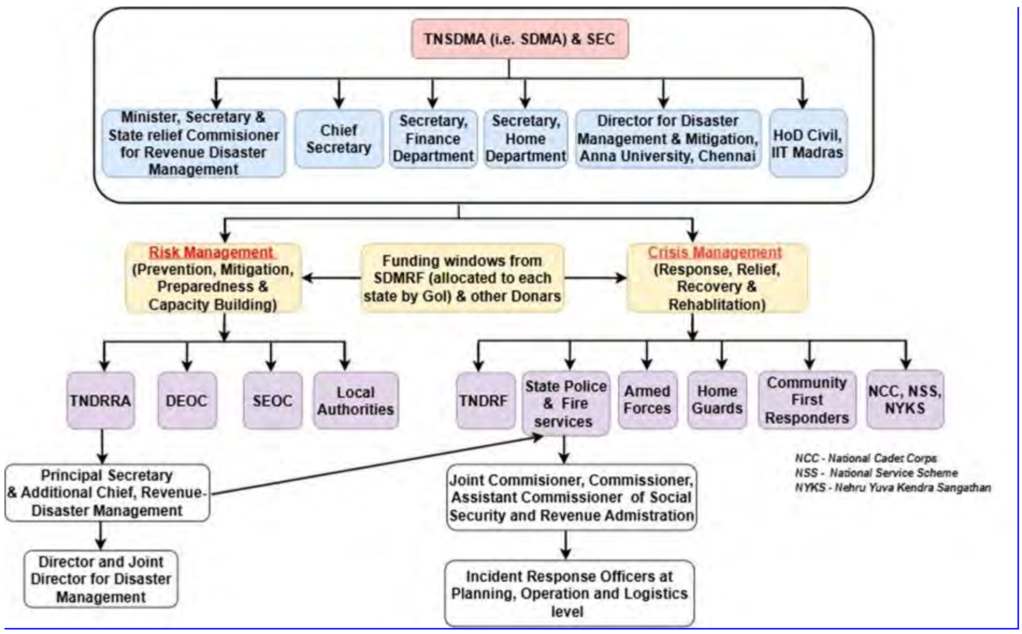
- Tamil Nadu State Disaster Management Policy (2023): The 2023 policy reflects Tamil Nadu's commitment to disaster risk management, prioritizing climate adaptation and resilience. It emphasizes multi-hazard approaches, integration of technology, and community participation. The policy provides a strategic framework for addressing both natural and human-induced disasters, aligning with international frameworks such as the Sendai Framework for DRR. However, it lacks detailed implementation guidelines and measurable targets, which can hinder operational clarity.
- Tamil Nadu State Disaster Management Plan: This plan is a detailed blueprint for disaster preparedness, response, and recovery, covering various disaster scenarios like floods, cyclones, and earthquakes across Tamil Nadu State. It also emphasizes the importance of inter-departmental coordination and risk communication. However, the plan could better address the unique challenges of coastal and urban areas in Tamil Nadu, particularly Chennai, which is highly vulnerable to flooding as a coastal urban area with a flat topography.
- Tamil Nadu State Disaster Management Perspective Plan (2018-30): The perspective plan outlines a long-term vision for disaster resilience, emphasizing infrastructure development, climate adaptation, and risk-sensitive urban planning. However, the plan tends to be general and lacks a detailed, localized disaster management approach. It should incorporate more region-specific data and establish robust monitoring and evaluation systems to enhance its implementation and relevance.
- District Disaster Management Plan: District-level plans effectively localize state policies and provide a roadmap for emergency response, recovery, and mitigation tailored to local contexts. They outline institutional responsibilities and disaster-specific protocols to ensure rapid and effective action. However, many plans are based on standardized templates, which fail to account for the unique vulnerabilities and capacities of specific districts.
- Chennai City Disaster Management Perspective Plan (2019-2030): This plan addresses Chennai's disaster risks, such as urban flooding, heatwaves, and cyclones, through measures like nature-based solutions and sustainable urban planning. It underscores the importance of early warning systems, public awareness, and resilient infrastructure. Despite its strengths, the plan lacks a clear focus on execution strategies, funding mechanisms, and stakeholder partnerships.
- Advisory Committee Report on Flood Risk (March 2023): The report provides an in-depth analysis of flood risks, identifying hotspots and recommending mitigation strategies such as infrastructure upgrades, early warning systems, and floodplain management. It also highlights the significance of integrating climate change considerations into flood risk planning.

- Vision Tamil Nadu 2023: Vision Tamil Nadu 2023 serves as a transformative roadmap for economic growth, infrastructure modernization, and social development. While it includes disaster management as a supporting goal, it doesn't adequately address urban resilience or climate adaptation, leaving gaps in safeguarding long-term growth. Aligning disaster risk reduction strategies with the state's economic priorities is critical.



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

6.1.3 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.

6.2 Past Major Floods and Current Flood Disaster Management Plans

6.2.1 Past Major Flood Events

Chennai experiences two main monsoon seasons: The southwest monsoon (June to September) and the northeast monsoon (October to December). The Southwest Monsoon brings rains primarily from the southwest, but the amount of rainfall Chennai receives during this period is relatively low compared to other regions in India. The Northeast Monsoon, however, is the most significant for Chennai. This monsoon is driven by the retreating southwest monsoon winds and the formation of low-pressure systems in the Bay of Bengal. The Northeast Monsoon often brings heavy and sustained rainfall, which is crucial for replenishing the region's water resources and filling reservoirs. 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: Overview of the Past Major Floods in Chennai

Flood History	Flood Information
1943	Flooding in the Cooum and Adyar rivers caused severe damage. Heavy rainfall in the city led to significant disruptions and property damage.
1976	For 24 hours long rainfall major damage has been observed in the Kosasthalayar basin, Cooum, and Adyar River. Max Daily Rainfall: 452.4 mm (Nungambakkam)
1996	This is the only flood due to the Southwest monsoon that happened in June. Max Daily Rainfall: 450.0 mm (Cholavaram & Thamaripakkam)
1998	The flooding resulted in disruptions to daily life, with transportation, power, and water supply systems severely affected. The 1998 floods underscored the vulnerability of Chennai's urban infrastructure to intense monsoonal rains.
2005	The unprecedented rainfall in a single day led to major rivers and canals like Adyar River, Cooum River, Otteri Nallah, Buckingham Canal, Virugambakam, and Arumbakkam Canal overflowing their banks. 42 killed and 37 were injured. Max Daily Rainfall: 312.0 mm (Tambaram)
2015	Airports and railways closed. 422 people were killed in the state and 289 in Chennai. Property damage worth Rs 14,602 crore. Max Daily Rainfall: 494.2 mm (Tambaram)
2020	Torrential rains of up to 300 mm caused flooding. However, fewer victims are due to improved weather forecasting and evacuation systems. Max Daily Rainfall: 300 mm (varied locations)
2021	34 people were killed, over 36,800 were affected, and 523 houses flooded above floor level. 31,668 Ha of farmland were inundated. Max Daily Rainfall: 224.65 mm (Viluppuram)
2023	Cyclone Michaung brought heavy rain and intense winds. The maximum 24-hour rainfall was 196 mm, and the three-day rainfall was 530 mm (Nungambakkam).

Source: JICA Expert Team

Table 6-2 (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 6-2: 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 Nungambakkam	11/25/1976	1264.5 (Meenambakkam)
1985	Fluvial & Pluvial	329.0 Nungambakkam	11/13/1985	1271.7 (Nungambakkam)
1996	Fluvial	450.0 Cholavaram &Thamaripakkam 347.0 Nungambakkam	6/14/1996	1704.6 (Nungambakkam)
2005	Fluvial & Pluvial	312.0 Tambaram	12/13/2005	2108.0 (Nungambakkam)
2015	Fluvial & Pluvial	494.2 Tambaram 475.0 Chembarambakkam	12/2/2015	2066.9 (Tambaram)
2021	Primary Pluvial	237.1 Mylapore - DGP Office	12/31/2021	1816.0 (Cholavaram) 1785.0 (Mylapore)
2023	Fluvial & Pluvial	293.4mm 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

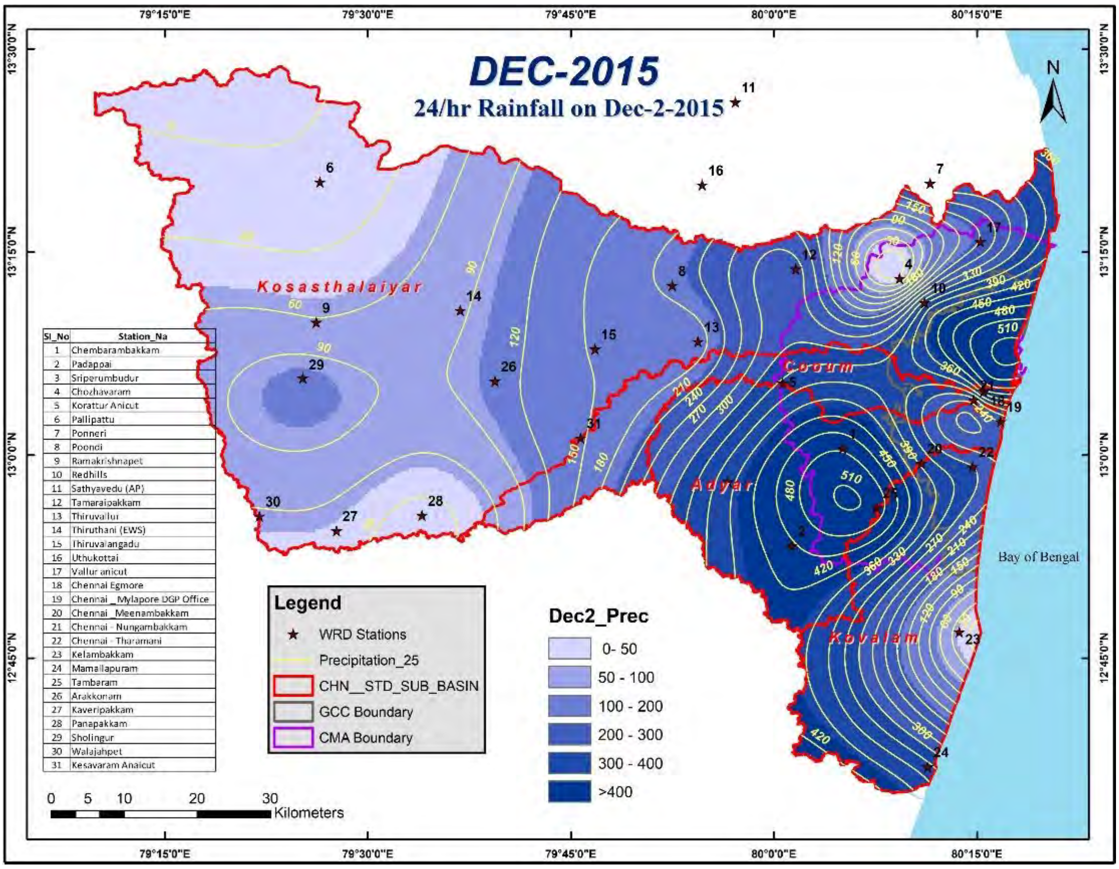
6.2.2 Details of the 2015 Flood

The 2015 flood in Chennai was selected for a more detailed study compared to other past floods due to its unprecedented scale and devastating impact on the city. It remains the most catastrophic flood in recent years, causing widespread destruction across various sectors, including infrastructure, agriculture, and human lives. The flood resulted in significant casualties, displaced thousands of people, and led to economic losses worth billions. The scale of rainfall, the overflow of reservoirs, and the failure of drainage systems highlighted the vulnerabilities in the city's preparedness and infrastructure. As such, the 2015 flood serves as a critical point of reference for understanding flood disaster management issues (before, during, and after) and improving disaster management strategies in Chennai.

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. Table 6-3 shows the rainfall using the Thiessen Polygon method, based on 31 rain gauges shown in Figure 6-4, for different periods during the December 2015 flood.

Table 6-4 shows the rainfall calculated using the Thiessen Polygon method, with rain gauges located in each basin or GCC and CMA.



Source: JICA Expert Team using WRD Stations

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

Table 6-3: Rainfall in the 2015 Flood in the Study Area using Thiessen Polygon method

Flood event	1day (mm/day)	2 days (mm/2 days)	3 days (mm/3 days)	4 days (mm/4 days)	5 days (mm/5 days)	6 days (mm/6 days)
Dec. 2015	220.6 (1/80-1/100)	277.3 (1/30-1/50)	299.2 (1/20-1/30)	318.2 (1/20-1/30)	354.6 (1/20-1/30)	389.3 (1/30-1/50)

The numbers in parentheses indicate the Rainfall Return Periods.

Source: JICA Expert Team

Table 6-4: Rainfall in 2015 flood in Basins and Admins using Thiessen Polygon method

Target Area	1day (mm/day)	2 days (mm/2 days)	3 days (mm/3 days)	4 days (mm/4 days)	5 days (mm/5 days)	6 days (mm/6 days)
CMA	361.2 (1/80-1/100)	397.7 (1/30-1/50)	428.9 (1/20-1/30)	452.9 (1/10-1/20)	463.6 (1/10-1/20)	487.6 (1/10-1/20)
GCC	334.8 (1/50-1/80)	378.4 (1/20-1/30)	418.3 (1/10-1/20)	442.1 (1/10-1/20)	494.8 (1/10-1/20)	514.7 (1/10-1/20)
Adyar Basin	394.2 (1/80-1/100)	440.1 (1/50-1/80)	465.5 (1/50-1/80)	482.6 (1/30-1/50)	503.2 (1/30-1/50)	533.3 (1/30-1/50)
Cooum Basin	245.4 (1/50-1/80)	291.0 (1/20-1/30)	313.0 (1/10-1/20)	399.9 (1/30)	445.0 (1/30-1/50)	491.6 (1/30-1/50)
Kosasthalayar Basin	185.0 (1/30-1/50)	224.8 (1/10-1/20)	232.1 (1/10-1/20)	276.1 (1/10-1/20)	316.0 (1/20-1/30)	334.7 (1/20-1/30)
Kovalam Basin	400.9 (>1/400)	464.0 (1/100-1/150)	495.7 (1/80-1/100)	519.4 (1/50-1/80)	551.7 (1/50-1/80)	614.9 (1/50-1/80)

The numbers in parentheses indicate the Rainfall Return Period.

Source: JICA Expert Team

Flooding affected several key river basins in and around the city, including the Adyar, Cooum, and Kosasthalayar basins. The city's extensive network of canals and rivers, which is normally used for stormwater drainage, became overwhelmed, leading to widespread flooding in densely populated areas. In total, approximately 10,000 houses were submerged, and more than 289 people lost their lives in the city alone. Thousands of others were affected by the displacement, and the economy suffered severe losses.

The floods caused extensive damage to infrastructure, including roads, bridges, and homes. Power outages were widespread, and communication systems were disrupted, making relief and rescue operations challenging. Many of the city's major hospitals and schools were also forced to shut down due to the flooding. The floodwater caused extensive damage to crop and agricultural land, particularly on the outskirts of the city, where 31,668 hectares of farmland were inundated.

In addition to the immediate human and property damage, the long-term impact on the economy was significant. 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. However, the 2015 event remains a stark reminder of the impacts of climate change and urbanization on flood risk in the city.

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.

6.3 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.

6.3.1 Lack of Flood Hazard Mapping

Flood hazard mapping is essential for identifying flood-prone areas, supporting urban planning, and enhancing disaster preparedness. In Chennai, a significant gap in flood management has been the lack of updated, accurate flood hazard maps. This gap became particularly evident during the recent floods in 2015, 2021, and 2023 when areas like Velachery, Madipakkam, and Saidapet experienced severe inundation. The populated low-lying areas in the Kovalam Basin, as well as those near the Adyar River and the residential zones between the Cooum and Kosasthalayar Rivers along the North Buckingham Canal, experienced significant flooding. Many residents were not evacuated in time, resulting in a poorly coordinated disaster response. During 2023 Flood, inundation along the North Buckingham Canal persisted for approximately three days, placing heavy pressure on local disaster management efforts. The lack of proper flood hazard mapping and timely evacuation orders further exacerbated the challenges faced by households in these areas.

Moreover, as urbanization in Chennai continues, flood risks are not adequately reflected in planning due to the absence of updated hazard maps. While the JICA Flood Control Master Plan has proposed new flood hazard maps for various flood return periods at different scales, these maps have yet to be fully disseminated and integrated into local urban planning, community preparedness, and emergency response frameworks. To address this, the following actions are proposed and prioritized in the next section.

6.3.2 Inadequate Early Warning Systems (EWS)

The India Meteorological Department (IMD) issues warnings for heavy rainfall in various categories—yellow, orange, and red. The Tamil Nadu Disaster Risk Reduction Authority (TNDRRA) also receives information about cyclone movements and localized heavy rainfall from the Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES). However, there is still a significant gap in precise flood forecasting and early warning systems for Chennai.

IMD heavy rainfall warnings are typically issued a few days before expected rainfall and are revised as the event approaches. However, these warnings are provided on a relatively large scale and do not specify detailed locations of basins for heavy rainfall. Furthermore, the forecasts lack detailed information about potential flooding areas and only provide a broad scale forecast of expected rainfall. For instance, the entire Chennai metropolitan area (CMA) and surrounding regions are often grouped as one district for IMD.

This deficiency has posed a major challenge, particularly during the 2015 floods when dam operators struggled to manage reservoir levels effectively due to inadequate early warning systems. It is essential to enhance the early warning systems to better prepare for and mitigate the impacts of flooding in Chennai.

The Early Warning System (EWS) is critical not only for dam operations but also for managing flood storage in waterbodies and tanks. Moreover, it is essential for issuing timely warnings to residents in flood-prone areas, enabling efficient evacuations. A Real-Time Flood Forecasting (RTFF) system is currently under development with World Bank financial support to improve flood management in the Chennai urban area. This system will also enhance dam operations by offering pre-emptive water release strategies, reducing the risk of dam overflow, and ensuring the safe handling of floodwater in advance of flood events.

6.3.3 Lack of Evaluation and Updating Standard Operating Procedures (SOPs)

An SOP in flood control refers to a standardized procedure or set of guidelines for managing flood-related activities, including preparation, response, and recovery actions during flood events. These procedures are essential for ensuring coordination, minimizing damage, and ensuring timely actions during flood disasters. Effective disaster response relies on the availability and timely activation of Standard Operating Procedures (SOPs). The National Disaster Management Authority (NDMA) in India has developed a range of guidelines, templates, and SOPs to provide guidance and standardize processes in disaster management. Following the 2015 floods, several SOPs were developed to guide various disaster management activities for Tamil Nadu State and Chennai District. However, floods in 2020, 2021, and again in 2023 reveal a lack of evaluation and updating SOPs given the evolving flood risks in Chennai. During the 2020 and 2021 floods, delayed activation of SOPs resulted in uncoordinated rescue operations in areas like Mugalivakkam and Porur, exacerbating the impact on affected communities.

Regularly reviewing and updating these SOPs are also important to address the recommendations from the JICA Comprehensive Flood Control Master Plan.

6.3.4 Fragmented Command and Control and Uncoordinated Inter and Intra-Agency Efforts

Effective disaster response requires seamless coordination among multiple agencies, but Chennai has faced significant challenges in this regard, often leading to delays and inefficiencies in responding to floods. The 2015 floods exemplified the lack of coordination, with overlapping responsibilities between the Tamil Nadu State Disaster Management Authority (TNSDMA), which had only been established in 2014 (one year before the 2015 flood), and the Greater Chennai Corporation (GCC) and other agencies such as TNWRD. This created confusion, particularly in Zone 8 and 10 of Chennai City, as well as the Chembarambakkam dam operation by TNWRD, resulting in delayed decision-making and response efforts, such as evacuations and the distribution of relief materials. The absence of a clear division of roles between these agencies complicated the response, delaying the timely assistance needed for affected communities.

Since then, significant improvements have been made. The 2023 floods showcased a much more coordinated response, with a clearer distribution of responsibilities between various agencies, which helped mitigate some of the confusion experienced in 2015. The State Emergency Operations Center (SEOC), established in 2016 and renewed/expanded in August 2024, has played a pivotal role in improving coordination across agencies, enabling more synchronized efforts in response activities. The flood management process was better coordinated, and agencies were able to share information in real-time, making decisions more efficiently and leading to quicker responses.

However, challenges remain. Despite improvements in overall coordination during response and recovery phases, some areas still need attention. One significant gap lies in the coordination of traffic management during flood events, which remains a challenge. Additionally, delays in recovery efforts caused by power and water outages, along with water pollution in flood-affected areas, remain significant challenges. During the 2023 floods, there were instances where roadways became severely congested, hindering the movement of emergency services and evacuees. **Table 6-5** Presents the approximate duration of inundation for major roads and highways in each basin during 10-year and 100-year return period floods. This shows the importance of proper traffic management before and during a flood.

Table 6-5: Duration of Inundation of Major Transportation Network

Basin	Return Period	0-12hrs	12-24hrs	24-36hrs	36-48hrs	More than 48hrs
Adyar	10 years	498.8	326.2	117.3	45.7	4.1
	100 years	612.3	401.8	220.3	101.3	26.3
Cooum	10 years	190.3	137.1	79.2	34.8	5.6
	100 years	315.2	205.2	139.2	68.5	11.9
Kovalam	10 years	368.5	269.4	125.1	76.4	26.6
	100 years	382.5	289.1	147.4	84.3	43.4
Kosasthalaiyar	10 years	602.3	454.5	257.1	116.4	48.7
	100 years	875.4	627.1	385.1	182.5	74.9

Source: JICA Expert Team

Additionally, issues concerning the protection of lifelines and utilities—such as power supply, water, and communications—remain problematic. For example, during the 2020 floods, power outages and disrupted water supply delayed recovery efforts in certain parts of the city. Another example is during the flood of 2023 when pollution was spread from the Chennai refinery into the flood-affected areas.

Furthermore, while coordination has improved for emergency response and post-flood period, preparedness activities still lack a similar level of integration. The coordination framework is currently more effective during flood events and immediate response phases but needs further strengthening in terms of preparedness activities, such as pre-positioning resources, traffic management planning, and ensuring the functionality of essential utilities during early warning phases.

To address these gaps, the establishment of a centralized coordination mechanism remains a key priority. A clear framework, with well-defined roles and responsibilities, would ensure that all agencies involved in flood management can act swiftly and efficiently. This mechanism would help minimize duplication of efforts and confusion, particularly in the preliminary stages of a flood event. By improving pre-flood coordination, especially in areas like traffic management, utility protection, and pre-positioning of resources, Chennai could significantly reduce delays and improve its overall flood resilience.

6.3.5 Poor Drainage Infrastructure Operation and Maintenance

Chennai’s drainage infrastructure is a significant weak point in its flood management system, comprising two main components: macro drainage and micro drainage. Macro drainage includes primary waterways like rivers and the Buckingham Canal, which manage fluvial flooding during heavy rainfalls and upstream discharges. Micro drainage systems that are smaller drains connected to macro drains and stormwater drains (SWDs) serve as secondary and tertiary networks to channel rainwater into macro systems, mitigating pluvial flooding. However, both systems are plagued by inadequate carrying capacities, limiting their ability to handle even moderate rainfall events. These issues have been addressed in Chapters 2 and 3 of this study. Chapter 2 focuses on proposing countermeasures to enhance the carrying capacities of rivers, while Chapter 3 addresses improvements to micro drainage systems, including Buckingham Canal and other connecting drains to the Adyar and Cooum Rivers.

However, the drainage network's functionality is frequently compromised by blockages caused by debris, improper solid waste disposal, and encroachments. The lack of routine maintenance and operation further exacerbates these issues, leading to severe waterlogging and flooding. These deficiencies not only disrupt daily life in the city but also undermine its resilience to extreme weather events, emphasizing the urgent need for coordinated efforts to upgrade, maintain, and optimize Chennai’s drainage infrastructure.

The 2023 floods in Chennai highlighted the deficiencies in the urban drainage network, particularly in neighborhoods such as Anna Nagar and Kodambakkam, where moderate rainfall caused prolonged waterlogging. Despite investments in drainage systems, their inefficiency underscored a pressing need for improved maintenance and capacity upgrades. Similar issues were observed during the 2015 and 2021 floods, where areas like Velachery and Tambaram faced significant challenges due to blocked drains and encroached waterways.

Several factors contribute to the inadequacy of Chennai's drainage system:

- Encroachments: Critical waterways and channels such as the Cooum River, Adyar River, and Buckingham Canal have been narrowed or blocked due to unauthorized construction and land reclamation, severely reducing their flood-carrying capacity.
- Blockage due to Solid Waste Disposal: Blockages in Chennai's rivers and drains caused by improper solid waste disposal significantly reduce their flow capacity, leading to waterlogging and heightened flood risks during heavy rainfall. Regular waste management and cleaning are essential to maintain their functionality. Furthermore, fostering a spirit of river conservation is crucial to ensure the long-term success of flood control measures. Efforts to clean and maintain rivers not only improve their flow capacity but also improve a sense of community responsibility. For example, rivers like the Tama and Sumida in Japan were once heavily polluted waterways. Their transformation into clean and functional rivers is a result of parallel efforts in flood control and river purification. Such integrated approaches serve as a valuable reference for addressing similar challenges in Chennai.
- Infrequent Maintenance: A lack of regular desilting and debris and bushes removal often leads to clogged drains, rendering the system ineffective during rainfall.
- Aging Infrastructure: Many drainage systems are outdated and not designed to handle the increased runoff caused by rapid urbanization and climate change.

As a result, these issues create a domino effect: waterlogging disrupts transportation, damages property, and poses health risks, while delayed response and inter-agency coordination further compound the problem.

6.3.6 Emergency Dams and Waterbodies Operation Protocols:

Chennai's four major dams—Chembarambakkam, Poondi, Redhills, and Cholavaram—are crucial for the city's water supply, but they currently do not have specific provisions for flood control. These dams were designed primarily to manage water resources, not to mitigate flood risks. As a result, during heavy rainfall events, these dams have struggled to manage excess water and inadequate flood control measures. This was most evident during the 2015 floods, where the discharging flood water from Chembarambakkam caused exacerbated flooding in downstream areas such as downstream of the confluence area, airport, Saidapet, etc. This situation was compounded by a lack of real-time monitoring, which made it difficult for authorities to make informed decisions about when and how much water to release. The floodwaters not only damaged property but also posed significant risks to human life and livelihoods in affected areas.

In addition to the challenges faced by these dams, the JICA Flood Control Master Plan highlights the importance of increasing the flood storage capacity of waterbodies and tanks, such as the 50 selected tanks and waterbodies identified in Adyar Basin. The need to update the dam operation protocols is evident, but updating protocols must extend beyond just the dams to include other waterbodies and tanks to effectively manage flood risks across the entire city.

6.3.7 IInsufficient pre-positioning of Resources, Shelter Management, and Livelihood Protection

Inadequate pre-positioning of emergency resources in vulnerable areas has been a significant challenge for Chennai's flood response system. The lack of pre-deployment of essential supplies hampers timely relief operations, leading to delays in assistance to affected populations during floods. During the 2015, 2020, and 2023 floods, areas such as Tambaram, Velachery, and Mudichur, which are highly prone to flooding, faced severe delays in receiving emergency supplies like food, water, and medical kits. Despite being identified as flood-prone, these areas lacked adequate pre-positioned resources, which significantly slowed down the relief efforts in particular food supply during the 2023 flood. The delay in reaching these areas resulted in heightened distress and prolonged suffering for residents. Similar delays were witnessed during the 2015 floods, where many parts of South Chennai faced difficulties in accessing timely aid due to logistical inefficiencies and poor resource distribution.

Shelter management is also a key component of flood response, ensuring that displaced populations have access to safe, secure, and adequately equipped shelters during and after a disaster. In Chennai, the 2015 floods revealed significant weaknesses in shelter management. Many affected areas, including parts of Anna Nagar and Kodambakkam, saw families displaced due to submerged homes, but temporary shelters were often overcrowded and lacked necessities like sanitation facilities, clean drinking water, and adequate ventilation. Similarly, during the 2023 floods, displaced people in flood-prone neighborhoods like Velachery and Tambaram were forced to seek refuge in poorly managed shelters. These shelters were either not well-prepared in terms of hygiene or lacked sufficient staff to manage the needs of the evacuees, leading to health risks and poor living conditions.

Livelihood protection is a crucial aspect of disaster resilience, particularly in flood-prone areas like Chennai, where recurrent floods can severely disrupt the economic activities of vulnerable communities. In Chennai, the 2015 and 2023 floods had significant impacts on local livelihoods, especially in informal sectors such as street vending, small-scale businesses, and agriculture. In the 2023 floods, for instance, floodwaters inundated small retail businesses in low-lying areas, washing away goods and disrupting trade for weeks. Farmers in suburban areas lost crops due to waterlogging and damaged irrigation systems, which threatened their seasonal harvests. Livelihoods that were already vulnerable due to climate change-induced erratic rainfall patterns were further jeopardized by the floods, with families facing longer-term economic insecurity.

The absence of strategic resource pre-positioning resources, shelter management, and livelihood protection exacerbate the flood response time. The delay in accessing vital supplies leads to preventable suffering and increased mortality during flood events. Additionally, vulnerable areas like Kotturpuram and Mudichur often lack adequate emergency response plans, as supplies are only mobilized once floodwaters have already overwhelmed infrastructure, complicating the distribution process.

6.3.8 Other Gaps

The following is a list of other major gaps that have been reported in the past major floods in Chennai.

6.3.8.1. Improper Flood Mitigation Practices and Construction of Temporary Barriers

Improper flood mitigation practices, such as poorly constructed or inadequately deployed temporary barriers, have been notable gaps in Chennai's flood management system, highlighting the need for careful monitoring and maintenance to ensure their effectiveness. During past flood events, such as the 2015 and 2023 floods, these issues became evident, as temporary flood barriers and mitigation measures were either poorly designed or insufficiently maintained to handle the scale of the disaster. For example, in the 2015 floods, temporary barriers made of sandbags were widely used in areas like Kotturpuram and parts of the Adyar Basin. However, due to improper placement and frequent breaches, these barriers failed to prevent water from spilling into vulnerable neighborhoods. Similarly, in the 2023 floods, attempts to create temporary barriers along the Kovalam Basin and North Buckingham Canal met with limited success, as the barriers could not withstand the surge of floodwater during heavy rainfall. In the Kovalam Basin, temporary barriers constructed hastily by local authorities were not able to hold back floodwater in the lower-lying areas. The barriers, which were primarily made of sandbags, failed to provide adequate protection as water levels rose due to the lack of reinforcement or maintenance.

6.3.8.2. Post-Flood Damage Assessment

Chennai's post-flood damage assessment has historically faced challenges that delay timely relief and recovery for affected communities. During the 2015 floods, the city faced significant difficulties in assessing the extent of damage across various areas, especially in neighborhoods in Adyar and Cooum Basins. This was due to a lack of a streamlined system for rapid damage assessment. In many cases, damage assessment was carried out weeks after the floods, leaving communities without support for critical repairs and exacerbating the vulnerability of those already hit by the disaster. In the 2023 floods, the situation remained largely unchanged, with post-flood damage assessment processes continuing to be slow and cumbersome. The absence of clear guidelines and standardized procedures for assessing damage led to inconsistencies in an accurate flood damage assessment, leaving many residents dissatisfied with the process.

6.4 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 6-6** and **Table 6-7** 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. Below is a summary of the proposed actions based on these tables, aimed at improving the overall flood management situation for each disaster cycle.

6.4.1 Before Flood Disaster (Preparedness and Flood Disaster Prevention)

- Flood Hazard Map
    - Flood hazard maps are created and made public.
    - Residents will be able to understand flood hazard maps and take action.
    - Consensus among the CPs to use unified flood hazard maps.
    - Flood hazard maps for different probability years (e.g., 1/10 and 1/100).
    - Disaster risk and evacuation info will be shared online.
- Disaster Management Plan
    - The state plan will be revised based on the situation and included in the urban master plan.
    - Disaster prevention and evacuation follow SOPs and the actual situation.
- Disaster Management Center
    - Relocate to a higher elevation to improve safety in floods and tsunamis.
    - Continues improvement of the command center to improve safety against fire.
    - Backup communication systems for power loss (Satellite disaster digitalization).
    - Flood disaster forecasting and warning systems will be fully digitized.
- Preventive Countermeasures

- Improve river and drainage flow capacity.
- Improve dam operation rules and dam warning systems to reduce flood damage.
- Developing integrated SWD.
- Removing blockage due to solid waste disposal and bushes, etc.
- Missing links for tanks and water bodies will be restored.

- Business Continuity Plan
  - Companies will develop disaster prevention plans to enhance DRR capabilities.
- Weather Observation and Accurate Forecast
  - Weather forecasts and warning systems have been improved and integrated.
  - Weather radar functionality will be upgraded for better rainfall accuracy.
  - Observation stations will be increased and improved based on river basin size.
- Risk Communication (Prevention Capacity)
  - Public awareness and training in schools enhance preparedness.
  - Informing risk areas of dam emergency discharge, proper warnings, and evacuation.
  - Better understanding and improvement in action for flood risk.
  - Evacuation facility shortages will be addressed, and hygiene will be improved.
  - Digital flood risk information will be accessible.
- Risk Communication (Training for Officials)
  - Enhanced technical training for disaster management and more skilled experts.
  - DDRF teams will gain flood response expertise for local activities.
- Risk Communication (Public Training)
  - DRRA will collaborate with DRF-led training to improve effectiveness.
  - Disaster leadership will ensure gender-neutral relief, prioritizing vulnerable groups.
  - Better access to information through disaster prevention digitization.

6.4.2 During Flood Disaster (Emergency Response and Mitigation)

- Flood Early Warning
  - Reliable communication using dedicated staff and departments.
  - Multiple communication methods: Mass media, internet, and analog systems.
  - Establishment of cell phone alerts, disaster radios, and bulletin boards.
- Evacuation Order and Coordination
  - Clear evacuation advisory and instruction criteria.
  - Development of media platforms for disaster updates.
  - Training local disaster leaders and providing communication tools.
- Rescue and Relief
  - State-local government cooperation for rapid disaster information collection.
  - Collaboration with the public sector for infrastructure damage reporting.
  - Policy prioritizing vulnerable groups during disasters.
  - Flood rescue and relief updates shared via various media.

- TNDRF conducts rescue operations based on community damage reports.

6.4.3 After Flood Disaster (Emergency Support, Recovery, and Reconstruction)

- Supporting Affected People
  - Plans for rebuilding disaster-affected homes and temporary housing quickly.
  - Utility operators (water, gas, electricity, transport) promptly schedule recovery.
  - Implement support measures prioritizing vulnerable groups.
  - Emergency supplies with disaster prevention warehouses and home kits.
  - Provide digital information on victim support, evacuation facilities, etc.
  - Fair evacuation systems addressing disparities and supporting the poor.
- Urgent Infrastructure Reconstruction
  - Collaboration for rapid emergency infrastructure repairs.
  - Speed up desilting operations after heavy rainfall.
  - Enhance flooded area drainage with portable pumps.
  - Accelerate restoration of damaged roads and drainage systems.
- Emergency Budget
  - Establish a fast financial support system for disaster response.
  - Improve risk management, introduce insurance, and create DRR benefit systems.
- Recovery and Reconstruction Plans
  - Develop reconstruction plans based on ground realities and flood countermeasures.
  - Upgrade disaster prevention centers and welfare facilities.
  - Facilitate and support area reconstruction efforts.

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

Proposals for Improving Flood Disaster Management in the Future

Disaster Cycle	Activities	Priority	Improved Situation	Main Agency	Operation Agency
Before Flood Disaster (Preparedness and Flood Disaster Prevention)	Flood Hazard Map	High	Flood hazard maps are created and made public	TNDRRA	TNDRRA
			Residents will be able to understand flood hazard maps and take action	TNDRRA	TNDRRA
			Consensus among the CPs to use unified flood hazard maps	TNDRRA	DDRRA
			Flood hazard maps for different probability years (e.g., 1/10 and 1/100)	TNDRRA	DDRRA
			Disaster risk and evacuation info will be shared online	TNDRRA	DDRRA
	Disaster Management Plan	Med	State plan will be revised based on situation and included in the urban master plan	TNDRRA	CMA Municipality
			Disaster prevention and evacuation follow SOPs and the actual situation	TNDRRA	CMA Municipality
	Disaster Management Center	Med	Relocate to a higher elevation to improve safety in flood and Tsunami	TNDRRA	TNDRRA
			Continues improvement of the command center to improve safety against fire	TNDRRA	TNDRRA
			Backup communication systems for power loss (Satellite disaster digitalization)	TNDRRA	TNDRRA
			Flood disaster forecasting and warning systems will be fully digitized	TNDRRA	TNDRRA
	Preventive Countermeasures	Med	Improve river and drainage flow capacity	TNWRD	TNWRD
			Improve dam operation rules and dam warning systems to reduce flood damage	TNWRD	TNWRD
			Developing integrated SWD	TNWRD GCC	GCC
			Removing blockage due to solid waste disposal and bushes, etc.	TNWRD GCC	GCC
			Missing links for tanks and water bodies will be restored	TNWRD GCC	GCC
	Business Continuity Plan	Med	Companies will develop disaster prevention plans to enhance DRR capabilities	TNDRRA TNMoI	TNDRRA TNMoI
	Weather Observation and Accurate Forecast	High	Weather forecasts and warning systems have been improved and integrated	TNIMD	TNIMD TNDRRA
			Weather radar functionality will be upgraded for better rainfall accuracy	TNIMD	TNIMD
			Observation stations will be increased and improved based on river basin size	TNIMD	TNIMD
	Risk Communication (Prevention Capacity)	Med	Public awareness and training in schools enhance preparedness	TNDRRA	CMA GCC
			Informing risk areas of dam emergency discharge, proper warnings and evacuation	TNWRD	CMA GCC
			Better understanding and improvement in action for flood risk	TNDRRA	TNDRRA
			Evacuation facility shortages will be addressed, and hygiene improved	TNDRRA	TNDRRA
			Digital flood risk information will be accessible	TNDRRA	TNDRRA
	Risk Communication (Training for	High	Enhanced technical training for disaster management and more skilled experts	TNDRRA TNDRF	DDRRA DDRF
			DDRF teams will gain flood response expertise for local activities	TNDRRA TNDRF	DDRRA DDRF
	Risk Communication (Public Training)	High	DRRA will collaborate with DRF-led training to improve effectiveness	TNDRF	DDRF
			Disaster leadership will ensure gender-neutral relief, prioritizing vulnerable groups	several	several
			Better access to information through disaster prevention digitization	TNDRF	DDRF

Current Situation of Flood Disaster Management and Gaps

Phase	Response details	The Existing Situation
Before Flood Disaster (Preparedness and Flood Disaster Prevention)	Flood Hazard Map	Flood hazard maps are not available to public and officials
		Residents lack awareness of flood hazards
		Hazard map requirements vary for each CPs
		Inland flood maps (1/10 probability) are needed
		Disaster risk and evacuation information are limited; digitalization lags
	Disaster Management Plan	Disaster plans lack reflection of actual situations
		Local disaster prevention measures at the district level are inadequate
	Disaster Management Center	The old one was established after the 2015 flood and renewedg. 2024
		A command centre in the fist floor is unsafe for flood and Tsunami
		Human damage assessments and communication rely solely on phones/Internet
		Disaster warning systems are insufficient
	Preventive Countermeasures	Downstream river improvements and drainage capacity are lacking
		Low awareness of the emergency dam releases risk
		Inadequet SWD and scattered drainage
		Solid waste and vegetation are blocking drainage systems.
		Missing links leading to poor drainage in several areas
	Business Continuity Plan	More companies are now formulating plans after 2015 floods, but still insufficient
	Weather Observation and Accurate Forecast	Prediction accuracy is low with poor coordination in warnings
		S-band radar lacks sufficient rainfall forecasting capability
		Poorly-gauged basins
	Risk Communication (Flood Disaster Prevention Capacity)	Residents lack awareness of flood risks
		No designated dam discharge danger zones; risk education is lacking
		Flood risks are poorly understood, with weak cooperation between states and cities
		Evacuation facilities face operational and quality issues
		Insufficient risk information during floods
	Risk Communication (Training for	Insufficient disaster management training for engineers
		Lack of flood response training for engineers
	Risk Communication (Public Training)	Few evacuation drills with resident participation
		Rescue plan excludes gender and special needs
		Residents unaware of available information sources

Source: JICA Expert Team

Table 6-7: 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

6.4.4 Details of Proposed Actions (Before, During and After):

6.4.4.1. Before Flood Disaster (Preparedness and Flood Disaster Prevention)

- **Flood Hazard Map**
  - **Distribute Flood Hazard Maps**: The flood hazard maps developed under the JICA Flood Control Master Plan should be distributed as visually simple, community-friendly tools that are easy for both the public and local officials to understand. This will help residents in vulnerable areas take personal precautions and support urban planning efforts.
  - **Flood Risk Assessment**: Update the flood risk assessment using the flood hazard maps, complemented by digital tools for data integration. This will provide more precise and detailed information on flood-prone areas at both city-wide and neighborhood levels, enhancing flood prediction and preparedness efforts before the flood occurs.
  - **Community Participation**: Organize community-level training and awareness programs to deepen the understanding of flood hazard maps and their role in disaster preparedness. Additionally, feedback collected from mobile surveys can be used to refine and improve the accuracy of these maps, incorporating local knowledge into the mapping process.
  - **Capacity Building**: Conduct workshops for local authorities and first responders to ensure they know how to effectively use the flood hazard maps in flood preparedness and response activities. This will enable timely and informed decision-making during flood events, improving overall disaster management.
- **Disaster Management Plan**
  - **Regular SOP Reviews and Updates**: Establish a system to routinely evaluate SOPs based on flood risk assessments, progress in the flood control master plan, and stakeholder feedback. The following is a list of missing SOPs or those needs renewal based on the JICA Flood Control Master Plan in Chennai: SOP for Flood Forecasting and Early Warning Systems, SOP for Flood Evacuation Planning and Implementation, SOP for Waterbody and Tanks Management to Optimize Flood Storage, SOP for Public Awareness and Community Engagement on Flood Preparedness, SOP for Residual Flood Risk Management and SOP for Flood Hazard Mitigation and Sustainable Urban Drainage Systems.
  - **Training and Capacity Building**: Conduct workshops and on-site training sessions for local authorities and first responders to familiarize them with updated SOPs and ensure their timely and effective implementation.
- **Disaster Management Center**

- **Centralized Coordination Hub**: Improve a unified command center for disaster management that integrates various agencies with clear communication protocols and centralized data sharing. Ensure that all agencies involved in disaster response have well-defined roles and responsibilities, reducing overlap and enhancing accountability.
- **Dedicated Emergency Communication Platform**: Create a shared digital platform for communication among all agencies involved in flood management, ensuring the real-time exchange of critical data before, during, and after floods. Implement a shared online platform or communication protocol for agencies to exchange information quickly and efficiently during a crisis.

➢ **Preventive Countermeasures**

- **Drainage System Maintenance**: Conduct routine inspections and maintenance of stormwater drains, ensuring they are free of debris and blockages. Develop simple tracking systems to document and schedule regular maintenance activities.
- **Flood Hazard Maps**: Utilize flood hazard maps to identify waterlogging-prone areas and guide targeted interventions for drainage system maintenance.
- **Inter- and Intra-Agency Coordination**: Establish a communication protocol supported by a shared online platform to ensure seamless coordination among TNWRD, GCC, and other municipalities, and disaster management agencies and other authorities to coordinate drainage infrastructure operation and maintenance.
- **Community Participation**: Collaborate with community leaders to enhance preparedness and ensure timely reporting of drainage issues and managing solid waste disposal before and during monsoon seasons. Conduct public awareness campaigns to educate residents about the importance of keeping drains clear and avoiding encroachments.
- **Post-Flood Damage Assessment**: Use basic GIS tools and ground surveys to document drainage system performance during floods and prioritize recovery and improvement measures.

➢ **Business Continuity Plan**

- **Capacity Building for Local Authorities**: Organize training programs for local government officials to improve their knowledge of resource management and disaster response procedures, ensuring that personnel are ready to act swiftly when flood warnings are issued.

➢ **Weather Observation and Accurate Forecast**

- **Improving Hydro-meteorological Observation Network**: Hydro-meteorological observations in Chennai's largely ungauged basins are crucial for effective flood management. Recent initiatives, including JICA's installation of automated water level recorders at 15 locations and efforts by the World Bank and local authorities like GCC to establish hourly rainfall gauging stations, mark significant progress. However, collecting basin-level data on hourly rainfall, water levels, and discharge from rivers and canals is vital for calibrating and verifying models, enhancing flood forecasting, and improving early warning systems.

- **Flood Control Room**: Establish a platform for integrating data from weather stations, sensors, and flood models, allowing agencies to respond more swiftly with better coordination during flood events.

➢ **Risk Communication (Prevention Capacity)**

- **Evacuation Planning and Drills**: Evacuation plans are based on flood hazard maps and raise awareness among the public through evacuation drills, local media, and public boards. This will help vulnerable populations in areas like Tondiarpet, Vyasarpadi, Perambur, Kodungaiyur, Purasaiwalkam, Egmore, Nungambakkam, T. Nagar, Saidapet, Velachery, Madipakkam, Sholinganallur, Pallikaranai, Tambara, Chromepet, Medavakka, Mugalivakkam, Porur, Madhanandapuram, and AmbatturVelachery better understand flood risks, evacuation routes, and the importance of hazard maps. Informing residents about how to use these maps can significantly aid in making evacuation decisions and identifying safe shelter locations.
- **Community Awareness Campaigns**: Launch public campaigns to raise awareness about the upgraded EWS, educating the public on how to use it and how to respond to flood alerts, especially in high-risk areas.

➢ **Risk Communication (Training for Officials)**

- **Training and Capacity Building**: Conduct workshops for local authorities and disaster management teams on using advanced flood forecasting tools and EWS to enable swift decision-making and effective disaster response.

➢ **Risk Communication (Public Training)**

- **Community Awareness and Engagement**: Collaborate with local community leaders to raise awareness about emergency preparedness and encourage residents to participate in resource management initiatives to ensure quicker distribution during crises.

6.4.4.2. During Flood Disaster (Emergency Response and Mitigation)

➢ **Flood Early Warning**

- **Proper Early Warning Systems (EWS)**: Develop and implement an advanced EWS using proper technologies for real-time data collection on rainfall, water levels, and drainage systems. This will help issue timely and accurate warnings, enabling better flood response.

- **Public Communication and Alerts**: Strengthen communication systems to ensure the public receives timely warnings via SMS, mobile apps, and community radios. The system should be accessible to vulnerable populations, particularly in flood-prone areas like Kotturpuram and T. Nagar.

➢ **Evacuation Order and Coordination**

- **Integrated Traffic Management**: Develop a traffic management plan with coordination between local traffic authorities and disaster response teams to ensure clear evacuation routes and efficient transportation of resources.
- **Pre-Flood Preparedness Coordination**: Enhance coordination during preparedness activities by setting up regular drills and ensuring all agencies have clear, actionable roles ahead of flood events.

➢ **Rescue and Relief**

- **Emergency Resource Pre-positioning**: Establish inventory management systems to ensure that essential resources (food, water, medical supplies) are pre-positioned in flood-prone areas. These resources should be strategically placed to reduce response time and enhance efficiency during emergencies.
- **Emergency Resource Distribution**: Efficient distribution of emergency resources is crucial for mitigating the impact of floods and ensuring timely relief to affected populations. In Chennai, delays in resource distribution during past floods, such as the 2020 floods in Tambaram and Mudichur, highlighted gaps in logistical coordination and infrastructure. Often, essential supplies like food, water, and medical kits were delayed due to inefficient supply chains, lack of coordination among agencies, and road blockages caused by flooding. To address these challenges, it is vital to establish a streamlined distribution network that ensures quick and equitable access to resources, especially in hard-to-reach areas. This can be achieved by setting up mobile distribution units, using GPS tracking for real-time monitoring, and improving coordination among local authorities, disaster response teams, and NGOs. Timely and organized resource distribution not only alleviates immediate suffering but also plays a critical role in reducing mortality and ensuring a swift recovery process during and after flood events.
- **Shelter Management**: To improve shelter management in future flood events, proposed actions include the establishment of a well-defined shelter management framework, ensuring that shelters are equipped with adequate resources, including food, water, medical aid, and hygiene supplies. Early identification of potential

shelter locations and pre-positioning of resources, such as tents and bedding, can help avoid overcrowding and ensure a smoother response. Moreover, community-based participation in shelter planning and management can ensure that the needs of vulnerable groups, such as the elderly, women, and children, are adequately addressed. Implementing a real-time monitoring system to track shelter occupancy and resources, along with clear guidelines for inter-agency coordination, will enhance the effectiveness of shelter management during floods.

6.4.4.3. After Flood Disaster (Emergency Support, Recovery, and Reconstruction)

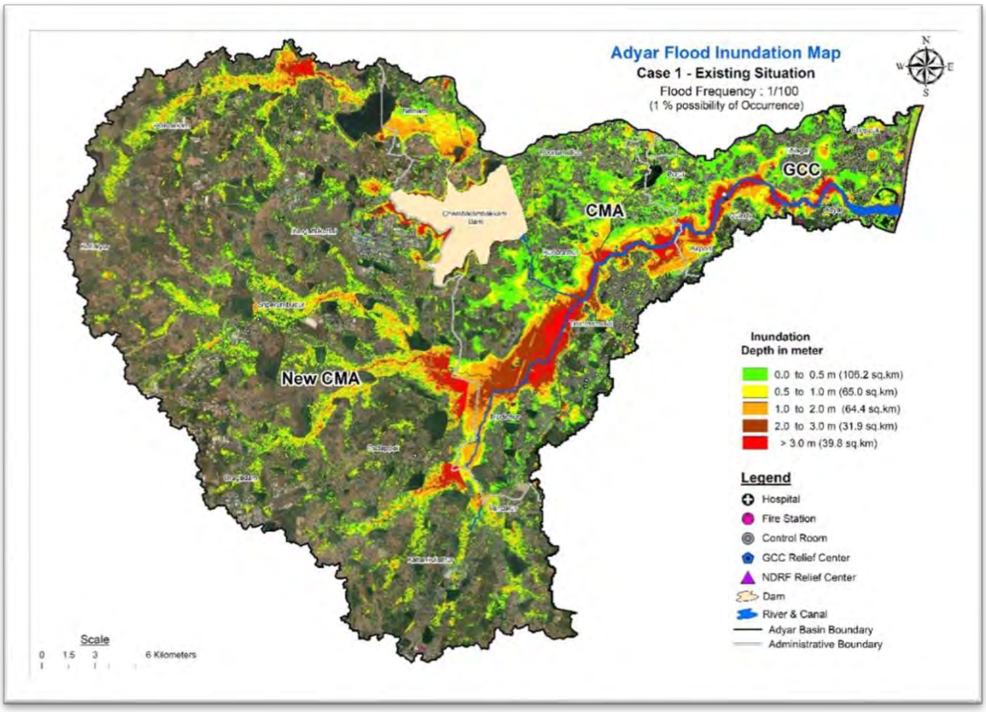
- **Supporting Affected People**
  - **Livelihood Protection**: To enhance livelihood protection in future flood events, proposed actions include the development of livelihood recovery frameworks that focus on the economic resilience of vulnerable communities. These frameworks should integrate financial support mechanisms, such as disaster relief funds and insurance schemes for small businesses and farmers, ensuring quick disbursement in the aftermath of floods. Additionally, improving early warning systems for floods can help businesses and farmers take preventive actions to protect their assets before disasters strike.
- **Urgent Infrastructure Reconstruction**
  - **Updating Emergency Dam Operation Protocols**: Chennai's emergency dam operation protocols must be updated to include actionable thresholds for water release, particularly in the event of heavy rainfall. Additionally, monitoring systems should be integrated into the operation compendiums of Chembarambakkam and Poondi dams to ensure that water release decisions are based on real-time data rather than delayed assessments.
  - **Developing New Operation Protocols for Selected Waterbodies and Tanks**: Developing new operation protocols for selected waterbodies and tanks is essential for enhancing Chennai's flood management capacity. As part of the JICA Flood Control Master Plan, the aim is to increase the flood storage capacity of various waterbodies and tanks, which will help manage excess water during heavy rainfall. These new protocols should include detailed procedures for monitoring water levels, setting predefined thresholds for water release, and ensuring timely and coordinated actions between local authorities, allowing for more responsive and proactive management of flood risks. Additionally, integrating these protocols with the broader flood control framework will help ensure that these waterbodies and tanks play a significant role in reducing flood impacts, minimizing damage, and protecting downstream areas.

- **Emergency Budget**
  - **Emergency Resource Distribution**: Efficient distribution of emergency resources is crucial for mitigating the impact of floods and ensuring timely relief to affected populations. In Chennai, delays in resource distribution during past floods, such as the 2020 floods in Tambaram and Mudichur, highlighted gaps in logistical coordination and infrastructure. Often, essential supplies like food, water, and medical kits were delayed due to inefficient supply chains, lack of coordination among agencies, and road blockages caused by flooding. To address these challenges, it is vital to establish a streamlined distribution network that ensures quick and equitable access to resources, especially in hard-to-reach areas. This can be achieved by setting up mobile distribution units, using GPS tracking for real-time monitoring, and improving coordination among local authorities, disaster response teams, and NGOs. Timely and organized resource distribution not only alleviates immediate suffering but also plays a critical role in reducing mortality and ensuring a swift recovery process during and after flood events.
- **Recovery and Reconstruction Plans**
  - **Post-Flood Damage Assessment**: Use basic GIS tools and ground surveys to document drainage system performance during floods and prioritize recovery and improvement measures.

6.5 Recommendations for the creation and publication of flood hazard maps

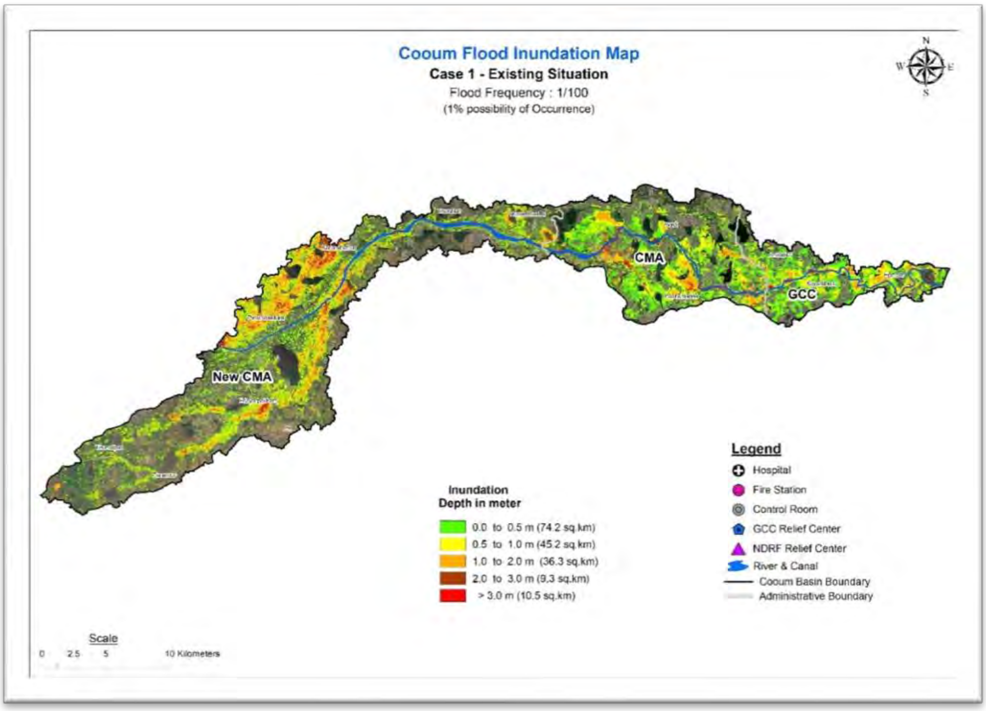
Flood hazard maps have been developed for different return periods, including 100 and 10 years, at various spatial scales, ranging from basin-level to ward-level flood hazard maps. The following figures display samples of the flood hazard maps for a 100-year return period flood at different spatial scales. 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 6-8** Provides suggested formats for the presentation of these flood hazard maps and recommendations for their distribution and utilization.



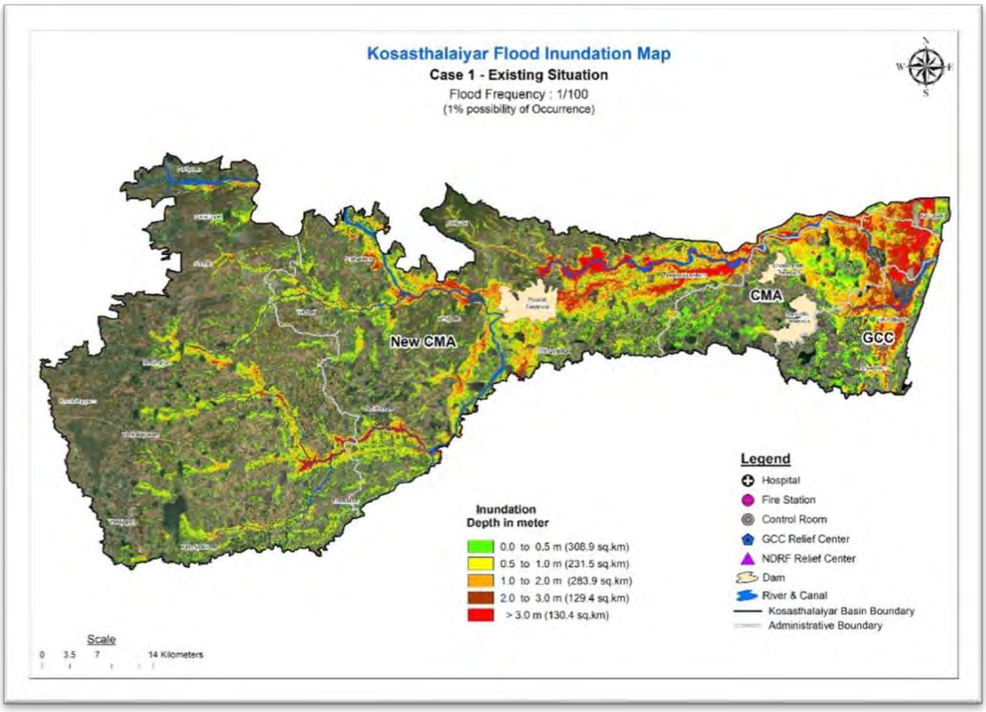
Source: JICA Expert Team

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



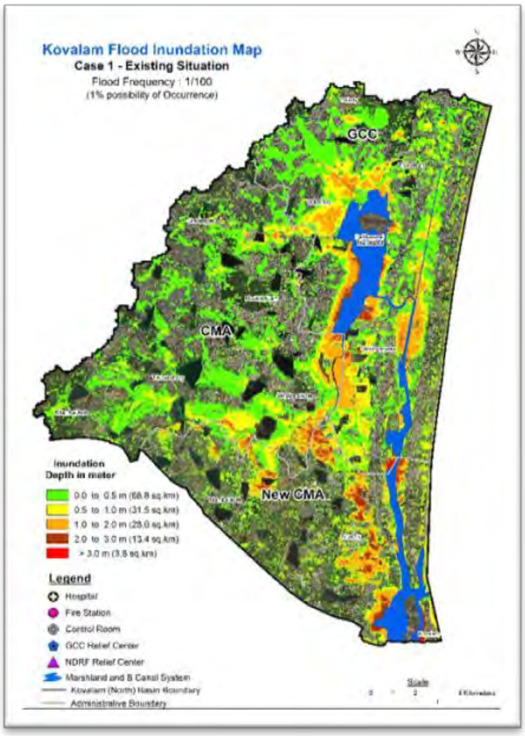
Source: JICA Expert Team

Figure 6-6: Flood Hazard Map for Cooum Basin (100-year Return Period)



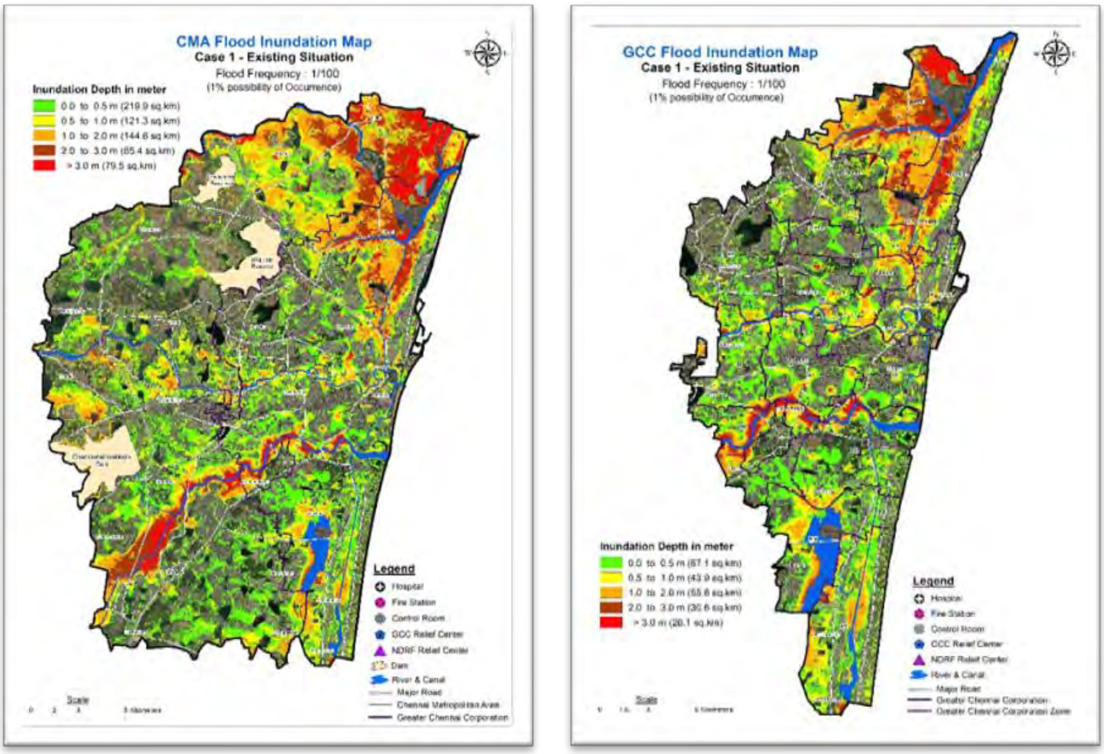
Source: JICA Expert Team

Figure 6-7: Flood Hazard Map for Kosasthalayar Basin (100-year Return Period)



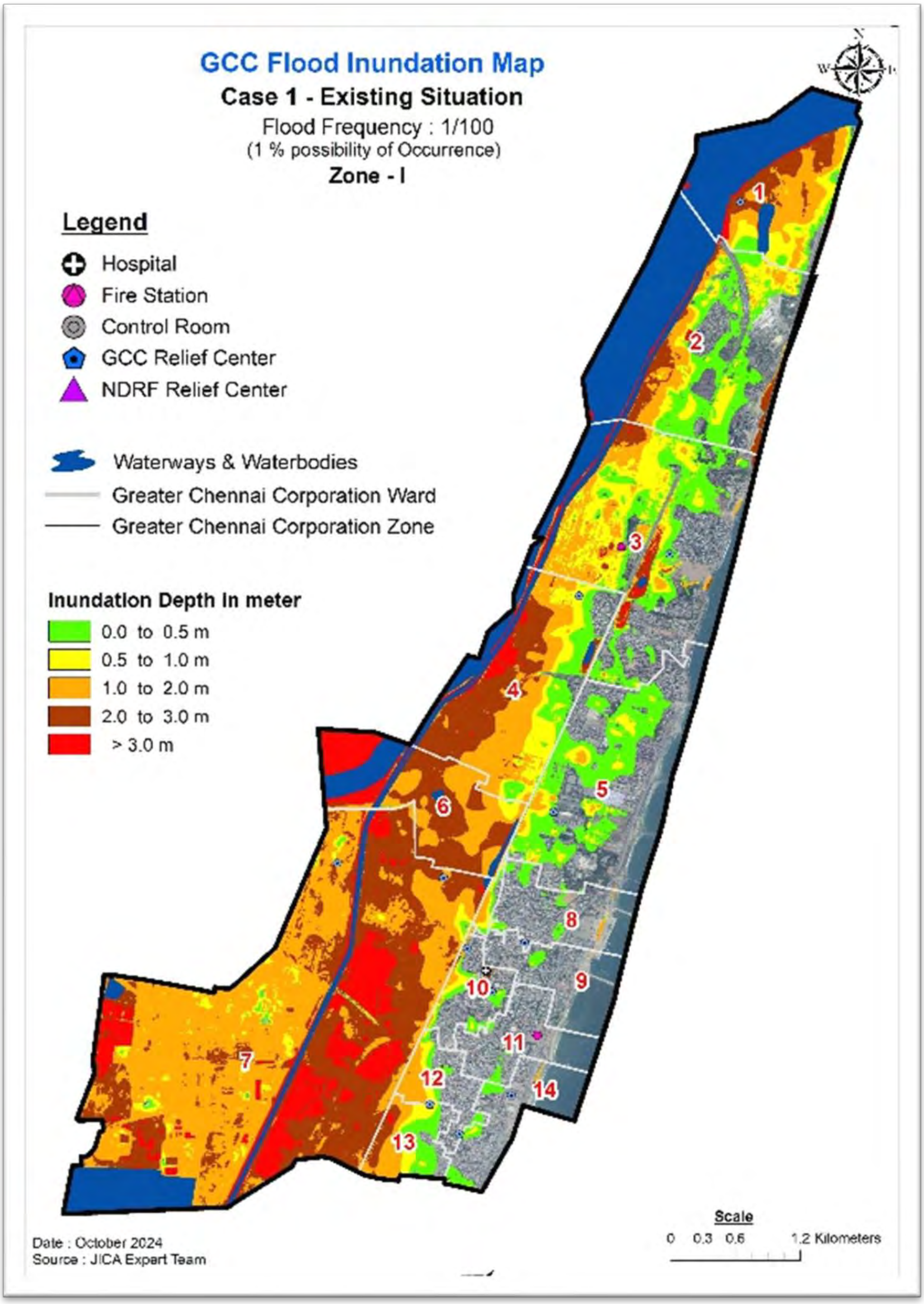
Source: JICA Expert Team

Figure 6-8: Flood Hazard Map for Kovalam Basin (100-year Return Period)



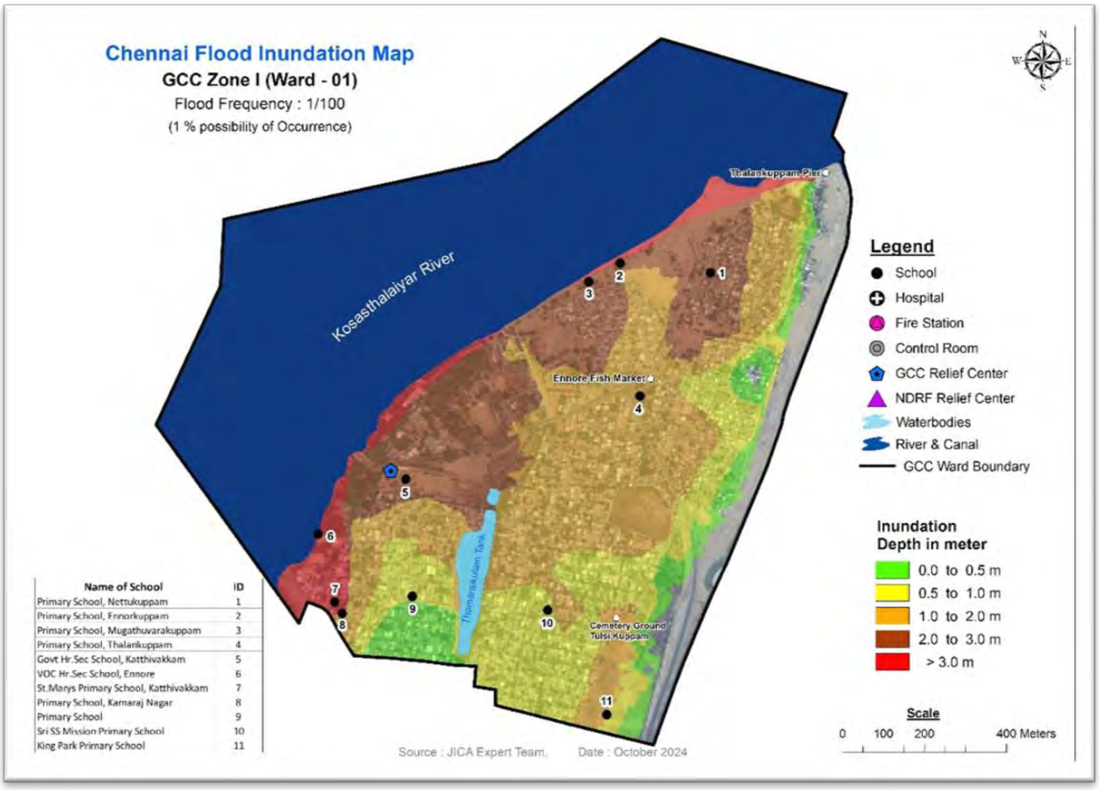
Source: JICA Expert Team

Figure 6-9: Flood Hazard Map for CMA and GCC (100-year Return Period)



Source: JICA Expert Team

Figure 6-10: Flood Hazard Map for Kovalam Basin (100-year Return Period)



Source: JICA Expert Team

Figure 6-11: Flood Hazard Map for Kovalam Basin (100-year Return Period)

Table 6-8: 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) • TNDRRA Emergency Control Room • TNWRD Basin Managers • 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) • TNDRRA Emergency Control Room • Annex to the 3rd Urban Development Master Plan • MAWS will distribute it to other major cities in TN as a pilot. • 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) • TNDRRA Emergency Control Room • GCC Disaster Management Control Room • TNUIFSL will be used as supplementary information for the World Bank flood forecasting project. • 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) • TNDRRA Emergency Control Room • GCC Disaster Management Control Room • 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) • TNDRRA Emergency Control Room • GCC Disaster Management Control Room • GCC ward offices will discuss it using ward community meetings.

Source: JICA Expert Team

6.6 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 Analysis

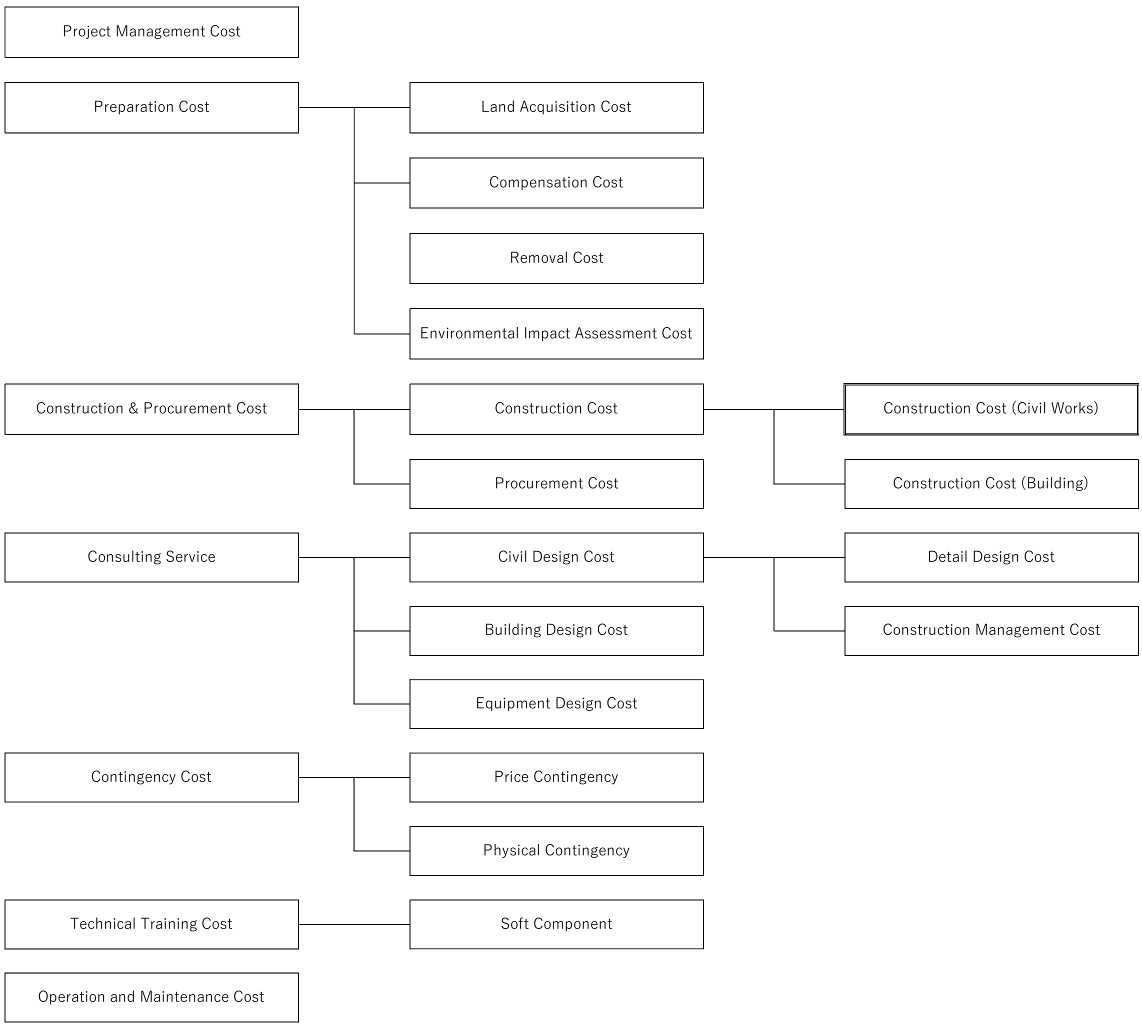
7.1 Preliminary Cost Estimation

7.1.1 Pre-condition

7.1.1.1. Summary of project cost estimation

The construction cost is estimated using the construction unit cost method, referring to the Manual for Design and Estimation of Preparatory Studies for Cooperation, Trial Version (JICA, March 2009). **Figure 7-1** show the composition of the construction cost.

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



Source: Manual for Design and Estimation of Preparatory Studies for Cooperation, Trial Version (JICA, March 2009) & JICA Expert Team

Figure 7-1: Target Basins and Administrative Boundaries

7.1.1.2. Date of implementation of cost estimation

The date for cost estimation shall be as of May 1, 2024.

7.1.1.3. Currency conversion

For currency conversion, the base foreign exchange rate (U.S. dollar) shall be 150 Japanese yen for every 1 U.S. dollar of the U.S. currency, as the figure to be applied during May 2024, as announced by the Bank of Japan.

The arbitrage foreign exchange rate (for Indian rupee) shall be US$0.0120 per Indian rupee as the market rate of the relevant currency against the U.S. currency during May 2024, as arbitrated by the reference foreign exchange rate.

Based on the above, 1 Indian rupee = (150 x 0.0120=) 1.80 yen.

7.1.1.4. Foreign and local currency

In this project, the main construction work is river widening and tank excavation, and local currency will be used. On the other hand, foreign currency may be used for the following parts of the project, such as some pump gate facilities and the Underground Bypass. In this project, the main construction types are river widening and tank excavation, and the local currency is used. On the other hand, the following parts of the project, such as some pump gate facilities and the Underground Bypass, are estimated using foreign currency.

- Cost of materials requiring high quality comparable to foreign products
- Cost of equipment requiring high quality comparable to foreign products

7.1.1.5. References

For the schematic design, the following guidelines and manuals that compile Indian Standard Codes (IS codes) related to each countermeasure are used as references.

<Design Standard Documents>

- Handbook for Anti-Erosion, Flood Protection & River Training Works
- Manual on Storm Water Drainage Systems

<Standard Cost Estimation Documents>

The following standard schedule of rates is used for the cost estimation.

- Government of Tamil Nadu Water Resources Department, Standard Schedule of Rates (WRD SOR) 2022-2023, with effect from 19.07.2022
- Government of Tamil Nadu Public Works Department, Standard Schedule of Rates (PWD SOR) 2022-2023, with effect from 19.07.2022
- Tamil Nadu Water Supply and Drainage Board, Standard Schedule of Rates (TWAD SOR) 2021-2022
- Greater Chennai Corporation, Standard Schedule of Rates (GCC SOR) 2021-2022

- Chennai Metropolitan Water Supply and Sewerage Board, Standard Schedule of Rates (CMWSSB SOR) 2021-2022
- In addition, the following manuals are used for the structure of the project cost estimation.
- Manual for Design and Estimation of Preparatory Survey for Cooperation (Trial Version), March 2009 Edition, Japan International Cooperation Agency (JICA)

The following Japanese standards are used for the construction cost, which accounts for the main part of the project cost, assuming international competitive bidding for the indirect construction cost (including on-site expenses) and the general cost concept.

- Ministry of Land, Infrastructure, Transport and Tourism's Estimating Standards for Civil Engineering Works, 2023 edition

7.1.1.6. Schedule of Rates

The major labor and material costs listed in the Schedule of Rates (SOR), which includes a table of unit costs, are listed in **Table 7-1** and **Table 7-2**, respectively. The unit prices for each type of work are discussed in the later part.

Table 7-1: Major Labor Rates

Sl No.	Sch. Item No.	Description of Labour	Unit	Basic Rate 2022-2023
2	-	Semi- Skilled Category	-	-
7	5	Boat Mazdoor	Day	611.00
8	25	Hammer Mazdoor	Day	586.00
9	26	Head Mazdoor for Well Sinking	Day	611.00
10	38	Mason for Stone Works-1 Class	Day	947.00
11	40	Mechanic-1 Class	Day	729.00
12	42	Mopla-1 Class	Day	727.00
13	43	Navagonies or Javali Man-1 Class	Day	611.00
14	46	Pile Driver	Day	672.00
3	-	Semi- Skilled Category	-	-
25	39C	Head Mazdoor	Day	639.00
31	69A	Mechanic-2 Class	Day	796.00
36	79	Mixer Operator (including concrete mixer)	Day	672.00
37	80	Mixer Driver	Day	639.00
38	99	Heavy Mazdoor	Day	

Source: PWD SOR 2022-2023, with effect from 19.07.2022

Table 7-2: Major Material Rates

Sl No.	Sch. Item No.	Description of Materials	Unit	Basic Rate 2022-2023
1	27	Rough Stone for masonry works (Hard Granite)	cum.	449.40
2	28	Rough Stone for revetment works	cum.	388.70
3	29	Jeddy size for revetment (Hard Granite)	cum.	428.00
4	29a	Cut Stone Pillar of size 0.15 x 0.15 x 2.1m	Each	165.60
5	30	From boulders without blasting for revetment	cum.	114.10
6	30a	From boulders without blasting for masonry	cum.	747.45
7	32	Course Rubble Stone for masonry works	cum.	358.50

Source: PWD SOR 2022-2023, with effect from 19.07.2022

7.1.2 Cost Estimation Methodology Overview

7.1.2.1. Method of estimating the items that make up the project cost

Project costs consist of project management costs, preparation costs, construction and procurement costs, design management costs, etc. Since construction and procurement costs account for the highest percentage, they are calculated as the main component. Preparation costs are calculated separately because they are mainly for site acquisition. The remaining cost items are calculated based on construction and procurement costs, taking into account that they are generally estimated in approximate cost at the master plan and preliminary design stages. The ratios are set based on the results of hearings from the counterparts. **Table 7-3** shows the estimation method for each cost item comprising the project cost.

Table 7-3: Method of Estimating Each Cost That Constitutes the Project Cost

Item	Sub Item	Description
Project Management Cost		Project management cost, which is the overhead cost of the project proponent, is set at 3% of the total amount of construction and procurement costs, design and supervision costs, and reserve costs.
Preparation Cost	Land Acquisition Cost	The area of land required to implement the measures is multiplied by the unit cost of land acquisition for each land category.
	Compensation Cost	Compensation costs incurred for resettlement, environmental protection, etc., due to land acquisition, etc., and for this project, relocation, and building costs are included in this category.
	Environmental Impact Assessment Cost	It is included in the project management expenses.
Construction & Procurement Cost		The total direct construction costs, indirect construction costs, and general and administrative costs are calculated by multiplying the direct construction unit cost shown in the Schedule of Rates by the quantity of work, including Goods & Service Tax (GST).
Consulting Service Cost	Design Cost	Design cost is set at 5% of construction and procurement cost.
	Construction Supervision Cost	Construction supervision cost is set at 3% of the construction and procurement cost.
Contingency Cost		Contingency cost is set at 3% of the total construction & procurement, and design & supervision cost.
Technical Training Cost		Technical training cost is to be included in project management cost.
Maintenance Cost		Annual maintenance dredging costs are set at 0.5% of construction and procurement costs. Annual maintenance dredging costs for each river are included separately.

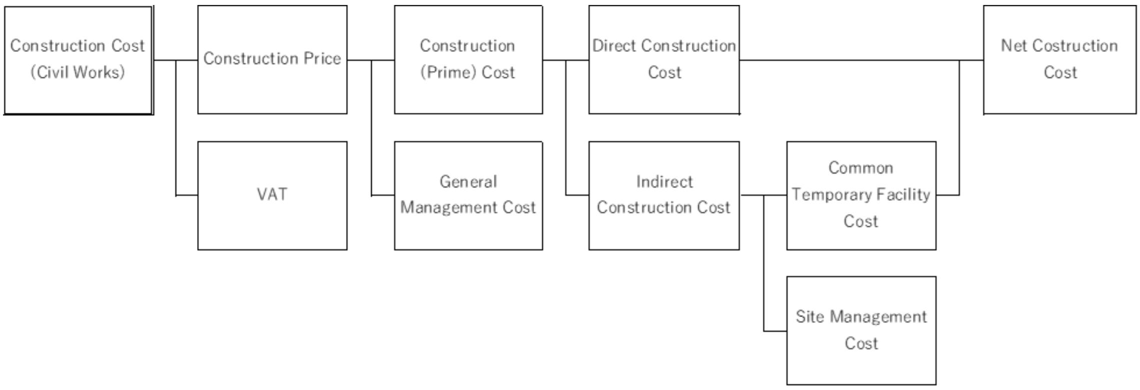
Source: Prepared by the JICA Expert Team based on the JICA Cooperation Preparatory Survey Design and Costing Manual (trial version) and counterpart interview results.

7.1.2.2. Preparation cost

The preparation cost consists of land acquisition cost and compensation cost. Based on the results of interviews with counterparts, the land acquisition cost and compensation cost shall be calculated based on the basic gazetted price published by the Tamil Nadu State Government. Details of the calculation process are described in the Appendix.

7.1.2.3. Construction and procurement cost

Construction and procurement costs consist of construction costs, consisting of civil and building construction costs, and equipment procurement costs. The main component of this project is the civil construction cost. The civil construction cost consists of the construction cost, which is the sum of direct construction cost and indirect construction cost (common temporary construction cost and site management cost), plus general and administrative costs. The composition of civil engineering and construction costs is shown in **Figure 7-2**



Source: Ministry of Land, Infrastructure, Transport and Tourism, Estimation Standard for Civil Engineering Works 2022 & JICA Expert Team

Figure 7-2: Composition of Construction and Procurement Costs (Construction Costs, example from Japan)

Each cost in the table is as follows.

Direct construction costs: Costs directly required for construction, consisting of labor, materials, and direct expenses (other costs directly related to the execution of the work).

- Indirect construction costs: Construction costs and expenses other than direct construction costs, which are classified into common temporary construction costs and site management costs
- Construction cost: Sum of direct construction cost and indirect construction cost.
- Common temporary construction costs: Costs for transportation, preparation, safety, technical management, etc.
- Site management cost: Expenses other than common temporary construction costs required to manage the construction work in the construction process.
- Administrative expenses, etc.: Expenses necessary for the ongoing operation of a company engaged in construction work, consisting of general and administrative expenses and additional profit.
- Construction price: Sum of construction cost and administrative expenses.

In India, on the other hand, there is no distinction between indirect construction costs and general administrative costs, and labor welfare funds, petty supervision fees, bidding expenses, and photography costs are regarded as indirect costs or other expenses and added to the direct construction costs that are calculated from the schedule of rate. The cost of transporting heavy equipment, concrete formwork support, and other temporary construction costs associated with the construction work are included in the unit price list. The table below shows an example of cost estimation from "Comprehensive Flood Management (TNPWD)," which is used as a reference material when estimating, and about 6% of the so-called direct construction cost is included.

Table 7-4: Example of Cost Estimation in Chennai, Comprehensive Flood Management （TNPWD）

Description of Item	Direct Cost x	Amount (INR)
Construction of Regulator Across River Adyar Near Somagalam Village		22,437,768
Civil cost (Direct Cost)		22,437,768
Provision for GST 12% (→ 18% as of May 2024)	12.0%	2,692,532
Provision for Labor Welfare fund	1.00%	224,378
Provision for Petty Supervision Charges Up to 2.5%	2.50%	560,944
Provision for Tender Publication charges	1.70%	382,000
Provision for photographic charges	0.01%	2,378
Provision for Documentation charges	0.45%	100,000
Other Cost	5.66%	1,269,700
Ground Total		26,400,000

Source: Prepared by JICA Expert Team based on Comprehensive Flood Management (TNPWD)

For reference, an example of the Japanese estimating method is shown in **Table 7-5** For comparison. In the case of river construction, costs other than direct construction costs are about 30%.

Table 7-5: Example of Japanese Cost Estimation (Indirect Cost, for reference)

Item	Descriptions	Rate (%)
Direct Cost	In the case of River Training Works	100.00
Subtotal		100.00
Indirect Cost		
Common Temporary Costs		
Accumulated portion	2% of direct construction cost (assumed)	2.00
Rate portion	4.77% of direct construction cost	4.77
Site Management Cost	（Direct Cost＋Common Temporary Cost） x 14.75%	15.75
General Administrative Cost	(Direct Cost + Indirect Cost (Common Temporary Cost + Site Management Cost)) x 7.41%	9.08
	The ratio of indirect construction costs and general administrative costs to direct construction costs	32.00

Source: Prepared by the JICA Expert Team based on the MLIT's Estimating Standards for Civil Engineering Works

For dredging, earthwork, block revetment, etc., which have already been implemented in India locally, the overhead and general administrative costs used in India are to be used.

On the other hand, since foreign companies are expected to participate in some pump gate facilities and Underground Bypass, etc., the concept of indirect costs and expenses assuming international bidding shall be adopted.

7.1.2.4. List of countermeasure works

In this Master Plan, countermeasure works are proposed in the Fluvial (River), Pluvial (Urban), Coastal Area, and River Mouth. A list of each countermeasure is shown in **Table 7-6** to **Table 7-8**.

Table 7-6: River Flood Control Countermeasures

Countermeasure	Basin	Works to be implemented
River Widening	Adyar	Phase1: Dredging of about 1 to 4 m Phase 2: Widening of 0 to 50 m and dredging of 3 to 6 m *Including replacement of bridges in the target section.
	Cooum	Phase1: Dredging of about 2 to 4 m Phase 2: Widening of 0 to 50 m and dredging of 2 to 4 m *Including replacement of bridges in the target section.
	Kosasthalaiyar	Phase1: Dredging of about 2 to 4 m Phase 2: Widening of 0 to 130 m and dredging of 2 to 4 m *Including replacement of bridges in the target section.
Improvement of Existing Tanks	Adyar	Improvement of the top 50 existing tanks by area in the basin. *Including construction of connecting channels between tanks.
	Cooum	Improvement of the top 31 existing tanks by area in the basin. *Including construction of connecting channels between tanks.
	Kosasthalaiyar	Improvement of the top 113 existing tanks by area in the basin. *Including construction of connecting channels between tanks.
New Tanks Construction	Kosasthalaiyar	Construction of 7 new tanks in the watershed.
Underground Bypass	Adyar	Construction of an underground bypass with a length of 12.3 km and an internal space of 113 m^2

Source: JICA Expert Team

Table 7-7: Urban Flood Control Countermeasures

Countermeasure	Basin/Sub Basin	Works to be implemented
Improvement of Existing Tanks	Adyar	The following is a New Development: Pammal (1 site)
	NBC	The following item is New Development Kodungaiyur (2 sites: K1, K2) Captain Cotton (2 sites: C1, C2) Otteri Nullah (5 sites: O1, O2, O3, O4, O5) North B Canal (1 site: North B Canal RB)
	Kovalam	The following is an Improvement of the Existing one: 61 sites

Countermeasure	Basin/Sub Basin	Works to be implemented
Improvement of Urban Drainage Channel	Adyar	The following is an Improvement of the Existing one: Nandanam Mambalam Chelammal Guindy MGR Kolapakkam Manapakkam Kundrathur Pammal
	Cooum	The following is an Improvement of the Existing one: Virugumbakkan Nungambakkam Trustpuram Padikuppam
	NBC	The following is an Improvement of the Existing one: NBC (0.0-8.1k and 8.1-17k) Captain Cotton (0.0-1.8k and 1.8-2.7k) Kodungaiyur (0.0-2.0k and 2.0-4.5k) Otteri Nullah (0.0-4.8k and 4.8-10.2k)
	CBC	The following is an Improvement of the Existing one: CBC (0.0-4.68k and 4.68-7.19k)
Gate and Pump	Adyar	Gate: 3 sites(Mambalam, Manapakkam, Kuradrathur)
	Cooum	Gate: 1 site(Vigrrambakkam Arunbakkam)
	Kovalam	Gate: 4 sites (B-canal/Adyar, B-canal / Muttukadu, Okkiyam Maduvu Diversion, B-canal-Bay of Bangal Bypass) Pump Station: 1 site
	NBC	Gate: 11 sites (Kodungaiyur (2 sites: K1, K2), Captain Cotton(2 sites: C1, C2), Otteri Nullah (5 sites: O1, O2, O3, O4, O5), North B Canal RB (Right bank side)、North B Canal/Cooum (Confluence) Pump Station: 8 sites(Kodungaiyur(2 sites: K1, K2), Captain Cotton(2 sites: C1, C2), Otteri Nullah(5 sites: O1, O2, O3, O4, O5) , North B Canal
	CBC	Gate: 1 site (Central B Canal / Cooum confluence)
Bypass	NBC	Otteri Nulla-Cooum Diversion Channel
	North Kovalam Basin	B-canal-Bay of Bengal Bypass

Source: JICA Expert Team

Table 7-8: Coastal Area and River Mouth Flood Control Plan

Works	Basin	Application
Training Wall	Muttukadu	Fill type, L=230m
Dredging	Muttukadu	30,000m (assuming L=20km for transportation)

Source: JICA Expert Team

7.1.2.5. Soils from construction

The project involves river channel improvement, improvement of existing tanks, and construction of bypass channels, all of which result in the excavated construction sediment. Although specific disposal sites have not yet been determined, excavated sediment from the three main rivers (Adyar, Cooum, and Kosasthalaiyar) and urban waterways is to be used as effectively as possible in projects such as road embankments to control flooding. On the other hand, sediment generated from the improvement of existing tanks is moved to undeveloped land in the area near the tanks for effective use in the development of residential land, etc.

7.1.3 River channelization

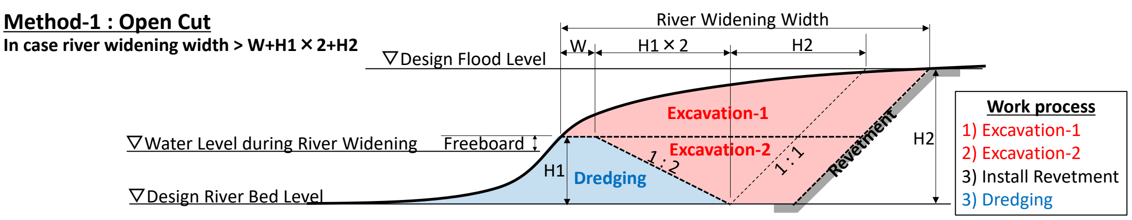
7.1.3.1. General

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 excavation work is to be implemented in the following phases.

Phase 1: Excavation work is to be implemented with little channel widening. The excavation volume is approximately 24,000,000 m^3.

Phase 2: River channel widening to be implemented. The excavation volume is approximately 50,000,000 m^3.

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 7-3: River Widening Construction Method

Table 7-9: Applicable Locations of Each Embankment Structure

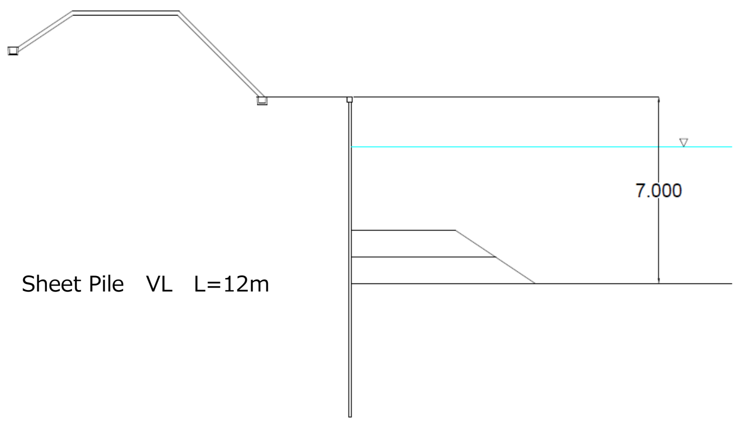
	River Section	Cross Section			Distance from Sea (m)			Slope Gradient	Design Depth (m)	Average depth of excavation(m) = Average riverbed height - Planned riverbed height	Widening width (m)	Average Flow Velocity (m/s)	Type of Revetment
Adyar	Adyar13	-2088	～	4678	0.00	～	4.54	20%	6	1.11	50	2.47	Concrete block
	Adyar_CA2	4794	～	5310	4.66	～	5.14		7	1.69	50	2.65	
	Adyar12	5512	～	7746	5.32	～	7.56		7	2.83	50	2.66	
	Adyar11	7800	～	8753	7.64	～	8.58	Straight wall	7	4.41	50	2.79	Steel sheet piles (VL type, L=12m)
	Adyar10	8873	～	9420	8.72	～	9.29		7	4.31	50	2.78	
	Adyar9	9466	～	11010	9.34	～	10.91		7	4.15	50	2.76	
	Adyar8	11078	～	12180	10.98	～	12.08		7	3.97	50	2.74	
	Adyar7	12270	～	16292	12.17	～	16.24	20%	7	4.79	50	2.64	Concrete block
	Adyar6	16380	～	17914	16.34	～	17.19		7	4.74	0	2.67	
	Adyar5	17294	～	22378	17.29	～	22.46		7	5.32	50	2.83	
	Adyar4	22445	～	24690	22.53	～	24.92		7	6.05	50	2.81	Steel sheet piles (VL type, L=12m)
	Adyar_CA	24766	～	24990	25.00	～	25.22		7	6.57	50	2.80	
	Adyar3	8446	～	12505	25.35	～	29.37		7	6.06	50	2.60	
	Adyar2	12525	～	17251	29.41	～	34.17	Straight wall	7	5.35	50	2.83	
	Adyar1	17300	～	20405	34.23	～	37.33	20%	5	3.28	50	2.45	Concrete block
	Adhanur	20520	～	26754	37.44	～	43.61		5	3.65	0	3.47	
Cooum	Cooum08	60	～	570	0.00	～	0.48	20%	4	1.87	0	2.08	Concrete block
	Cooum06	720	～	2400	0.66	～	2.34		6	1.80	0	2.52	

	River Section	Cross Section			Distance from Sea (m)			Slope Gradient	Design Depth (m)	Average depth of excavation(m) = Average riverbed height - Planned riverbed height	Widening width (m)	Average Flow Velocity (m/s)	Type of Revetment
	Cooum05	2460	～	6300	2.41	～	6.23		7	2.36	50	2.67	
	Cooum04	6390	～	9930	6.32	～	9.87		7	3.47	50	2.67	
	Cooum03	10020	～	15400.75	9.99	～	15.33		7	4.14	50	2.67	
	Cooum02	15421	～	16980	15.39	～	16.96		6	3.55	50	2.73	
	Cooum01_b	17402	～	19261	17.02	～	18.90		5	2.94	50	2.51	
		19321	～	25230	18.96	～	24.98		5	3.44	50	2.51	
		25290	～	26608	25.04	～	26.37		4	0.87	0	5.03	
		26668	～	34593	26.43	～	34.24		4	1.33	50	2.43	
		34652	～	41140	34.30	～	40.93						
	Cooum01	41349.39	～	43607.45	40.96	～	43.54						
		43864.28	～	63040.18	43.79	～	63.67						
		63207.3	～	73030.68	63.83	～	73.68						
Kosas	Kosas08	2	~	1727	0.00	~	1.74	20%	3	1.01	0	1.38	Sod
	Kosas07+KL 3	493	~	2198	1.85	~	3.58		4	2.46	0	1.66	
	Kosas06	185	~	489	3.63	~	4.18		5	2.60	50	1.85	
	KL2	274	~	3477	4.24	~	8.05		7	2.50	130	2.23	Concrete block
	Kosas03	102	~	1442	8.08	~	9.57		7	1.75	50	2.13	
	Kosas02+KL 1	160	~	4134	9.63	~	13.66		5	1.85	0	1.86	Sod
	Kosas01	152	~	18014	13.72	~	31.65						

	River Section	Cross Section			Distance from Sea (m)			Slope Gradient	Design Depth (m)	Average depth of excavation(m) = Average riverbed height - Planned riverbed height	Widening width (m)	Average Flow Velocity (m/s)	Type of Revetment
		18245	~	19517.5	31.87	~	32.86						
		20026	~	21670	33.37	~	35.37						
		22174	~	56344	35.52	~	69.26						
Redhills	Kosas05	199	~	2510	0.00	~	2.31	20%	3	2.29	0	0.50	Sod
	Redhills	151	~	475	2.54	~	2.88		3	1.71	0	0.50	
	Redhills	661	~	3669	3.06	~	6.07		3	0.96	180	0.50	
	Redhills	3723	~	9455	6.13	~	11.81		3	0.95	0	1.68	
	Redhills	9639	~	14311	11.98	~	16.64		3	0.98	0	2.05	Concrete block
	Redhills	14379	~	14780	16.71	~	17.10		3	0.81	0	4.60	

Source: JICA Expert Team

The standard cross-section of a steel sheet pile revetment as a straight wall is shown in **Figure 7-4**.



Source: JICA Expert Team

Figure 7-4: Standard Cross Section of Steel Sheet Pile Revetment

The average transport distance to the construction soil disposal site is estimated to be 10 km. The quantities for each type of work are shown in **Table 7-10**.

Table 7-10: Quantity of River Normalization Work

Works		Unit	Adyar River			Cooum River			Kosasthalaiyar River			Total
			Phase1	Phase2	Total	Phase1	Phase2	Total	Phase1	Phase2	Total	
Excavation		m^3	5,963,470	28,008,025	33,971,495	8,232,626	13,228,028	21,460,655	10,275,266	8,840,908	19,116,174	74,548,324
	Onshore excavation	m^3	1,192,694	11,285,606	12,478,300	6,586,101	10,582,423	17,168,524	8,220,213	7,072,726	15,292,939	44,939,763
	Underwater (dredging)	m^3	4,770,776	16,722,419	21,493,195	1,646,525	2,645,606	4,292,131	2,055,053	1,768,182	3,823,235	29,608,561
Transportation	L＝10km	m^3	5,963,470	28,008,025	33,971,495	8,232,626	13,228,028	21,460,655	10,275,266	8,840,908	19,116,174	74,548,324
Embankment	-	m^3	3,248,656	8,721,138	11,969,794	4,995,400	6,474,160	11,469,560	8,274,800	2,598,119	10,872,919	34,312,274
Revetment	-	m^2	324,866	872,114	1,196,979	499,540	647,416	1,146,956	827,480	259,812	1,087,292	3,431,227
(Breakdown)	Concrete block	m^2	234,293	685,548	919,841	499,540	647,416	1,146,956	283,340	182,160	465,500	2,532,297
	Steel sheet piles (VL type, L=12m)	m^2	90,573	186,566	277,138	0	0	0	0	0	0	277,138
	Sod	m^2	0	0	0	0	0	0	544,140	77,652	621,792	621,792

Source: JICA Expert Team

7.1.3.2. Unit rate

See the Appendix for details on the construction unit price used to estimate this countermeasure work.

7.1.3.3. Construction and procurement cost

The construction and procurement costs of the river widening planned for each river are shown in **Table 7-11**. 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 as described in 7.1.2.

Table 7-11: Construction and Procurement Cost for River Channelization

				Phase1		Phase2		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
	Bridge Reconstruction	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

				Phase1		Phase2		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
	Bridge Reconstruction	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

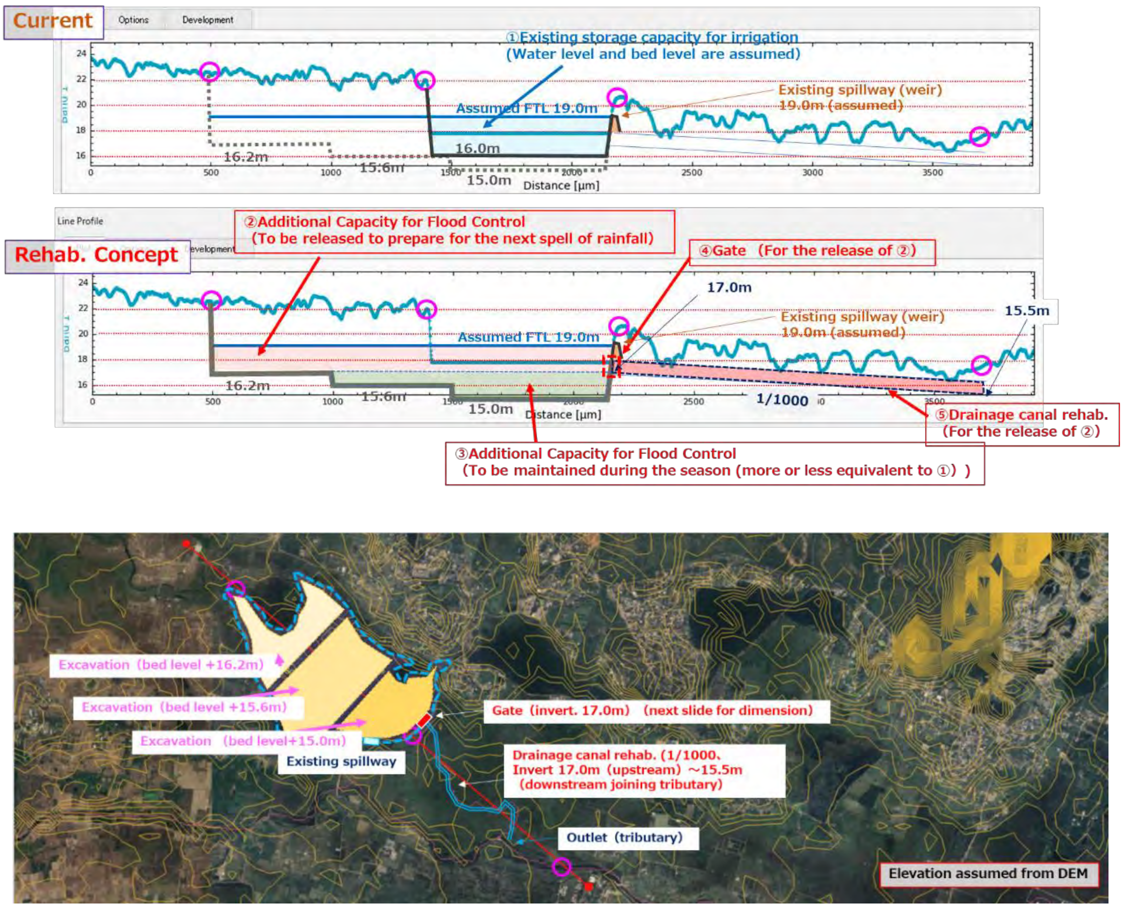
				Phase1		Phase2		Total	
River	Works	Unit Rate	Unit	Quantity	Total (INR)	Quantity	Total (INR)	Quantity	Total (INR)
	Civil Cost				3,544,543,746		3,211,481,227		6,756,024,973
	Provision for GST 18%				638,017,874		578,066,621		1,216,084,495
	Expense（6% of Civil Cost）				212,672,625		192,688,874		405,361,498
	Bridge Reconstruction	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

7.1.4 Improvement of Existing Tanks

7.1.4.1. General

Estimated costs are calculated for the construction and procurement costs of the existing tank improvements proposed in the Master Plan. The construction types are dredging, sediment excavation, revetment, and spillway. The average length of the construction soil disposal area is estimated to be 5 km, assuming that the land in the vicinity of each tank would be redeveloped with fill, reclamation of low-lying areas, and use for beach nourishment materials. A standard diagram of a typical tank to be improved is shown in **Figure 7-5**.



Source: JICA Expert Team

Figure 7-5: Typical Section of Tanks

Table 7-12: Quantity of Tanks Improvement Works

Works		Unit	Adyar Basin	Cooum Basin	Kosasthalaiyar Basin (Existing)	Kosasthalaiyar Basin (New)	Total
Excavation		m^3	290,495	246,136	557,048	22,250	1,115,930
Dredging		m^3	29,049	24,614	55,705	2,225	111,593
Transportation	L=5km	m^3	319,544	270,750	612,753	24,475	1,227,523
Embankment		m^3	29,049	24,614	55,705	2,225	111,593
Revetment		m^2	193,867	164,622	369,738	14,534	742,761
Discharge Channel		m^2	398,870	338,163	763,738	30,375	1,531,146
Gate A		LS	39	22	95	11	167
Gate B		LS	23	18	43	1	85

Source: JICA Expert Team

The tanks are to be equipped with gates and channels for the pre-release of water before flooding during the rainy season. The gates and channels are sized to meet the capacity of the tanks and are a combination of the following three sizes. (1.2mx1.2m) x 2 gates & B=3.0m H=2.0m, (1.2mx1.2m) x 1 gate & B=2.5m H=1.8m, (1.0mx1.0m) x 1 gate & B=2.0m H=1.6m where B is the bottom width and H is the height for a bare ditch channel. In the case of gravity retaining wall type and Cut & Cover type, B=6.0m & H=2.0m, B=5.0m & H=1.8m, and B=4.0m & H=1.6m, respectively. The length of the channel is 997 m.

Table 7-13 shows the size and number of gates and channels to be installed in the tanks.

Table 7-13: Size of Channel and Gate

(a) Adyar

Areas of tanks (km^2)	No.	Gate (size, No.)	Channel(size)
1) 0 to 0.49	23.00	(1.0m*1.0m) *1 gate	B=2.0m, H=1.6m, L=500m
2) 0.50 to 0.99	19.00	(1.2m*1.2m) *1 gate	B=2.5m, H=1.8m, L=500m
3) 1.00 to 1.99	4.00	(1.2m*1.2m) *2 gates	B=3.0m, H=2.0m, L=500m
4) 2.00 to 2.99	2.00	(1.2m*1.2m) *4 gates	B=3.0m, H=2.0m, L=1000m
5) 3.00 to 3.99	1.00	(1.2m*1.2m) *6 gates	B=3.0m, H=2.0m, L=1500m
6) 4.00 to 4.99	0.00	(1.2m*1.2m) *8 gates	B=3.0m, H=2.0m, L=2000m
7) 5.00 to 5.99	1.00	(1.2m*1.2m) *10 gates	B=3.0m, H=2.0m, L=2500m

Source: JICA Expert Team

(b) Cooum

Areas of tanks (km^2)	No.	Gate (size, No.)	Channel(size)
1) 0 to 0.49	18.00	(1.0m*1.0m) *1 gate	B=2.0m, H=1.6m, L=500m
2) 0.50 to 0.99	6.00	(1.2m*1.2m) *1 gate	B=2.5m, H=1.8m, L=500m
3) 1.00 to 1.99	6.00	(1.2m*1.2m) *2 gates	B=3.0m, H=2.0m, L=500m
4) 2.00 to 2.99	0.00	(1.2m*1.2m) *4 gates	B=3.0m, H=2.0m, L=1000m
5) 3.00 to 3.99	0.00	(1.2m*1.2m) *6 gates	B=3.0m, H=2.0m, L=1500m
6) 4.00 to 4.99	1.00	(1.2m*1.2m) *8 gates	B=3.0m, H=2.0m, L=2000m
7) 5.00 to 5.99	0.00	(1.2m*1.2m) *10 gates	B=3.0m, H=2.0m, L=2500m

Source: JICA Expert Team

(c) Kosasthalaiyar (Existing)

Areas of tanks (km^2)	No.	Gate (size, No.)	Channel(size)
1) 0 to 0.49	43.00	(1.0m*1.0m) *1 gate	B=2.0m, H=1.6m, L=500m
2) 0.50 to 0.99	45.00	(1.2m*1.2m) *1 gate	B=2.5m, H=1.8m, L=500m
3) 1.00 to 1.99	22.00	(1.2m*1.2m) *2 gates	B=3.0m, H=2.0m, L=500m
4) 2.00 to 2.99	3.00	(1.2m*1.2m) *4 gates	B=3.0m, H=2.0m, L=1000m
5) 3.00 to 3.99	0.00	(1.2m*1.2m) *6 gates	B=3.0m, H=2.0m, L=1500m
6) 4.00 to 4.99	0.00	(1.2m*1.2m) *8 gates	B=3.0m, H=2.0m, L=2000m
7) 5.00 to 5.99	0.00	(1.2m*1.2m) *10 gates	B=3.0m, H=2.0m, L=2500m

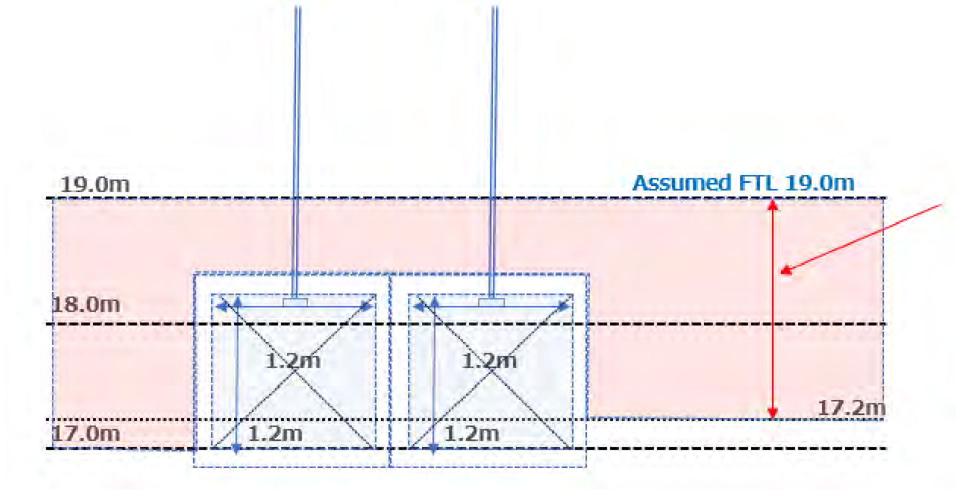
Source: JICA Expert Team

(d) Kosasthalaiyar (New)

Areas of tanks (km^2)	No.	Gate (size, No.)	Channel(size)
1) 0 to 0.49	1.00	(1.0m*1.0m) *1 gate	B=2.0m, H=1.6m, L=500m
2) 0.50 to 0.99	3.00	(1.2m*1.2m) *1 gate	B=2.5m, H=1.8m, L=500m
3) 1.00 to 1.99	0.00	(1.2m*1.2m) *2 gates	B=3.0m, H=2.0m, L=500m
4) 2.00 to 2.99	2.00	(1.2m*1.2m) *4 gates	B=3.0m, H=2.0m, L=1000m
5) 3.00 to 3.99	0.00	(1.2m*1.2m) *6 gates	B=3.0m, H=2.0m, L=1500m
6) 4.00 to 4.99	1.00	(1.2m*1.2m) *8 gates	B=3.0m, H=2.0m, L=2000m
7) 5.00 to 5.99	0.00	(1.2m*1.2m) *10 gates	B=3.0m, H=2.0m, L=2500m

Source: JICA Expert Team

A standard drawing of the gate is shown in **Figure 7-6** (type of 5) shown in the table).

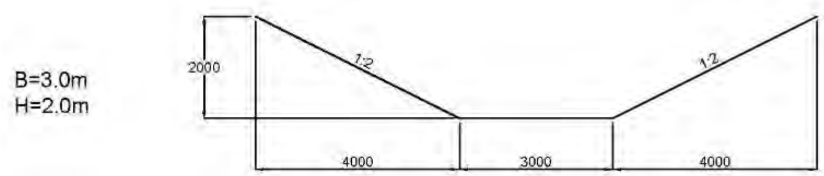


Source: JICA Expert Team

Figure 7-6: Standard Cross Section of Gate in Channel

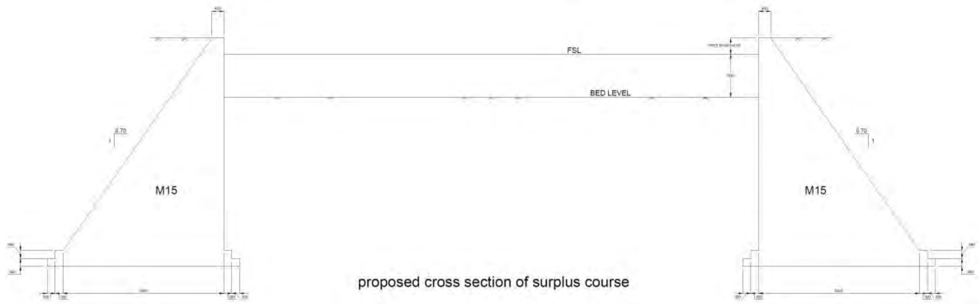
The construction of the channels is based on excavated channels. Cut & Cover or gravity retaining walls are to be used near gates and road crossings where there are site constraints. These structural types are described in "Comprehensive Flood Management, Adyar, Lower Palar, Kovalam.... Sub Basins, TNPWD WRD" (e.g., 14.3.9 Formation of Surplus Course Partly as Open Drain Retaining Wall and Partly as Cut a Cover from Nandhivaram Tank and Chapakkam Tank Surplus Course to Mannivakkam Tank in Oingalpattu Taluk of Kancheepuram District).

Examples of standard cross-sections in each of these compositional types are shown in **Figure 7-7** through **Figure 7-9**. See the Appendix for standard cross sections for each size (3 structures x 3 sizes) (9 cross sections in total).



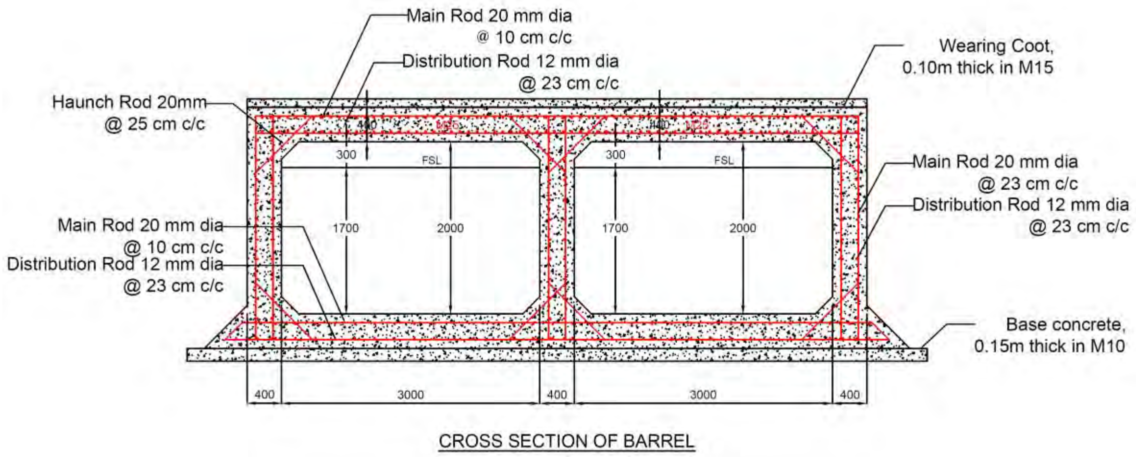
Source: JICA Expert Team

Figure 7-7: Standard Cross Section: Open Excavated Channel (B=3.0m, H=2.0m)



Source: JICA Expert Team

Figure 7-8: Standard Cross Section: Gravity Retaining Wall Type (B=6.0m, H=2.0m)



Source: Comprehensive Flood Management, Adayar, Lower Palar, Kovalam... Sub Basins, TNPWD WRD

Figure 7-9: Standard Cross Section: Cut & Cover (B=6.0m, H=2.0m)

Of the 997 m channel length here, 499 m is considered as an open channel, 249 m as Cut & Cover, and 249 m as a gravity-type retaining wall. The calculation process and results of the construction quantities are shown in the Appendix.

7.1.4.2. Unit rate

See the Appendix for details on the construction unit price used to estimate this countermeasure work.

7.1.4.3. Construction and procurement cost

The construction and procurement costs of the planned tanks for each river basin are shown in **Table 7-14**.

Table 7-14: Construction Cost for Tank Improvement

(a) Adyar Basin

River	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

River	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)

River	Works	Unit	Quantity	Unit Rate (INR)	Total (INR)		
Kosasthalaiyar Basin (Existing)	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) & Total

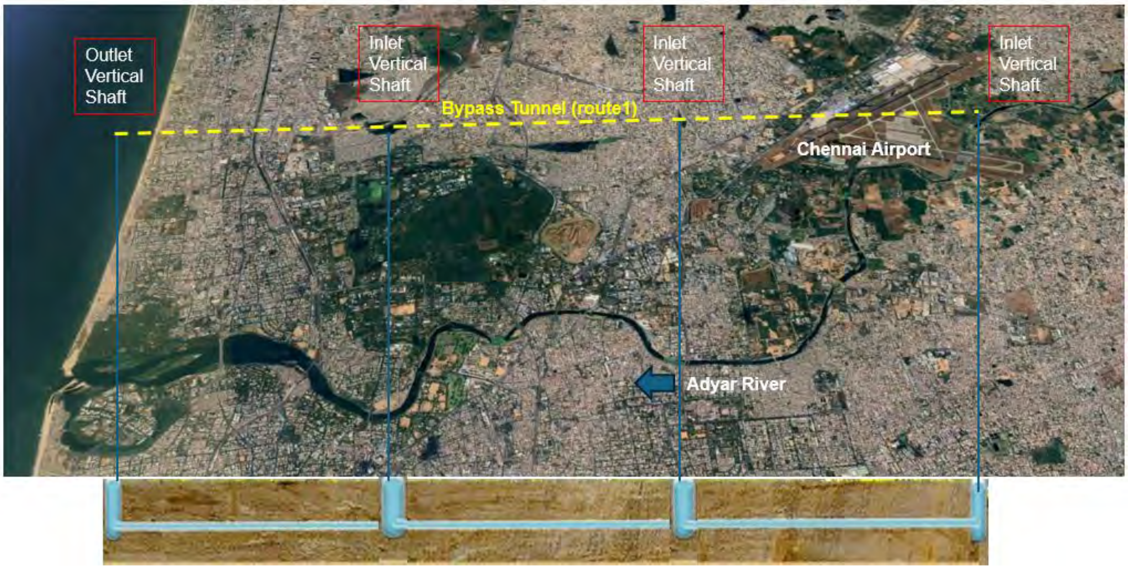
River	Works	Unit	Quantity	Unit Rate (INR)	Total (INR)		
Kosasthalaiyar River (New)	Excavation	m^3	22,250	51.45	1,144,763		
	Dredging	m^3	2,225	485	1,079,125		
	Transportation	m^3	24,475	57.26	1,401,439		
	Embankment	m^3	2,225	56.5	125,713		
	Revetment	m^2	14,534	54.95	798,668		
	Discharge Channel	LS	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 River 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

7.1.5 Underground Bypass

7.1.5.1. General

The Underground Bypass proposed in the Master Plan has specifications of 12.3 km in length and 113.1 m^2 of internal cross-sectional area. A summary is given below.



Source: JICA Expert Team

Figure 7-10: Outline of Underground Bypass

7.1.5.2. Construction unit cost

See the Appendix for details on the construction unit price used to estimate this countermeasure work.

7.1.5.3. Construction and procurement cost

Construction and procurement costs are as shown below.

Table 7-15: Construction and Procurement Cost for Underground Bypass

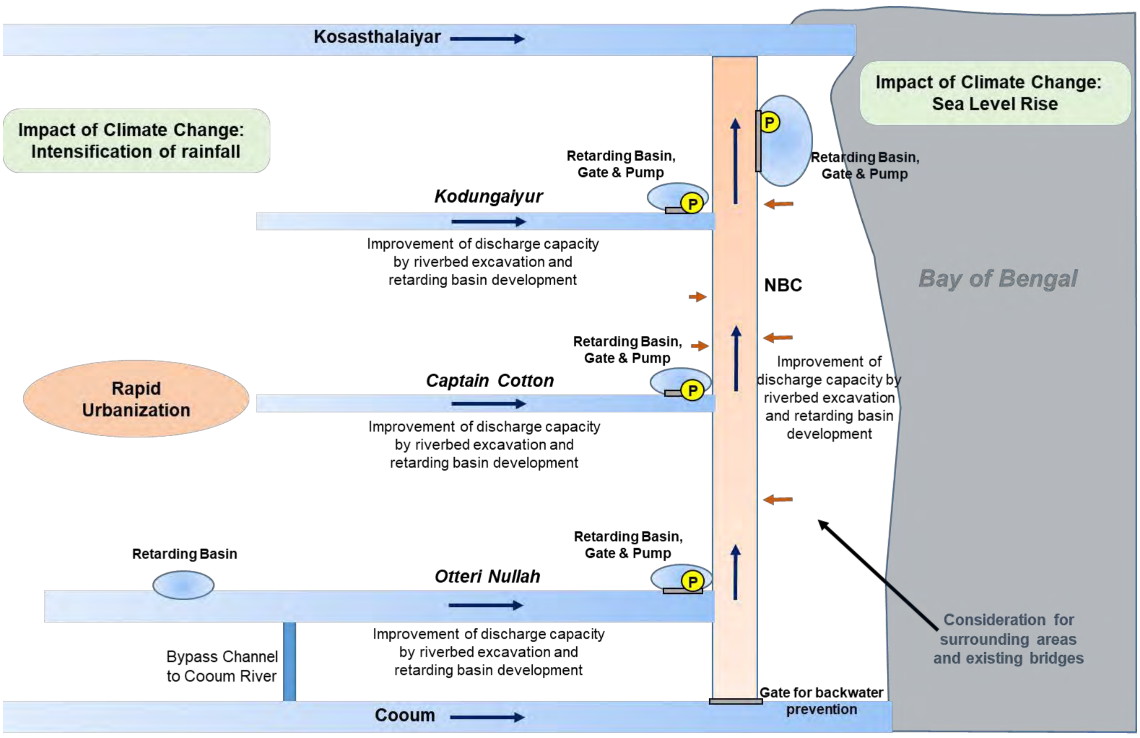
Extension	m	12,300
(Underground reservoir part)	m	4,000
Cross-sectional area	m^2	113
Unit Rate (INR)	INR/m^3	57,315
Phase1 (INR)	INR	**79,730,737,566**
Phase2 (INR)	INR	**0**
Total (INR)	INR	**79,730,737,566**

Source: JICA Expert Team

7.1.6 Improvement of Existing Urban Tanks

7.1.6.1. 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 in **Figure 7-11**. The quantities of the main types of works are shown in **Table 7-16**.



Source: JICA Expert Team

Figure 7-11: Location and the Outline of Countermeasures of North B Canal and Its Connecting Drainage (Including existing tanks to be improved)

Table 7-16: Quantity of Urban Tanks Improvement Works

			NBC										Kovalam	Total
			Kodungaiyur		Captain Cotton		Otteri Nullah					North B Canal		
			K1	K2	C1	C2	O1	O2	O3	O4	O5	North B Canal RB	61 locations	
			Existing	Existing	Existing	Existing	Existing	Existing	Existing	Existing	Existing	Existing	Existing	
Excavation		m^3	360,000	120,000	400,000	360,000	320,000	160,000	400,000	240,000	490,000	1,200,000	82,350	4,132,350
Dredging		m^3												0
Transportation	L = 5km	m^3	360,000	120,000	400,000	360,000	320,000	160,000	400,000	240,000	490,000	1,200,000	0	4,050,000
Embankment		m^3	36,000	12,000	40,000	36,000	32,000	16,000	40,000	24,000	49,000	120,000	0	405,000
Revetment		m^2	2,400	1,386	2,400	2,530	2,263	1,600	2,530	1,960	2,800	4,382	0	24,249
Concrete Placement		m^3	360	120	400	360	320	160	400	240	490	1,200	51,240	55,290

Source: JICA Expert Team

7.1.6.2. Construction unit rate

See the Appendix for details on the construction unit price used to estimate this countermeasure work.

7.1.6.3. Construction and procurement cost

Construction costs for the existing tank improvements are shown in **Table 7-17**.

Table 7-17: Construction Cost of Existing Tanks 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

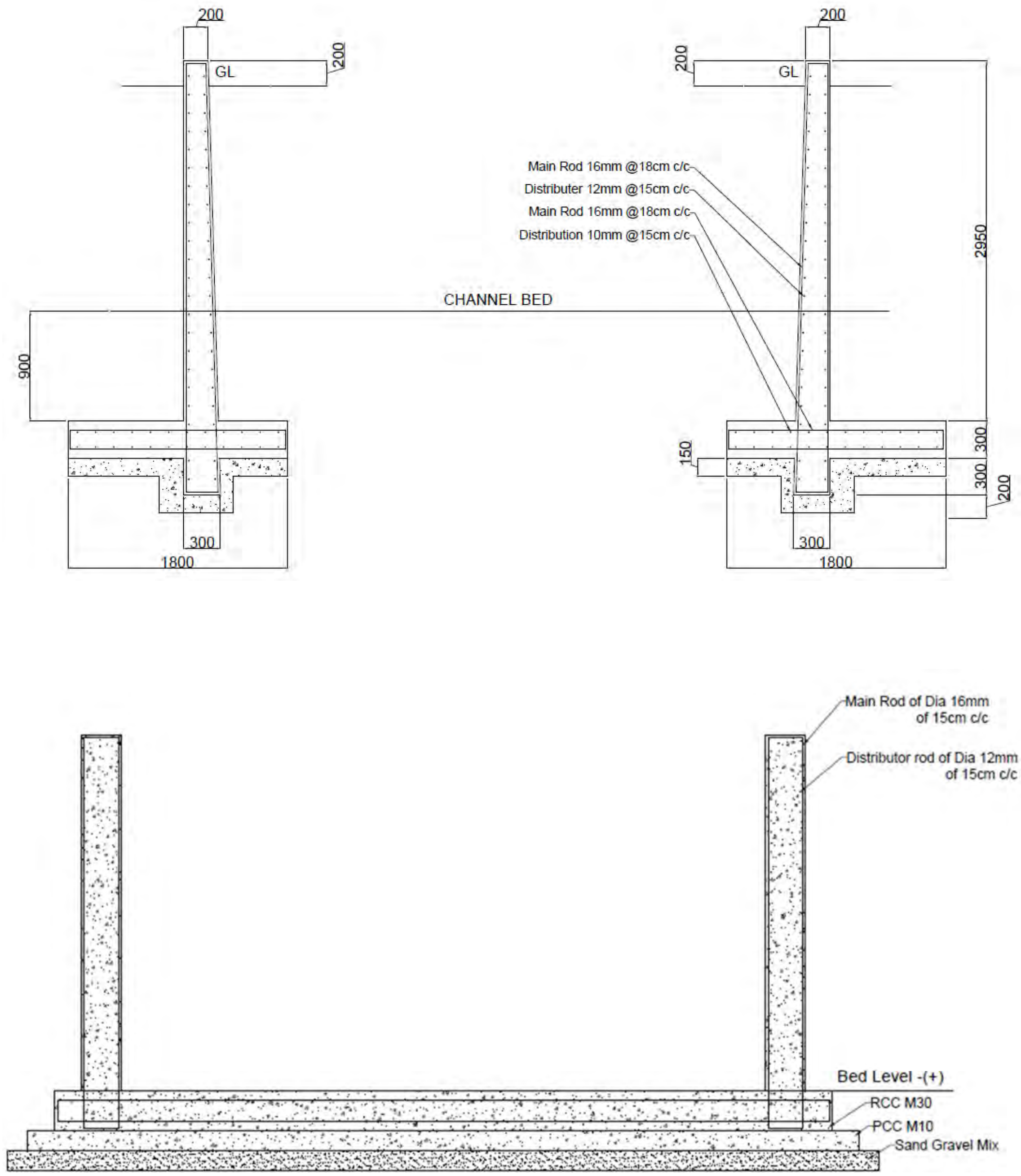
7.1.7 Improvement of Urban Drainage Channel

7.1.7.1. General

The Urban drainage channel is primarily constructed of two types of concrete structures as follows.

(1) Concrete wall type (retaining wall)

Concrete retaining wall channel in urban areas is planned for the connecting drainage improvement for the project. A standard cross-sectional view is shown in **Figure 7-12**.

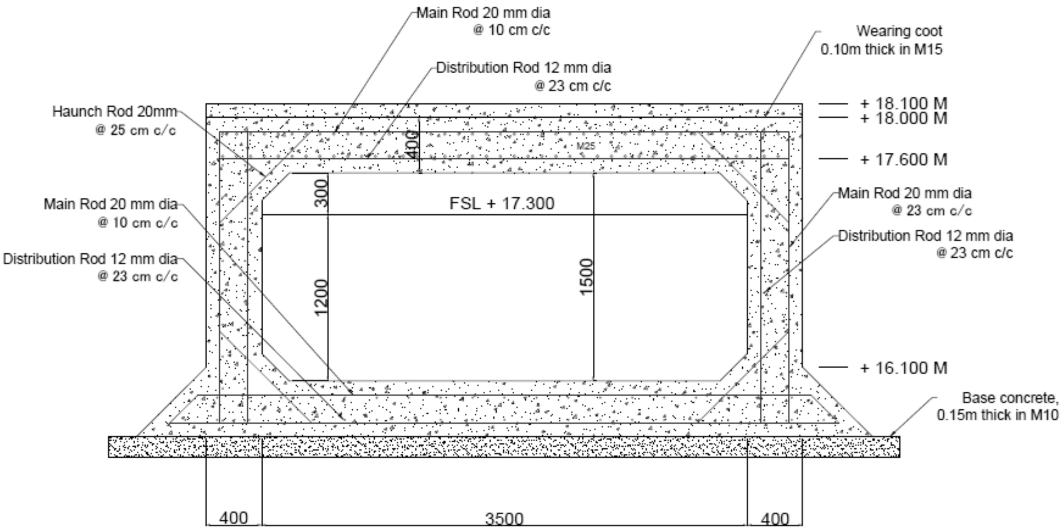


Source: Project example: Improvements to Gerugambakkam Channel in Gerugambakkam Village in Kundrathur Taluk of Kancheepuram, TNPWD

Figure 7-12: Standard Section of Concrete Wall Type

(2) Cut & Cover

Box culvert made of reinforced concrete and placed underground. The upper part of the structure can be used for traffic, etc. Based on experience, Cut & Cover channels have been applied to channels with a flow rate of approximately 40 m^3/s and a width of 10 m or less. A standard cross-sectional view is shown in **Figure 7-13**.



Source： Comprehensive Flood Management, Adayar, Lower Palar, Kovalam...Sub Basins, TNPWD WRD

Figure 7-13: Typical Section of Cut & Cover

Table 7-18: Urban Channel Construction Quantity

		Adyar							NBC								CBC		Adyar		Cooum				Total
		Adyar							NBC		Captain Cotton		Kodungaiyur		Otteri Nullah		CBC		Kundrathur	Pammal	Virugumbakkan	Nungambakkam	Trustpuram	Padikuppam	
		Nandanam	Iambalam	Chelammal	Guindy	MGR	Kolapakkam	Manapakkam	0.0-8.1k	8.1-17k	0.0-1.8k	1.8-2.7k	0.0-2.0k	2.0-4.5k	0.0-4.8k	4.8-10.2k	0.0-4.68k	.68-7.19k	Existing	Existing					
Excavation	m³	34,932	215,081	9,293	47,589	88,525	172,358	729,479	1,717,281	1,212,652	81,131	45,790	84,552	100,835	365,755	396,333	522,143	292,330	31,800	50,500	399,492	45,504	66,563	124,297	,834,21
Dredging	m³				0	0		0												0					0
Transport L = 5 km	m³	34,932	215,081	9,293	0	0	172,358	0	1,717,281	1,212,652	81,131	45,790	84,552	100,835	365,755	396,333	522,143	292,330	31,800	0	399,492	45,504	66,563	124,297	,918,12
Embankment	m³		0	3,797	0	0		0												0					3,797
Revetment	m²	7,723	51,227		16,075	25,157	33,629	118,436	265,397	336,643	21,350	11,120	31,732	52,230	95,899	160,855	226,264	119,679	2,792	4,984	142,451	9,592	20,979	16,748	,770,96
Concrete	m³	5,565	33,538	1,426	7,211	9,571	13,212	49,944	67,716	78,409	6,898	3,521	8,880	12,760	23,923	42,336	56,160	30,120	167	167	46,868	7,072	8,841	12,422	526,72
Cut&Cover Q = 86 m³/s	m																			90					90

Source: JICA Expert Team

7.1.7.2. Unit rate

See the Appendix for details on the construction unit price used to estimate this countermeasure work.

7.1.7.3. Construction and procurement cost

Construction cost for the Connecting Drainage (Micro-Drainage) Improvement is shown in the **Table 7-19**.

Table 7-19: 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

7.1.8 Gate and Pump

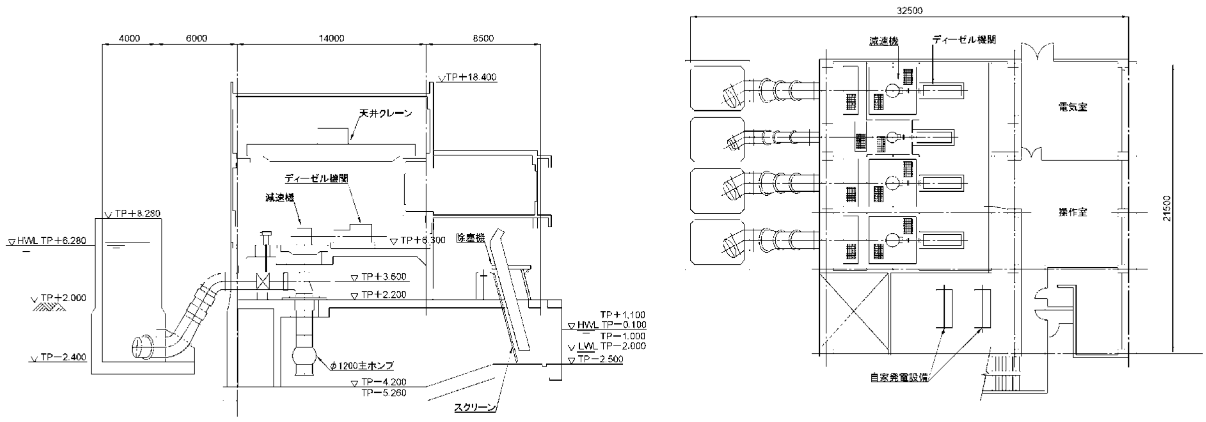
7.1.8.1. General

The planned gates and pumps are listed in **Table 7-20** and a standard diagram of the storm drain pump station is shown in **Figure 7-14**. See Figure X for a location map of the tributaries in the North Buckingham Canal.

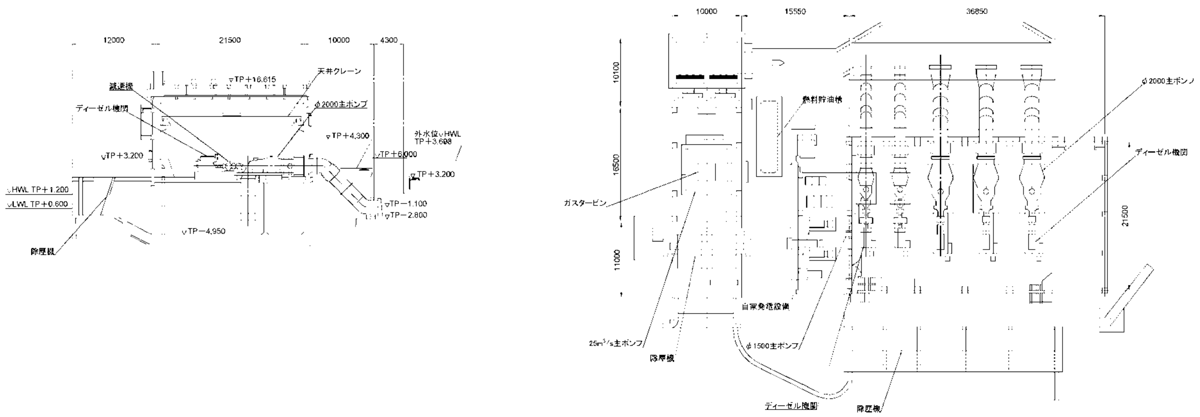
Table 7-20: Gate and Pump

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



(a) Small-scale drainage pumping stations (estimated planned drainage volume: 7.68 m^3/s or less)



(b) Medium-scale drainage pump stations (estimated planned drainage volume: 60 m^3/s or less)

Source: JICA Expert Team

Source: JICA Expert Team

Figure 7-14: Standard Drawing of Drainage Pump Stations

Source: JICA Expert Team

Figure 7-15: Location Map of Tributary Rivers in the North Buckingham Canal

7.1.8.2. Unit rate

See the Appendix for details on the construction unit price used to estimate this countermeasure work.

7.1.8.3. Construction and procurement cost

The construction cost of the gate pump is shown in **Table 7-21**.

Table 7-21: 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)
Adyar								
1	Mambalam	4.71	15.5	73	58,994,205	0	0	58,994,205
2	Manapakkam	8.45	10		3,315,789	0	0	3,315,789
3	Kuradrathur	4.56	8	36	22,021,197	0	0	22,021,197
	Sub Total				84,331,192		0	84,331,192
Cooum								
1	Vigrrambakkam Arunbakkam	7.54	15		83,625,000	0	0	83,625,000
	Sub Total				83,625,000		0	83,625,000
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
	Sub Total				1,505,768,055		886,821,790	2,392,589,846
Kovalam								
1	Inland water exclusion					1.40625	83,748,366	83,748,366
	Sub Total				0		83,748,366	83,748,366
NBC/CBC								
1	K1	1.7	2	3	4,289,621	2	98,842,120	103,131,741
2	K2	1.7	2	3	4,289,621	1	73,421,060	77,710,681
3	C1	1.1	2	2	3,927,853	0.5	60,710,530	64,638,383
4	C2	1.1	2	2	3,927,853	0.5	60,710,530	64,638,383

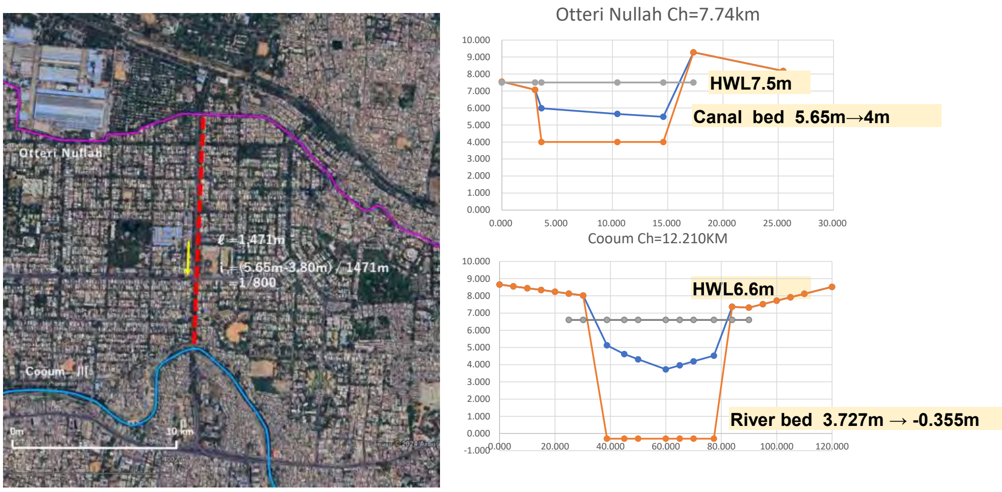
Sl. No.	Canal	Gate St H m	Gate W m	Gate S M2	Amount 1) Gate (INR)	Pump Q m^3/s	Amount 2) Pump st. (INR)	Amount 1)+2) (INR)
5	O1	2.3	2	5	4,671,095		48,000,000	52,671,095
6	O2	2.3	2	5	4,671,095		48,000,000	52,671,095
7	O3	1	2	2	3,869,474	2	98,842,120	102,711,594
8	O4	1	2	2	3,869,474	2	98,842,120	102,711,594
9	O5	1	2	2	3,869,474	2	98,842,120	102,711,594
10	North B Canal RB	3.6	2	7	5,565,221	2	98,842,120	104,407,341
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
	Total	INR			**1,752,853,069**		**1,755,622,876**	**3,508,475,945**
			Breakdown	**phase1**	**1,752,853,069**		**1,755,622,876**	**3,508,475,945**
				phase2	**0**		**0**	**0**

Source: JICA Expert Team

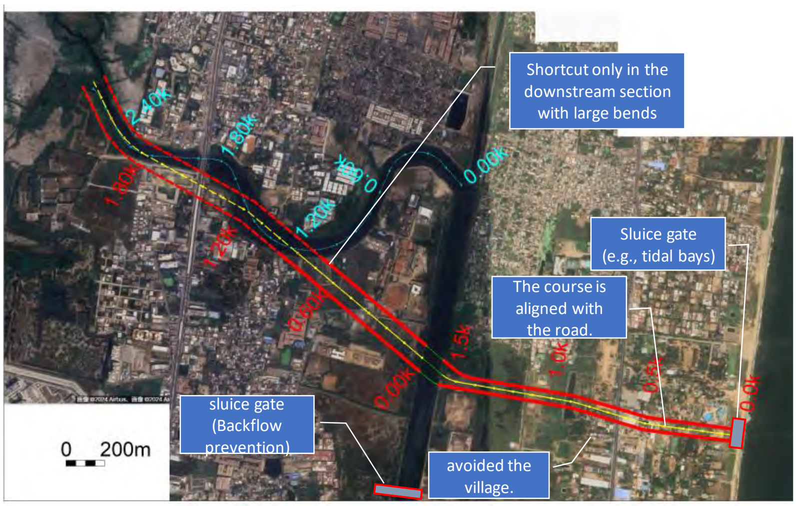
7.1.9 Bypass

7.1.9.1. General

The location of the discharge channel, Bypass is shown in **Figure 7-16**, and the standard cross-section is shown in **Figure 7-16**.



(a) OtteriNulla-Cooum Diversion Channel



(b) Okkiyam Maduvu Bypass

Source: JICA Expert Team

Figure 7-16: Location of Bypass

The list of Bypass is shown in **Table 7-22**.

Table 7-22: 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
South Buckingham Okkiyam Maduvu to Adyar River		256	0	10,000	0	10,000
South 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 to the Bay of Bengal	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

7.1.9.2. Unit rate

See the Appendix for details on the construction unit price used to estimate this countermeasure work.

7.1.9.3. Construction cost

The calculated construction cost of the Bypass is shown in **Table 7-23**.

Table 7-23: Construction Cost for Bypass

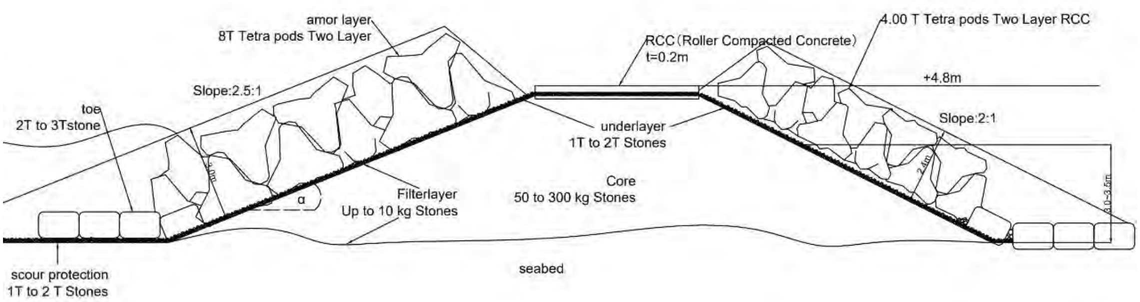
Works	Unit	Quantity	Unit Rate (INR)	Total (INR)			
Bypass	m	3,051	83,000	253,233,000			
Dredging	m^3	916,246	485	444,379,310			
Transportation	m^3	916,246	115	104,910,167			
Embankment	m^3	91,382	57	5,163,109			
Revetment	m^2	123,275	55	6,773,954			
Others （20% of Dredging, Transportation, and Embankment）				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**

Source: JICA Expert Team

7.1.10 Coastal management

7.1.10.1. General

The coastal and estuarine measures are the dredging of Muttukadu and the construction of a guide wall.



Source: JICA Expert Team

Figure 7-17: Standard Cross Section of a Guide Embankment

7.1.10.2. Construction unit price

See the Appendix for details on the construction unit price used to estimate this countermeasure work. Preparation costs are not to be included because it is expected that site acquisition is not to be required in this project.

Table 7-24: 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

7.1.10.3. Construction cost

The construction and procurement costs for coastal measures are shown in **Table 7-25**.

Table 7-25: 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 (None due 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

7.1.10.4. Maintenance cost

The following two types of maintenance costs shall be accounted for:

- Maintenance and management cost (1) Annual maintenance cost of 0.5% of construction and procurement cost
- Maintenance and management cost (2) Annual maintenance dredging for the three rivers and related design and supervision costs (for a total of approximately 10,000 m^3 per year for the three rivers)

Table 7-26: Annual Maintenance Cost

	Phase1	Phase2	Total
	(Unit: INR)		
Maintenance cost (1) (per year)	4,221,812,380	6,379,397,179	10,684,566,393
Maintenance cost (2) (per year)	13,490,506	13,490,506	13,490,506
Maintenance cost subtotal (per year)	4,235,302,886	6,392,887,685	10,698,056,898

Source: JICA Expert Team

Table 7-27: Annual Maintenance Cost (2): Breakdown

	Works	Unit	Quantity	Unit Rate (INR)	Total (INR)
Adyar River	Dredging	m^3	3,000	485	1,455,000
Cooum River	Dredging	m^3	3,000	485	1,455,000
Kosasthalaiyar River	Dredging	m^3	3,000	485	1,455,000
Coastal Area and River Mouth	Dredging	m^3	4,000	485	1,940,000
Adyar River	Transportation（L=20km）		3,000	212.4	637,200
Cooum River	Transportation（L=20km）		3,000	212.4	637,200
Kosasthalaiyar River	Transportation（L=20km）		3,000	212.4	637,200
Coastal Area and River Mouth	Transportation（L=20km）		4,000	212.4	849,600
	Other works （20% of the above total）				1,813,240
	Civil Cost				10,879,440
	Provision for GST 18%				1,958,299
	Expenses （6% of Civil Cost）				652,766
	Total				**13,490,506**

Source: JICA Expert Team

7.1.11 Preliminary cost estimation

7.1.11.1. Preliminary Project Cost

Preliminary Project Cost is shown in **Table 7-28**.

Table 7-28: Preliminary Project Cost

Source: JICA Expert Team

Item				Phase1	Phase2	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
			Tanks 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	2,544,402,656	0	2,544,402,656
		Coastal Area and River Mouth		0	0	0
	2-2	Compensation Cost		0	0	0
	2-3	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
			River Channelization	16,939,421,024	33,885,599,128	50,825,020,152

Item				Phase1	Phase2	Total
				(Unit: INR)		
			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
			Tanks 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 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
			Subtotal	0	0	0
7	Operation and Maintenance Cost			0	0	0

Item				Phase1	Phase2	Total
				(Unit: INR)		
			(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

7.1.11.2. Project plan (schedule)

The project is planned to take 3 years for preparation and 30 years for construction, for a total of 33 years.

The planned project cost by year is shown in **Table 7-29**.

The rate of price increase used in the reserve cost calculation is set at 5.0%, based on the following.

The official figures of the Government of India, Ministry of Statistics and Programme Implementation for Tamil Nadu State wise Inflation Rates (%) for Apr 2024 (based on CPI).

According to the official figures of the Tamil Nadu State Inflation Rates (%) for Apr 2024 (based on CPI), the official figure is 4.93% (https://mospi.gov.in/dataviz-cpi-map). Meanwhile, another private website puts the inflation rate for 2019-2022 at between 3.73% and 6.70% (https://www.macrotrends.net/global-metrics/countries/IND/india/inflation-rate-cpi).

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Table 7-29: Project Plan (Schedule)

(a) Case 5

Item	Unit	Q	Cost		Duration (Year)	Year												
			Phase1	crore.INR		1	2	3	4	5	6	7	8	9	10	11	12	13
1 Project Management Cost	LS	1	4,636,985,983	464	13	36	36	36	36	36	36	36	36	36	36	36	36	36
2 Preparation Cost	LS	1	95,085,817,157	9,509	3	3,170	3,170	3,170										
3 Construction & Procurement Cost	LS	1	138,948,399,361	13,895	10	0	0	0	1,389	1,389	1,389	1,389	1,389	1,389	1,389	1,389	1,389	1,389
3-1 Fluvial (River) Flood Control	LS	1	104,246,815,084	10,425	10	0	0	0	1,042	1,042	1,042	1,042	1,042	1,042	1,042	1,042	1,042	1,042
(1) River Channelization	LS	1	16,939,421,024	1,694	10				169	169	169	169	169	169	169	169	169	169
(2) Rehabilitation of Existing Water Tank	LS	1	7,576,656,494	758	10				76	76	76	76	76	76	76	76	76	76
(3) Underground Bypass	LS	1	79,730,737,566	7,973	10				797	797	797	797	797	797	797	797	797	797
3-2 Pluvial (Urban) Flood Control Plan	LS	1	34,470,363,074	3,447	10				345	345	345	345	345	345	345	345	345	345
(1) Reservoir Improvement	LS	1	3,206,747,749	321	10				32	32	32	32	32	32	32	32	32	32
(2) Connecting Drainage (Micro-Drainage) Improvement	LS	1	26,503,881,369	2,650	10				265	265	265	265	265	265	265	265	265	265
(3) Bypass	LS	1	1,251,258,011	125	10				13	13	13	13	13	13	13	13	13	13
(4) Gate and Pump	LS	1	3,508,475,945	351	10				35	35	35	35	35	35	35	35	35	35
3-3 Coastal Area and River Mouth	LS	1	231,221,203	23	10				2	2	2	2	2	2	2	2	2	2
4 Consultant Service Cost	LS	1	11,115,871,949	1,112	13	86	86	86	86	86	86	86	86	86	86	86	86	86
5 Contingency Cost	LS	1	4,501,928,139	450	13	35	35	35	35	35	35	35	35	35	35	35	35	35
5-1 Price Contingency	LS	1	1,500,642,713	150	13	0% 12	0% 12	0% 12	0% 12	0% 12	0% 12	0% 12	0% 12	0% 12	0% 12	0% 12	0% 12	0% 12
5-2 Physical Contingency	LS	1	3,001,285,426	300	13	23	23	23	23	23	23	23	23	23	23	23	23	23
6 Technical Training Cost	LS	1	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0
7 Operation and Maintenance Cost	LS	1	0	0	0													
7-1 Maintenance cost(1) (per year)	LS	1	0	0	0													
7-2 Maintenance cost(2) (per year)	LS	1	0	0	0													
Total **(Excluding OM Cost)**			254,289,002,590	25,429		3,337	3,337	3,337	1,557	1,557	1,557	1,557	1,557	1,557	1,557	1,557	1,557	1,557

Source: JICA Expert Team

(b) Case 2

Item		Unit	Q	Cost Phase1	crore. INR	Cost Phase2	crore. INR	Cost Total	crore.INR	Duration(Year) Phase1	Duration(Year) Phase2
1	Project Management	LS	1	4,636,985,983	464	1,383,678,395	138	6,020,664,378	602	13	26
2	Preparation	LS	1	95,085,817,157	9,509	591,204,918,784	59,120	686,290,735,941	68,629	3	6
3	Construction &Procurement	LS	1	138,948,399,361	13,895	41,462,255,622	4,146	180,410,654,983	18,041	10	20
3-1	FluvFluvial (River) Flood Control	LS	1	104,246,815,084	10,425	41,462,255,622	4,146	145,709,070,706	14,571	10	
(1)	River Channelization	LS	1	16,939,421,024	1,694	33,885,599,128	3,389	50,825,020,152	5,083	10	20
(2)	Rehabilitation of Existing Water Tank	LS	1	7,576,656,494	758	7,576,656,494	758	15,153,312,988	1,515	10	20
(3)	Underground Bypass	LS	1	79,730,737,566	7,973	0	0	79,730,737,566	7,973	10	20
3-2	Pluvial (Urban) Flood Control Plan	LS	1	34,470,363,074	3,447	0	0	34,470,363,074	3,447	10	20
(1)	Reservoir Improvement	LS	1	3,206,747,749	321	0	0	3,206,747,749	321	10	20
(2)	Connecting Drainage (Micro-Drainage) Improvement	LS	1	26,503,881,369	2,650	0	0	26,503,881,369	2,650	10	20
(3)	Bypass			1,251,258,011	125	0	0	1,251,258,011	125	10	20
(4)	Gate and Pump	LS	1	3,508,475,945	351	0	0	3,508,475,945	351	10	20
3-3	Coastal Area and River Mouth	LS	1	231,221,203	23	0	0	231,221,203	23	10	3
4	Consultant Service Cost	LS	1	11,115,871,949	1,112	3,316,980,450	332	14,432,852,399	1,443	13	26
5	Contingency Cost	LS	1	4,501,928,139	450	1,343,377,082	134	5,845,305,221	585	13	
5-1	Price Contingency	LS	1	1,500,642,713	150	447,792,361	45	1,948,435,074	195	13	
5-2	Physical Contingency	LS	1	3,001,285,426	300	895,584,721	90	3,896,870,148	390	13	26
6	Technical Training Cost	LS	1	0	0	0	0	0	0	13	26
7	Operation and Maintenance Cost	LS	1	6,960,910,474	696	2,086,603,287	209	9,034,023,255	903	0	0
7-1	Maintenance cost(1) (per year)	LS	1	6,947,419,968	695	2,073,112,781	207	9,020,532,749	902	0	0
7-2	Maintenance cost(2) (per year)	LS	1	13,490,506	1	13,490,506	1	13,490,506	1	0	0
Total	**(Excluding OM Cost)**			254,289,002,590	25,429	638,711,210,332	63,871	893,000,212,922	89,300		

Item (Year)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1	36	36	36	36	36	36	36	41	41	41	41	41	41	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
2	3,170	3,170	3,170					9,853	9,853	9,853	9,853	9,853	9,853																				
3	0	0	0	1,389	1,389	1,389	1,389	1,389	1,389	1,389	1,389	1,389	1,389	207	207	207	207	207	207	207	207	207	207	207	207	207	207	207	207	207	207	207	207
3-1	0	0	0	1,042	1,042	1,042	1,042	1,042	1,042	1,042	1,042	1,042	1,042	207	207	207	207	207	207	207	207	207	207	207	207	207	207	207	207	207	207	207	207
(1)				169	169	169	169	169	169	169	169	169	169	169	169	169	169	169	169	169	169	169	169	169	169	169	169	169	169	169	169	169	169
(2)				76	76	76	76	76	76	76	76	76	76	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38
(3)				797	797	797	797	797	797	797	797	797	797	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-2				345	345	345	345	345	345	345	345	345	345	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(1)				32	32	32	32	32	32	32	32	32	32																				
(2)				265	265	265	265	265	265	265	265	265	265																				
(3)				13	13	13	13	13	13	13	13	13	13																				
(4)				35	35	35	35	35	35	35	35	35	35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3-3				2	2	2	2	2	2	2	2	2	2																				
4	86	86	86	86	86	86	86	98	98	98	98	98	98	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
5	35	35	35	35	35	35	35	40	40	40	40	40	40	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
5-1	0% 12	0% 12	0% 12	0% 12	0% 12	0% 12	0% 12	0% 13	0% 13	0% 13	0% 13	0% 13	0% 13	0% 2	0% 2	0% 2	0% 2	0% 2	0% 2	0% 2	0% 2	0% 2	0% 2	0% 2	0% 2	0% 2	0% 2	0% 2	0% 2	0% 2	0% 2	0% 2	0% 2
5-2	23	23	23	23	23	23	23	27	27	27	27	27	27	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7														696	696	696	696	696	696	696	696	696	696	696	696	696	696	696	696	696	696	696	696
7-1														695	695	695	695	695	695	695	695	695	695	695	695	695	695	695	695	695	695	695	695
7-2														1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Total	3,337	3,337	3,337	1,557	1,557	1,557	1,557	11,435	11,435	11,435	11,435	11,435	11,435	928	928	928	928	928	928	928	928	928	928	928	928	928	928	928	928	928	928	928	928

Source: JICA Expert Team

7.2 Preliminary Economic Evaluation

7.2.1 Economic evaluation

7.2.1.1. Socio-economic study development of GIS-based database

Basic data related to the socio-economy in the target area is organized based on GIS.

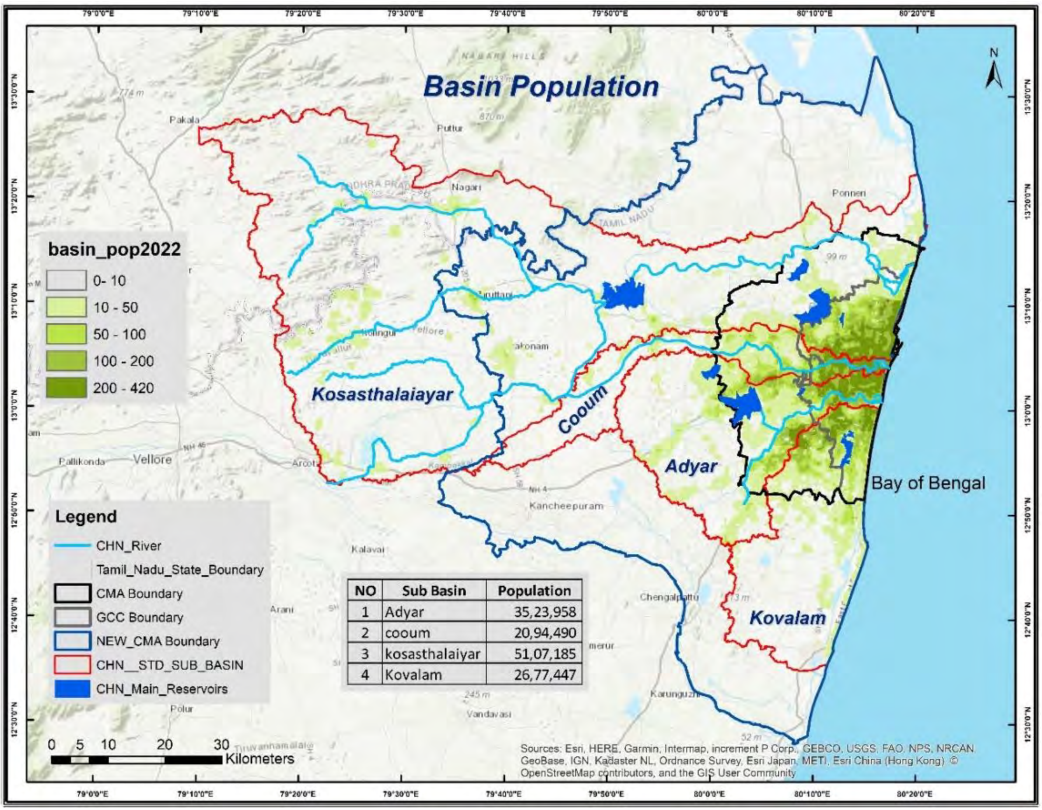
(1) Population

The following figure shows the estimated population distribution in 2022, created by the population distribution data of UN World Pop based on the 2011 census population statistics by multiplying the population growth rate. The estimated population for each administrative boundary and each basin in the target area is shown in the table below.

Table 7-30: Population for Each Administrative Boundary and Each Basin in the Target Area

	GCC	CMA	New CMA	Tamil Nadu	Adyar	Cooum	Kovalam	Kosastha laiyar	4 Basins
Population (person)	6,221,000	11,503,000	15,900,000	76,536,000	6,467,477	3,843,991	4,913,885	9,373,155	24,598,507

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



Source: JICA Expert Team

Figure 7-18: Population Distribution in the Target Area

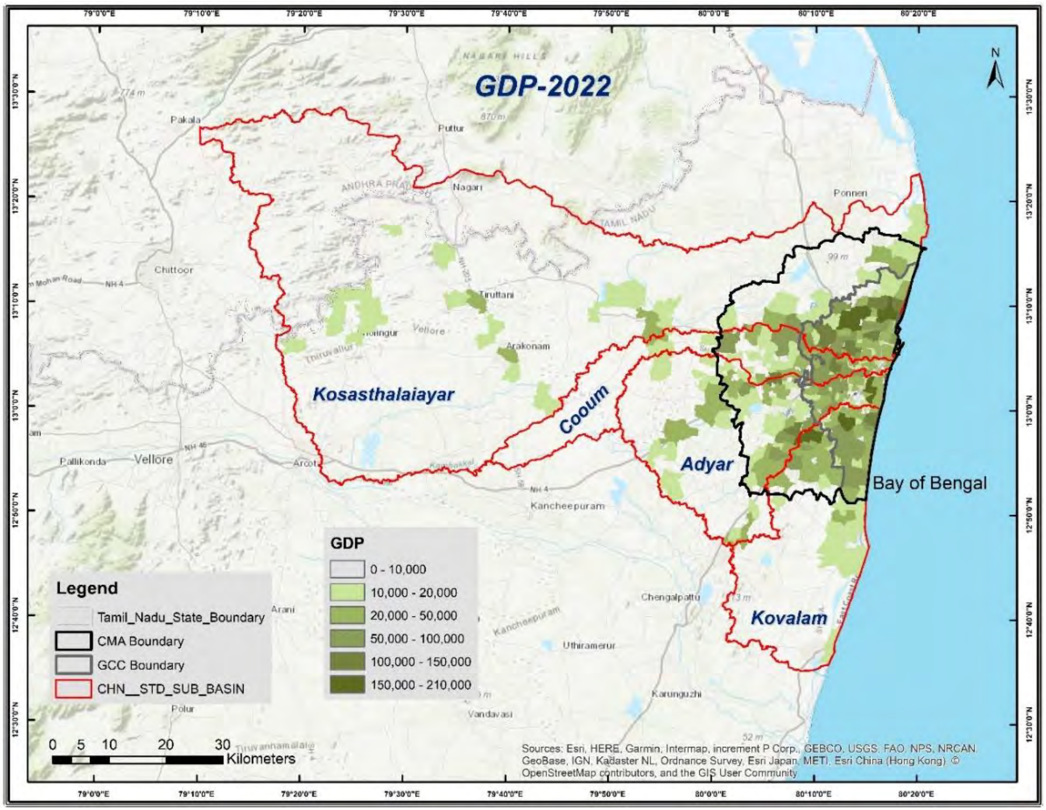
(2) GDP

The distribution of estimated GDP, created based on the population distribution data in (1), is shown in the figure below. The GDP for each administrative boundary and each basin in the target area is also shown in the table below.

Table 7-31: GDP for Each Administrative Boundary and Each Basin in the Target Area

	GCC	CMA	New CMA	Tamil Nadu	Adyar	Cooum	Kovalam	Kosastha laiyar	4 Basins
GDP (US$ billion)	26.03	48.14	66.53	320.27	27.06	16.09	20.56	39.22	102.93

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



Source: JICA Expert Team using available data

Figure 7-19: GDP Distribution in the Target Area

(3) Land use

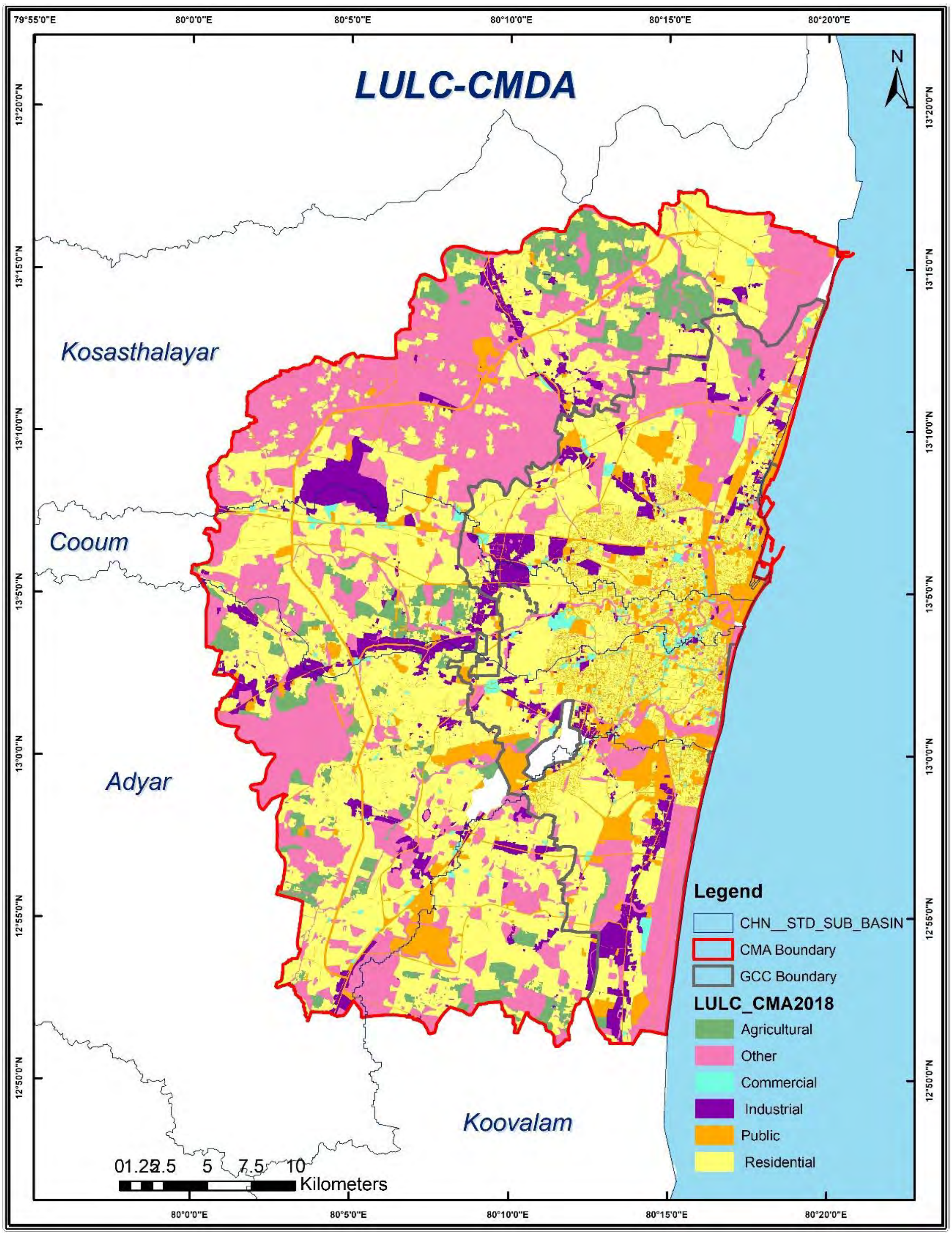
Based on the available 2018 land use map of the Chennai Metropolitan Area (CMA), the table and figure below show the area per land use category for each administrative division and each basin in the subject area; 46.8% of the CMA area is residential, 7.2% is a public-related area, 6.8% industrial, 5.7% is agricultural, and 1.4% commercial.

Table 7-32: Land Use in Administrative Boundaries and Basins

Area (km^2 (%))	GCC	CMA	New CMA	Tamil Nadu	Adyar	Cooum	Kovalam	Kosasthalaiyar
Residential	222.2	556.3	N/A	N/A	148.0	88.1	100.0	188.3
	(52.2%)	(46.8%)	(-)	(-)	(17.3%)	(20.2%)	(12.8%)	(4.6%)
Industrial	33.1	81.0	N/A	N/A	16.8	11.2	16.6	23.6
	(7.8%)	(6.8%)	(-)	(-)	(2.0%)	(2.6%)	(2.1%)	(0.6%)
Commercial	12.5	16.5	N/A	N/A	4.5	4.6	1.9	4.7
	(2.9%)	(1.4%)	(-)	(-)	(0.5%)	(1.1%)	(0.2%)	(0.1%)
Agricultural	3.0	67.8	N/A	N/A	16.8	9.9	9.2	31.9
	(0.7%)	(5.7%)	(-)	(-)	(2.0%)	(2.3%)	(1.2%)	(0.8%)
Public related	68.3	85.7	N/A	N/A	14.2	21.0	8.1	21.7
	(16.0%)	(7.2%)	(-)	(-)	(1.7%)	(4.8%)	(1.0%)	(0.5%)
Others	87.0	381.8	N/A	N/A	49.9	9.2	58.9	169.2
	(20.4%)	(32.1%)	(-)	(-)	(5.8%)	(2.1%)	(7.5%)	(4.1%)
Unknown*	-	-	N/A	N/A	603.6	291.3	587.7	3,642.6
	(-)	(-)	(-)	(-)	(70.7%)	(66.9%)	(75.1%)	(89.2%)
Total	426.0	1,189.0	5,904.0	130,100.0	853.7	435.4	782.2	4,081.9

**Note: The available land use data is only within the CMA area, so the area beyond the CMA area is counted as "N/A," and the area is not categorized as the category above is summarized as "Unknown."*

Source: Counted by the JICA Study Team based on GIS data.



Source: JICA Expert Team based on CMA's 2018 land use

Figure 7-20: CMA's Land Use Map as of 2018

(4) Public facilities (Social infrastructure)

Main infrastructure

Based on the GIS data, the table below shows the total length and unit of each public facility (social infrastructure) for each administrative division and each basin in the target area, and the figure below shows the network of the main social infrastructure, respectively.

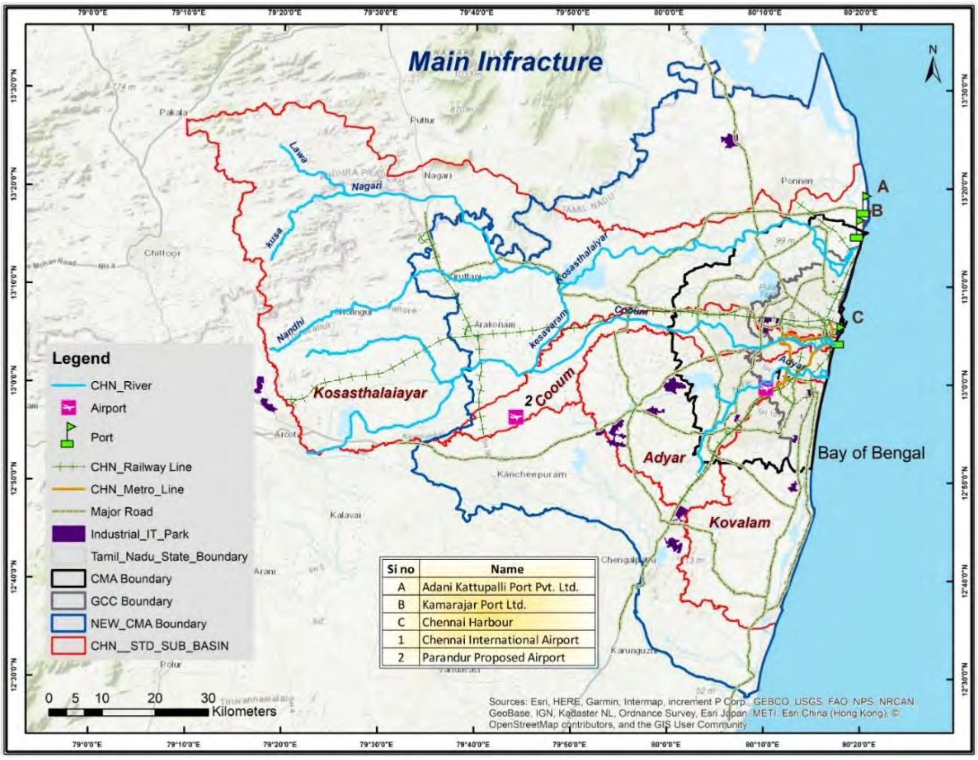
Chennai has major trunk roads and railways spreading out in a fan shape, as well as a metro system in the center of the city. Chennai Port (C) is located in the center of Chennai, and Kamarajar (Ennore) Port (B) and Kattupalli Port (A) are located in the northern part of the city. Chennai International Airport (1) is located in the center of the city, and a new airport (2) is planned to be constructed in Parandur, a suburb of Chennai.

The distribution of various power-related facilities is also shown in the figure below. Substation facilities are scattered over a wide area, and pillar box is installed mainly in the GCC area. Distribution transformers, High-tension electricity transmission lines (HT), and Low-tension electricity transmission (LT) lines are installed throughout the target area.

Table 7-33: Total Length of Each Public Facility (Social Infrastructure) in the Target Area

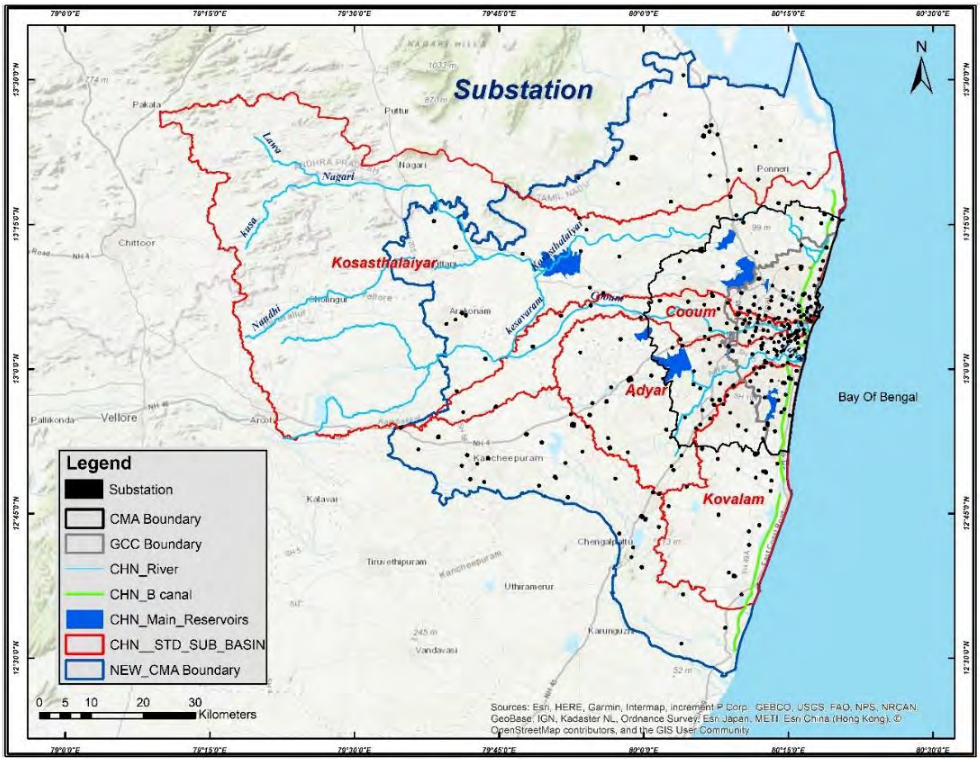
	GCC	CMA	New CMA	Tamil Nadu	Adyar	Cooum	Kovalam	Kosasthalaiyar
Road length (km)	5,950.5	15,649.9	29,046.3	236,235.1	6,954.0	3,351.5	5,950.5	8,454.2
Railway length (km)	871.9	1,174.0	1,703.6	8,491.2	265.8	284.0	169.9	952.5
Water Distribution line length (km)	4,125.5	N/A	N/A	N/A	946.9	558.0	926.3	1,687.1
Substations (unit)	164.0	217.0	338.0	N/A	85.0	55.0	51.0	90.0
Pillar-box (unit)	92,073.0	96,907.0	98,697.0	N/A	28,681.0	19,260.0	14,076.0	36,504.0
Distribution Transformers (unit)	21,864.0	33,650.0	50,268.0	N/A	12,710.0	7,829.0	9,821.0	13,147.0
HT Line length (km)	1,807.7	4,445.0	12,266.2	N/A	2,306.4	1,236.4	2,160.3	3,245.6
LT Line length (km)	2,954,546.0	4,415,367.0	5,879,277.0	N/A	144,678.0	863,380.0	1,169,751.0	1,786,448.0

Source: JICA Expert Team



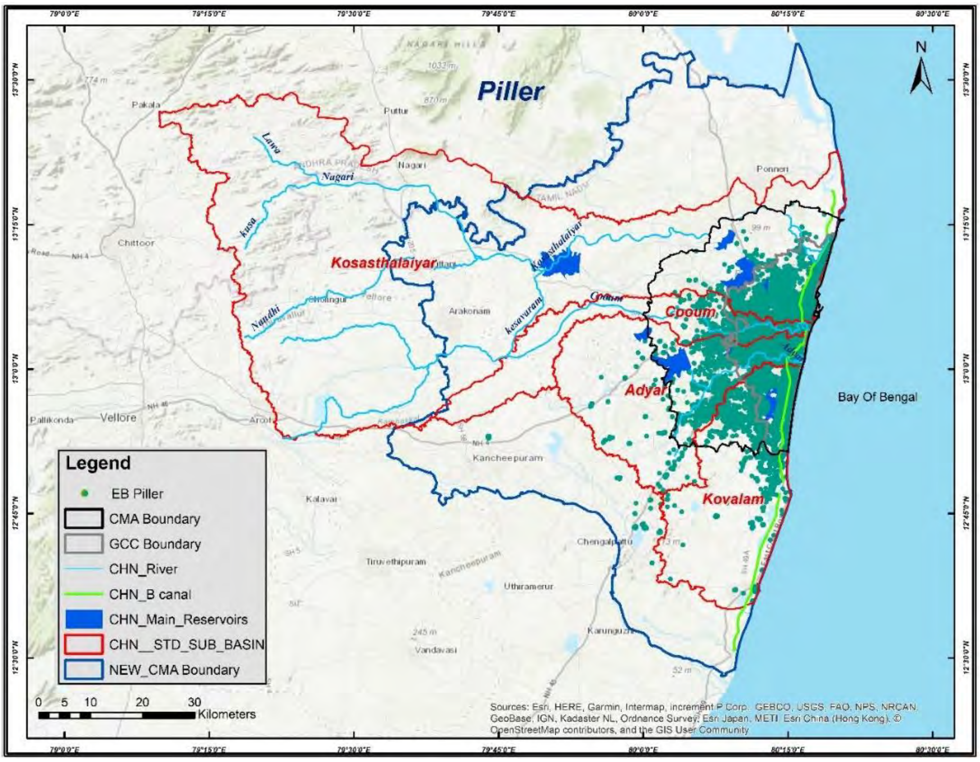
Source: JICA Expert Team

Figure 7-21: Main Infrastructure in the Target Area



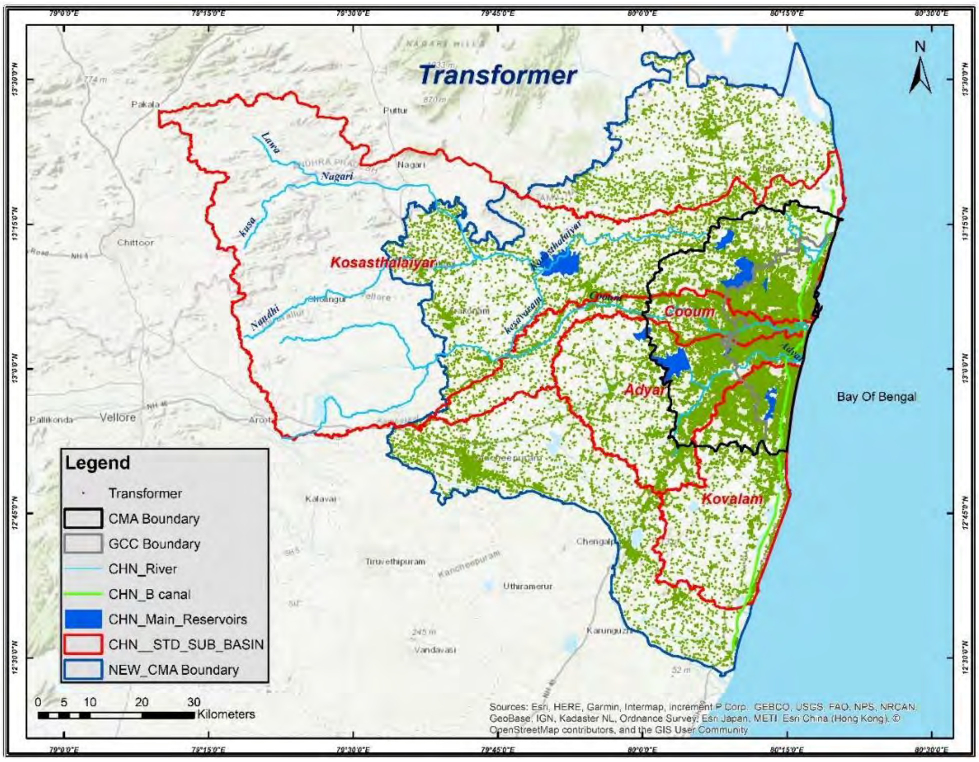
Source: JICA Expert Team

Figure 7-22: Substations in the Target Area



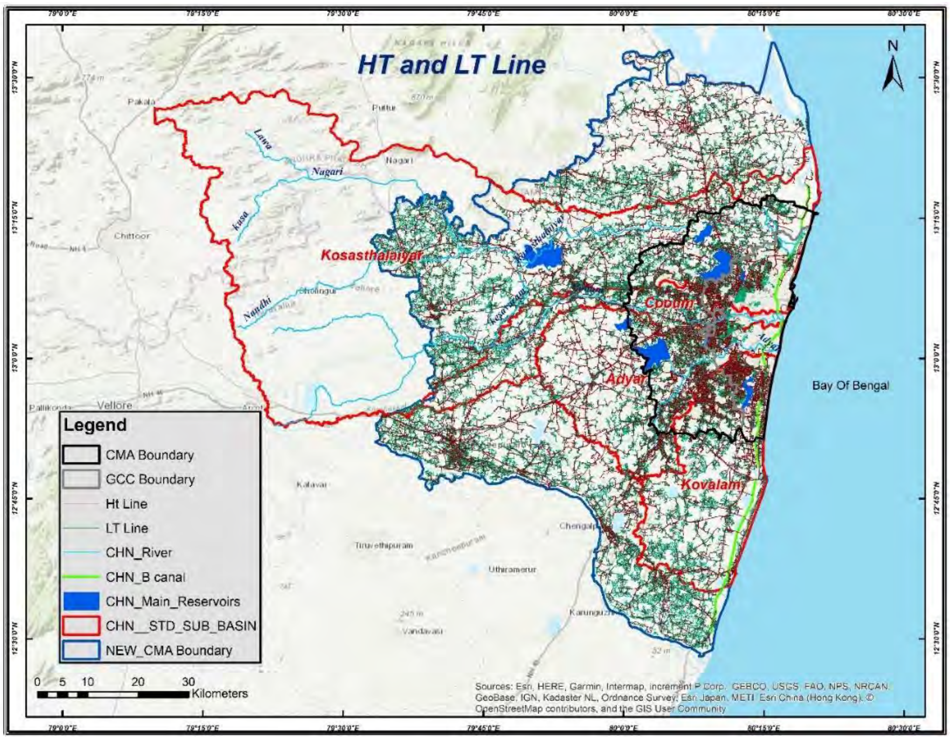
Source: JICA Expert Team

Figure 7-23: Pillar Boxes in the Target Area



Source: JICA Expert Team

Figure 7-24: Distribution of Transformers in the Target Area

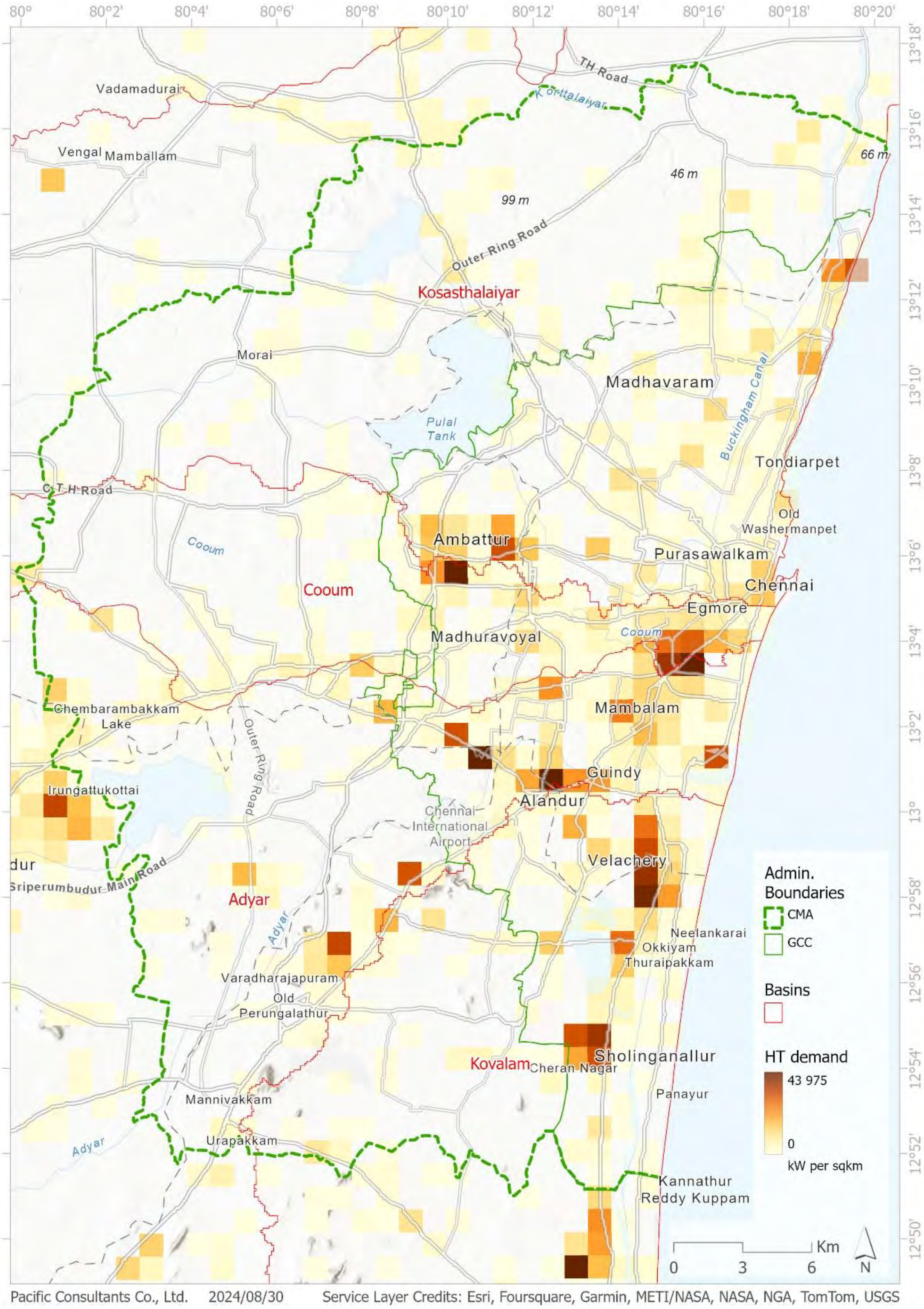


Source: Created by JICA Expert Team based on the information of TANGEDCO

Figure 7-25: HT and LT Electricity Transmission Lines

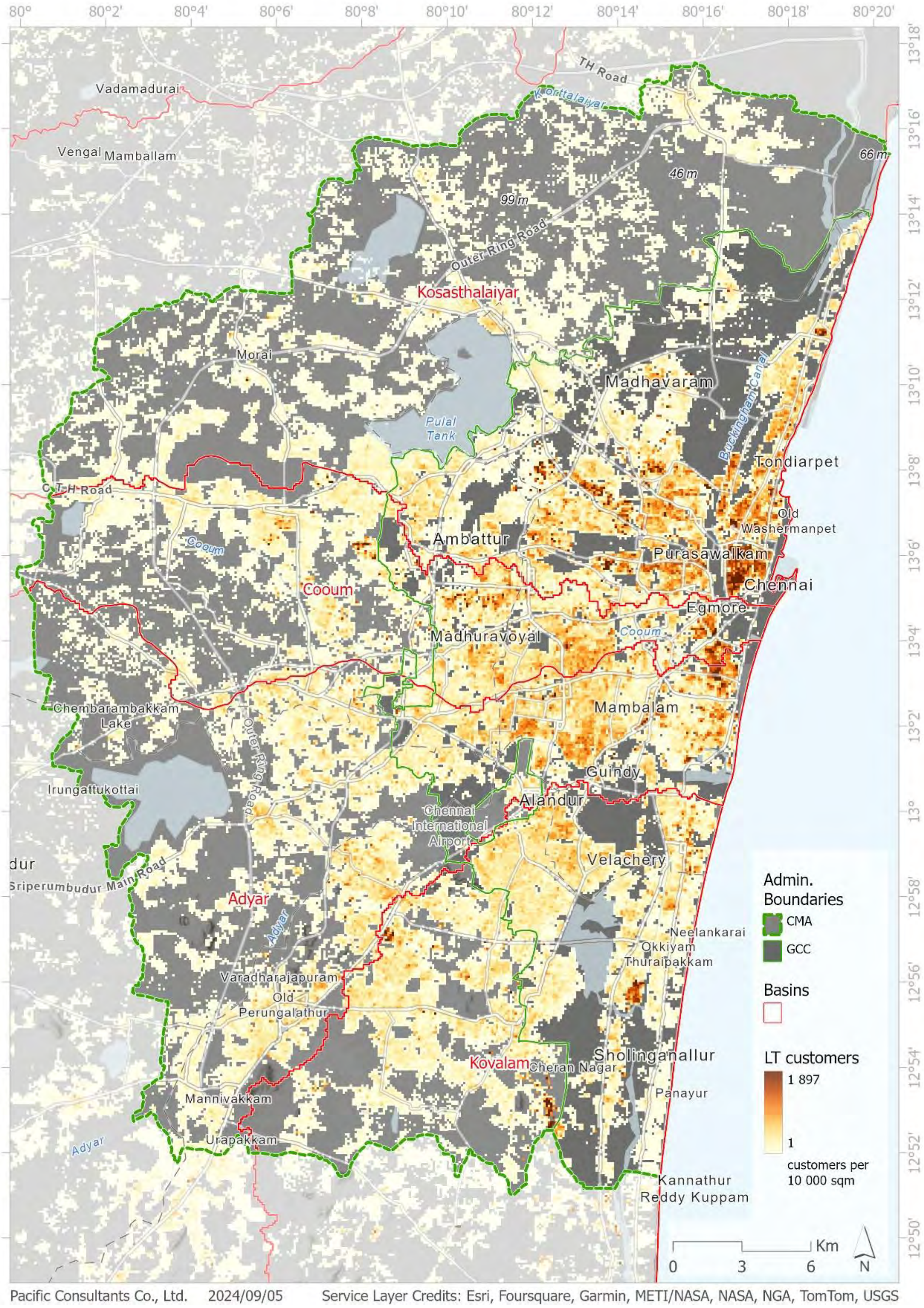
Electricity consumer distribution

The distribution of electricity consumers in the target area is shown below. Consumers of high-tension (HT) electricity mainly include business entities, such as small and medium-sized facilities (e.g., factories and commercial facilities), while consumers of low-tension (LT) electricity mainly include general households and small stores and offices. The demand for HT electricity is distributed mainly in central areas such as the GCC area and the industrial parks in suburban areas, while consumers of LT electricity are widely distributed not only in central areas but also in suburban areas.



Source: Created based on TANGEDCO's GIS data by JICA Expert Team

Figure 7-26: Distribution of High-Tension (HT) Electricity Demand



Source: Created based on TANGEDCO's GIS data by JICA Expert Team

Figure 7-27: Distribution of Low-Tension (LT) Electricity Consumers

7.2.1.2. Economic analysis

(1) Methodology of economic analysis

As there are no specific flood control economic analysis manuals or other guidelines in India yet, this project shall conduct the economic evaluation based on the Manual for Economic Evaluation of Flood Control Investment (Draft), Ministry of Land, Infrastructure and Transport of Japan. It is carried out by the following procedure.

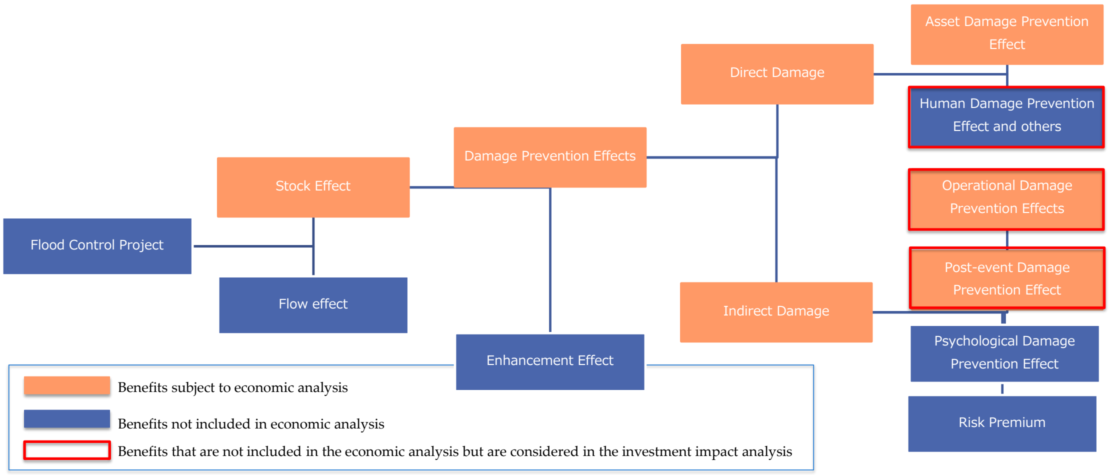
- Identify supposed damaged items
- Estimate the basic unit (damage intensity) of each damage item (amount/unit, or amount/km^2) based on statistical data and the amount of existing flood damage.
- Estimate the annual average flood damage for each assumed return period and calculate the expected damage reduction (economic benefit (B)) as compare the amount of damage in the case with countermeasures and without countermeasures, which is considered in the previous section.
- Calculate the cost of flood control measures considered in the previous section as the economic cost (C).
- Evaluate the economics of the project by comparing the economic benefits (B) and economic costs (C) of the project calculated above through indicators such as the Economic Internal Rate of Return (EIRR), Net Present Value (NPV (B-C)), and Benefit-Cost Ratio (B/C Ratio).
- The evaluation of project effectiveness in terms of non-monetary indicators is also conducted as benefits that cannot be considered economic value (Quantification Indicator Analysis).

(2) Implementation of economic analysis

Identification of flood damage items (asset items)

Assumptions in identifying damaged items (asset items) shall be as follows.

- Based on the "Manual for Economic Evaluation of Flood Control Investment (Draft)" by the Ministry of Land, Infrastructure and Transport of Japan, among the economic effects of flood control projects, the damage prevention effect of assets in the flood area is targeted among the stock effects that can be economically assessed at the present stage. Damage prevention effects can be classified into direct damage and indirect damage, with the asset damage prevention effect among direct damage and the operational damage prevention effect and the post-event damage prevention effect among indirect damage being subject to economic impact assessment. (**Figure 7-28**)



Source: Created by JICA Expert Team based on "Manual for Economic Evaluation of Flood Control Investment (Draft)" by the Ministry of Land, Infrastructure and Transport of Japan

Figure 7-28: Benefits Subject to the Economic Analysis

- Among direct and indirect damage, the asset damage that can be assessed economically at present is summarised in **Table 7-34** and **Table 7-35** as damage items (asset items) to be assessed, direct damage includes damage to general assets in the household, industrial, and agricultural sectors, damage to agricultural products, and damage to public facilities. Indirect damage includes losses due to the suspension of production activities in the industrial sector.

Table 7-34: Damage Items Subject to Direct Damage (Asset Items)

Type of damage		Target asset of damage
General Assets Damage	Household	Residential buildings (Depreciable asset)
		Household articles (Inventory assets)
	Industry (Business entities)	Depreciable assets (Office and facility etc.)
		Inventory assets (Product stock, etc.)
	Agriculture	Depreciable asset
		Inventory assets
Agricultural Products Damage		Damage to crop by flood
Public Facility Damage		Damage to infrastructure by flood

Source: " Manual for Economic Evaluation of Flood Control Investment (Draft)," Ministry of Land, Infrastructure, Transport and Tourism of Japan

Table 7-35: Damage Items Subject to Indirect Damage (Asset Items)

Type of damage		Target of damage
Business Suspension Damage	Industry (Business entities)	Opportunity loss by business suspension due to inundation

Source: " Manual for Economic Evaluation of Flood Control Investment (Draft)," Ministry of Land, Infrastructure, Transport and Tourism of Japan

- As statistical information equivalent to the assessed value of each asset, as indicated in the "Manual for Economic Evaluation of Flood Control Investment (Draft)" by the Ministry of Land, Infrastructure and Transport of Japan, is not available in India, the amount of damage for each asset, calculated based on the amount of damage from previous floods, shall be substituted for the assessed value as the basic unit of damage (damage intensity). (Table 7-36, Table 7-37)
- For general assets and damage to agricultural products from direct damage, the damage intensity is calculated based on the amount of damage from existing floods and the current land use map. For damage to public facilities (social infrastructure), the intensity is calculated based on the amount of damage from existing floods the total length and area of each major infrastructure, and the number of facilities, as there is no statistical information on the ratio of the amount of damage to public facilities to the amount of damage to general assets. Business interruption damage from indirect damage is not assessed separately here to avoid duplicate assessment, as it is considered to encompass business interruption damage, as the amount of damage in the industrial sector of general assets as direct damage is calculated based on actual damage. The calculation of the damage intensity is detailed in subsection. 0.
- Human damaged etc., is not included in the economic analysis as it is difficult to assess economically but is subject to consideration of project effectiveness as a non-monetary quantified indicator (detailed in subsection. 0).

Table 7-36: Method of Calculation of Subject Assets of Direct Damage in This Project

Type of damage		Target asset of damage	Calculation Method (Flood Control Economics Manual)	Calculate Method (Alternative)
1) General Assets Damage	Household	Depreciable asset (house)	"Area" x "House asset value per m^2*" (*Assessed value per m^2 of house)	"Total amount of actual damage to houses during the 2015 floods" / "Inundation area of residential areas during the 2015 floods" (Rp./m^2)
		Inventory assets (household articles)	"Number of Households" x "Household Assets value per Household*." (*Assessed value of household goods per household)	"Total amount of insurance claims during 2015 flooding" / "Inundation area of residential areas during 2015 flooding" (Rp./m^2)
	Industry	Depreciable assets (Office and facility etc.)	"Number of Employees" x "Depreciable Assets Value per Employee by Industry Classification"	"Private Sector Damage amount during 2015 Floods" / "Inundation Area of Industrial and Commercial Areas during 2015 Floods" (Rp./m^2)
		Inventory assets (Product stock, etc.)	"Number of Employees" x "Inventory Asset Value per Employee by Industry Classification"	
	Agriculture	Depreciable asset	"Number of farm households" x "Depreciable Assets Value per household"	"Total agricultural damage amount during the 2015 floods" / "Inundation area of agricultural areas during the 2015 floods" (Rp./m^2)
		Inventory assets	"Number of farm households" x "Inventory Assets Value per household"	
2) Agricultural Products Damage		Damage to crop by flood	"Paddy and field area" x "Average yield" x "Crop price"	"Rice paddy and field area" x "Average yield" x "Crop prices (major commodities)"
3) Public Facility Damage		Damage to infrastructure by flood	"General property damage*" x "Ratio of damage to public civil engineering and utility facilities to general property damage" (Sum of damage amount of *1))	"Total amount of actual damage to infrastructure during the 2015 floods" / "Inundated area of infrastructure areas during the 2015 floods" (Rp./m^2)

Source: JICA Expert Team based on "Flood Control and Economic Research Manual (Draft), April 2020," Water Management and Land Conservation Bureau, Ministry of Land, Infrastructure, Transport and Tourism of Japan

Table 7-37: Method of Calculation of Subject Assets of Indirect Damage in This Project

Type of damage		Target of damage	Calculation Method (Flood Control Economics Manual)	Calculate Method (Alternative)
Business Suspension Damage	Industry (Business entities)	Opportunity loss by business suspension due to inundation	“Number of employees” x “total loss days due to business suspension or stagnation” x “value added per person per day”	Assumed to be encompassed in the amount of the industrial sector as general asset damage or direct damage.

Source: JICA Expert Team based on "Flood Control and Economic Research Manual (Draft), April 2020," Water Management and Land Conservation Bureau, Ministry of Land, Infrastructure, Transport and Tourism of Japan

Estimate of the basic unit of each damaged item (damage intensity)

As there is no information on the assessed value of each asset in Chennai, India, the basic units of damage (amount (USD)/unit, or amount (USD)/km^2) for each inundation depth shall be estimated from the amount and quantity of damage from previous floods to replace the assessed value of damage (assets). As for previous floods, actual damage figures from the most recent flood in December 2015, which was large in scale and for which information is relatively readily available, shall be used.

Setting of damage rates

The table below sets out the damage rates for estimating the amount of damage by flood depth, using the damage rates figures for flood damage in Asia as presented in the report "JRC TECHNICAL REPORTS Global flood depth-damage functions" by the European Commission.

Table 7-38: Setting of Damage Rates

Inundation depth	Residential	Commerce	Industrial	Agricultural	Transport Infrastructure	Infrastructure
0m	0.00	0.00	0.00	0.00	0.00	0.00
0m < 0.5m	0.33	0.38	0.28	0.17	0.36	0.25
0.5m < 1.0m	0.49	0.54	0.48	0.37	0.57	0.42
1.0m <1.5	0.62	0.66	0.63	0.51	0.73	0.55
1.5m < 2.0m	0.72	0.76	0.72	0.56	0.85	0.65
2m <	0.87	0.88	0.86	0.69	1.00	0.80

Source: European Commission, JRC TECHNICAL REPORTS Global flood depth-damage functions

Calculation of the damage amount by depths of inundation in existing flood

General assets damage and agricultural products damage

Damages to general assets (households, industry, and agriculture sector) and agricultural products (crops, etc.) were calculated from the actual damages from the December 2015 floods, as there is no information on the assessed value of each asset in India. Mainly, the amount of the actual damages was summarized based on the report "Memorandum on Damages due to Extremely Heavy Rainfall in Tamil Nadu" (hereinafter, "MDEHR Report") by the Revenue and Disaster Management Department of Tamil Nadu State and damage estimates reported in various media reports during the December 2015 floods. Depreciable assets[1] and inventory assets[2], as well as actual damage amount and damage estimates for which direct and indirect damage cannot be clearly distinguished, are combined. In estimating the amount of damage to each asset by inundation depth, the damage rates set out in 7.2.1.2(2)00 were used.

Table 7-39: Damage Amount of December 2015 Flood (Household, Industrial, Agricultural

[1] As for "Household" of General Asset, the depreciable assets mean "residential buildings".

[2] As for "Household" of General Asset, the inventory assets mean "household articles".

Sectors) (Crore INR)

Flood Block	Damage Amount of 2015 December flood (Crore INR)					
	Household asset		Industrial asset**	Commercial asset***	Agricultural asset	Agricultural crop asset
	Residential building	Household articles asset*				
<0.5	16.53	3,624.65	9,943.77	2,253.64	6.04	13.12
0.5m < 1.0m	1.86	407.32	1,595.55	347.58	10.16	22.07
1.0m <1.5	2.50	548.14	1,433.87	227.98	1.20	2.61
1.5m < 2.0m	0.93	203.19	1,012.37	142.02	1.22	2.65
2m <	0.08	16.70	14.43	28.78	1.70	3.69
Total	21.89	4,800.00	14,000.00	3,000.00	20.32	44.15

** Household articles asset damage is based on the estimation by insurance companies.*
*** The damage in the industrial sector is based on the estimation of economic loss of Small & Medium Industrial Units reported by the Indian Express.*
**** The Damage to commerce is based on damage estimates for the IT sector, which accounts for much of the service sector (The Economic Times).*
Source: JICA Expert Team using CRA/TNDRRA Additional Memorandum of Understanding on Flood Damage in Tamil Nadu (December 2015) and other source of information available in public domain and media

Public facility damage (infrastructure damage)

Damage to public facilities is also calculated based mainly on the actual damage reported in the MDEHR Report by the Revenue and Disaster Management Department of Tamil Nadu State and damage estimates reported in various media reports during the December 2015 floods.

Table 7-40: Damage Amount of December 2015 Flood (Infrastructure) (Crore INR)

Flood Block	Damage Amount of 2015 December flood (Crore INR)								
	Road	Railway	Water Distribution line	Electricity Infrastructure					Other public facilities
				Substations	Pillar-box	Distribution Transformers	HT Line length	LT Line length	
<0.5	1,684.98	319.12	50.50	322.64	97.43	4.50	38.36	59.63	1,418.30
0.5m < 1.0m	221.76	26.19	8.72	1,116.16	300.62	12.30	62.30	84.33	249.12
1.0m <1.5	253.21	14.30	5.65	104.64	4.92	0.98	13.00	13.33	182.00
1.5m < 2.0m	119.56	1.22	5.66	113.36	2.37	1.08	14.93	14.03	54.60
2m <	12.78	1.17	0.96	87.20	11.25	0.93	11.13	11.88	32.12
Average	2,292.29	362.00	71.49	1,744.00	416.60	19.80	139.72	183.19	1,936.14

** Damage to railways is based on damage estimates by Southern Railways (The Economic Times).*
Source: JICA Expert Team using CRA/TNDRRA Additional Memorandum of Understanding on Flood Damage in Tamil Nadu (December 2015) and other source of information available in public domain and media

Estimation of the quantity of damage by inundation depth in existing floods

Statistical information on the quantity of damage to general assets (household, industrial, and agricultural sectors), agricultural products, and public facilities identified in(2)0 (e.g., the number of houses, factories, and stores etc.) was not developed in the GIS in Chennai. Thus, the table below shows the counts in the GIS of the inundated area and inundated extension/number of inundated assets (social infrastructure) for each administrative division and each basin in the target area (CMA area) by inundation depth, using the currently available land use map and public facilities (social infrastructure) and satellite images for the agricultural sector.

However, the figures for the extension of inundation of public facilities (infrastructure) are counted based on the available GIS data and, therefore, do not exactly match the figures in the above-mentioned report of the Revenue and Disaster Management Department of Tamil Nadu, MDEHR Report.

I. General assets damage and agricultural products damage

i. Household sector

In residential areas, which make up nearly half of the CMA area, some areas are inundated by more than 2m, and the most inundated area is less than 1m.

Table 7-41: Residential Area affected by 2015 Flood in December (km^2)

Inundation depth	GCC	CMA	New CMA	Tamil Nadu	Adyar	Cooum	Kovalam	Kosasthalaiyar
0m < 0.5m	61.35	132.61	N/A	N/A	32.76	17.00	22.82	20.92
0.5m < 1.0m	11.36	14.90	N/A	N/A	5.10	1.09	1.19	3.95
1.0m <1.5	12.14	20.05	N/A	N/A	2.32	1.80	2.32	3.08
1.5m < 2.0m	7.38	7.43	N/A	N/A	0.00	0.05	1.86	5.45
2m <	0.58	0.61	N/A	N/A	0.58	0.00	0.00	0.00
Total	92.81	175.61	N/A	N/A	40.76	19.93	28.19	33.41

Source: JICA Expert Team

ii. Industry sector

Manufacture sector

In industrial areas (manufacturing sector), most are inundated by less than 1m, but some area is simulated as inundated areas of more than 1m.

Table 7-42: Manufacturing Area Affected by 2015 Flood in December (km^2)

Inundation depth	GCC	CMA	New CMA	Tamil Nadu	Adyar	Cooum	Kovalam	Kosasthalaiyar
0m < 0.5m	8.38	10.33	N/A	N/A	2.94	1.33	3.06	3.66
0.5m < 1.0m	1.66	1.66	N/A	N/A	0.19	0.11	0.35	1.06
1.0m <1.5	1.49	1.49	N/A	N/A	0.43	0.04	0.22	0.84
1.5m < 2.0m	1.05	1.05	N/A	N/A	0.00	0.00	0.06	1.01
2m <	0.02	0.02	N/A	N/A	0.02	0.00	0.00	0.00
Total	12.59	14.55	N/A	N/A	3.58	1.48	3.68	6.57

Source: JICA Expert Team

Commercial sector

As for the commercial areas, about 90% of the total commercial areas are inundated area as a result of the simulation.

Table 7-43: Commercial Area Affected by 2015 Flood in December (km²)

Inundation depth	GCC	CMA	New CMA	Tamil Nadu	Adyar	Cooum	Kovalam	Kosasthalaiyar
0m < 0.5m	5.76	6.03	N/A	N/A	1.96	2.17	0.72	1.20
0.5m < 1.0m	0.93	0.93	N/A	N/A	0.57	0.13	0.00	0.35
1.0m <1.5	0.61	0.61	N/A	N/A	0.38	0.03	0.01	0.28
1.5m < 2.0m	0.38	0.38	N/A	N/A	0.00	0.00	0.05	0.07
2m <	0.08	0.08	N/A	N/A	0.08	0.00	0.00	0.00
Total	7.75	8.03	N/A	N/A	2.98	2.32	0.77	1.89

Source: JICA Expert Team

iii. Agriculture sector

In agricultural areas, more than half is simulated as less than 1m inundation area.

Table 7-44: Agricultural Area Affected by 2015 Flood in December (km²)

Inundation depth	GCC	CMA	New CMA	Tamil Nadu	Adyar	Cooum	Kovalam	Kosasthalaiyar
0m < 0.5m	0.60	28.39	125.22	N/A	31.07	18.31	16.91	58.84
0.5m < 1.0m	0.08	47.78	272.88	N/A	67.71	39.90	36.86	128.22
1.0m <1.5	0.00	5.65	46.02	N/A	11.42	6.73	6.22	21.62
1.5m < 2.0m	0.06	5.74	43.48	N/A	10.79	6.36	5.87	20.43
2m <	0.00	7.99	58.16	N/A	14.43	8.50	7.86	27.33
Total	0.74	95.56	545.76	N/A	135.42	79.79	73.72	256.43

Source: JICA Expert Team

Public facilities (social infrastructure)

i. Roads

More than 80% of the roads in the CMA area are simulated to be flooded, most of them are less than 1 meter inundated.

Table 7-45: Inundated Road in December 2015 Flood (km)

Inundation depth	GCC	CMA	New CMA	Tamil Nadu	Adyar	Cooum	Kovalam	Kosasthalaiyar
0m < 0.5m	3112.67	4124.39	N/A	N/A	1265.99	778.37	1141.81	938.23
0.5m < 1.0m	542.80	542.80	N/A	N/A	196.69	47.45	61.03	237.63
1.0m <1.5	619.80	619.80	N/A	N/A	194.98	71.94	113.60	239.28
1.5m < 2.0m	292.65	292.65	N/A	N/A	0.00	6.38	59.67	226.61
2m <	31.29	31.29	N/A	N/A	31.29	0.00	0.00	0.00
Total	4599.21	5610.93	N/A	N/A	1688.95	904.13	1376.11	1641.75

Source: JICA Expert Team

ii. Railways

The simulation results show that nearly 90% of the railways are inundated, and 80% of them are 1 meter or less inundated.

Table 7-46: Inundated Railway in December 2015 Flood (km)

Inundation depth	GCC	CMA	New CMA	Tamil Nadu	Adyar	Cooum	Kovalam	Kosasthalaiyar
0m < 0.5m	1003.35	1126.80	N/A	N/A	79.59	95.80	56.16	168.83
0.5m < 1.0m	92.49	92.49	N/A	N/A	19.96	0.00	6.42	66.11
1.0m <1.5	50.51	50.51	N/A	N/A	19.88	7.59	3.10	19.93
1.5m < 2.0m	4.31	4.31	N/A	N/A	0.00	0.00	2.60	0.00
2m <	4.12	4.12	N/A	N/A	4.40	0.00	0.00	0.00
Total	1154.77	1278.22	N/A	N/A	123.83	103.39	68.28	254.87

Source: JICA Expert Team

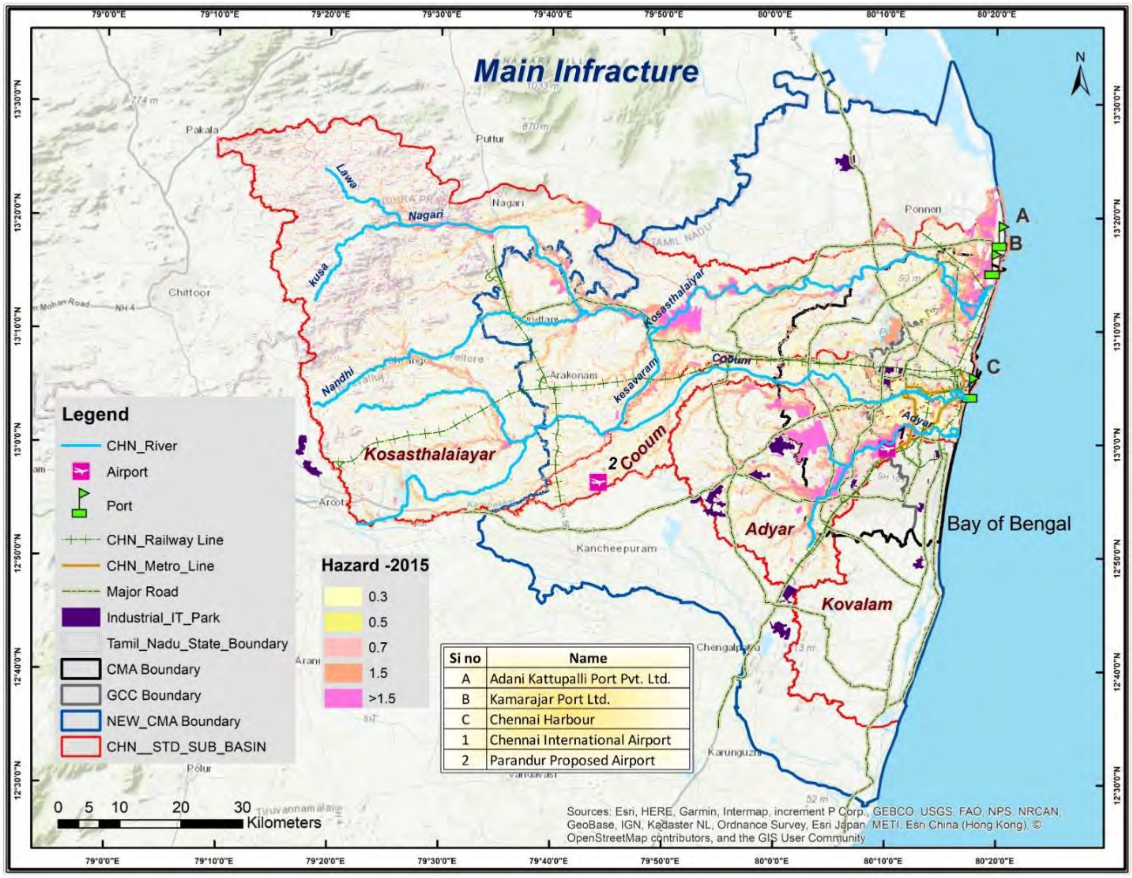
iii. Water supply

In the GCC area, the simulation results showed that 60% of the water supply systems are damaged by flooding, and nearly 70% are inundated by 0.5 m or less.

Table 7-47: Affected Water Supply Network in December 2015 Flood (km)

Inundation depth	GCC	CMA	New CMA	Tamil Nadu	Adyar	Cooum	Kovalam	Kosasthalaiyar
0m < 0.5m	1683.00	1775.15	N/A	N/A	483.99	306.01	519.09	466.06
0.5m < 1.0m	320.98	306.44	N/A	N/A	147.64	35.27	19.85	103.68
1.0m <1.5	287.83	198.60	N/A	N/A	44.06	0.69	44.06	109.78
1.5m < 2.0m	173.37	199.04	N/A	N/A	0.00	0.00	13.86	185.18
2m <	21.82	33.70	N/A	N/A	33.70	0.00	0.00	0.00
Total	2487.01	2512.94	N/A	N/A	709.40	341.97	596.87	864.70

Source: JICA Expert Team



Source: JICA Expert Team

Figure 7-29: Distribution of Major Infrastructure in the Simulated Inundation Area

iv. Electricity-related facilities

The simulation results showed that 70% to 90% of the power-related facilities other than Low-Tension power lines, which are spread over a wider area outside the target area, are inundated.

① Substations

Table 7-48: Inundated Substations by Flood Depth in December 2015 Flood (Unit)

Inundation depth	GCC	CMA	New CMA	Tamil Nadu	Adyar	Cooum	Kovalam	Kosasthalaiyar
0m < 0.5m	25	37	51	N/A	5	22	39	24
0.5m < 1.0m	114	128	151	N/A	54	34	60	65
1.0m <1.5	4	12	19	N/A	10	2	23	7
1.5m < 2.0m	1	13	18	N/A	10	1	14	7
2m <	7	10	14	N/A	9	0	18	5
Total	151	200	253	N/A	88	59	154	108

Source: JICA Expert Team

② Pillar boxes

Table 7-49: Inundated Pillar Boxes by Flood Depth in December 2015 Flood (Unit)

Inundation depth	GCC	CMA	New CMA	Tamil Nadu	Adyar	Cooum	Kovalam	Kosasthalaiyar
0m < 0.5m	3,860	6,240	8,817	N/A	1,232	3,396	855	4,189
0.5m < 1.0m	13,032	17,054	20,679	N/A	7,353	4,578	742	8,748
1.0m <1.5	350	1,361	2,467	N/A	1,414	174	327	879
1.5m < 2.0m	32	1,499	2,035	N/A	1,411	91	292	533
2m <	511	1,288	1,625	N/A	1,162	0	322	463
Total	17,785	27,442	35,623	N/A	12,572	8,239	2,538	14,812

Source: JICA Expert Team

③ Distribution transformers

Table 7-50: Inundated Distribution Transformers by Flood Depth in December 2015 Flood (Unit)

Inundation depth	GCC	CMA	New CMA	Tamil Nadu	Adyar	Cooum	Kovalam	Kosasthalaiyar
0m < 0.5m	3,860	6,240	8,817	N/A	1,232	3,396	855	4,189
0.5m < 1.0m	13,032	17,054	20,679	N/A	7,353	4,578	742	8,748
1.0m <1.5	350	1,361	2,467	N/A	1,414	174	327	879
1.5m < 2.0m	32	1,499	2,035	N/A	1,411	91	292	533
2m <	511	1,288	1,625	N/A	1,162	0	322	463
Total	17,785	27,442	35,623	N/A	12,572	8,239	2,538	14,812

Source: JICA Expert Team

④ Electricity HT lines

Table 7-51: Inundated Electricity HT Lines by Flood Depth in December 2015 Flood (km)

Inundation depth	GCC	CMA	New CMA	Tamil Nadu	Adyar	Cooum	Kovalam	Kosasthalaiyar
0m < 0.5m	243.17	925.96	2,301.66	N/A	465.89	5.21	175.81	1,265.44
0.5m < 1.0m	662.14	1,503.87	2,934.21	N/A	918.83	5.08	144.76	1,459.79
1.0m <1.5	74.73	313.82	928.10	N/A	385.27	0.92	65.97	442.19
1.5m < 2.0m	13.24	360.35	626.26	N/A	327.02	0.21	64.61	276.62
2m <	103.15	268.71	420.81	N/A	236.80	0.00	82.13	184.02
Total	1,096.43	3,372.71	7,211.05	N/A	2,333.81	11.41	533.29	3,628.05

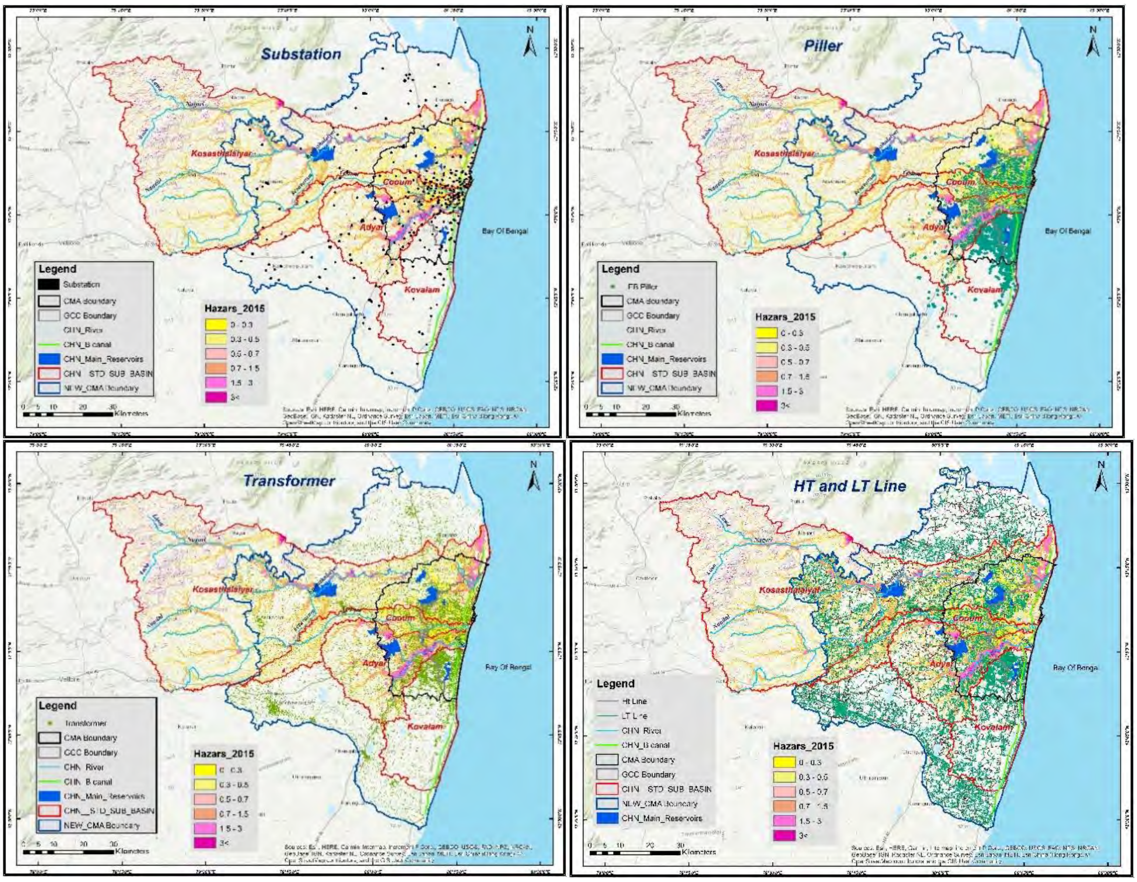
Source: JICA Expert Team

⑤ Electricity LT lines

Table 7-52: Inundated Electricity LT Lines by Flood Depth in December 2015 Flood (km)

Inundation depth	GCC	CMA	New CMA	Tamil Nadu	Adyar	Cooum	Kovalam	Kosasthalaiyar
0m < 0.5m	750.76	2,460.73	5,001.00	N/A	641.05	1297.14	264.72	3063.27
0.5m < 1.0m	1,488.92	3,479.98	6,488.72	N/A	1685.96	1387.18	218.54	3415.57
1.0m <1.5	129.35	550.06	1,546.55	N/A	524.56	183.69	93.80	838.31
1.5m < 2.0m	29.52	578.91	1,025.43	N/A	558.57	24.78	83.85	442.08
2m <	75.82	490.19	739.28	N/A	386.72	-	86.97	352.55
Total	2,474.38	7,559.88	N/A	N/A	3796.87	2892.79	747.89	8111.79

Source: JICA Expert Team



Source: JICA Expert Team based on information by TANGEDCO

Figure 7-30: Distribution of Power-Related Facilities in the Simulated Inundation Area

v. Other public-related areas

Table 7-53: Inundated Public Facilities by Flood Depth in December 2015 (km^2)

Inundation depth	GCC	CMA	New CMA	Tamil Nadu	Adyar	Cooum	Kovalam	Kosasthalaiyar
0m < 0.5m	10.00	13.25	N/A	N/A	3.96	2.48	2.73	3.44
0.5m < 1.0m	2.33	2.33	N/A	N/A	1.12	0.23	2.73	0.89
1.0m <1.5	1.70	1.70	N/A	N/A	0.07	0.15	0.07	0.62
1.5m < 2.0m	0.51	0.51	N/A	N/A	0.16	0.00	0.08	0.57
2m <	0.30	0.30	N/A	N/A	0.00	0.00	0.00	0.00
Total	14.84	18.09	N/A	N/A	5.31	2.86	5.61	5.52

Source: JICA Expert Team

Estimate of the basic unit of each damaged item (damage intensity)

The basic unit (intensity) of each damage item (asset item) is calculated based on the sectoral damage amounts and damage quantities discussed above (Table 7-55). As the calculations are based on actual damage and damage estimates as of 2015, the Consumer Price Index (CPI) is used as a deflator for correction and is converted to present value (Table 7-54).

Table 7-54: Setting of Deflators

Year	Consumer Price Index (CPI) (Base year=2016)	Deflator (Base year=2015)
2008	51.7	0.54
2009	57.4	0.59
2010	63.1	0.65
2011	67.3	0.70
2012	75.3	0.78
2013	84.0	0.87
2014	90.5	0.94
2015	96.6	1.00
2016	100.0	1.04
2017	103.8	1.07
2018	107.6	1.11
2019	114.8	1.19
2020	120.0	1.24
2021	123.6	1.28
2022	-	1.28
2023	-	1.28
2024	-	1.28

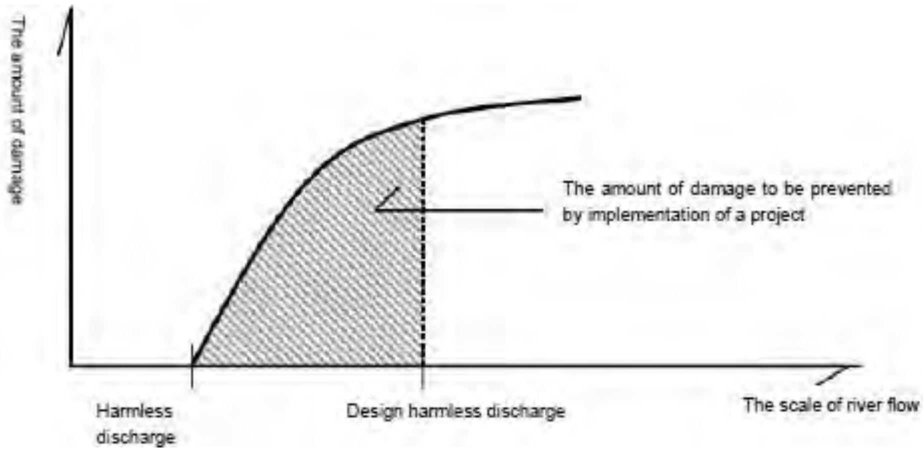
Source: Created based on the Consumer Price Index (CPI) in Government of Tamil Nadu Department of Economics and Statistics Statistical Hand Book 2020-21, 29.3 ALL INDIA & TAMIL NADU CONSUMER PRICE INDEX NUMBERS FOR INDUSTRIAL WORKERS by Tamil Nadu State

Table 7-55: 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.

Calculation of economic benefits
The total benefits during the period subject to the economic evaluation should be calculated by adding the benefits that are the difference in damage between with- and without-project conductions to the residual values of a flood control facility as of the end of the period subject to the economic evaluation.



Source "Manual for Economic Evaluation of Flood Control Investment (Draft)" by the Ministry of Land, Infrastructure and Transport of Japan

Figure 7-31: Benefits of a Flood Control Project

a. Assumptions

- The amount of flood damage for each of the assumed Return Periods (Scale of river flow) of 2, 3, 5, 10, 20, 30, 50, 80, and 100 years is calculated for each of the cases with and without flood control countermeasures considered in the previous Section. The amount of damage for the case without the countermeasures minus the amount of damage for the case with the countermeasures is calculated as the amount of expected damage reduction.
- The annual average damage reduction is calculated by multiplying the average damage reduction by reach (sectional average damage reduction) between flow scales by the probabilities (sectional probabilities) of flood occurrence. The annual average damage reduction benefit of the project is calculated by accumulating the annual average damage reduction for all sections.
- The period of the countermeasure development is assumed to be 30 years, from 2024 to 2053. The period covered by the evaluation after the completion of the facility is 50 years, from 2054 to 2104, but benefits are assumed to continue to arise after 2104 and are valued at residual value.
- For the social discount rate, 7% is used, taking into account the interest rate on 10-year government bonds in India over the past 10 years.

Table 7-56: Trends in Interest Rates on India 10-Year Government Bonds

2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
7.758%	6.516%	7.318%	7.370%	6.554%	5.894%	6.454%	7.327%	7.176%	7.074%

Source: World Government Bonds, "India 10 Years Bond - Historical Data"

b. Benefit evaluation

Using the results of the simulation of Phase 2 completion, the calculated aggregated annual average damage reduction (=expected annual average damage reduction) for the four basins (Adyar, Cooum, Kovalam, and Kosasthalaiyar) are shown in **Table 7-57**.

Table 7-57: 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

Calculation of economic costs

a. Costs to be evaluated

In principle, when a river improvement plan is developed, and a newly adopted river and/or dam project is evaluated, the economic efficiencies of these projects should be assessed based on the current conditions of the river channel to be improved. Therefore, the costs of a flood control investment consist of the future costs that will be spent to complete a planned flood control facility (the construction costs of a planned flood control facility, costs of land, and compensation costs) and the maintenance costs that will be spent during the period subject to the economic evaluation (for the next 50 years following the completion of a planned flood control facility)

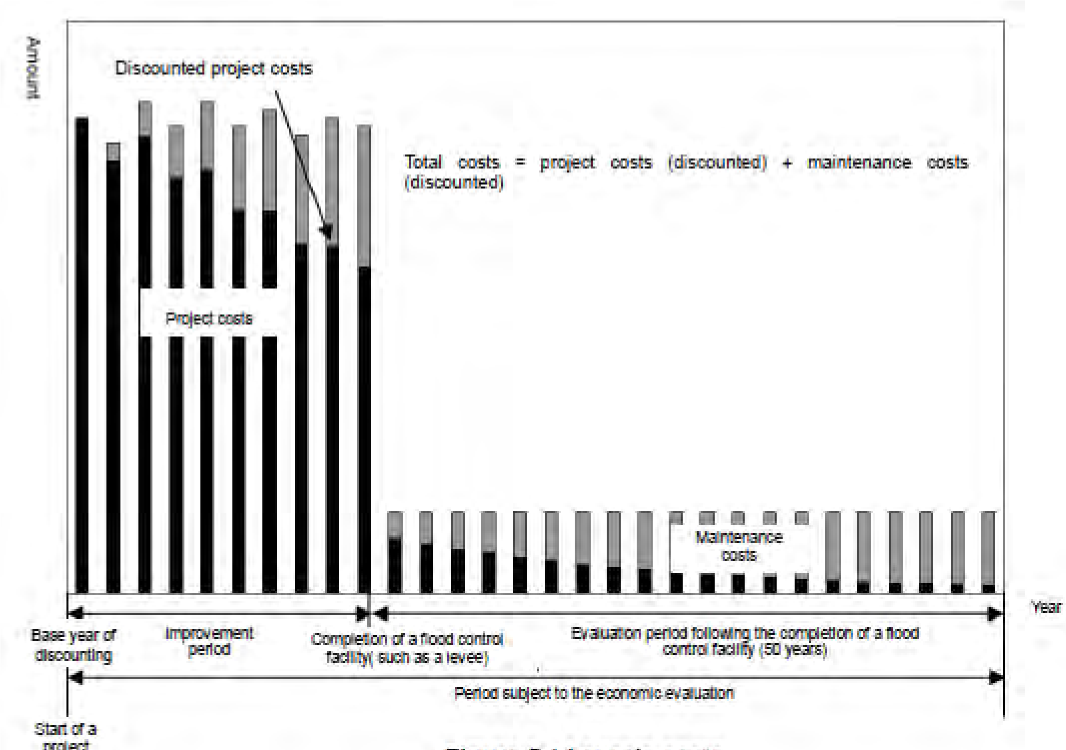


Figure-5.1 Levee's costs

Source "Manual for Economic Evaluation of Flood Control Investment (Draft)" by the Ministry of Land, Infrastructure and Transport of Japan

Figure 7-32: Costs of Project

Calculation of the financial costs
See the previous section for details on financial costs.

Estimation of the economic costs
I. Standard Conversion Factor (SCF)
The financial cost calculated above is estimated based on the fixed price of India's domestic price as of the time of this Master Plan. This financial cost needs to be converted to economic cost integrated at border prices, and the Standard Conversion Factor (SCF) is estimated by the following equation as the conversion factor for this purpose.

$$SCF = \frac{\sum I + \sum E}{(\sum I + \sum I_{customs}) + \left(\sum E - \sum E_{tax} + \sum E_{subsidy}\right)}$$

I = Total imports (CIF price)

E = Total export (FOB price)

$I_{customs}$ = Total import duties

E_{tax} = Export tax

$E_{subsidy}$ = Total export subsidies

As shown in the table below, the SCF for India was estimated at 0.9739.

Table 7-58: Estimation of Standard Conversion Factor (SCF)

Year	Export	Import	Customs	Export duties	Subsidies
2018	323,241.51	508,980.58	15,774.19	0.00	N/A
2019	324,830.13	479,868.82	21,406.31	0.00	N/A
2020	287,537.64	402,397.63	17,798.58	0.00	N/A
2021	394,463.71	570,020.14	23,155.02	0.00	10,245.57
Total	1,330,072.99	1,961,267.17	78,134.09	0.00	10,245.57

Source IMF, Exports and Imports by Area and Countries、Ministry of Commerce and Industry Department of Commerce, Press Releases" Government Provides Big Boost to"

Tax
Taxes are also transfer pricing items and should be excluded when converting to economic costs.

i. Goods and Services Tax (GST)
Value Added Tax (Goods and Services Tax: GST) 18% calculated in 00 is excluded.

Economic evaluation
a. Evaluation indicators
As mentioned above, the project compares economic benefits (B) with economic costs (C) and assesses the economics of the project through indicators such as Benefit-Cost ratio (B/C Ratio), Net Present Value (NPV (i.e. B-C)), and Economic Internal Rate of Return (EIRR).

The benefit-cost ratio (B/C Ratio) is given by the following formulation. When the present value of economic benefits is divided by the present value of economic costs, the project can be said to be sufficiently reliable to be implemented if the result is equal to or greater than '1.00'.

$$B/C = \sum_{t=1}^{n} \frac{B_t}{(1+r)^t} \bigg/ \sum_{t=1}^{n} \frac{C_t}{(1+r)^t}$$

B_t = Economic benefits of the project at project life t year

C_t = Economic cost of the project at project life t year

r = Discount rate (the discount rate such that economic costs and benefits are equal at present value)

n = Project life (year)

The Net Present Value (NPV) is 'B-C,' which is given by the following formulation. If the present value of economic benefits minus the present value of the economic costs is positive (>0), then the project under consideration is credible enough to be implemented.

$$NPV = B - C = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^t}$$

The EIRR is calculated using the economic cost and economic benefit cash flows over the entire project life, which is the discount rate at which the NPV is 0 (zero), calculated as follows: if the EIRR is equal to or greater than the discount rate adopted, this indicates that the project is likely to be economically viable.

$$\sum_{t=1}^{n} \frac{C_t}{(1+r)^t} = \sum_{t=1}^{n} \frac{B_t}{(1+r)^t}$$

The project life is 50 years after the completion of construction for the projects. The cash flow of economic costs and benefits should be created from the first year of construction to the last year of the respective project life. Annual maintenance costs must also be taken into account.

b. Evaluation results
The economic cost and economic benefit cash flows for this Master Plan are shown in Appendix (7.3.4).

The cost-effectiveness is calculated in 3 cases: Phase 1, Phase 2, and the remaining project evaluation (Phase 2-Phase 1), which is the evaluation of the project in case of Phase 2 to be done after Phase 1 is completed. The results of the economic internal rate of return (EIRR), economic net present value (ENPV) (=B-C), and cost-benefit ratio (B/C) for each case are shown in the table below.

The results are quite high because the target rivers have a very low flow capacity. Generally, in the project evaluation, the project effect is high in the initial stage of the project, but as the project progresses, the degree of safety increases, and the evaluation value decreases in the latter half of the project.

Therefore, in the remaining project evaluation, at the start of Phase 2, the project is assumed to have secured a certain degree of safety up to the return period (RP) of 1/10 by implementing the Phase 1 project and damage of 1/10 RP or less is set as the case where the Phase 1 starting project is implemented (With) and the case where the project is not implemented (Without). The remaining projects with 1/10 RP to 1/100 RP were considered for the evaluation of projects in the case that Phase 2 projects were implemented.

Based on the above assumptions and the results of each indicator in each case, it is believed that this project is appropriate from the standpoint of economic feasibility.

Table 7-59: The Results of Economic Indicators for the Flood Control Projects

	Phase1	Phase2	Remaining project (Phase2-Phase1)
B/C	16.9	3.6	2.2
NPV (B-C)	207,488 (Crore INR)	116,212 (Crore INR)	39,652 (Crore INR)
EIRR	41%	13%	12%

Source: JICA Expert Team

Benefits that cannot be assessed in terms of economic value
The Ministry of Land, Infrastructure, Transport and Tourism of Japan's Guidance for Analysing Damage Indicators of Flood Damage (H25 Trial Version) presents some of the items in the stock effects of flood control projects that cannot be converted into monetary values as quantification indicators. Of these, the project presents some indicators that can be analyzed from the available data.

I. Damage Indicators for Human Damage
- Population within the inundated area
- Number of people in need of disaster assistance within the inundated area
- Estimated number of fatalities
- Number of people isolated for more than 3 days
- Number of evacuations per decade
- Total number of evacuees per decade, etc.

II. Damage Indicators for Social Functional Impairment Damage
- Number of medical facilities with reduced functionality
- Number of inpatients treated in medical facilities with reduced functionality
- Number of dialysis patients treated in deteriorating medical facilities
- Number of social welfare facilities with declining functionality
- Number of users of social welfare facilities with declining function
- Number of major disaster preparedness facilities with declining functions
- Population within the jurisdiction of the facility of the disaster prevention center with declining functionality etc.

III. Damage indicators of ripple damage
- Major roads to be disrupted
- Traffic volume affected by road disruption
- Travel time, cost increased due to road disruption (traffic association)

III. Damage Indicators for Spillover Damage (cont.)
- Major railroads to be disrupted
- Number of users affected by railroad disruption
- Population affected by electricity, gas, water, and sewerage outages
- Population affected by telecommunications (fixed and mobile) outages
- Economic ripple damage using economic models such as Input-Output analysis
- Impact on supply chain of companies affected by the disaster
- Number of listed companies affected by flooding
- Number of employees at business establishments affected by inundation, etc.

IV. Other Damage Indicators
- Subway lines, stations inundated by flooding
- Number of passengers affected by inundation of subways, etc.
- Inundated underground malls and underground facilities
- Number of users affected by flooding of underground malls and underground facilities
- Cultural facilities to be inundated
- Amount of flood waste generated
- Cost of disposal of flood waste, etc.

Source "Guide to Analysing Damage Indicators for Flood Damage" (H25 Trial Version)" by Bureau of Water

Management and Land Conservation, Ministry of Land, Infrastructure and Transport of Japan

Figure 7-33: Quantification Index for Items That Cannot Be Converted into Monetary Value of Water Damage

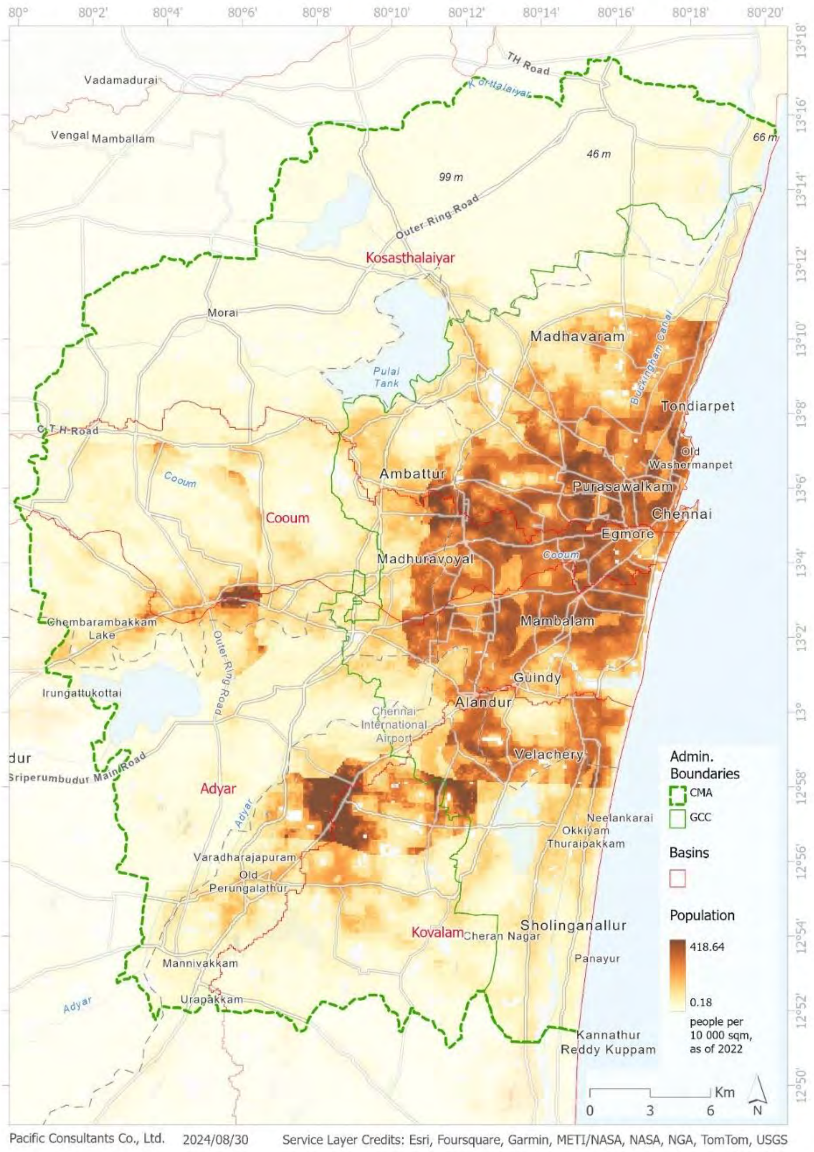
a. Quantification indicators
I. Damage indicators for human damage
i. Population in inundated areas

The damage to the population within the inundation area in the CMA area is estimated to be 2.08 million at 1/2 return period (RP), 4.02 million at 1/10RP, 4.57 million at 1/50RP, and 4.81 million at 1/100RP, is assumed to be eliminated by the implementation of the Master Plan project.

Table 7-60: The Number of Population within the Inundation Area in the CMA Area by Return Period (Person)

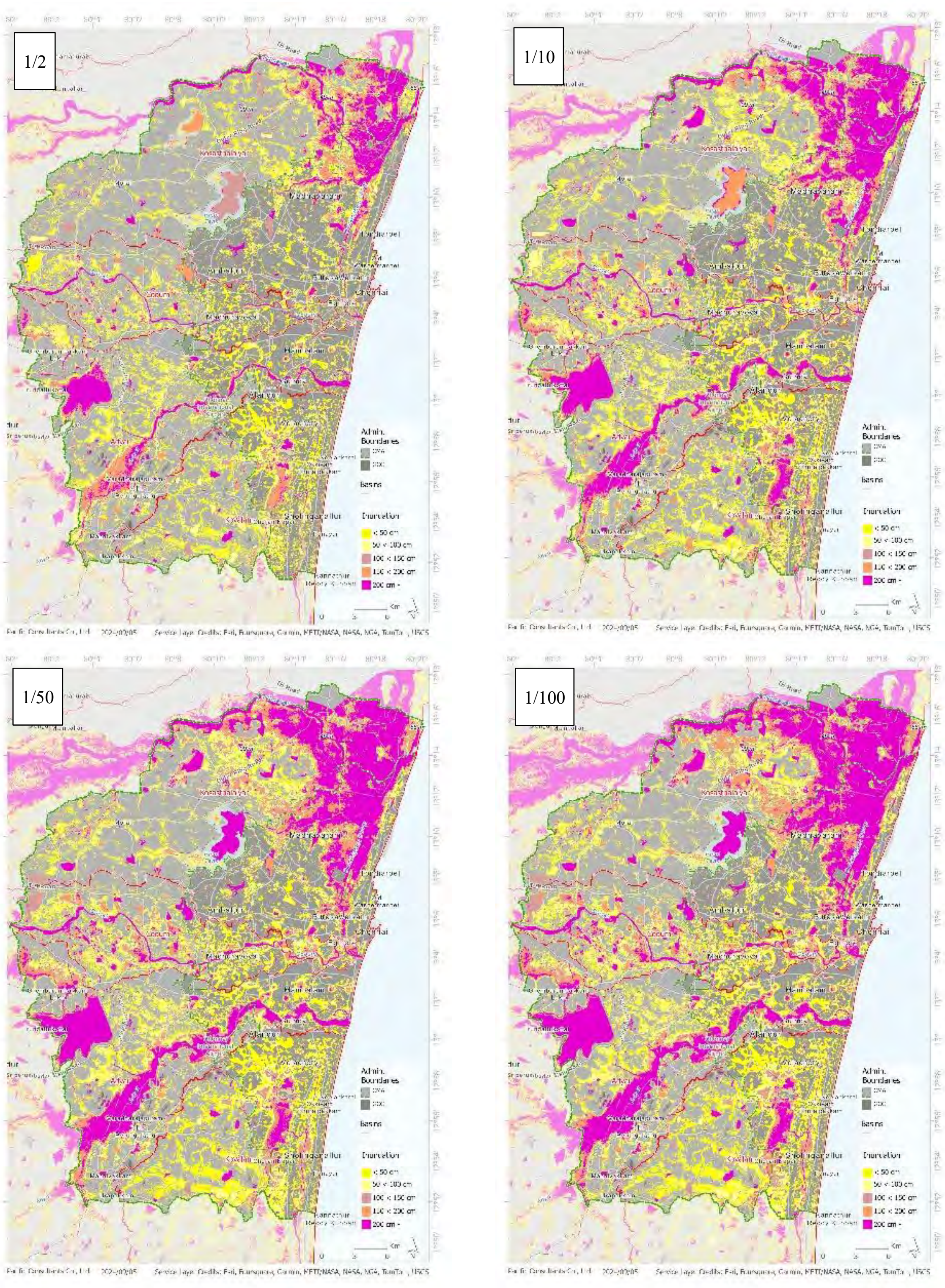
Inundation depth	1/2	1/10	1/50	1/100
0m < 0.5m	1,130,574	1,680,456	1,758,175	1,743,950
0.5m < 1.0m	482,706	965,803	972,917	1,021,102
1.0m <1.5	163,692	397,949	474,728	508,692
1.5m < 2.0m	135,853	384,200	496,142	546,456
2m <	171,556	587,384	864,860	994,494
Total	2,084,381	4,015,792	4,566,823	4,814,694

Source: JICA Expert Team



Source: JICA Expert Team

Figure 7-34: (Ref.) Population Distribution



Source: JICA Expert Team

Figure 7-35: (Ref.) Inundation Distribution

Damage indicators of ripple-off damage

i. Ripple effects from transportation disruption

① Major roads and railroads to be disrupted

Damage to major railroads in the CMA area is assumed to be 25.9 km at 1/2 return period (RP), 39.3 km at 1/10 RP, 47.9 km at 1/50 RP, and 62.9 km at 1/100 RP. It is assumed that these will be eliminated by implementing the projects in this Master Plan.

Table 7-61: The Length of Inundated Railroads in the CMA Area by Return Period (km)

Inundation depth	1/2	1/10	1/50	1/100
0m < 0.5m	6.5	7.0	7.1	18.4
0.5m < 1.0m	8.2	10.7	12.9	13.1
1.0m <1.5	3.3	6.5	5.2	6.2
1.5m < 2.0m	2.5	5.8	8.2	7.9
2m <	5.4	9.3	14.5	17.4
Total	25.9	39.3	47.9	62.9

Source: JICA Expert Team

Damage to major roads in the CMA area is assumed to be 3,785 km at 1/2 return period (RP), 5,123 km at 1/10 RP, 5,946 km at 1/50 RP, and 6,323 km at 1/100 RP. It was assumed that these would be eliminated by implementing the projects in this Master Plan.

Table 7-62: The Length of Inundated Roads in the CMA Area by Return Period (km)

Inundation depth	1/2	1/10	1/50	1/100
0m < 0.5m	2,175	2,392	2,497	2,489
0.5m < 1.0m	861	1,233	1,322	1,385
1.0m <1.5	288	476	618	670
1.5m < 2.0m	255	457	611	707
2m <	206	566	898	1,072
Total	3,785	5,123	5,946	6,323

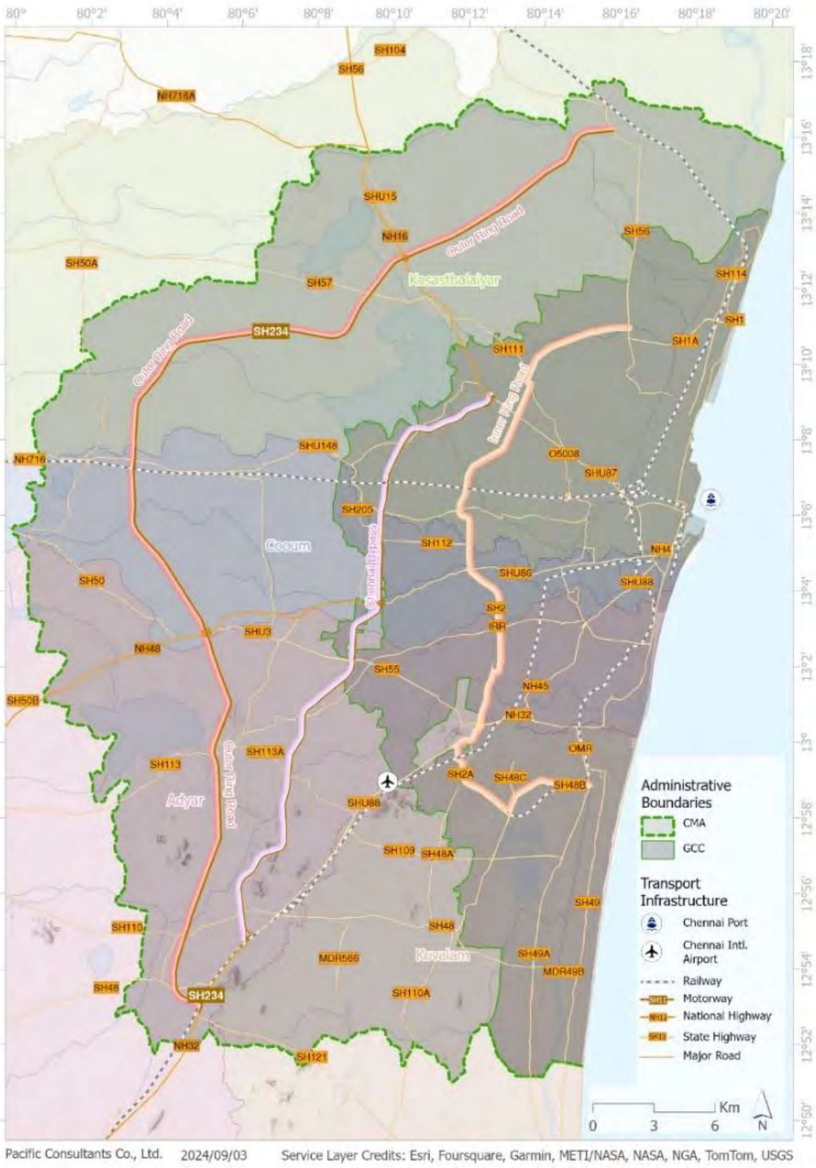
Source: JICA Expert Team

For roads, the table below shows the inundation lengths for each inundation duration for roads and highways inundated by 0.5 m or more during floods with return periods of 1/10 and 1/100, calculated using the results of 2D model simulations.

Table 7-63: Inundated Road/Highway Length by 12-Hour Interval Inundation Time (km)

Basin	Return Period	0-12hrs	12-24hrs	24-36hrs	36-48hrs	More than 48hrs
Adyar	10 years	498.8	326.2	117.3	45.7	4.1
	100 years	612.3	401.8	220.3	101.3	26.3
Cooum	10 years	190.3	137.1	79.2	34.8	5.6
	100 years	315.2	205.2	139.2	68.5	11.9
Kovalam	10 years	368.5	269.4	125.1	76.4	26.6
	100 years	382.5	289.1	147.4	84.3	43.4
Kosasthaliyar	10 years	602.3	454.5	257.1	116.4	48.7
	100 years	875.4	627.1	385.1	182.5	74.9

Source: JICA Expert Team



Source: JICA Expert Team

Figure 7-36: (Ref.) Transportation Infrastructure Distribution

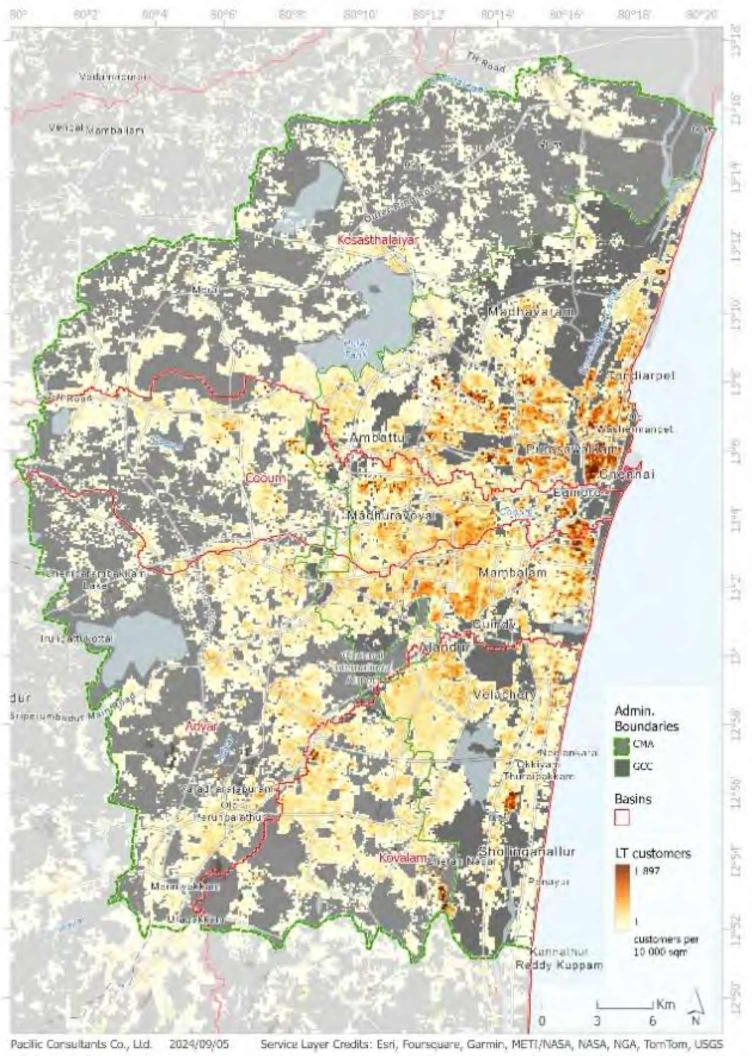
ii. Population affected by power outages

The population (Low-Tension (LT) electricity consumers) affected by the outage of electricity in the CMA area is assumed to be 877,000 with 1/2 return period (RP), 1,232,000 with 1/10 RP, 1,459,000 with 1/50 RP, and 1,574,000 with 1/100 RP. It is assumed that these would be eliminated by implementing the projects in this Master Plan.

Table 7-64: The Number of Inundated Low-Tension (Lt) Consumers Affected by the Outage of Electricity in the CMA Area by Return Period (Person)

Inundation depth	1/2	1/10	1/50	1/100
0m < 0.5m	601,686	711,132	761,855	772,946
0.5m < 1.0m	173,177	279,393	325,498	355,367
1.0m <1.5	46,643	90,874	126,901	149,809
1.5m < 2.0m	34,385	80,295	113,551	134,647
2m <	21,090	70,920	131,371	161,720
Total	876,981	1,232,614	1,459,176	1,574,489

Source: JICA Expert Team



Source: JICA Expert Team

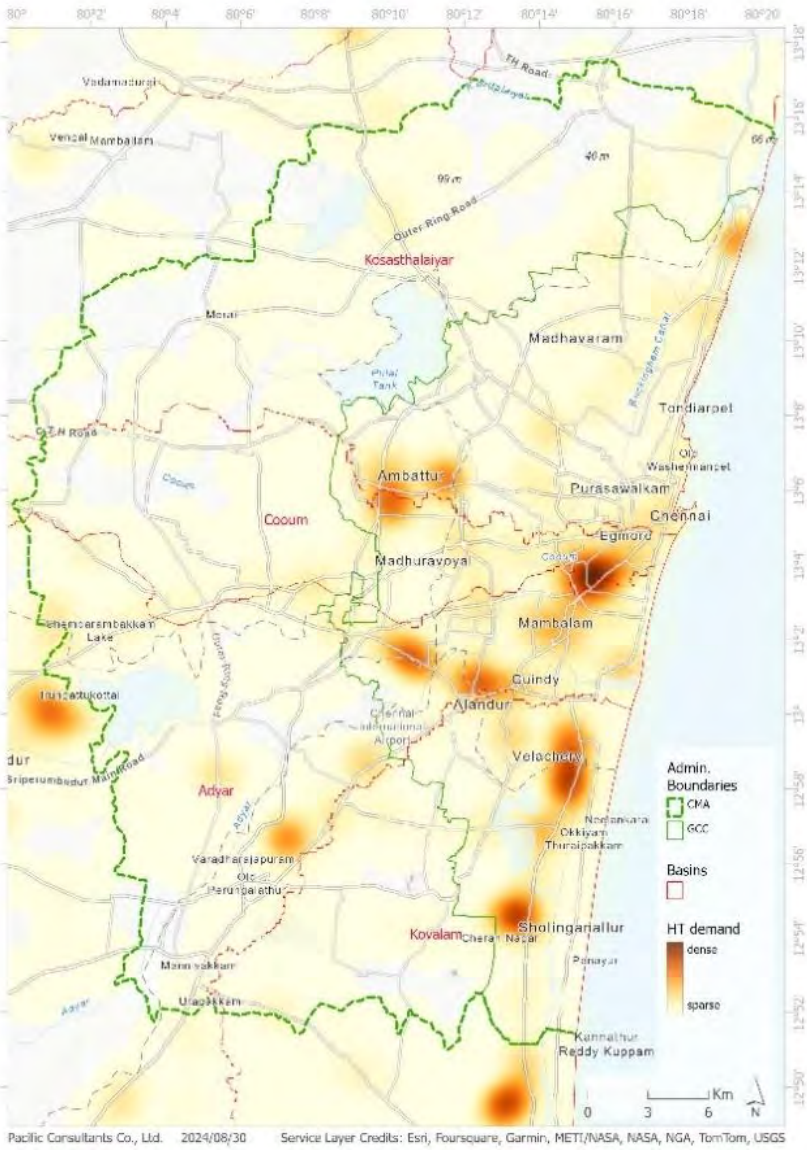
Figure 7-37: (Ref.) Distribution of Low-Tension (LT) Electricity Consumers

The number of business establishments (High-Tension (HT) electricity consumers) in the CMA area affected by the outage of electricity is assumed to be 332,000 business establishments at 1/2 return period (RP), 468,000 business establishments at 1/10 RP, 592,000 business establishments at 1/50 RP, and 638,000 business establishments at 1/100 RP. It is assumed that these will be eliminated by the implementation of this Master Plan project.

Table 7-65: The Number of Inundated High-Tension (HT) Consumers Affected by the Outage of Electricity in the CMA Area by Return Period (Business Establishments)

Inundation depth	1/2	1/10	1/50	1/100
0m < 0.5m	203,599	242,702	238,094	242,503
0.5m < 1.0m	80,729	104,638	167,180	176,883
1.0m <1.5	21,244	37,876	52,908	56,707
1.5m < 2.0m	11,930	50,402	53,812	69,121
2m <	15,397	32,048	80,147	93,312
Total	332,899	467,666	592,141	638,526

Source: JICA Expert Team



Source: JICA Expert Team

Figure 7-38: (Ref.) High-tension (HT) Electricity Demand Distribution

The table below shows the number of inundated pillar boxes susceptible to flooding, calculated for pillar boxes inundated by 0.5 m or more during floods with a return period (RP) of 1/10 and 1/100, using simulation results of 2D model for the duration of flooding.

Table 7-66: The Number of Pillar Boxes Expected to Be Flooded by 12-Hour Interval Flooding Time (Unit)

Basin	Return Period	0-12hrs	12-24hrs	24-36hrs	36-48hrs	More than 48hrs
Adyar	10 years	1,975	1,421	752	270	135
	100 years	3,125	2,201	1,220	up to	226
Cooum	10 years	1,442	959	584	237	37
	100 years	3,074	1,979	1,338	452	113
Kovalam	10 years	669	471	165	81	39
	100 years	682	489	177	87	44
Kosasthaliyar	10 years	2,738	1,691	743	270	71
	100 years	4,175	2,527	1,424	582	274

Source: JICA Expert Team

iii. Impact on airports due to flooding

The table below shows the closure of Chennai Airport for the past 10 years (2015-2024).

Also, the simulation results show that for a 1/20 return period (RP) flood, the airport would be inundated by more than 0.3 meters for about 24 hours. Simulation results for a 1/100 RP flood indicate that the inundation time would be 60 hours. However, it is assumed that this problem will be solved once the implementation of measures under this Master Plan is completed.

Table 7-67: Details of Chennai Airport Closures due to Flooding in the Last 10 Years (2015-2024)

Food Year	Date of Airport Shutdown	Shutdown Duration	Shutdown Type	Reason for Shutdown	No. of **Affected Flights**
2015	1~6 Dec.	5 days (120 hrs.)	Full Shutdown	Flooding of runways and terminal areas	N/A
2020	25~26 Nov.	12 hours	Partial Shutdown	Cyclone Nivar: Temporary shutdown for safety	N/A
2021	11 Nov.	N/A	Partial Shutdown	Heavy rains and strong crosswinds to suspend all arrivals flights.	N/A
2023	4 Dec.	14 hours	Full Shutdown	Cyclone Michaung: Grounded flights due to flooding	70 flights
2024	30 Nov ~1 Dec.	16 hours	Full Shutdown	Cyclone Fengal: Adverse weather conditions and flooding	110 flights

Source: JICA Expert Team

7.3 Appendix

7.3.1 Construction unit price

The unit cost of construction to be used for the estimation of each countermeasure work is set as follows.

7.3.1.1. River Channelization

(1) Excavation

The unit price for mechanical excavation on land shall be adopted. The unit price INR 51.45 shall be the unit price listed in SI No. 54, Sch. Item No. 54 of E. Rate for Earth Work Deploying Machinery in the unit price table "PWD SOR 2022-2023, with effect from 19.07.2022".

(2) Dredging

The unit price for dredging shall be the unit price INR 485 as stated in the project document "Name of Work: Standardization of OKKIYUM MADUVU by Dredging and Regrading of Existing Drain up to Buckingham Canal near KCG College of Technology Premises in Sholinganallur Taluk of Chennai District (2022)".

(3) Transportation

Transportation costs are calculated using Annexure-V, Conveyance Table A. Rates for Conveyance of Materials by Road in Plains and Table B. Rates for Conveyance of Materials by Road in Hills from the unit price table "PWD SOR 2022-2023, with effect from 19.07.2022. Rates for Conveyance of Materials by Road in the Hills. Here, the costs based on hauling distance are recalculated and summarized in **Table 7-68**. The cost of hauling on the plains is INR 57.26 for 5 km, 114.5 for 10 km, and 212.4 for 20 km, respectively.

Table 7-68: Transportation Rate Based on Haul Distance (INR)

km	km	Rate (Plains)	Amount (Plains)	Rate (Hills)	Amount (Hills)
0-10	10	11.45	114.5	22.90	229.0
10-20	20	9.79	212.4	19.58	424.8
20-30	30	8.43	296.7	16.86	593.4
30-40	40	8.43	381.0	16.86	762.0
40-50	50	7.91	460.1	15.82	920.2
50-60	60	7.91	539.2	15.82	1078.4
60-70	70	7.91	618.3	15.82	1236.6
70-80	80	7.91	697.4	15.82	1394.8

Source: Prepared by JICA Expert Team based on PWD SOR 2022-2023, with effect from 19.07.2022

(4) Embankment

The embankment shall be constructed by bulldozing and compaction by rollers. By referring to the unit price list "WRD SOR 2022-2023, with effect from 19.07.2022", the spreading rate by bulldozers is INR 19.55 from SI. No. 54, Sch. Item No. 78A (Breaking clods, consolidating and sectioning the earth scooped by Bull Dozers), and the compaction rate by roller is INR 36.95 from SI. No. 57, Sch. Item No. B (By power roller, including hire charges), and the combined rate is INR 56.5.

(5) Revetment

Three types of revetments are considered: concrete block revetments, steel sheet piles, and turf revetments. The unit construction cost for the concrete block revetment and the VL-type, L=12m steel sheet pile is set at INR1,700/m^2 and INR8,500/m^2, respectively, based on the results of interviews with several Indian contractors and actual construction results.

For the turf revetment with the shaping of slopes and grass vegetation, the unit price table “PWD SOR 2022-2023, with effect from 19.07.2022” indicates that the slope shaping shall be Item No. 43A (Trimming the bed and the side slope of the bank in all soils except hard rock upto the bank) and Item No. 43B (Trimming the bed and the side slope of the bank in all soils except hard rock upto the bank in all soils except hard rock down to the bank in all soils). All soils except hard rock upto a thickness of 7.5 cm and making it ready to receive the concrete) from INR 18.00 and grass vegetation from Item No. 82A (Turfing in slopes Grass vegetation shall be INR 36.95 from Item No. 82A (Turfing in slopes including watering and fixing with initial lead up to 50m) for a total of INR 54.95 (/m^2).

(6) Replacement of existing bridges

The river widening will require the replacement of existing bridges. The construction and procurement costs for the new bridge are calculated at 250,000 yen/m^2 per area of the bridge, based on the construction costs (150,000-350,000 yen/m^2) for the installation of steel road bridges in Japan. Since the removal costs of the existing bridge are almost the same as those required to install the bridge in Japan, the construction and procurement costs required to remove the bridge are also assumed to be 250,000 yen/m^2, and the unit cost of replacing the bridge is set at 500,000 yen/m^2

as the unit cost of construction in Japan. The following construction cost comparison published on the website as of May 2024 by Arcadis NV, a global design, engineering, and management consulting firm headquartered in Zuidas, Amsterdam, the Netherlands, is used to determine the unit construction cost to be used for the construction in Japan and the unit construction cost in India. The construction cost of the bridge replacement project in India is assumed to be one-third of the unit construction cost in Japan, i.e., about 100,000 yen/m^2 or 560,000 INR/m^2.

<Internal Construction Cost Index by Arcadis NV>

Tokyo 120-180 (Average 150)

Mumbai 35-45 (Average 40)

Table 7-69: List of Bridges to Be Replaced

			Adyar				Cooum River			
			Phase1		Phase2		Phase1		Phase2	
Works	Unit	Quantity	Number of Locations	Replacement Area [m^2]	Number of Locations	Replacement Area [m^2]	Number of Locations	Replacement Area [m^2]	Number of Locations	Replacement Area [m^2]
Bridge	m^2	500	10	5,000	27	13,500	23	11,500	26	13,000

			Kosasthalaiyar River			
			Phase1		Phase2	
Works	Unit	Quantity	Number of Locations	Replacement Area[m^2]	Number of Locations	Replacement Area [m^2]
Bridge	m^2	500	0	0	0	0

Source: JICA Expert Team

(7) Other Works

The unit rate for other types of work related to river widening, taken from the "PWD SOR 2022-2023, with effect from 19.07.2022", is shown in **Table 7-70**.

Table 7-70: Unit Rate for Other Works Related to River Channelization

Item No.	Description of Works	Unit	Basic Rate 2022-2023
	A. Clearing the Site		
2	Clearing (Light) Jungle	spm.	5.55
4	Uprooting & Removing (Large) Palmyrah / Coconut Stumps	Each	152.65
9	Removing Weeds in the Channel and Drain	sqm.	1.95
9C	Cleaning Juliflora Jungle with Uprooting	sqm.	8.45
	B. Dismantling		
18	Cut Stone Slab over culverts (up to 3.3m height below GL)	cum.	1017.00
23	Grouted Stones Apron or Revetment, stacking within 40m lead	cum.	132.40

Source: Prepared by JICA Expert Team based on PWD SOR 2022-2023, with effect from 19.07.2022

7.3.1.2. Improvement of Existing Tanks

(1) Excavation

The unit price for mechanical excavation on land described in the previous section is set at INR 51.45.

(2) Dredging

The unit price for dredging described in the previous section is set at INR 485.

(3) Transport

The transport distance on flat land described in the previous section is set at 5 km and INR 57.26.

(4) Embankment

The unit cost of bulldozer leveling and roller compaction described in the previous section, INR 58.7, is used.

(5) Channel between tanks

The unit cost for the excavation and revetment of the open bypass is shown above.

For the Cut & Cover type of concrete structures, the following formulas were used as described in Section. 7.1.7, Connecting Drainage (Micro-Drainage) Improvement (Urban Area).

Unit cost per meter (INR) = 4481 x discharge + 63841 (m^3/s)

Note that the gravity retaining wall type is the one described in the Case Study of "Comprehensive Flood Management, Adayar, Lower Palar, Kovalam.... Sub Basins, TNPWD WRD", and the same unit cost of Cut & Cover was used since the unit cost per meter is almost equal.

From the above, the concrete channel structures (gravity retaining wall and Cut & Cover) are 108,651 INR/m for B = 6.0 m & H = 2.0 m (Q = 10 m^3/s), 86,246 INR/m for B = 5.0 m & H = 1.8 m (Q = 5 m^3/s), B = 4.0 m & H = 1.6 m (Q = 3 m^3/s) and 77,284 INR/m.

7.3.1.3. Underground Bypass

For the Underground Bypass proposed in the Master Plan, the unit construction cost of INR57,315/m^3 shall be set for the construction of the shield tunnel in Chennai Metro (Phase 2), which was constructed in Chennai, India, and the unit construction and procurement cost of the tunnel.

7.3.1.4. Improvement of existing urban tanks

The construction unit price used for the countermeasure work "river channelization" described in the previous section is used.

7.3.1.5. Improvement of the urban drainage channel

Among the unit construction costs, those described in the previous section are used for excavation, dredging, transport, embankment, and revetment.

For concrete placement and Cut & Cover, the unit costs are calculated using examples of construction in the local area. The calculation procedure is described below.

(1) Concrete placement

Excavation rate

The excavation rate is the average of the unit cost of excavation for Schedule Items 50 and 62, shown in **Table 7-71** below, where Item 50 is mainly for sandy soil and Item 62 is mainly for hard clay and stony soil. The unit cost of excavation is 88.6 INR, as shown below.

(No. 50 + No. 62) / 2 = (70.95 + 106.25) = 88.60

Table 7-71: Excavation Rate in the SOR

Sl No.	Sch. Item No.	Description of Works	Unit	Basic Rate 2022-2023
41	50	Ordinary Soil (SS20B) Earth Work excavating and depositing on a bank with an initial lead of 10m & initial lift of 2m in Sand, silt or other loose soil, wet sand or silt not under water, light black cotton soil, sandy loam and ordinary soil including excavated earth (SS20B)	cum.	70.95
47	62	HGS SS.20.B. Earth work excavating and depositing on a bank with an initial lead of 10m & initial lift of 2m in Hard stiff clay, stiff black cotton, hard red earth, shales, murram, gravel, stony earth, and earth mixed with small size boulders SS.20B	cum.	106.25

Source： PWD SOR 2022-2023, with effect from 19.07.2022

Modification of the excavation rate
The unit price is then doubled based on the construction conditions for the narrow section shown in Earthwork in **Table 7-72** of the SOR below. In other words, the revised unit cost of excavation is 177.2 INR.

88.60 x 2 = 177.2

Table 7-72: Modification of the Rate

Earthwork	
3	Double the relevant rate for standard specification No.20B will apply to excavation in all soils and rock classifications given above for the foundation of buildings, abutments, piers, wings and wings and returns of bridges, culverts, sluices, regulators, and cross masonry works, retaining walls, toe walls, cut-off walls and body walls of anicuts, weirs, retaining walls of causeway, bed dams, trenches for water supply and drainage works for laying pipes and sewers, pits and avenue trees, trial pits and pits for poles and towers and toe wall for revetment,

Source: PWD SOR 2022-2023, with effect from 19.07.2022

Refilling
Item 85 of Schedule Item's unit cost of backfilling is shown in **Table 7-73** below is adopted. Since the amount of backfill is 0.33 m^3 per m^3 excavated, the unit cost of excavation is 12.32 INR, as shown below.

Refilling Charges: 36.95 x 0.33m^3= 12.32

Table 7-73: Rate of Refilling in the SOR

Sl No.	Sch. Item No.	Description of Works	Unit	Basic Rate 2022-2023
62	85	Refilling with excavated soil (other than sand) complying with standard specifications for filling in the foundation and basement.	cum.	36.95

Source: PWD SOR 2022-2023, with effect from 19.07.2022

Structure excavation
From the above, the unit cost of structural excavation is 189.52 INR.

Table 7-74 shows the unit cost of spreading sand and gravel for foundation, M15 (leveling) concrete, M30 concrete, formwork, rebar, etc., calculated in the same manner. The total cost of the structure is 174,310,917 INR for a length of 2,100 m. The unit cost per meter of extension is 83,000 INR, and the unit cost per m^3 of structure (M30) concrete is 30,500 INR. This unit price does not include GST and expenses.

Table 7-74: Cost of Concrete Retaining Wall

		unit	Rate	Quantity	Amount
1	Structure excavation	cum.	189.52	21,300	4,036,075
2	Supplying and Spreading sand and gravel (1:1, t=15cm)	cum.	1,220.46	1,630	1,989,345
3	Supplying and laying of M15 ready-mix concrete	cum.	6,952.72	2,450	17,034,157
4	Supplying and laying of M30 ready-mix concrete	cum.	7,452.72	5,720	42,629,542
5a	Supplying and erection centering for PCC (0-0.9m height)	sqm.	480.70	4,550	2,187,197
5b	0 to 2.7m &3.0m	sqm.	623.22	24,820	15,468,365
6	Supplying and fabrication and placing Mild Steel (0.15t/m^3)	Qty (=100kg)	8,425.75	7,807	65,779,846
7	Conveying the excavated surplus earth a lead of 10km	cum.	114.5	21,300	2,438,850
8	Providing, laying, spreading, and compacting graded stone aggregates (Sub Base/Base course)	cum.	2,140.53	1,700	3,638,901

9	Providing and placing PCC (M10)	cum.	5,261.46	1,020	5,366,694
10	Dewatering 10 HP diesel engine pump set	cum.	558.28	1,800	1,004,904
11	Supplying and Fixing of Bitumen pad for 12mm thick	sqm.	479.00	190	91,010
12	Shoring and strutting with sheet piles	sqm.	3,010.81	4,200	12,645,402
	Total				174,310,917

Source: Excerpt from Project example: Improvements to Gerugambakkam Channel in Gerugambakkam Village in Kundrathur Taluk of Kancheepuram, TNPWD

(2) Cut & Cover

The unit cost of Cut & Cover construction is calculated using plans in the Adyar basin. An extract from the plan is shown in **Table 7-75**. Amounts do not include GST and expenses.

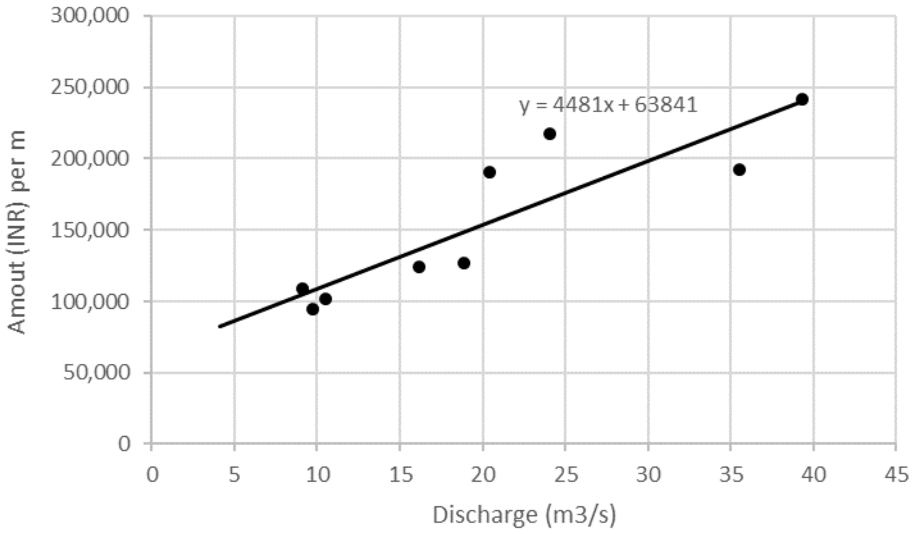
Table 7-75: An Extract of Cut & Cover Plan

	Discharge	Width of the channel	Height of the channel	W x H	Length of the channel	Channel Type	Amount	Amount/m	Amount/m/Q
	m^3/s	m	m	m^2	m	-	INR	INR	INR
14.3.1	10.51	3.0	1.8	5.40	520	Single	52,974,844	101,875	9,698
14.3.2	16.14	4.0	2.1	8.40	1,510	Single	187,352,595	124,075	7,687
14.3.3	9.11	3.5	1.5	5.25	1,315	Single	142,785,309	108,582	11,918
14.3.4	9.77	2.5	1.5	3.75	535	Single	50,516,368	94,423	9,666
14.3.5	24.07	8.0	1.9	15.20	1,580	Double	342,998,510	217,088	9,019
14.3.5	35.51	9.0	2.3	20.70	1,580	Double	303,225,106	191,915	5,405
14.3.5	39.36	9.0	2.4	21.60	460	Double	111,291,404	241,938	6,147
14.3.6	20.39	7.0	2.1	14.70	950	Double	181,078,354	190,609	9,349
14.4.16	18.86	4.0	2.4	9.60	1,225	Single	155,804,201	127,187	6,744

Source: Prepared by JICA Expert Team based on Comprehensive Flood Management

The actual results show that the unit construction cost per meter is approximately 100,000 INR for the Single type and approximately 200,000 INR for the Double type.

Here, it is compared the relationship between the target flow rate and the construction cost per meter and the estimated construction cost of Cut & Cover at the planned target flow rate is obtained by using this relationship. The relationship between the target flow rate and the construction cost per meter is shown in **Figure 7-39**.



Source: JICA Expert Team

Figure 7-39: Relationship Between Target Flow Rate of Cut & Cover and Direct Construction Cost Per Meter

From the above figure, the unit cost of construction for improving a channel with Cut & Cover is determined by the following equation.

Unit cost per meter (INR/m) = 4481 x discharge + 63841 (m^3/s)

7.3.1.6. Gate and pump

The estimated construction procurement cost of the drainage pump station is calculated as follows.

Estimated construction cost of drainage pump station:

= (A) civil and equipment construction cost (for equipment construction: complete set of equipment excluding dust collector) + (B) equipment construction cost (for equipment construction: dust collector).

For (A), the unit cost of construction per planned drainage volume (m^3/s) is set at INR 26,842,110 (m^3/s) based on the drainage pump station design case study in India (ISWD for Kosasthalaiyar-Final_2018).

In the drainage pumping station design case referenced in (A) in India, a dust collector is not planned. On the other hand, the local drainage channels are noticeably filled with debris, such as household waste, even under normal conditions, and it is expected that additional floating debris will flow in during floods.

Therefore, it is assumed that dust collectors will be installed to ensure the flow rate of the drainage channels and pumps and to avoid equipment wear and failures due to clogging by debris.

Regarding the installation cost of the dust collectors (B), it is set as follows based on the results of interviews with Japanese companies.

Table 7-76: (B) Equipment Construction Cost (Equipment Construction Object: Dust Collector)

#		planned maximum drainage capacity (m^3/s)	Unit cost of construction
			(B) Equipment construction cost (Equipment construction object: dust collector) INR
1	Small-scale pumping station	7.68	48,000,000
2	Medium-scale pump station	60	158,000,000

Source: JICA Expert Team

The estimated construction procurement cost of the gate will be calculated using the following correlation formula based on the past design work by the JICA Expert Team and the results of interviews with manufacturers.

Gate construction procurement cost = $65,000 \times A^2 + 25,000,000 * A + 315,000 * (1/5)$

A = gate door area (m^2)

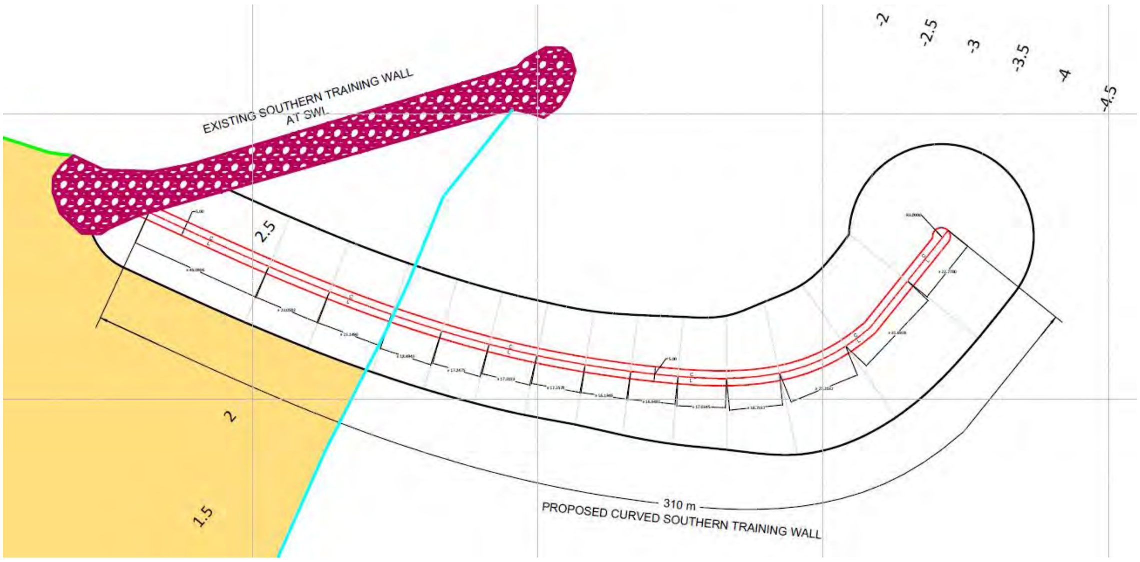
7.3.1.7. Bypass

The unit cost of a concrete retaining wall channel is used, with a unit cost of 83,000 INR per meter of extension.

However, due to the wide width of the channel, excavation and transportation costs are separately calculated.

7.3.1.8. Coastal management

The river mouth of the Cooum River is often blocked by the formation of a sea bar caused by coastal drift, which not only causes flooding in urban areas but also poses a serious sanitation problem due to the retention of industrial waste. To solve this problem, construction of a conduit dike is underway at the mouth of the river as of May 2024. **Figure 7-40** shows a planned view of the southern embankment and **Table 7-77** lists the construction specifications.



Source: Report to accompany the Estimate for the Work of 'Construction of Curved Training walls (Groynes) in the Northern and Southern Sides of the Cooum River Mouth and its allied works'

Figure 7-40: Guide Wall Under Construction at the Mouth of the Cooum River (South Side)

Table 7-77: Summary of Works

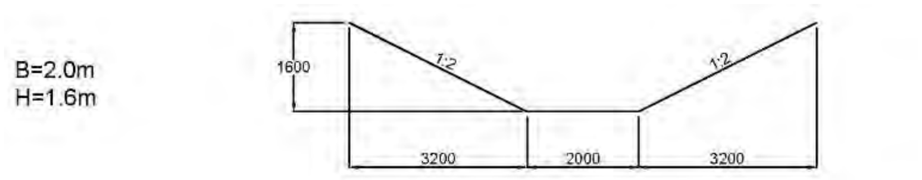
Item	Contents
Title	Construction of Curved Training walls (Groynes) in the Northern and Southern Sides of the Cooum River Mouth and its allied works
Major construction types and quantities	National Institute of Ocean Technology - Capital dredging of 305000m^3 - Construction of curved training walls - Annual maintenance dredging of 75000m^3
Guide Wall	Northern Training Wall: L= 265m Southern Training Wall: L= 310m
Specification	Crest Elevation: + 4.80 m Crest Width: 5.00 m Slope: Sea Side 2.5 :1, Lee Side 2:1

Source: 'Report to accompany the Estimate for the Work of 'Construction of Curved Training walls (Groynes) in the Northern and Southern Sides of Edited by JICA Expert Team based on 'Report to accompany the Estimate for the Work of "Construction of Curved Training walls (Groynes) in the Northern and Southern Sides of the Cooum River Mouth and its allied works."

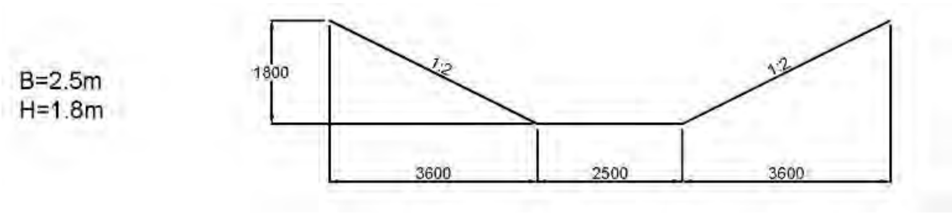
The works consisted of the construction of a 575 m long guide embankment with a total cost of 700,000,000 INR, with a unit cost of 619,936 INR per meter of construction (indirect costs, excluding GST).

7.3.2 Standard cross-sections and estimated quantities for channels between tanks in the improvement of existing tanks.

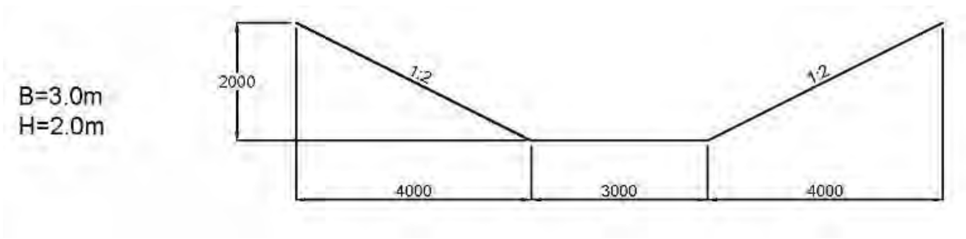
Standard cross-sections for the open excavation, Cut & Cover, and gravity retaining wall construction types considered for this work are shown below.



(a) B=2.0m ,H=1.6m



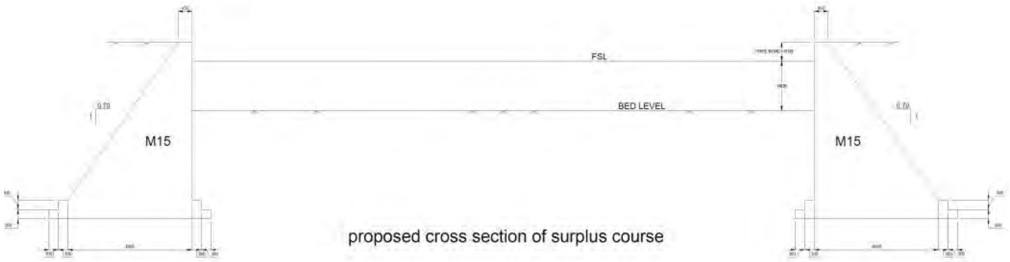
(b) B=2.5m ,H=1.8m



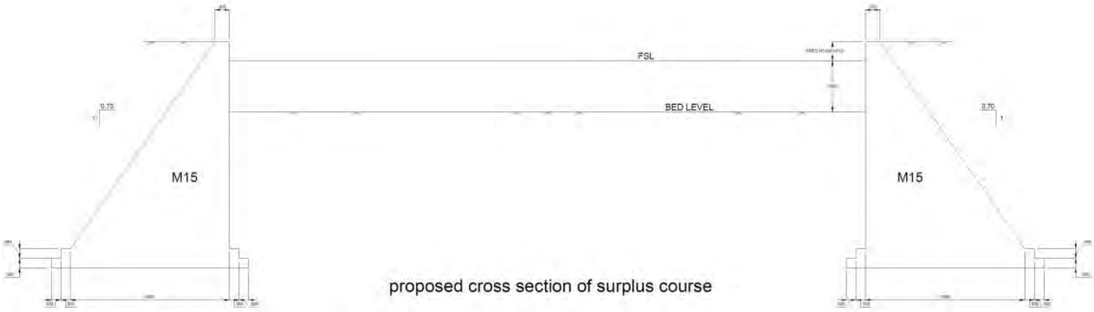
(c) B=3.0m ,H=2.0m

Source: JICA Expert Team

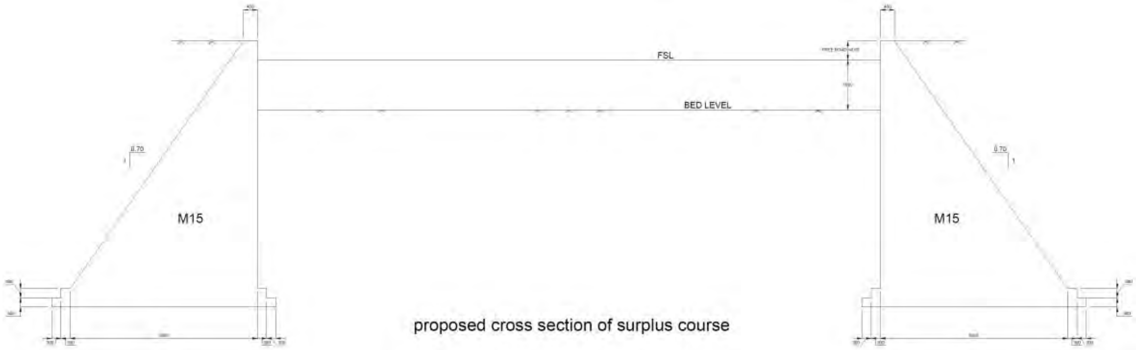
Figure 7-41: Standard Cross Section Drawing (Earth Canal)



(a) B=4.0m, H=1.6m



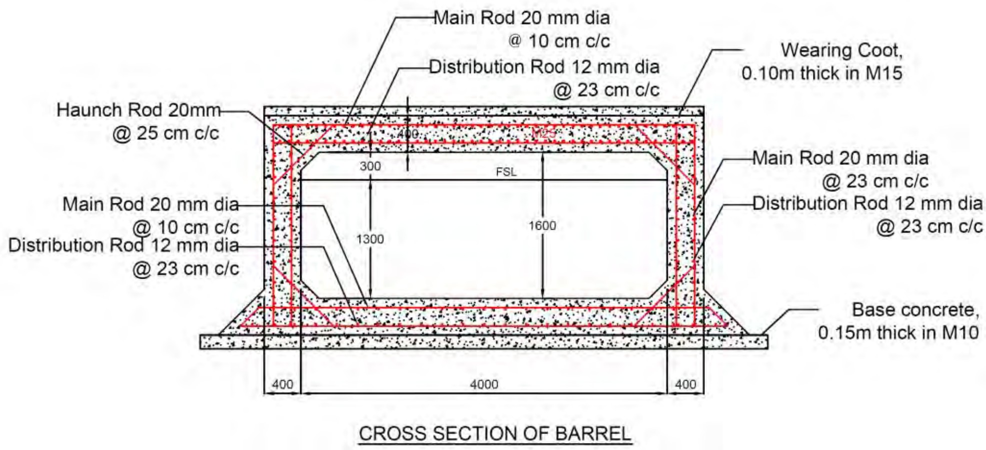
(b) B=5.0m, H=1.8m



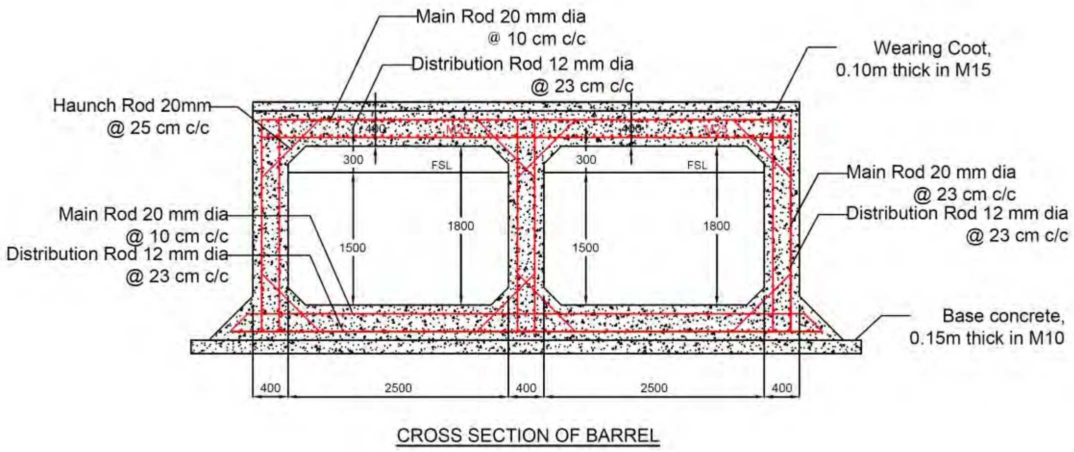
(c) B=6.0m, H=2.0m

Source: JICA Expert Team

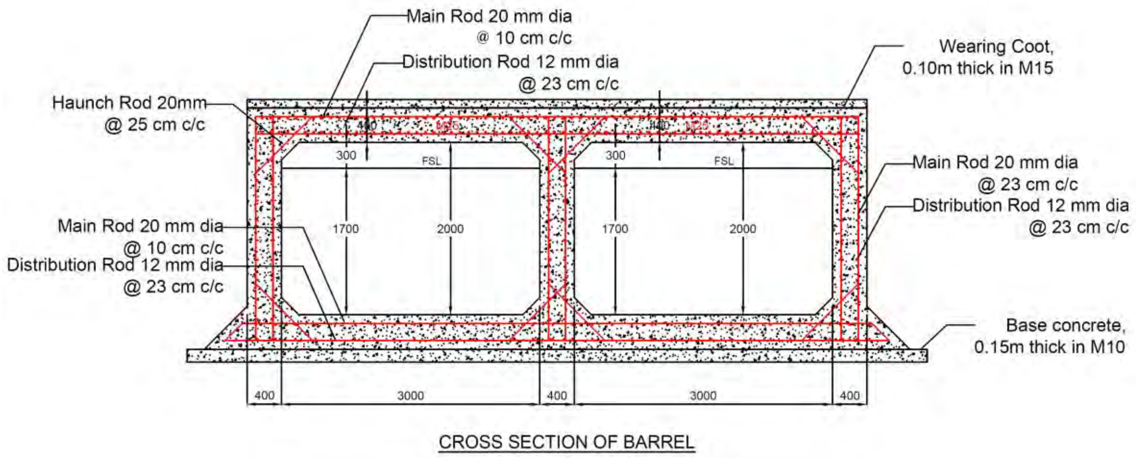
Figure 7-42: Standard Cross Section Drawing (Gravity Retaining Wall)



(a) B=4.0m, H=1.6m



(b) B=5.0m, H=1.8m



(c) B=6.0m, H=2.0m

Source: JICA Expert Team

Figure 7-43: Standard Cross Section Drawing (Cut & Cover)

The construction quantities for the channels calculated based on these standard cross-sections are shown in **Table 7-78**.

Table 7-78: Quantity of Channel Construction

		Nos	Length	Excavtion					Revetment		Concrete Structure			Land
			L (m)	Bbottom (m)	H (m)	Bcrest (m)	A (m^2)	V (m^3)	(m)	A (m^2)	type	Nos.	L (m)	A (m^2)
Adyar	1_Earth Channel	1	498	3.0	2.0	11	14	6,976	8.94	4,457				5,481
	2_Earth Channel	0	498	3.0	2.0	11	14	0	8.94	0				0
	3_Earth Channel	1	498	3.0	2.0	11	14	6,976	8.94	4,457				5,481
	4_Earth Channel	2	498	3.0	2.0	11	14	13,952	8.94	8,913				10,962
	5_Earth Channel	4	498	3.0	2.0	11	14	27,903	8.94	17,827				21,924
	6_Earth Channel	19	498	2.5	1.8	9.7	12.2	115,500	8.05	76,210				91,832
	7_Earth Channel	23	498	2.0	1.6	8.4	10.4	119,188	7.16	82,004				96,267
	1_Retaining Gravity Wall	1	249			8.0					6.0m x 2.0m, Q=10m^3/s	5	1,246	1,993
	2_Retaining Gravity Wall	0	249			8.0					6.0m x 2.0m, Q=10m^3/s	4	0	0
	3_Retaining Gravity Wall	1	249			8.0					6.0m x 2.0m, Q=10m^3/s	3	747	1,993
	4_Retaining Gravity Wall	2	249			8.0					6.0m x 2.0m, Q=10m^3/s	2	997	3,986
	5_Retaining Gravity Wall	4	249			8.0					6.0m x 2.0m, Q=10m^3/s	1	997	7,972
	6_Retaining Gravity Wall	19	249			7.0					5.0m x 1.8m, Q=5.0m^3/s	1	4,734	33,135
	7_Retaining Gravity Wall	23	249			6.0					4.0m x 1.6m, Q=3.0m^3/s	1	5,730	34,381
	1_Cut & Cover	1	249			8.0					6.0m x 2.0m, Q=10m^3/s	5	1,246	1,993
	2_Cut & Cover	0	249			8.0					6.0m x 2.0m, Q=10m^3/s	4	0	0
	3_Cut & Cover	1	249			8.0					6.0m x 2.0m, Q=10m^3/s	3	747	1,993
	4_Cut & Cover	2	249			8.0					6.0m x 2.0m, Q=10m^3/s	2	997	3,986
	5_Cut & Cover	4	249			8.0					6.0m x 2.0m, Q=10m^3/s	1	997	7,972
	6_Cut & Cover	19	249			7.0					5.0m x 1.8m, Q=5.0m^3/s	1	4,734	33,135
	7_Cut & Cover	23	249			6.0					4.0m x 1.6m, Q=3.0m^3/s	1	5,730	34,381
Cooum	1_Earth Channel	0	687	3.0	2.0	11	14	0	8.94	0				0
	2_Earth Channel	1	687	3.0	2.0	11	14	9,615	8.94	6,143				7,554
	3_Earth Channel	0	687	3.0	2.0	11	14	0	8.94	0				0
	4_Earth Channel	0	687	3.0	2.0	11	14	0	8.94	0				0
	5_Earth Channel	6	687	3.0	2.0	11	14	57,688	8.94	36,856				45,326
	6_Earth Channel	6	687	2.5	1.8	9.7	12.2	50,271	8.05	33,170				39,970
	7_Earth Channel	18	687	2.0	1.6	8.4	10.4	128,562	7.16	88,454				103,839
	1_Retaining Gravity Wall	0	343			8.0					6.0m x 2.0m, Q=10m^3/s	5	0	0
	2_Retaining Gravity Wall	1	343			8.0					6.0m x 2.0m, Q=10m^3/s	4	1,374	2,747
	3_Retaining Gravity Wall	0	343			8.0					6.0m x 2.0m, Q=10m^3/s	3	0	0
	4_Retaining Gravity Wall	0	343			8.0					6.0m x 2.0m, Q=10m^3/s	2	0	0
	5_Retaining Gravity Wall	6	343			8.0					6.0m x 2.0m, Q=10m^3/s	1	2,060	16,482
	6_Retaining Gravity Wall	6	343			7.0					5.0m x 1.8m, Q=5.0m^3/s	1	2,060	14,422
	7_Retaining Gravity Wall	18	343			6.0					4.0m x 1.6m, Q=3.0m^3/s	1	6,181	37,085
	1_Cut & Cover	0	343			8.0					6.0m x 2.0m, Q=10m^3/s	5	0	0
	2_Cut & Cover	1	343			8.0					6.0m x 2.0m, Q=10m^3/s	4	1,374	2,747
	3_Cut & Cover	0	343			8.0					6.0m x 2.0m, Q=10m^3/s	3	0	0
	4_Cut & Cover	0	343			8.0					6.0m x 2.0m, Q=10m^3/s	2	0	0
	5_Cut & Cover	6	343			8.0					6.0m x 2.0m, Q=10m^3/s	1	2,060	16,482
	6_Cut & Cover	6	343			7.0					5.0m x 1.8m, Q=5.0m^3/s	1	2,060	14,422
	7_Cut & Cover	18	343			6.0					4.0m x 1.6m, Q=3.0m^3/s	1	6,181	37,085
Kosasthalaiyar River (Existing)	1_Earth Channel	0	414	3.0	2.0	11	14	0	8.94	0				0
	2_Earth Channel	0	414	3.0	2.0	11	14	0	8.94	0				0
	3_Earth Channel	0	414	3.0	2.0	11	14	0	8.94	0				0
	4_Earth Channel	3	414	3.0	2.0	11	14	17,379	8.94	11,103				13,655
	5_Earth Channel	22	414	3.0	2.0	11	14	127,448	8.94	81,424				100,138
	6_Earth Channel	45	414	2.5	1.8	9.7	12.2	227,172	8.05	149,894				180,621
	7_Earth Channel	43	414	2.0	1.6	8.4	10.4	185,048	7.16	127,317				149,462
	1_Retaining Gravity Wall	0	207			8.0					6.0m x 2.0m, Q=10m^3/s	5	0	0
	2_Retaining Gravity Wall	0	207			8.0					6.0m x 2.0m, Q=10m^3/s	4	0	0
	3_Retaining Gravity Wall	0	207			8.0					6.0m x 2.0m, Q=10m^3/s	3	0	0
	4_Retaining Gravity Wall	3	207			8.0					6.0m x 2.0m, Q=10m^3/s	2	1,241	4,966
	5_Retaining Gravity Wall	22	207			8.0					6.0m x 2.0m, Q=10m^3/s	1	4,552	36,414
	6_Retaining Gravity Wall	45	207			7.0					5.0m x 1.8m, Q=5.0m^3/s	1	9,310	65,172
	7_Retaining Gravity Wall	43	207			6.0					4.0m x 1.6m, Q=3.0m^3/s	1	8,897	53,379
	1_Cut & Cover	0	207			8.0					6.0m x 2.0m, Q=10m^3/s	5	0	0
	2_Cut & Cover	0	207			8.0					6.0m x 2.0m, Q=10m^3/s	4	0	0
	3_Cut & Cover	0	207			8.0					6.0m x 2.0m, Q=10m^3/s	3	0	0
	4_Cut & Cover	3	207			8.0					6.0m x 2.0m, Q=10m^3/s	2	1,241	4,966
	5_Cut & Cover	22	207			8.0					6.0m x 2.0m, Q=10m^3/s	1	4,552	36,414
	6_Cut & Cover	45	207			7.0					5.0m x 1.8m, Q=5.0m^3/s	1	9,310	65,172
	7_Cut & Cover	43	207			6.0					4.0m x 1.6m, Q=3.0m^3/s	1	8,897	53,379

		Nos	Length	Excavtion					Revetment		Concrete Structure			Land
			L (m)	Bbottom (m)	H (m)	Bcrest (m)	A (m^2)	V (m^3)	(m)	A (m^2)	type	Nos.	L (m)	A (m^2)
Kosasthalaiyar River (New)	1_Earth Channel	0	250	3.0	2.0	11	14	0	8.94	0				0
	2_Earth Channel	1	250	3.0	2.0	11	14	3,500	8.94	2,236				2,750
	3_Earth Channel	0	250	3.0	2.0	11	14	0	8.94	0				0
	4_Earth Channel	2	250	3.0	2.0	11	14	7,000	8.94	4,472				5,500
	5_Earth Channel	0	250	3.0	2.0	11	14	0	8.94	0				0
	6_Earth Channel	3	250	2.5	1.8	9.7	12.2	9,150	8.05	6,037				7,275
	7_Earth Channel	1	250	2.0	1.6	8.4	10.4	2,600	7.16	1,789				2,100
	1_Retaining Gravity Wall	0	125			8.0					6.0m x 2.0m, Q=10m^3/s	5	0	0
	2_Retaining Gravity Wall	1	125			8.0					6.0m x 2.0m, Q=10m^3/s	4	500	1,000
	3_Retaining Gravity Wall	0	125			8.0					6.0m x 2.0m, Q=10m^3/s	3	0	0
	4_Retaining Gravity Wall	2	125			8.0					6.0m x 2.0m, Q=10m^3/s	2	500	2,000
	5_Retaining Gravity Wall	0	125			8.0					6.0m x 2.0m, Q=10m^3/s	1	0	0
	6_Retaining Gravity Wall	3	125			7.0					5.0m x 1.8m, Q=5.0m^3/s	1	375	2,625
	7_Retaining Gravity Wall	1	125			6.0					4.0m x 1.6m, Q=3.0m^3/s	1	125	750
	1_Cut & Cover	0	125			8.0					6.0m x 2.0m, Q=10m^3/s	5	0	0
	2_Cut & Cover	1	125			8.0					6.0m x 2.0m, Q=10m^3/s	4	500	1,000
	3_Cut & Cover	0	125			8.0					6.0m x 2.0m, Q=10m^3/s	3	0	0
	4_Cut & Cover	2	125			8.0					6.0m x 2.0m, Q=10m^3/s	2	500	2,000
	5_Cut & Cover	0	125			8.0					6.0m x 2.0m, Q=10m^3/s	1	0	0
	6_Cut & Cover	3	125			7.0					5.0m x 1.8m, Q=5.0m^3/s	1	375	2,625
	7_Cut & Cover	1	125			6.0					4.0m x 1.6m, Q=3.0m^3/s	1	125	750
Total														
Adyar	Earth Channel							290,495		193,867				
	Retaining Gravity Wall	6.0m x 2.0m, Q=10m^3/s											3,986	
		5.0m x 1.8m, Q=5.0m^3/s											4,734	
		4.0m x 1.6m, Q=3.0m^3/s											5,730	
	Cut & Cover	6.0m x 2.0m, Q=10m^3/s											3,986	
		5.0m x 1.8m, Q=5.0m^3/s											4,734	
		4.0m x 1.6m, Q=3.0m^3/s											5,730	
	Land													398,870
Cooum	Earth Channel							246,136		164,622				
	Retaining Gravity Wall	6.0m x 2.0m, Q=10m^3/s											3,434	
		5.0m x 1.8m, Q=5.0m^3/s											2,060	
		4.0m x 1.6m, Q=3.0m^3/s											6,181	
	Cut & Cover	6.0m x 2.0m, Q=10m^3/s											3,434	
		5.0m x 1.8m, Q=5.0m^3/s											2,060	
		4.0m x 1.6m, Q=3.0m^3/s											6,181	
	Land													338,163
Kosasthalaiyar River (Existing)	Earth Channel							557,048		369,738				
	Retaining Gravity Wall	6.0m x 2.0m, Q=10m^3/s											5,793	
		5.0m x 1.8m, Q=5.0m^3/s											9,310	
		4.0m x 1.6m, Q=3.0m^3/s											8,897	
	Cut & Cover	6.0m x 2.0m, Q=10m^3/s											5,793	
		5.0m x 1.8m, Q=5.0m^3/s											9,310	
		4.0m x 1.6m, Q=3.0m^3/s											8,897	
	Land													763,738
Kosasthalaiyar River (New)	Earth Channel							22,250		14,534				
	Retaining Gravity Wall	6.0m x 2.0m, Q=10m^3/s											1,000	
		5.0m x 1.8m, Q=5.0m^3/s											375	
		4.0m x 1.6m, Q=3.0m^3/s											125	
	Cut & Cover	6.0m x 2.0m, Q=10m^3/s											1,000	
		5.0m x 1.8m, Q=5.0m^3/s											375	
		4.0m x 1.6m, Q=3.0m^3/s											125	
	Land													30,375

Source: JICA Expert Team

7.3.3 Preparation cost

Basic published prices are updated on the website of the Resident Department (tnregimet.gov.in), and unit prices as of May 2024 were used to calculate the preparation costs.

The method for calculating the cost of land acquisition and compensation from the base published value is given in the Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation, and Resettlement Act, 2013, issued by the State of Tamil Nadu. 2013', as follows.

(a) Land value per sqm is determined by adding the Accepted value (Accepted value based on private negotiation) to the basic published value, where the Accepted value is determined by the distance from the urban center of Chennai with a premium of 225% to 425%. The range is determined by the distance from the urban center of Chennai.

(b) The compensation cost is determined as the value of buildings and crops (Building value), which is 50% of the basic published price.

(c) The compensation cost is defined as 100% of the above Building value plus

(d) The sum of the land value (Land value per sqm) in (a) above plus the compensation cost (Building value) in (c) above is adopted as the determined land acquisition cost and compensation cost.

The cost of land acquisition and compensation calculated in the above way is multiplied by the area of land required for the construction of each measure to calculate the cost of land expropriation for the construction of each measure.

The preparation costs (final land acquisition costs and compensation costs) calculated in the above manner are shown in **Table 7-79**.

Table 7-79: Preparation Costs

	Unit	Quantity	Total (INR)
(1) Fluvial (River) Flood Control Plan			
River Channelization			
Adyar	LS	1	250,136,126,518
Cooum	LS	1	253,281,730,201
Kosasthalaiyar	LS	1	5,604,556,392
Subtotal			509,022,413,111
Rehabilitation of Existing Water Tank			0
Adyar	LS	1	36,908,800,238
Cooum	LS	1	23,638,243,774
Kosasthalaiyar	LS	1	103,817,967,333
Subtotal			164,365,011,345
Underground Bypass	LS	1	2,011,557,031
(2) Pluvial (Urban) Flood Control Plan			0
Tanks Improvement	LS	1	6,199,126,172
Connecting Drainage (Micro-Drainage) Improvement	LS	1	0
B Canal Improvement	LS	1	0
Bypass	LS	1	2,148,225,625
Gate and pump, Conduit flap gate installation	LS	1	2,544,402,656
Subtotal			10,891,754,453
(3) Coastal Area and River Mouth	LS	1	0
(4) Disaster Management	LS	1	0
Total			**686,290,735,941**

Source: JICA Expert Team

The preparation costs for each measure of construction are summarized below. Note that soil disposal sites required for the construction are not included in the costs.

7.3.3.1. River channelization

Table 7-80 through

Table 7-82 show the total preparation cost for river Channelization for each river. The following conditions are used for the calculations.

- Set that 50% of the land acquisition area is public land.

Table 7-80: Preparation Costs for River Channelization (Adyar)

			①	②		③=①×②		④=③×0.5	
Distance from Sea [km]			Land acquisition area [m2]	Unit price [Rs/m2]		Land acquisitio cost [Rs]		Preparation costs [Rs]	
				Left bank	Right bank	Left bank	Right bank	Left bank	Right bank
0.000	~	4.543	227,148	1,005,773	1,005,773	114,229,712,139	114,229,712,139	57,114,856,070	57,114,856,070
4.661	~	5.140	29,875	765,263	612,209	11,431,120,264	9,144,865,869	5,715,560,132	4,572,432,935
5.321	~	7.555	120,734	765,263	612,209	46,196,648,499	36,957,196,179	23,098,324,250	18,478,598,089
7.637	~	8.580	51,245	349,842	437,298	8,963,743,989	11,204,549,873	4,481,871,994	5,602,274,936
8.722	~	9.291	35,535	349,842	437,298	6,215,908,527	7,769,795,432	3,107,954,263	3,884,897,716
9.340	~	10.910	80,942	306,109	338,904	12,388,629,043	13,715,864,716	6,194,314,521	6,857,932,358
10.981	~	12.084	58,709	306,109	338,904	8,985,687,648	9,948,354,716	4,492,843,824	4,974,177,358
12.175	~	16.243	207,976	62,842	174,931	6,534,777,063	18,190,707,092	3,267,388,531	9,095,353,546
16.336	~	17.193	0	65,609	43,733	0	0	0	0
17.293	~	22.459	263,304	50,304	48,110	6,622,611,123	6,333,799,493	3,311,305,562	3,166,899,747
22.527	~	24.920	123,043	63,416	74,344	3,901,408,520	4,573,720,430	1,950,704,260	2,286,860,215
25.001	~	25.218	14,905	63,416	74,344	472,604,945	554,046,797	236,302,473	277,023,398
25.353	~	29.367	207,446	63,416	74,344	6,577,658,872	7,711,156,781	3,288,829,436	3,855,578,391
29.410	~	34.166	239,983	63,416	74,344	7,609,335,967	8,920,618,078	3,804,667,984	4,460,309,039
34.226	~	37.328	158,073	63,416	74,344	5,012,149,045	5,875,869,797	2,506,074,523	2,937,934,898
37.439	~	43.606	0	63,416	74,344	0	0	0	0
			Information provided by TT2	Refer to the unit price around the widening section		Total		250,136,126,518	
								Assuming 50% of the land is public land	

Preparation Cost of River Channelization (Adyar River) : 250,136,126,518 Rs (Phase1)

Source: JICA Expert Team

Table 7-81: Preparation Costs for River Channelization (Cooum)

			①	②		③=①×②		④=③×0.5	
Distance from Sea [km]			Land acquisition area [m2]	Unit price [Rs/m2]		Land acquisitio cost [Rs]		Preparation costs [Rs]	
				Left bank	Right bank	Left bank	Right bank	Left bank	Right bank
0.000	~	0.483	0	677,808	524,753	0	0	0	0
0.664	~	2.342	92,960	677,808	524,753	31,504,507,125	24,390,525,250	15,752,253,563	12,195,262,625
2.405	~	6.225	194,130	459,164	470,092	44,568,759,727	45,629,498,180	22,284,379,863	22,814,749,090
6.315	~	9.872	182,360	629,708	520,731	57,416,742,601	47,480,262,357	28,708,371,301	23,740,131,178
9.988	~	15.333	273,040	470,092	459,154	64,176,961,933	62,683,668,324	32,088,480,966	31,341,834,162
15.393	~	16.964	81,540	185,859	456,889	7,577,486,719	18,627,367,078	3,788,743,359	9,313,683,539
17.024	~	18.897	96,660	134,473	240,520	6,499,081,114	11,624,364,742	3,249,540,557	5,812,182,371
18.957	~	24.977	304,000	199,313	211,934	30,295,500,000	32,213,906,250	15,147,750,000	16,106,953,125
25.037	~	26.366	0	65,602	83,262	0	0	0	0
26.426		34.243	393,850	52,992	58,090	10,435,486,523	11,439,342,480	5,217,743,262	5,719,671,240
34.303	~	40.928	0	33,587	17,660	0	0	0	0
40.958	~	43.539	0	33,587	17,660	0	0	0	0
43.785	~	63.667	0	33,587	17,660	0	0	0	0
63.829	~	73.678	0	33,587	17,660	0	0	0	0
			Information provided by TT2	Refer to the unit price around the widening section		Total		253,281,730,201	
								Assuming 50% of the land is public land	

Preparation Cost of River Channelization (Cooum River) : 253,281,730,201 Rs (Phase1)

Source: JICA Expert Team

Table 7-82: Preparation Costs for River Channelization (Kosasthalaiyar)

			①	②		③=①×②		④=③×0.5	
Distance from Sea [km]			Land acquisition area [m2]	Unit price [Rs/m2]		Land acquisitio cost [Rs]		Preparation costs [Rs]	
				Left bank	Right bank	Left bank	Right bank	Left bank	Right bank
0	~	0.4832	0	9,835	13,981	0	0	0	0
0.6635	~	2.3424	0	9,835	13,981	0	0	0	0
2.4053	~	6.225	194,130	9,835	13,981	954,605,870	1,357,103,178	477,302,935	678,551,589
6.315	~	9.872199	474,136	9,835	13,981	2,331,493,765	3,314,538,174	1,165,746,882	1,657,269,087
9.987799	~	15.333	273,040	9,835	13,981	1,342,633,757	1,908,738,041	671,316,878	954,369,020
15.3934	~	16.9638	0	9,835	13,981	0	0	0	0
17.024	~	18.897	0	9,835	13,981	0	0	0	0
18.957	~	24.977	0	9,835	13,981	0	0	0	0
25.037	~	26.366	0	9,835	13,981	0	0	0	0
26.426		34.243	0	9,835	13,981				
			Information provided by TT2	Refer to the unit price around the widening section		Total		5,604,556,392	
								Assuming 50% of the land is public land	

Preparation Cost of River Channelization (Kosasthalaiyar River) : 5,604,556,392 Rs (Phase1)

Source: JICA Expert Team

7.3.3.2. Improvement of existing tanks

Preparation costs for the tank improvements, estimated for each river, are shown in **Table 7-83** through **Table 7-86**. The following conditions are used for the calculations.

- The land acquisition area is defined as 10%* of the tank area after the improvement.

  *Average ratio of the area before and after the improvement of the target tanks

- Assume that 50%* of the land acquisition area is public land.

  *Based on consultation with CPs.

- The entire land acquisition area is assumed to be the area to be leased and 7%* of the cost of land acquisition.

  *Following local guidelines received from the CP, and only one payment for it

Table 7-83: Preparation Costs for Tanks Improvements (Adyar)

	①	②=①×0.1×0.5	③	④=②×③×0.07
Tank_Name	Area [km2]	Area subject to lease [m2]	Unit price [Rs/m2]	Preparation costs [Rs]
Nemam	5.976	298,822	282,440	5,907,949,493
Sriperumbudur Tank	3.140	156,982	282,440	3,103,654,887
Pillaipakkam Tank	2.851	142,562	282,440	2,818,563,179
Manimangalam Tank	2.594	129,682	282,440	2,563,917,487
Gunduperumbedu Tank	1.350	67,524	282,440	1,334,998,314
Nandivaram Tank	1.224	61,221	282,440	1,210,395,928
Adanur Tank	1.148	57,384	282,440	1,134,522,587
Somangalam Big Tank	1.100	55,019	282,440	1,087,776,551
Amarambedu Tank	0.934	46,675	282,440	922,805,193
Padappai Tank	0.928	46,423	282,440	917,814,059
Orathur Tank	0.809	40,471	282,440	800,134,412
Kolathur Tank	0.765	38,270	282,440	756,620,899
Total	**37.337**	**1,866,836**	-	**36,908,800,238**

①：Information provided by TT2 (Tank area after improvements)
②：Assuming that 10% of the improved tank area is within the land acquisition area
Assuming that 50% of the area within the land acquisition area is public land
③：Refer to the unit price around the Tanks
④：Assuming that all of the land acquisition area is subject to lease, and that 7% of the land acquisition cost is required for Preparation Cost

Preparation Cost of Improvement of Reservoirs (Adyar River) : 36,908,800,238 Rs (Phase1: 50%, Phase2: 50%)

Source: JICA Expert Team
**Partial excerpt of the table*

Table 7-84: Preparation Costs for Tanks Improvements (Cooum)

	①	②=①×0.1×0.5	③	④=②×③×0.07
Tank_Name	Area [km2]	Area subject to lease [m2]	Unit price [Rs/m2]	Preparation costs [Rs]
Coovam Big Tank	4.065	203,260	355,586	5,059,341,081
Parandur Large Tank	1.666	83,285	355,586	2,073,050,283
Edayarpakkam Tank	1.484	74,192	355,586	1,846,703,745
Valathur Tank	1.321	66,063	355,586	1,644,377,046
Govindavadi Large Tank	1.308	65,402	355,586	1,627,934,035
Veliyur Tank	1.279	63,948	355,586	1,591,731,283
Thirumalpur Tank	1.193	59,639	355,586	1,484,482,078
Pullalur Peria Eri	0.861	43,044	355,586	1,071,409,291
Kottavakkam Tank	0.850	42,500	355,586	1,057,871,062
Govindavadi Chitheri	0.838	41,916	355,586	1,043,339,682
Veppamchittu Periya Eri	0.630	31,490	355,586	783,807,184
Satharai Tank	0.596	29,791	355,586	741,518,577
Total	**18.993**	**949,669**	-	**23,638,243,774**

①：Information provided by TT2 (Tank area after improvements)
②：Assuming that 10% of the improved tank area is within the land acquisition area
Assuming that 50% of the area within the land acquisition area is public land
③：Refer to the unit price around the Tanks
④：Assuming that all of the land acquisition area is subject to lease, and that 7% of the land acquisition cost is required for Preparation Cost

Preparation Cost of Improvement of Reservoirs (Cooum River) : 23,638,243,774 Rs (Phase1: 50%, Phase2: 50%)

Source: JICA Expert Team
**Partial excerpt of the table*

Table 7-85: Preparation Costs for Tanks Improvements (Kosasthalaiyar: Existing)

Tank_Name	① Area [km2]	②=①×0.1×0.5 Area subject to lease [m2]	③ Unit price [Rs/m2]	④=②×③×0.07 Preparation costs [Rs]
Mahendravadi Tank	2.611	130,572	16,189	147,966,416
Manavur Hissa Tank	2.033	101,645	16,189	115,186,292
Mudhur hissa tank	2.008	100,409	16,189	113,785,564
Beddekalakattur Big Tank	1.958	97,882	16,189	110,922,159
Kilveethi big Tank	1.825	91,266	16,189	103,424,901
Nagavedu Tank	1.822	91,083	16,189	103,216,830
Paranji tank	1.646	82,293	16,189	93,255,960
Perumuchi Banal Eri	1.588	79,398	16,189	89,974,988
Sholinghar tank	1.389	69,461	16,189	78,714,279
Polur big tank	1.368	68,404	16,189	77,516,994
Vellur hissa tank	1.322	66,121	16,189	74,929,212
Uliyanallur Tank	1.271	63,541	16,189	72,005,613
Total	**81.310**	**4,065,500**	-	**4,607,109,780**

①：Information provided by TT2 (Tank area after improvements)
②：Assuming that 10% of the improved tank area is within the land acquisition area
Assuming that 50% of the area within the land acquisition area is public land
③：Refer to the unit price around the Tanks
④：Assuming that all of the land acquisition area is subject to lease, and that 7% of the land acquisition cost is required for Preparation Cost

Preparation Cost of Improvement of Reservoirs (Kosasthalaiyar River: Existing) : 4,607,109,780 Rs (Phase1: 50%, Phase2: 50%)

Source: JICA Expert Team

Table 7-86: Preparation Costs for New Tanks Construction (Kosasthalaiyar: New)

Sl no	① Area [km2]	②=①×0.5 Area subject to lease [m2]	③ Unit price [Rs/m2]	④=②×③ Preparation costs [Rs]
New Tank 2	4.678	2,338,962	16,189	37,865,149,245
New Tank 1	2.966	1,482,906	16,189	24,006,567,904
New Tank 3	2.033	1,016,578	16,189	16,457,251,515
New Tank 4	0.804	402,237	16,189	6,511,755,369
New Tank 7	0.765	382,548	16,189	6,193,012,660
New Tank 5	0.644	321,920	16,189	5,211,521,799
New Tank 6	0.366	183,188	16,189	2,965,599,061
Total	**12.257**	**6,128,337**	-	**99,210,857,553**

①：Information provided by TT2 (Tank area to be newly constructed)
②：Assuming that 50% of the area within the land acquisition area is public land
③：Refer to the unit price around the Tanks
④：Due to the new establishment, the entire area is subject to land acquisition

Preparation Cost of Improvement of Reservoirs (Kosasthalaiyar River: New) : 99,210,857,553 Rs（Phase1: 50%, Phase2: 50%）

Source: JICA Expert Team

*For newly constructed tanks, the entire area of the tank will be designated as the land acquisition area.

As with other rivers, it is assumed that 50% of the land acquisition area is public land.

7.3.3.3. Underground Bypass

Preparation costs for the Underground Bypass are shown in **Table 7-87**. The following condition is used for the calculations.

- Vertical shafts are to be installed at the beginning and end of the underground discharge channel, as well as one every 6 km.

  *Extension of Underground Bypass: 12.3 km.

- The required site area per shaft shall be 1500 m^2.

  *Refer to the Shield Tunnel Design and Construction Guideline: Japan Railway Construction, Transport, and Technology Agency to determine the required area.

Table 7-87: Preparation Costs for Underground Bypass

Refer to the unit price around the shafts　　Unit price ×1500㎡

Shafts	**Unit price [Rs/m2]**	**Preparation costs [Rs]**
Shaft 1	43,733	65,599,219
Shaft 2	291,532	437,297,656
Shaft 3	1,005,773	1,508,660,156
合計		**2,011,557,031**

Preparation Cost of Underground River: 2,011,557,031 Rs (Phase1)

Source: JICA Expert Team

7.3.3.4. Improvement of existing urban tanks

Preparation costs for the construction of new tanks (urban area) are shown in **Table 7-88**. The following conditions are used for the calculations.

- The entire land acquisition area is covered by the lease, which shall require 7% of the cost of land acquisition (following the local guidelines received from the CP, only one payment).

Table 7-88: Preparation Costs for New Etarding Ponds (Urban Area) Construction

Drain	Name	① Area subject to lease [m2]	② Unit price [Rs/m2]	③=①×② ×0.07 Preparation costs [Rs]
Kodungaiyur	K1	90,000	87,466	551,033,438
Kodungaiyur	K2	30,000	87,466	183,677,813
Captain Cotton	C1	90,000	87,466	551,033,438
Captain Cotton	C2	100,000	87,466	612,259,375
Otteri Nullah	O1	80,000	87,466	489,807,500
Otteri Nullah	O2	40,000	87,466	244,903,750
Otteri Nullah	O3	100,000	87,466	612,259,375
Otteri Nullah	O4	60,000	87,466	367,355,625
Otteri Nullah	O5	122,500	87,466	750,017,734
North B Canal	North B Canal RB	300,000	87,466	1,836,778,125
Total				6,199,126,172

①：Information provided by TT2 (Reservoir area after improvement)
②：Refer to the unit price around the reservoir.
③：Assuming that all of the land acquisition area is subject to lease, and that 7% of the land acquisition cost is required for Preparation Cost

Preparation Cost of Reservoir Improvement: 6,199,126,172 Rs (Phase1)

Source: JICA Expert Team

7.3.3.5. Gate and pump

The preparation cost of the gate pump is shown in **Table 7-89**.

- Assume that 50% of the land acquisition area is public land.
- The size of the area is divided according to the volume of pumped water, and the area of each is assumed.
  - Small-scale: less than 7.5 m^3/s :Required area 7,000 m^2
  - Medium-scale: 7.5 m^3/s or more but less than 60 m^3/s :Required area 12,000 m^2
  - Large-scale: 60 m^3/s or more but less than 90 m^3/s :Required area 15,000 m^2
  - Extra-large scale 90 m^3/s or more but less than 150 m^3/s :Required area 17,500 m^2

Table 7-89: Preparation Cost for Gate Pump Maintenance

Name	① Pump capacity [m3/s]	Scale	②＝Area×0.5 Area [㎡]	③ Unit price [Rs/m2]	④＝②×③ Preparation costs [Rs]
K1	1.5	Small	3,500	87,466	306,129,688
K2	0.5	Small	3,500	87,466	306,129,688
C1	2.0	Small	3,500	87,466	306,129,688
C2	2.0	Small	3,500	87,466	306,129,688
O1	-	-	-	-	-
O2	-	-	-	-	-
O3	2.0	Small	3,500	87,466	306,129,688
O4	1.5	Small	3,500	87,466	306,129,688
O5	2.0	Small	3,500	87,466	306,129,688
North B Canal RB	2.0	Small	3,500	87,466	306,129,688
New Diversion/～	28.7	Medium	6,000	10,038	60,230,625
Inland water ～	1.4	Small	3,500	10,038	35,134,531
Total			37,500	-	2,544,402,656

Information provided by TT2

Refer to the unit price around the gate and pump

②：
Scale of area is determined according to the volume of water discharge of pumps. Assuming 50% of the land is public land.

Small scale: Less than 7.5 m^3/s
⇒ Required area: 7,000 ㎡

Medium scale: More than 7.5 m^3/s but less than 60 m^3/s
⇒ Required area: 12,000 ㎡

Large scale: More than 60 m^3/s but less than 90 m^3/s
⇒ Required area: 15,000 ㎡

Extra-large scale: More than 90 m^3/s but less than 150 m^3/s
⇒ Required area: 17,500 ㎡

Preparation Cost of Gate and Pump: 2,544,402,656 Rs (Phase1)

Source: JICA Expert Team

7.3.3.6. Bypass

The preparation costs for the construction of the Bypass are shown in **Table 7-90**.

Table 7-90: Preparation Costs for Construction of the Bypass

① Area [㎡]	② Unit price [Rs/m2]	③＝①×② Preparation costs [Rs]
214,000	10,038	**2,148,225,625**

Information provided by TT2

Refer to the unit price around the Bypass

Preparation Cost of Bypass: **2,148,225,625 Rs (Phase1)**

Source: JICA Expert Team

7.3.4 Economic cost and economic benefit cash flows

The table below shows the cash flows of economic costs and benefits for the three cases of this Master Plan: Phase 1, Phase 2, and the remaining project when Phase 2 is implemented after the completion of Phase 1 (Phase 2-Phase 1).

Table 7-91: Economic Costs and Economic Benefits Cash Flows of Phase 1

(Unit: Crore INR)

	Year	t	Discount rate 7%	Benefit				Cost						Cost−Benefit Ratio	Net Present Value (NPV)	Economic Internal Rate of Return
				Benefit		② Residual value	Total	③ Construction		④ Operation and Maintenance		Total ③+④				
				Benefit	① Present value		①+②	Cost	Present value	Cost	Present value	Cost	Present value	B/C	B−C	EIRR
Construction period (13 years)	2024	0	1.000	0	0		0	0	0	0	0	0	0		0	
	2025	1	0.935	0	0		0	3,160	2,953	0	0	3,160	2,953		−2,953	
	2026	2	0.873	0	0		0	3,160	2,760	0	0	3,160	2,760		−2,760	
	2027	3	0.816	0	0		0	3,160	2,580	0	0	3,160	2,580		−2,580	
	2028	4	0.763	0	0		0	819	625	0	0	819	625		−625	
	2029	5	0.713	2,757	1,966		1,966	819	584	0	0	819	584		1,382	
	2030	6	0.666	5,515	3,675		3,675	819	546	4	2	823	548		3,127	
	2031	7	0.623	8,272	5,152		5,152	819	510	7	5	827	515		4,638	
	2032	8	0.582	11,030	6,419		6,419	819	477	11	6	830	483		5,936	
	2033	9	0.544	13,787	7,499		7,499	819	446	15	8	834	454		7,045	
	2034	10	0.508	16,544	8,410		8,410	819	417	18	9	838	426		7,984	
	2035	11	0.475	19,302	9,170		9,170	819	389	22	10	841	399		8,771	
	2036	12	0.444	22,059	9,795		9,795	819	364	25	11	845	375		9,420	
	2037	13	0.415	24,817	10,298		10,298	819	340	29	12	848	352		9,946	
Total				1,502,781	220,294	249	220,543	17,675	12,991		252	19,440	13,055	16.9	207,488	41%

Source: JICA Expert Team

Table 7-92: Economic Costs and Economic Benefits Cash Flows of Phase 2

(Unit: Crore INR)

	Year	t	Discount rate 7%	Benefit				Cost						Cost−Benefit Ratio	Net Present Value (NPV)	Economic Internal Rate of Return
				Benefit		② Residual value	Total	③ Construction		④ Operation and Maintenance		Total ③+④				
				Benefit	① Present value		①+②	Cost	Present value	Cost	Present value	Cost	Present value	B/C	B−C	EIRR
Construction period (33 years)	2024	0	1.000	0	0		0	0	0	0	0	0	0		0	
	2025	1	0.935	0	0		0	3,160	2,953	0	0	3,160	2,953		−2,953	
	2026	2	0.873	0	0		0	3,160	2,760	0	0	3,160	2,760		−2,760	
	2027	3	0.816	0	0		0	3,160	2,580	0	0	3,160	2,580		−2,580	
	2028	4	0.763	0	0		0	819	625	0	0	819	625		−625	
	2029	5	0.713	458	326		326	819	584	4	3	823	587		−261	
	2030	6	0.666	915	610		610	819	546	7	5	827	551		59	
	2031	7	0.623	1,373	855		855	819	510	11	7	830	517		338	
	2032	8	0.582	8,262	4,809		4,809	10,586	6,161	15	9	10,601	6,170		−1,361	
	2033	9	0.544	10,042	5,462		5,462	10,586	5,758	18	10	10,604	5,768		−306	
	2034	10	0.508	11,823	6,010		6,010	10,586	5,382	22	11	10,608	5,393		617	
	2035	11	0.475	13,603	6,463		6,463	10,586	5,029	25	12	10,612	5,041		1,422	
	2036	12	0.444	15,384	6,831		6,831	10,586	4,700	29	13	10,615	4,713		2,118	
	2037	13	0.415	17,164	7,122		7,122	10,586	4,393	33	14	10,619	4,407		2,715	
	2038	14	0.388	37,299	14,465		14,465	468	181	36	14	504	195		14,270	
	2039	15	0.362	37,560	13,613		13,613	468	170	38	14	506	184		13,429	
	2040	16	0.339	37,821	12,811		12,811	468	158	40	14	508	172		12,639	
	2041	17	0.317	38,082	12,056		12,056	468	148	43	14	510	162		11,895	
	2042	18	0.296	38,343	11,344		11,344	468	138	45	13	512	151		11,193	
	2043	19	0.277	38,605	10,674		10,674	468	129	47	13	514	142		10,532	
	2044	20	0.258	38,866	10,044		10,044	468	121	49	13	516	134		9,910	
	2045	21	0.242	39,127	9,450		9,450	468	113	51	12	519	125		9,325	
	2046	22	0.226	39,388	8,890		8,890	468	106	53	12	521	118		8,772	
	2047	23	0.211	39,649	8,364		8,364	468	99	55	12	523	111		8,253	
	2048	24	0.197	39,910	7,868		7,868	468	92	57	11	525	103		7,765	
	2049	25	0.184	40,172	7,402		7,402	468	86	59	11	527	97		7,305	
	2050	26	0.172	40,433	6,962		6,962	468	81	61	11	529	92		6,871	
	2051	27	0.161	40,694	6,549		6,549	468	75	63	10	531	85		6,464	
	2052	28	0.150	40,955	6,160		6,160	468	70	65	10	533	80		6,080	
	2053	29	0.141	41,216	5,793		5,793	468	66	67	10	535	76		5,718	
	2054	30	0.131	41,477	5,449		5,449	468	61	70	9	537	70		5,379	
	2055	31	0.123	41,738	5,124		5,124	468	57	72	9	539	66		5,058	
	2056	32	0.115	42,000	4,819		4,819	468	54	74	9	541	63		4,757	
	2057	33	0.107	42,261	4,532		4,532	468	50	76	8	543	58		4,474	
Evaluation period after completion of the construction (50 years)	2058	34	0.100	42,522	4,262		4,262			78	8	78	8		4,254	
	2059	35	0.094	42,522	3,983		3,983			78	7	78	7		3,976	
	2060	36	0.088	42,522	3,722		3,722			78	6.8	78	6.8		3,715	
	2061	37	0.082	42,522	3,479		3,479			78	6.4	78	6.4		3,473	
	2062	38	0.076	42,522	3,251		3,251			78	5.9	78	5.9		3,245	
	2063	39	0.071	42,522	3,038		3,038			78	5.6	78	5.6		3,032	
	2064	40	0.067	42,522	2,840		2,840			78	5.2	78	5.2		2,835	
	2065	41	0.062	42,522	2,654		2,654			78	4.9	78	4.9		2,649	
	2066	42	0.058	42,522	2,480		2,480			78	4.5	78	4.5		2,476	
	2067	43	0.055	42,522	2,318		2,318			78	4.2	78	4.2		2,314	
	2068	44	0.051	42,522	2,166		2,166			78	4.0	78	4.0		2,162	
	2069	45	0.048	42,522	2,025		2,025			78	3.7	78	3.7		2,021	
	2070	46	0.044	42,522	1,892		1,892			78	3.5	78	3.5		1,889	
	2071	47	0.042	42,522	1,768		1,768			78	3.2	78	3.2		1,765	
	2072	48	0.039	42,522	1,653		1,653			78	3.0	78	3.0		1,650	
	2073	49	0.036	42,522	1,545		1,545			78	2.8	78	2.8		1,542	
	2074	50	0.034	42,522	1,444		1,444			78	2.6	78	2.6		1,441	
	2075	51	0.032	42,522	1,349		1,349			78	2.5	78	2.5		1,347	
	2076	52	0.030	42,522	1,261		1,261			78	2.3	78	2.3		1,259	
	2077	53	0.028	42,522	1,178		1,178			78	2.2	78	2.2		1,176	
	2078	54	0.026	42,522	1,101		1,101			78	2.0	78	2.0		1,099	
	2079	55	0.024	42,522	1,029		1,029			78	1.9	78	1.9		1,027	
	2080	56	0.023	42,522	962		962			78	1.8	78	1.8		960	
	2081	57	0.021	42,522	899		899			78	1.6	78	1.6		897	
	2082	58	0.020	42,522	840		840			78	1.5	78	1.5		839	
	2083	59	0.018	42,522	785		785			78	1.4	78	1.4		784	
	2084	60	0.017	42,522	734		734			78	1.3	78	1.3		733	
	2085	61	0.016	42,522	686		686			78	1.3	78	1.3		685	
	2086	62	0.015	42,522	641		641			78	1.2	78	1.2		640	
	2087	63	0.014	42,522	599		599			78	1.1	78	1.1		598	
	2088	64	0.013	42,522	560		560			78	1.0	78	1.0		559	
	2089	65	0.012	42,522	523		523			78	1.0	78	1.0		522	
	2090	66	0.011	42,522	489		489			78	0.9	78	0.9		488	
	2091	67	0.011	42,522	457		457			78	0.8	78	0.8		456	
	2092	68	0.010	42,522	427		427			78	0.8	78	0.8		426	
	2093	69	0.009	42,522	399		399			78	0.7	78	0.7		398	
	2094	70	0.009	42,522	373		373			78	0.7	78	0.7		372	
	2095	71	0.008	42,522	349		349			78	0.6	78	0.6		348	
	2096	72	0.008	42,522	326		326			78	0.6	78	0.6		325	
	2097	73	0.007	42,522	305		305			78	0.6	78	0.6		304	
	2098	74	0.007	42,522	285		285			78	0.5	78	0.5		285	
	2099	75	0.006	42,522	266		266			78	0.5	78	0.5		266	
	2100	76	0.006	42,522	249		249			78	0.5	78	0.5		249	
	2101	77	0.005	42,522	232		232			78	0.4	78	0.4		232	
	2102	78	0.005	42,522	217		217			78	0.4	78	0.4		217	
	2103	79	0.005	42,522	203		203			78	0.4	78	0.4		203	
	2104	80	0.004	42,522	190		190			78	0.3	78	0.3		190	
	2105	81	0.004	42,522	177		177			78	0.3	78	0.3		177	
	2106	82	0.004	42,522	166		166			78	0.3	78	0.3		166	
	2107	83	0.004	42,522	155		155			78	0.3	78	0.3		155	
Total				3,000,714	160,338	334	160,672	85,629	44,036	5,174	424	90,803	44,460	3.6	116,212	13%

Source: JICA Expert Team

Table 7-93: Economic Costs and Economic Benefits Cash Flows of the Remaining Project

(Phase 2-1)

(Unit: Crore INR)

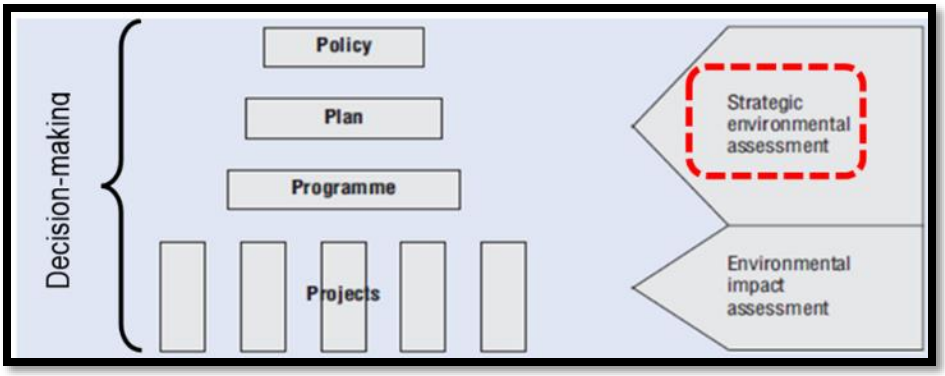
	Year	t	Discount rate 7%	Benefit				Cost						Cost−Benefit Ratio	Net Present Value (NPV)	Economic Internal Rate of Return
				Benefit		② Residual value	Total	③ Construction		④ Operation and Maintenance		Total ③+④				
				Benefit	① Present value		①+②	Cost	Present value	Cost	Present value	Cost	Present value	B/C	B−C	EIRR
Construction period (33 years)	2024	0	1.000	0	0		0	0	0	0	0	0	0		0	
	2025	1	0.935	0	0		0	0	0	0	0	0	0		0	
	2026	2	0.873	0	0		0	0	0	0	0	0	0		0	
	2027	3	0.816	0	0		0	0	0	0	0	0	0		0	
	2028	4	0.763	0	0		0	0	0	0	0	0	0		0	
	2029	5	0.713	0	0		0	0	0	4	3	4	3		−3	
	2030	6	0.666	0	0		0	0	0	7	5	7	5		−5	
	2031	7	0.623	0	0		0	0	0	11	7	11	7		−7	
	2032	8	0.582	0	0		0	9,767	6,161	15	9	10,601	6,170		−6,170	
	2033	9	0.544	0	0		0	9,767	5,758	18	10	10,604	5,768		−5,768	
	2034	10	0.508	0	0		0	9,767	5,382	22	11	10,608	5,393		−5,393	
	2035	11	0.475	0	0		0	9,767	5,029	25	12	10,612	5,041		−5,041	
	2036	12	0.444	0	0		0	9,767	4,700	29	13	10,615	4,713		−4,713	
	2037	13	0.415	0	0		0	9,767	4,393	33	14	10,619	4,407		−4,407	
	2038	14	0.388	9,725	3,771		3,771	468	181	36	14	504	195		3,576	
	2039	15	0.362	9,986	3,619		3,619	468	170	38	14	506	184		3,435	
	2040	16	0.339	10,247	3,471		3,471	468	158	40	14	508	172		3,299	
	2041	17	0.317	10,508	3,327		3,327	468	148	43	14	510	162		3,166	
	2042	18	0.296	10,770	3,186		3,186	468	138	45	13	512	151		3,035	
	2043	19	0.277	11,031	3,050		3,050	468	129	47	13	514	142		2,908	
	2044	20	0.258	11,292	2,918		2,918	468	121	49	13	516	134		2,784	
	2045	21	0.242	11,553	2,790		2,790	468	113	51	12	519	125		2,665	
	2046	22	0.226	11,814	2,667		2,667	468	106	53	12	521	118		2,549	
	2047	23	0.211	12,075	2,547		2,547	468	99	55	12	523	111		2,436	
	2048	24	0.197	12,336	2,432		2,432	468	92	57	11	525	103		2,329	
	2049	25	0.184	12,598	2,321		2,321	468	86	59	11	527	97		2,224	
	2050	26	0.172	12,859	2,214		2,214	468	81	61	11	529	92		2,123	
	2051	27	0.161	13,120	2,111		2,111	468	75	63	10	531	85		2,026	
	2052	28	0.150	13,381	2,013		2,013	468	70	65	10	533	80		1,933	
	2053	29	0.141	13,642	1,918		1,918	468	66	67	10	535	76		1,843	
	2054	30	0.131	13,903	1,826		1,826	468	61	70	9	537	70		1,756	
	2055	31	0.123	14,164	1,739		1,739	468	57	72	9	539	66		1,673	
	2056	32	0.115	14,426	1,655		1,655	468	54	74	9	541	63		1,593	
	2057	33	0.107	14,687	1,575		1,575	468	50	76	8	543	58		1,517	
Evaluation period after completion of the construction (50 years)	2058	34	0.100	14,948	1,498		1,498			78	8	78	8		1,490	
	2059	35	0.094	14,948	1,400		1,400			78	7	78	7		1,393	
	2060	36	0.088	14,948	1,308		1,308			78	7	78	6.8		1,301	
	2061	37	0.082	14,948	1,223		1,223			78	6	78	6.4		1,217	
	2062	38	0.076	14,948	1,143		1,143			78	6	78	5.9		1,137	
	2063	39	0.071	14,948	1,068		1,068			78	6	78	5.6		1,062	
	2064	40	0.067	14,948	998		998			78	5	78	5.2		993	
	2065	41	0.062	14,948	933		933			78	5	78	4.9		928	
	2066	42	0.058	14,948	872		872			78	5	78	4.5		868	
	2067	43	0.055	14,948	815		815			78	4	78	4.2		811	
	2068	44	0.051	14,948	762		762			78	4	78	4.0		758	
	2069	45	0.048	14,948	712		712			78	4	78	3.7		708	
	2070	46	0.044	14,948	665		665			78	4	78	3.5		662	
	2071	47	0.042	14,948	622		622			78	3	78	3.2		619	
	2072	48	0.039	14,948	581		581			78	3	78	3.0		578	
	2073	49	0.036	14,948	543		543			78	3	78	2.8		540	
	2074	50	0.034	14,948	507		507			78	3	78	2.6		504	
	2075	51	0.032	14,948	474		474			78	3	78	2.5		472	
	2076	52	0.030	14,948	443		443			78	2	78	2.3		441	
	2077	53	0.028	14,948	414		414			78	2	78	2.2		412	
	2078	54	0.026	14,948	387		387			78	2	78	2.0		385	
	2079	55	0.024	14,948	362		362			78	2	78	1.9		360	
	2080	56	0.023	14,948	338		338			78	2	78	1.8		336	
	2081	57	0.021	14,948	316		316			78	2	78	1.6		314	
	2082	58	0.020	14,948	295		295			78	2	78	1.5		294	
	2083	59	0.018	14,948	276		276			78	1	78	1.4		275	
	2084	60	0.017	14,948	258		258			78	1	78	1.3		257	
	2085	61	0.016	14,948	241		241			78	1	78	1.3		240	
	2086	62	0.015	14,948	225		225			78	1	78	1.2		224	
	2087	63	0.014	14,948	211		211			78	1	78	1.1		210	
	2088	64	0.013	14,948	197		197			78	1	78	1.0		196	
	2089	65	0.012	14,948	184		184			78	1	78	1.0		183	
	2090	66	0.011	14,948	172		172			78	1	78	0.9		171	
	2091	67	0.011	14,948	161		161			78	1	78	0.8		160	
	2092	68	0.010	14,948	150		150			78	1	78	0.8		149	
	2093	69	0.009	14,948	140		140			78	1	78	0.7		139	
	2094	70	0.009	14,948	131		131			78	1	78	0.7		130	
	2095	71	0.008	14,948	123		123			78	1	78	0.6		122	
	2096	72	0.008	14,948	115		115			78	1	78	0.6		114	
	2097	73	0.007	14,948	107		107			78	1	78	0.6		106	
	2098	74	0.007	14,948	100		100			78	1	78	0.5		100	
	2099	75	0.006	14,948	93		93			78	1	78	0.5		93	
	2100	76	0.006	14,948	87		87			78	1	78	0.5		87	
	2101	77	0.005	14,948	82		82			78	0	78	0.4		82	
	2102	78	0.005	14,948	76		76			78	0	78	0.4		76	
	2103	79	0.005	14,948	71		71			78	0	78	0.4		71	
	2104	80	0.004	14,948	67		67			78	0	78	0.3		67	
	2105	81	0.004	14,948	62		62			78	0	78	0.3		62	
	2106	82	0.004	14,948	58		58			78	0	78	0.3		58	
	2107	83	0.004	14,948	54		54			78	0	78	0.3		54	
Total				991,513	73,270	284	73,554	67,954	33,478	5,174	424	78,046	33,902	2.2	39,652	12%

Source: JICA Expert Team

Chapter 8. Strategic Environmental Assessment Study

8.1 Introduction

The environmental and social consideration study, one of the study components related to the proposed Comprehensive Flood Control Master Plan (CFCMP), is envisaged based on the JICA's Environmental and Social Consideration Guideline (issued in 2022). As the subject of the assessment is in the planning stage, the environmental assessment stage is considered to be a Strategic Environmental Assessment (SEA) instead of an Environmental Impact Assessment (EIA), based on the decision-making hierarchy illustrated in **Figure 8-1**. SEA predicts and evaluates the impact of strategic action on the environment and uses that information in decision-making. It is an environmental impact assessment of strategic actions, policies, plans, and programs, aiming to ensure that environmental aspects are considered effectively in this decision-making period.



Source: UNDP arranged partly by the JET

Figure 8-1: Positioning of SEA

There are several benefits of SEA:

SEA can safeguard the environmental assets and opportunities upon which all people depend, particularly the poor, and thus promote sustainable poverty reduction and development.

SEA can improve decision-making related to policies and plans and thus improve development outcomes by:

- Supporting the integration of the environment and development,
- Providing environment-based evidence to support informed decisions,
- Improving the identification of new opportunities,
- Preventing costly mistakes,
- Building public engagement in decision-making for improved governance and
- Facilitating transboundary co-operation.

8.2 Study Objectives

Keeping in view the current situation of the river basins in Metropolitan Chennai, it is important to assist the Government in formulating a comprehensive flood control Master Plan for the selected river basins. Therefore, the study objectives of the SEA study are:

To identify and assess potential negative impacts on the natural and social environment caused by the Master Plan,

To prepare a preliminary environmental and social impact study for the prioritized project proposed in the Master Plan and

To prepare an Environmental and Social Monitoring Plan (ESMP), which shall include mitigation actions, monitoring parameters, methods, implementation stage, frequency, and responsible organization (s) for each negative impact for each mitigation action at minimum.

The SEA study shall be performed under all requirements of the EIA-related Indian legislations such as the Environment (Protection) Act of 1986, the Environmental Impact Assessment Notification of 2006 and its subsequent Amendments, the Water (Prevention and Control of Pollution) Act of 1974 and its subsequent Amendments, and the Air (Prevention and Control of Pollution) Act of 1981 and its subsequent amendments. In addition to the above-mentioned relevant Indian legislation, the JICA Guidelines for Environmental and Social Considerations (2022) shall be taken into consideration for both studies.

8.3 Approach and Process

SEA study primarily focuses on the quantitative assessment of the expected plan or program and the consequences of its implementation. Hence, the approach shall be based on the following principles:

For the selection of suitable methods, criteria, indicators, impact types, alternatives, Indian laws, and policies about SEA and EIA would be considered in addition to JICA guidelines.

Appropriate SEA tools relevant to the local context will be selected. Similarly, local environmental and social issues and their impacts will be addressed.

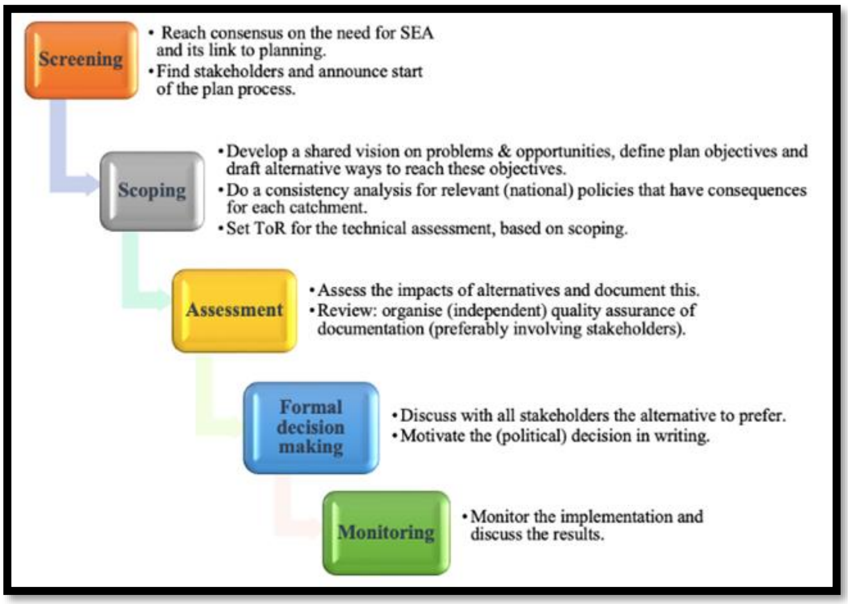
Adaptation of data and scopes ensures that the method chosen shall be based on cause & effect relations.

Reliable approach – It will be ensured that the results are reliable and technically accurate.

Implementability – At the time of discussing alternatives, attention shall be paid to suitable alternative options and measures, which shall reduce the expected negative impact.

Importance in decision-making – Important problems and conciliations shall be described.

The process flow chart is depicted as follows.



Source: JICA Expert Team

Figure 8-2: Common SEA Study Process

8.4 Laws, Regulation for Natural and Social Environment

8.4.1 Laws relevant to the natural environment

India has a well-defined institutional and legislative framework for environmental and social considerations. The legislation covers all components of environmental regulation, including air, water, soil, terrestrial and aquatic flora and fauna, natural resources, and sensitive habitats. India is also a signatory to various international conventions and protocols. The environmental legislations in India are framed to protect the valued environmental components and comply with its commitment to the international community under the above conventions and protocols.

Environment (Protection) Act of 1986 and Environmental Impact Assessment Notification and Amendments of 2006, 2009, and 2013 stipulate requirements and procedures for environmental impact assessment. Environmental Impact Assessment reports cover an overview of the project and its impacts on the natural and social environment. Mitigation measures are disclosed to the public via media and other forms, and opinions of the public gathered through public hearings are incorporated in the reports.

Environmental procedures fall under the jurisdiction of the Ministry of Environment, Forest and Climate Change (MoEFCC), but depending on the category of a project, the jurisdiction is transferred to a state government. The project category is decided based on the notification from the MoEFCC. A project is categorized into eight types depending on the activities of a project and into categories A or B depending on the size. In terms of infrastructure development, the notification by the MoEFCC has categories such as dam construction and dredging works for port and harbor construction; however, there is no framework for flood control work. Therefore, for this project, discussion and cooperation with the central government or the Department of Environment (DOE) of a state government will be necessary.

MoEFCC will issue Environmental Clearance for projects falling under Category A based on the recommendation of the Expert Appraisal Committee (EAC). The State Environmental Impact Assessment Authority (SEIAA) will issue Environmental Clearance for projects falling under Category B based on recommendations by the State Expert Appraisal Committee (SEAC).

A project with flood control and drainage facility development working in the Coastal Regulation Zone (CRZ) is required to obtain Environmental Clearance from MoEFCC.

MoEFCC published the Environmental Impact Assessment Notification in 2020 and is accepting objections or suggestions from the citizens. Within two years, the scrutinized notification will be published.

The table below summarizes India's acts and rules regarding environmental impact assessment.

Table 8-1: Laws Related to Environmental Considerations

Law	Year	Overview	Responsible Authority
Environment			
Environment (Protection) Act.	1986	Aims for comprehensive environmental protection and improvement	MoEFCC
1.1Environmental Impact Assessment			
Environmental Impact Assessment Notification and Amendments	2006, 2009, 2013	Sets procedures for EIA and Environmental Clearance	MoEFCC
1.2 Pollution Prevention			
Water (Prevention and Control of Pollution and Amendments Act	1974	Aims for prevention and control of water pollution, maintenance and restoration of cleanliness of water	TNPCB
Air (Prevention and Control of Pollution) Act (and subsequent Amendments)	1981	Aims for prevention, control, and mitigation of air pollution, establishment of committees	TNPCB
Hazardous Waste (Management, Transboundary Rules), 2008	2008	Stipulates handling, storage, transport, and disposal of hazardous waste	TNPCB
Municipal Solid Waste Rules	2016	Stipulates segregation, handling, and safe disposal of domestic, hazardous, construction, and plastic waste	TNPCB
Noise Pollution (Regulation and Control) Rules, 2000	2000	Aims for regulation and control of noise pollution	TNPCB
Natural Environment, Cultural Remains			
Wildlife Protection Act	1972	Aims for the establishment of national parks and wildlife sanctuaries to protect wildlife, including birds	MoEFCC and TNFD
Forest Conservation Act and Forest Rights Act	1980 (1988 amend), 2006	Restricts conversion of forest into non-forest for protection and management as a check for deforestation	TNFD and MoEFCC
Biological Diversity Act	2002	Aims at the conservation of biological resources, managing their sustainable use, and enabling fair and equitable sharing of benefits	TN Biodiversity Board

Law	Year	Overview	Responsible Authority
The Ancient Monuments and Archaeological Sites and Remains (Amendment and Validation) Act	2010	Aims for the protection of ancient monuments and archaeological sites and remains	TN Department of Archaeology
Coastal Regulation Zone Act (CRZ) Notification	2019	Regulates construction in the coastal regulation zones	TNCZMA
National Green Tribunal (NGT) ACT	2010	Enforcement of the environment and giving relief and compensation for damages to persons and property	National Green Tribunal, Southern Zone Bench
Laws and regulations to comply with in construction			
Notification on the use of fly ash	2007	Mandates reuse of fly ash	MoEFCC
Batteries (Management and Handling) Rules 2001	2001	Stipulate recycling of batteries	TNPCB
Public Liability and Insurance Act, 1991	1991	Aims for protection from accidents due to hazardous materials	CC/PIU
Minor Minerals and Development Conservation Rules, 2010	2010	Clarifies rules to open new quarries	District Collectorate and Mining & Geology Dept.
Explosive Act 1984 and Explosive Rules 2008	2008	Stipulates safe transport and storage of explosives	Chief Controller of Explosives
Tamil Nadu Minor Minerals and Concession Rules, 1956	1956	Clarifies rules to open new quarries in Tamil Nadu	District Collectorate Mining & Geology Dept.

Source: JICA Expert Team

8.4.2 Laws relevant to the social environment

In 2013, the Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation, and Resettlement Act was enacted to protect the rights of landowners and other families affected by land acquisition for development projects. This Act ensures adequate compensation to the affected persons. The table below summarizes the legislation related to social considerations.

Table 8-2: Laws Related to Social Considerations

Law	Overview	Responsible Authority
1. Constitution		
The Constitution of India (as of)	Article 300 A "Persons not to be deprived of property save by authority of law." Article 31 stipulates the protection of estates from unlawful acquisition	Ministry of Law and Justice
2. Land Acquisition		
The Right to Fair Compensation and Transparency in the Land Acquisition, Rehabilitation and Resettlement Act, 2013, 2017 (LARR Act)	Clarifies conditions for land acquisition and implementation of social impact survey, mandates formulation of resettlement plan, stipulates fair compensation, prevents land use for other purposes after land acquisition, and stipulates monitoring	Ministry of Rural Development
Tamil Nadu Land Encroachment Act, 1905 (amended in 1975)	Deals with unauthorized occupation of Government land in Tamil Nadu and provides for liability of those occupying un-authorized land and manner of eviction	TN state and local government
3. Human Rights		
The Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006.	Recognizes and vests the rights of forest-dwelling Scheduled Tribes and other traditional forest dwellers to protect their livelihood	Ministry of Tribal Affairs

Law	Overview	Responsible Authority
Right to Information Act, 2005	Stipulates the right of the citizens to information through newspapers, media, and public hearings	Ministry of Law and Justice
The Street Vendors (Protection of Livelihood and Regulation of Street Vending) Act, 2014 Tamil Nadu Street Vendors (Protection of Livelihood and Regulation of Street Vending) Rules, 2015	Aims to regulate street vendors in public areas and protect their rights. It provides for a periodic survey of all street vendors under the jurisdiction of the Town Vending Committee and registration and issuance of a Certificate of Vending to them. These Rules have been made by the government in the exercise of the powers conferred by the 2014 Street Vendors Act. It provides for the constitution of the Town Vending Committee, Grievance Redressal, and Dispute Resolution Committees.	Parliament of India

Source: JICA Expert Team

The Constitution of India provides the following safeguards for environmental and social measures.

Article 14

Right to equality and environmental protection. Equality before the law and equal protection of the law has been granted to all citizens of this country.

Article 21

Guarantees the fundamental right to life, which is interpreted as the right to a clean environment. The right to a healthy environment is an important attribute of the right to live with dignity.

Article 48-A

The State shall endeavor to protect and improve the environment and safeguard the forests and wildlife of the country.

Article 51-A (g)

"It shall be the duty of every citizen of India to protect and improve the natural environment, including forests, lakes, rivers, and wildlife, and to have compassion for living creatures."

Table 8-3: Law and Policies Related to Social Safeguards

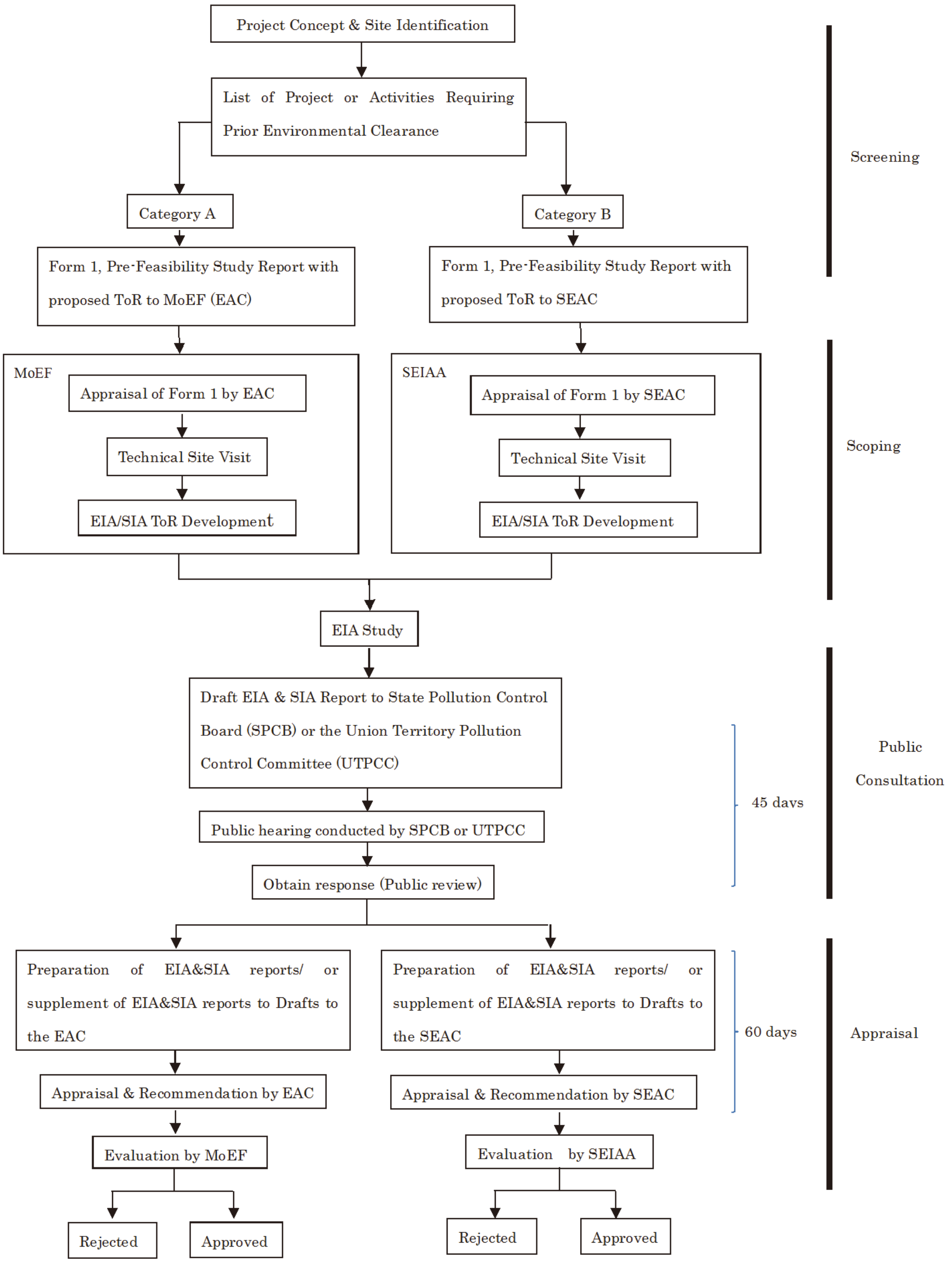
Name of the Law /Act and provisions	Relevance to the project
Tamil Nadu Town and Country Planning Act, 1971 The Chennai Metropolitan Water Supply and Sewerage Act, 1978 Development and Control Rules for Chennai Metropolitan Area, 2004 National Disaster Management Act, 2005 The provisions of water supply and sanitation services by CMWSSB are governed by this act.	Drinking and irrigation water management will be relevant to the countermeasures related to the water tank rehabilitation or development.
Citizen Charters of CMWSSB, CMA, GCC, TNDRRA Towards the citizen charter of these agencies, people-orientation will be guided by the following aspects. Feedback from consumers /citizens/users Delivering excellence in products and services Doing business with ethics and integrity Continuous endeavor to improve the quality of service	The Act will have a close relationship with citizens' awareness of pollution control and the beautification of the river environment.

Name of the Law /Act and provisions	Relevance to the project
Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013 & Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2017 Emphasizes social assessment and resettlement planning even before issuance of the preliminary notification and proposes to provide an arrangement of R&R benefits along with the compensation package. Some of the highlights are as follows: Offers compensation up to 4 times the market value in rural areas and 2 times the market value in urban areas. No displacement or dispossession until full payment of compensation and RR benefits are made and alternative sites for the resettlement and rehabilitation have been prepared. Bill requires the consent of no less than 70 percent and 80 percent, respectively (in both cases) of those whose land is sought to be acquired in case of PPP or private projects. To safeguard food security and to prevent arbitrary acquisition, the Bill directs States to impose limits on the area under agricultural cultivation that can be acquired. In case land remains unutilized after acquisition, the new Bill empowers states to return the land either to the owner or to the State Land Bank. No income tax shall be levied, and no stamp duty shall be charged on any amount that accrues to an individual as a result of the provisions of the new law. Specifies some additional provisions for SC and STs.	This Act is related to fair compensation for loss of assets when involuntary resettlement or land acquisition will be required for the flood control measures during the project phase. Appropriate resettlement activities shall be implemented based on the relevant Acts.
Street Vendors (Protection of Livelihood and Regulation of Street Vending) Act, 2014 & Tamil Nadu Street Vendors (Protection of Livelihood and Regulation of Street Vending) Rules, 2015 This Act aims to regulate street vendors in public areas and protect their rights. It provides for a periodic survey of all street vendors under the jurisdiction of the Town Vending Committee (in each zone or ward of the local authority) and registration and issuance of a Certificate of Vending to them. These Rules have been made by the government in the exercise of the powers conferred by the 2014 Street Vendors Act. It provides for the constitution of the Town Vending Committee, Grievance Redressal, and Dispute Resolution Committees.	Relocation of the street vendor shall be followed by the Acts when the flood control measures will be associated with land acquisition of road property such as river channelization. An appropriate action plan shall be prepared during the project phase before implementation of the measures.
Tamil Nadu Land Encroachment Act, 1905 This Act deals with the unauthorized occupation of Government land in Tamil Nadu and provides for liability of those unauthorizedly occupying land and the manner of eviction.	A resettlement action plan shall be prepared appropriately based on the Acts during the project phase for the flood mitigation measures if the projected measures include relocations of informal settlements.
National Urban Sanitation Policy (NUSP) 2008 The policy on integrated city-wide sanitation covers institutional strengthening, awareness generation, behavioral changes, pro-poor approaches, and cost-effective technologies under city sanitation plans that should lead to open defecation-free cities, as well as sanitary and safe disposal of all human and liquid wastes.	This act will be relevant to the future pollution control measures for the river environment. The flood control project could lead to additional related projects from different perspectives, from controlling to progress for a good sanitary environment.
Prohibition of Employment of Manual Scavengers and their Rehabilitation Act, 2013 (Central Act 25 of 2013) No person, local authority, or any agency to engage or employ, either directly or indirectly, any person for hazardous cleaning of a sewer or a septic tank.	This act will be relevant to the establishment of an appropriate employment environment during the construction phase of the flood control measures.

Source: JICA Expert Team

8.4.3 Procedure of Environmental Impact Assessment

Although there is no legal requirement for preparing the SEA report during the policy, planning, and program stage in India, preparation of the Environmental Impact Assessment (EIA) Study will be required for the particular development project speculated in the EIA Notification during the project stage. The table below shows the flow of Environmental Impact Assessments to obtain Environmental Clearance.



Source: MOEFCC

Figure 8-3: EIA Flow

8.4.4 Environmental regulations

8.4.4.1. Air quality

The ambient air quality standards for pollution control, as shown below, are prepared by the Central Pollution Control Board (CPCB) under the Ministry of Environment, Forest and Climate Change (MoEFCC).

Table 8-4: National Ambient Air Quality Standards

Pollutant	Time Weighted Average	Concentration in Ambient Air	
		Industrial, Residential, Rural, and Other Areas	Ecologically Sensitive Area
Sulphur Dioxide (SO2)µg/ m3	Annual	50	20
	24 Hours	80	80
Oxides of Nitrogen (NO2)µg/ m3	Annual	40	30
	24 Hours	80	80
Particulate Matter (size less than 10µm) or PM10 µg/ m3	Annual	60	60
	24 Hours	100	100
Particulate Matter (size less than 2.5µm) or PM2.5µg/m3	Annual	40	40
	24 Hours	60	60
Carbon Monoxide (CO) mg/ m3	8 Hours	02	02
	1 Hour	04	04
Ozone (O3) µg/m3	8 Hours	100	100
	1 Hour	180	180
Lead (Pb) µg/m3	Annual	0.5	0.5
	24 Hours	1.0	1.0
Ammonia (NH3) µg/m3	Annual	100	100
	24 Hours	400	400

Source: CPCB

8.4.4.2. Water quality

The effluent water quality standards for pollution control, as shown below, are prepared by the Central Pollution Control Board (CPCB) under MoEFCC.

Table 8-5: National Water Quality Standards (for Industrial Cooling, Recreation (non-contact) and Aesthetics)

Parameter	Standards	Rationale/Remarks
pH range	6.5-8.5	The range is conducive to the propagation of aquatic species and restoring natural systems.
Dissolved Oxygen	3.0 mg/I or 40 percent saturation value, whichever is higher.	To protect aquatic lives.
Colour and Odour	No noticeable color or offensive odor	None in such concentration would impair usages specifically assigned to this class.
Floating Matters	No visible/obnoxious floating debris, oil slick, scum.	As in (3) above.
Faecal Coliform	500/100 ml (MPN)	Not exceeding 1000/100 ml in 20 percent of samples in the year and in 3 consecutive samples in monsoon months.

Parameter	Standards	Rationale/Remarks
Turbidity	30 NTU	Reasonably clear water for Recreation, Aesthetic appreciation, and Industrial cooling purposes.
Dissolved Iron (as Fe)	0.5 mg/l or less	It is desirable to have the collective concentration of dissolved Fe and Mn less or equal to 0.5 mg/I to avoid the scaling effect.
Dissolved Manganese (as Mn)	0.5 mg/l or less	

Source: CPCB

8.4.4.3. Noise and vibration

Noise nuisance standards for pollution control, as shown below, are prepared by the Central Pollution Control Board (CPCB) under MoEFCC. There is no applicable legislation for vibration nuisance as an environmental regulation in India.

Table 8-6: National Noise Standards

Area Code	Category of Area	Limits in dB (A) Leq	
		Day (6 AM-9 PM)	Night (10 PM-6 AM)
A	Industrial Area	75	70
B	Commercial Area	65	55
C	Residential Area	55	45
D	Silence Area	50	40

Source: MoEFCC

8.4.4.4. Sediment contamination control

There is no applicable legislation for sediment quality regulation in India/Tamil Nadu State. Meanwhile, according to "Guidance Document for Assessment and Remediation of Contaminated Sites in India, MoEFCC (2015)", parameters of response levels/intervention values for soil quality, in particular with metal contamination, are referred from the Dutch Target Intervention Values, as shown in the following Table.

Table 8-7: Target and Soil Remediation Intervention Values for Sediment (mg/kg dry matter)

Name of Metal	Target Value	Intervention Value
Antimony (Sb)	3	15
Arsenic (As)	29	55
Barium (Ba)	160	625
Cadmium (Cd)	0.8	12
Chromium (Cr)	100	380
Cobalt (Co)	9	240
Copper (Cu)	36	190
Mercury (Hg)	0.3	10
Lead (Pb)	85	530
Molybdenum (Mo)	3	200
Nickel (Ni)	35	210
Zinc (Zn)	140	720

Source: Dutch Target Intervention Values, 2000

8.4.4.5. Coastal development

Following the CRZ (Coastal Regulation Zone) Notification declared by the Central Government in 2019, the Tamil Nadu State Government prepared the Coastal Zone Management Plans to regulate physical development in the coastal area in the state. Depending on its environmental and social conditions as well as existing land use in the coastal area, the CRZ areas are mainly classified into four categories. The following table and figures summarize classification types and locations in Chennai, respectively.

Table 8-8: Classification of the CRZ

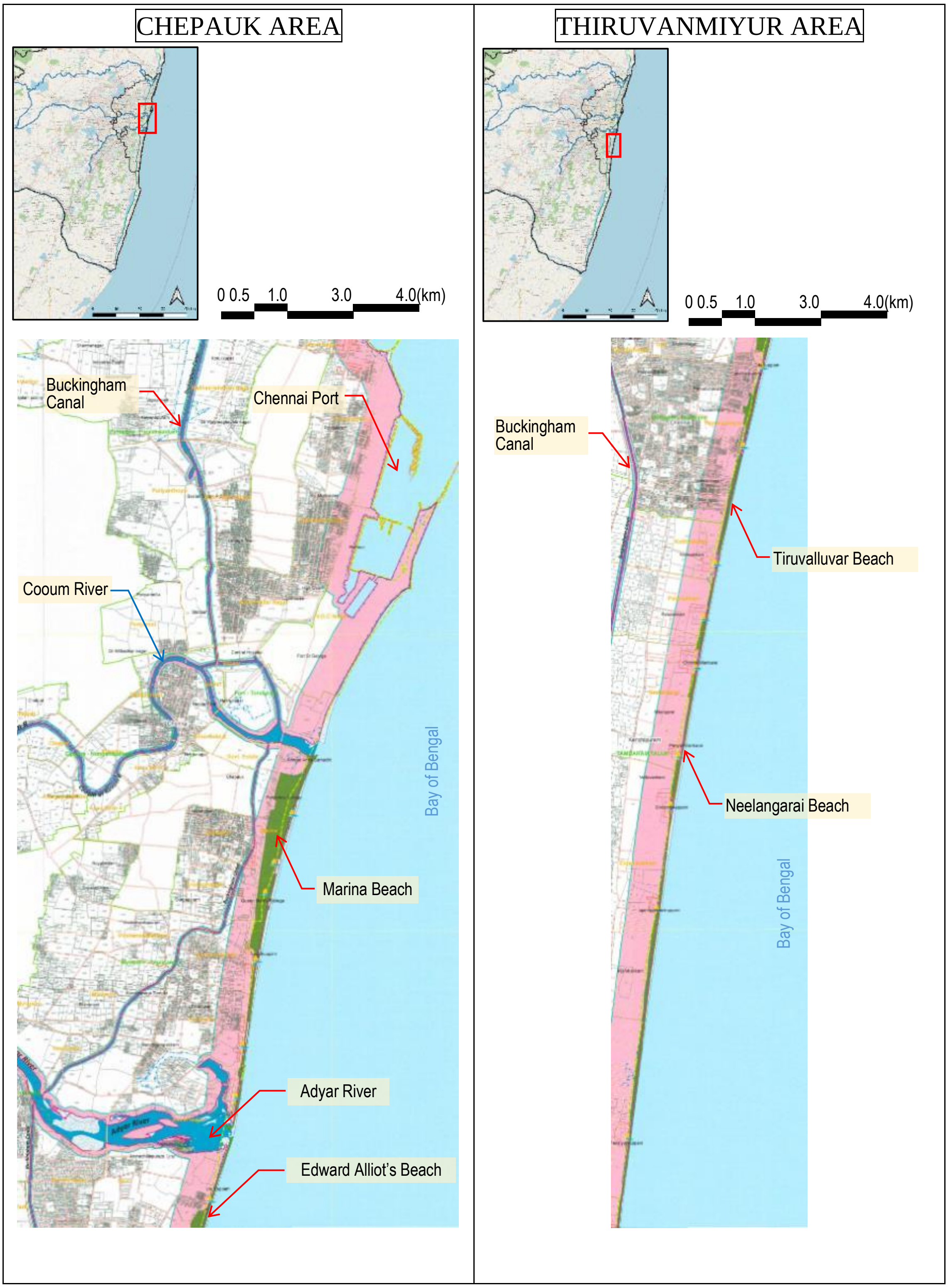
Classification Type		Description
CRZ-I	CRZ-I A	This zone constitutes the ecologically sensitive areas and the geomorphological features, including mangroves, coral reefs, dunes, biologically active mudflats, etc. Construction of roads and roads on stilts by way of reclamation in CRZ-I areas shall be permitted only in exceptional cases for defense, strategic purposes, and public utilities.
	CRZ-I B	The intertidal zone, i.e., the area between the low Tide line and High Tide line, shall constitute the CRZ-I B. Land reclamation for foreshore facilities, roads, mass rapid transit systems, erosion control facilities, stormwater drains, etc., shall be permitted.
CRZ-II		This zone constitutes the developed land areas up to or close to the shoreline, within the existing municipal limits, or in other existing legally designated urban areas. Construction of buildings for residential purposes, schools, hospitals, institutions, offices, public places, etc., shall be permitted only on the landward side of the existing road or on the landward side of existing authorized fixed structures, etc.
CRZ-III	CRZ-III A	Densely populated rural area (>2161/km2) earmarked as the No Development Zone (NDZ) It is permissible for structures for agriculture, horticulture, gardens, pastures, parks, playfields and forestry, dispensaries, schools, public rain shelters, community toilets, bridges, roads, provision of facilities for water supply, drainage, sewage, crematoria, cemeteries, and electric sub-station, etc.
	CRZ-III B	Non-populated rural areas (<2161/km2) are acknowledged as beyond the NDZ. It is permissible for the development of beach resorts or hotels, dwelling units, public rain shelters, community toilets, water supply drainage, sewerage, roads, bridges, etc.
CRZ-IV	CRZ-IV A	The water area and the seabed area between the Low Tide Line up to twelve nautical miles on the seaward side. It is permissible for development activities, including constructions of foreshore facilities, projects for defense or security purposes, measures for erosion control, installation of tidal regulators, laying of stormwater drains, etc.
	CRZ-IV B	This zone includes the water area, the bed area between LTL at the bank of the tidal-influenced water body to the LTL on the opposite side of the bank, extending from the mouth of the water body at the sea up to the influence of tide. The same development activities as CRZ-IV A can be permitted.

Source: TNDoE

While there are no legally required actions for CRZ-regulated initiatives in this Master Plan, it is necessary to consider that the detailed environmental studies and the CRZ management plan with the relevant permits through the consultation with national and state committees relevant to the development of CRZs will be required at the project stage.

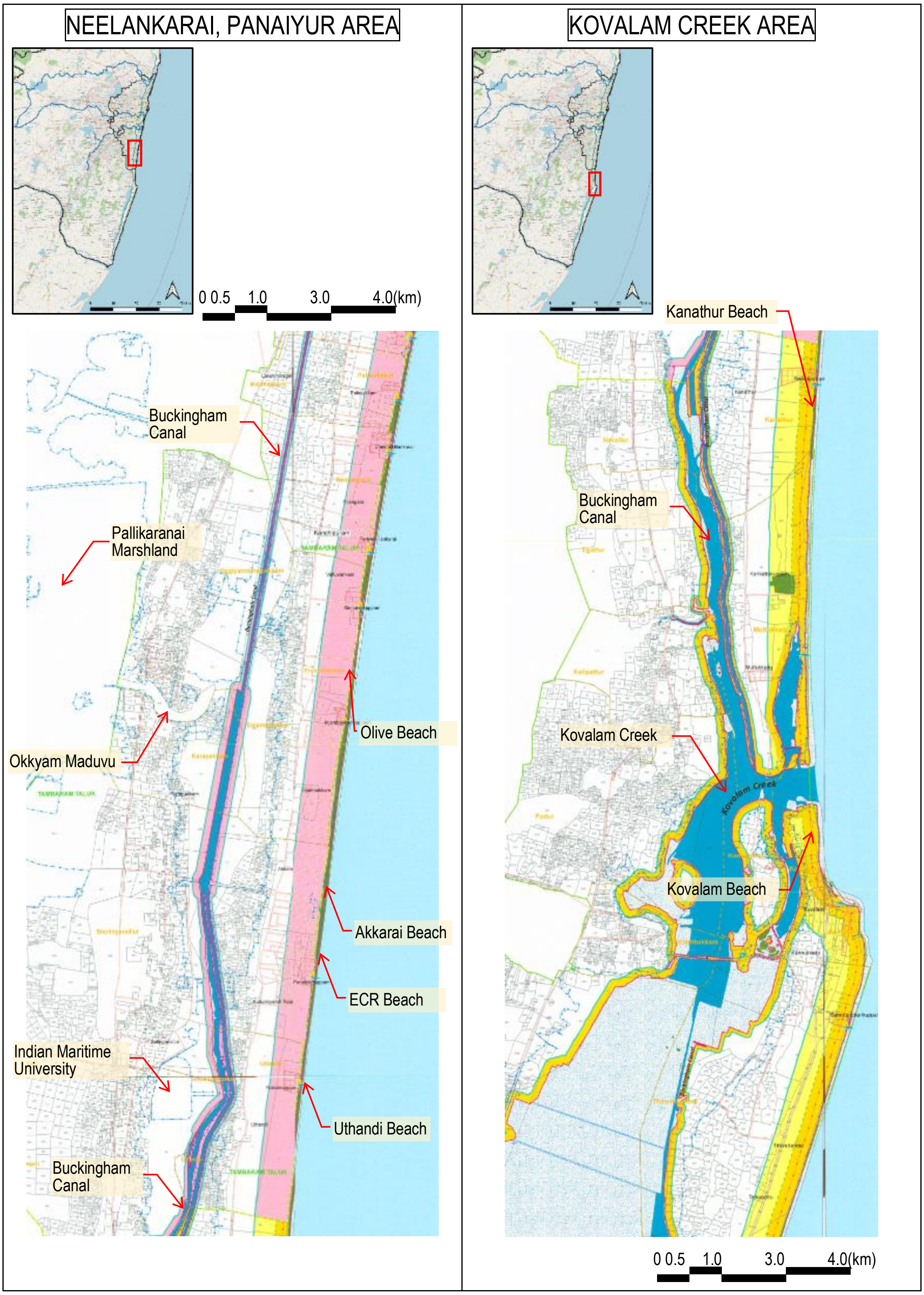
Source: TNDoE

Figure 8-4: Locations of CRZ in Chennai (1/3)



Source: TNDoE

Figure 8-5: Locations of CRZ in Chennai (2/3)



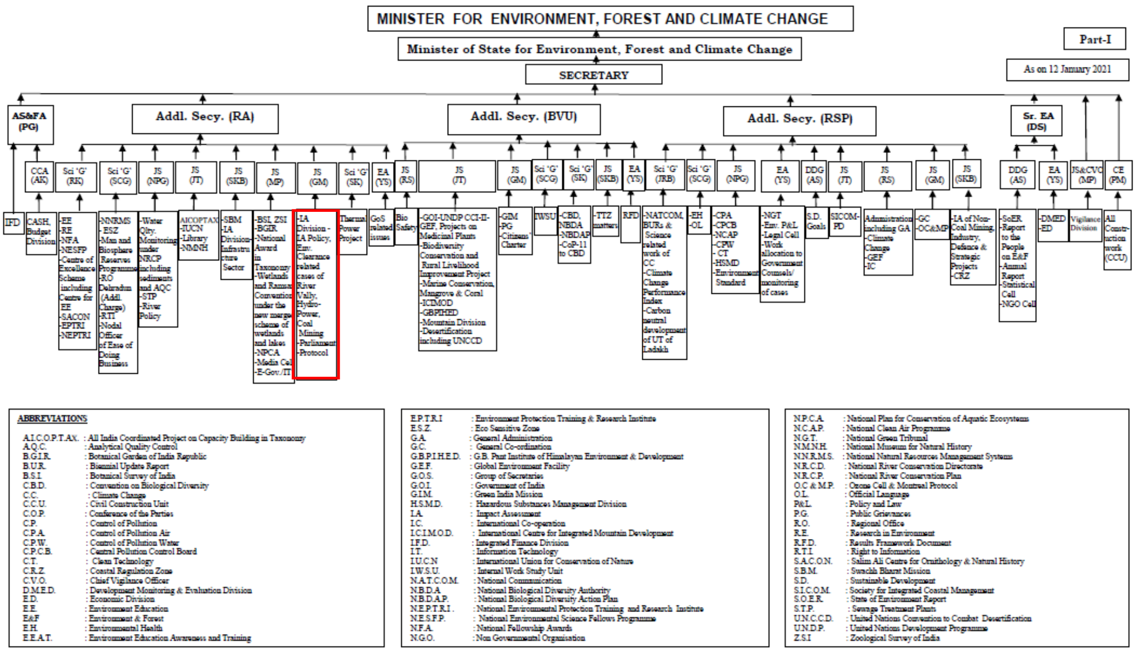
Source: TNDoE

Figure 8-6: Locations of CRZ in Chennai (3/3)

8.5 Institutional Framework Relevant to Environmental Issues

8.5.1 Ministry of Environment, Forestry and Climate Change (MoEFCC)

The Ministry of Environment, Forestry, and Climate Change (MoEFCC) is a responsible agency for formulating and implementing policies for the management and conservation of the environment, pollution measures, and the like. Established in 1985 as the Ministry of Environment and Forestry, it changed the name to the current one in 2014. The division responsible for Environmental Impact Assessment evaluates the Environmental Impact Assessment report as part of a process to issue a permit for projects falling under Category A. The organization chart of MoEFCC is shown below, with red indicating the division in charge of environmental impact assessment.



Source: MoEFCC

Figure 8-7: Organization Chart of the Ministry of Environment, Forestry and Climate Change

8.5.2 Tamil Nadu Department of Environment and Climate Change (TNDoECC)

Projects falling under Category B will be assessed by the State Environmental Impact Assessment Authority (SEIAA) with assistance from the State Expert Appraisal Committee (SEAC) before issuing the Environmental Clearance. In Tamil Nadu State, the Department of Environment (DoE) is in charge of environmental impact assessment as well as adaptation and mitigation of climate changes, management of coastal zones, environmental management of the urban areas, and raising environmental awareness.

8.5.3 Environmental authorities of other governmental bodies

8.5.3.1. Chennai Metropolitan Development Authority

Chennai Metropolitan Development Authority (CMDA) was constituted as an ad-hoc body in 1972 and became a statutory body in 1974 via the Tamil Nadu Town and Country Planning Act

1971. The vision of the Chennai Metropolitan Development Authority is to provide people-friendly administration in the process of ensuring a better quality of life in the Chennai Metropolitan Area through environmentally sustainable, economically progressive, technologically innovative management policies and programs.

8.5.3.2. Greater Chennai Corporation (GCC)

The Greater Chennai Corporation (previously Madras) is the Oldest Municipal Institution in India, established on the 29th of September 1688. A charter was issued on the 30th of December 1607 by East India Company, constituting the "Town of Fort St. George" and all the territories thereunto belonging, not exceeding the distance of ten miles from the Fort, into a corporation. The Parliamentary Act of 1792 gave the Corporation power to levy Municipal Taxes in the City. The Municipal administration properly commenced from the Parliamentary Act of 1792, making provision for the good order and administration of the city. The Municipal Act has been amended by introducing, from time to time, major changes in the constitution and powers of the Corporation. The Madras Municipal Corporation Act, 1919 (as amended) provides the basic Statutory authority for the administration now.

8.5.4 Other local municipality corporations (Tambaram and Avadi M.C.)

8.5.4.1. Tambaram Municipal Corporation

Tambaram is situated 24 km south of Chennai city. Tambaram is described as the Gateway of the Beautiful Metropolitan City of Chennai. Tambaram is very popular because of the existence of the world-renowned Madras Christian College, India Air Force training center, and the first commissioned suburban trains from Tambaram to Beach. All the environmental activities relevant to the daily life of Tambaram citizens regarding pollution control are managed by the Corporation.

8.5.4.2. Avadi Municipal Corporation

Before 1970, Avadi was a Municipality. In 1970, it was constituted as a Municipality comprising the Paruthipattu, Paleripattu, Villianjiampakkam, Sekkadu, Muthapudupet, Thandurai, Mittanamillee, Kovilpadagai & Thirumullaivoyal. In 1971, it was constituted as II Grade Municipality. Due to the rapid development and growth of the town commercially and residentially, the Municipality is now classified as a Special Grade Municipality. The population, as per the 2011 census, is 344,701. The extent of the municipality is 65.00 km2. In 2008, it was upgraded to Special Grade Municipality. Now, Tamil Nadu Acts and Ordinances provide for the establishment of a Municipal Corporation for the city of Avadi. The Municipal Council, comprising 48 ward councilors, takes care of environmental and social issues in the region by collecting opinions from the citizens to coordinate mitigation measures to resolve them.

8.5.5 Non-government sectors

8.5.5.1. Environmentalist Foundation of India (E.F.I.)

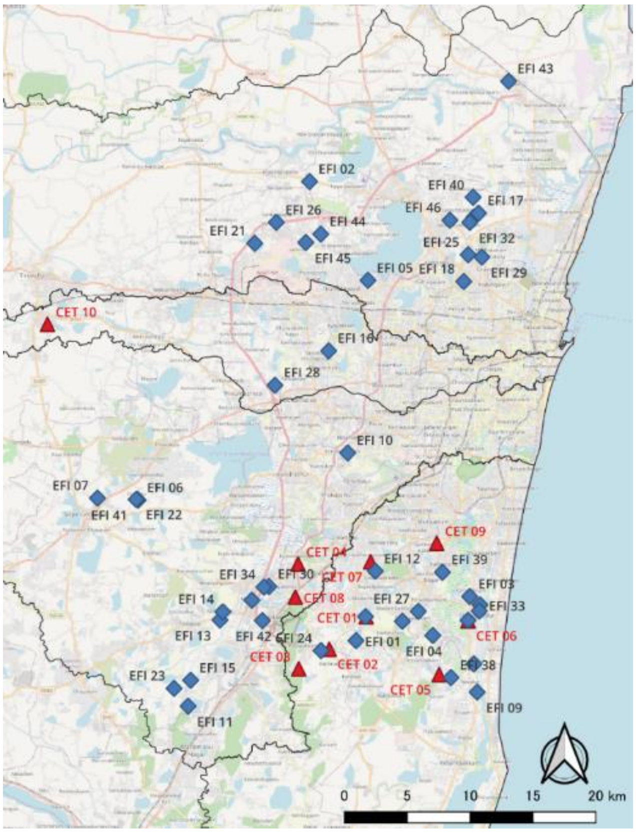
Environmentalist Foundation of India (E.F.I) is an environmental conservation group based out of 18 states in India covering prominent cities, including Chennai. E.F.I. started real-time and result-oriented conservation efforts, such as the restoration of water bodies, in 2007 and registered as a non-profit trust in 2011.

Regarding the water restoration efforts, E.F.I. has conducted 431 water bodies across 18 states in India, including 46 water bodies in Chennai. Key activities in Chennai vary from cleaning the water body area to expanding retention capacity by excavating it, depending on the circumstances of the projected sites.

8.5.5.2. Care Earth Trust (CET)

Care Earth Trust (CET) is a city-based technical NGO concerned with the conservation of biodiversity. The institute was established in 2000 under the Tamil Nadu Societies Act and has been engaged in biodiversity conservation in the city of Chennai. One of their main programs is wetland restoration and rejuvenation, including clearing off invasive flora, silt removal, and cleaning the surrounding environment in collaboration with the residents. Ten wetlands, including lakes, have been researched and restored by CET.

The following figures and tables show the locations of the water bodies restored by E.F.I and CET in Chennai.



Water Bodies restored by CET (▲)		
Code	Name	Size (m2)
CET 01	Madambakkam Wetland	904,900
CET 02	Narayanapuram Lake	171,700
CET 03	Perungalathur Lake	217,000
CET 04	Puduthangal Lake	77,500
CET 05	Sembakkam Lake	327,400
CET 06	Sholinganallur Wetland	172,800
CET 07	Thazhambur Wetland	419,900
CET 08	Unamancheri Wetland	77,400
CET 09	Vengambakkam Wetland	145,300
CET 10	Vengathur Wetland	742,600

Water Bodies restored by E.F.I. (◆)		
Code	Name	Size (m2)
EFI 01	Agaramthen Eri	705,500
EFI 02	Alamagee Lake	529,000
EFI 03	Anaikeni Pond	8,000
EFI 04	Arasankazhani Lake	134,200
EFI 05	Ayyan Kulam, Ambattur	3,100
EFI 06	Bommi Kuttai, Pennalur	1,000
EFI 07	Chellaperumal Nagar pond	5,200
EFI 08	Chettimadu Pond	8,700
EFI 09	Egatoor Pond	4,400
EFI 10	Gerugambakkam Pond	2,400
EFI 11	Kaattupakkam Kulam	3,200
EFI 12	Kamarajapuram Lake	25,200
EFI 13	Karasangal Lake	107,400
EFI 14	Karasangal Pond	3,600
EFI 15	Keezhakazhani Kulam	2,700
EFI 16	Koladi Lake	322,900
EFI 17	Kosapur Pond	48,500
EFI 18	Kullapan Kulam	3,800
EFI 19	Lakshmi Nagar Pond	1,300
EFI 20	Madambakkam Lake	904,900
EFI 21	Mittanamalli Lake	543,400
EFI 22	Mudhalai Kuttai, Pennalur	900
EFI 23	Nallathaneer Kulam	800
EFI 24	Nedunkundram Otteri	170,100
EFI 25	Oma Kulam, Madhavaram	8,300
EFI 26	Panayan Thangal	10,200
EFI 27	Perumbakkam Lake	878,400
EFI 28	Poonamallee Eri	388,400
EFI 29	Ramachandra Nagar Pond	5,600
EFI 30	Ranga Nagar Pond	8,600
EFI 31	RG Pond	1,100
EFI 32	Samuel Nagar Pond	2,900
EFI 33	School Street Pond	2,100
EFI 34	Seekana Lake	893,300
EFI 35	Sholinganallur Thamarai Keni	48,300
EFI 36	Sholinganallur TNHB	4,400
EFI 37	Sithalapakkam Lake	764,100
EFI 38	Thalambur Pond	8,200
EFI 39	Thandukarai Pond	4,600
EFI 40	Theeyampakkam Gandhi Nagar Kulam	2,200
EFI 41	Unnamed pond near mudhalai kuttai	2,000
EFI 42	Vandalur Lake	370,100
EFI 43	Varadaraja Perumal Koil Pond, Minjur	10,700
EFI 44	Vellanur Citheri	106,800
EFI 45	Vellanur Periya Eri	681,100
EFI 46	Vinayagapuram Pond	4,500

Source: Map arranged by the JICA Expert Team, Tables from the website of E.F.I. and CET

Figure 8-8: Location of the Water Bodies Restored by E.F.I. and CET

8.6 Policy, Plan, and Programs Related to Environmental Issues

8.6.1 Environmental Policy in Chennai

CMDA has been preparing the 3rd Master Plan for the Chennai Metropolitan Area and has raised issues of environmental challenges, including climate change, in the Inception Report of the Master Plan. The report approaches two major agendas of the environmental challenges, namely as 'Chennai Floods' and 'Rise in Sea Levels.'

By stating the major causes of the periodic floodings in Chennai, clarified in the previous studies carried out by various organizations, the report expresses the necessity of reinforcing water storage capacity and drainage networks through the development of the 'integrated flood management system.'

Additionally, with mentioning a projection of the future sea level rise studied by NCCR and inadequacy of open spaces followed by the URDPFI Guidelines of the MoUD, GoI, as well as references of other overseas cities as a good practice such as Singapore, the report expresses the significance of controlling urban development with adequate greenery spaces to realize a contribution to a 'healthy city' not only for the natural and social environment but also for reduction of life at risk and damaged properties in CMA.

Environment, Climate Change and Forest Department of Tamil Nadu State launches the Policy Note to formulate environmental direction every year. The document published in 2023 speculates eleven (11) environmental strategies, as shown in the following table. It should be noted that the first item addresses conservation and preservation of natural resources, and four (4) items are related to a climate change issue, which indicates that climate change actions are construed as one of the most urgent issues of all.

Table 8-9: Strategies of Tamil Nadu Environment, Climate Change and Forest Department

#	Strategies
1	**Conserve and preserve natural resources** and promote their sustainable use by maintaining balanced ecosystems as well as the functions of the environment.
2	Prepare a holistic Climate Change Policy for Tamil Nadu that **supports climate change mitigation, adaptation, and resilience** cutting across all sectors of governance.
3	In **consonance with the Coastal Regulation Zones**, the Coastal Zone Management Plan has been prepared as per CRZ notification to protect 1076 Km of the coastline, preparing the Shoreline Protection Management Plan.
4	**Create sustainable tourism and healthy coastal management** through Beach Management and Aesthetics Management Systems (BEAMS).
5	**Educate and empower local communities** in the management of climate change at ground zero while promoting best practices of adaptation and mitigation.
6	**Creating awareness for sustainable use of natural resources** with the support of the National Green Corps.
7	**Build standards for energy-efficient infrastructure** to save energy and reduce consumption by creating practical models for green mobility to reduce carbon emissions and bring in regulatory mechanisms.
8	**Promote a multi-stakeholder approach to fast-track climate action** in a synergized fashion by creating a robust and dynamic monitoring mechanism that ensures better compliance with Environmental Standards through transparent and credible systems.
9	Develop collaborations and strengthen community engagement to build long-term **commitment for a Net Zero Carbon** future for Tamil Nadu.
10	**Develop climate-resilient technologies** in collaboration with various research institutions to create green models and develop an evidence base for scaling up and replication.
11	**Develop comprehensive Data Repository Infrastructure** related to climate science and climate modeling for future projections and effective policy and decision-making.

Source: Tamil Nadu Environment, Climate Change and Forest Department, Policy Note 2023-2024

Regarding the challenges against climate change, Tamil Nadu State has established three (3) implementation programs, known as Tamil Nadu Climate Change Mission, Green Tamil Nadu Mission, and Tamil Nadu Wetland Mission, in parallel to the revision of the Tamil Nadu State Action Plan on Climate Change (TNSAPCC) 2.0. Amid the activation of the missions, it is directed that these missions should be coordinated with comprehensive and collaborative partnerships to overcome the challenges of Climate Change.

Tamil Nadu Wetland Mission, which is closely related to the flood control master plan, defines 'Wetland Ecosystem Services in Climate Change Mitigation and Adaptation' in the mission document (Figure XX) and identifies issues to be addressed to maintain and restore the water balance in an ecosystem.

Source: Mission Document, Tamil Nadu Wetland Mission

Figure 8-9: Wetland Ecosystem Services in Climate Change Mitigation and Adaptation

8.6.2 Projects associated with environmental activities

The following table shows the ongoing projects associated with environmental activities in Chennai carried out by the Tamil Nadu State Government or other government sectors in Chennai.

Table 8-10: On-going Project Associated with Environmental Activities in Chennai

#	Title of the project	Name of the Executing Agency	Summary	Duration
1	Tamil Nadu sustainably harnessing ocean resources and blue economy (TN-SHORE), also known as Tamil Nadu Coastal Restoration Mission.	Department of Environment and Climate Change	With assistance from the World Bank, Tamil Nadu State would be pumping in a whopping Rs 1,675 crore over the next five years to arrest sea erosion, reduce marine pollution, and conserve marine biodiversity.	5 years starting from 11th January 2024
2	Tamil Nadu biodiversity conservation and greening project (TBCGB)	Tamil Nadu Forest Department	The government of Tamil Nadu and the Japan International Cooperation Agency (JICA) signed an MoU for the implementation of the greening project for climate change response in the state. This month will see the start of an eight-year Rs. 920.52 crore initiative to combat climate change.	2022 to 2029
3	River restoration project implemented in Adyar, Cooum, and Kosasthalaiyar river basins.	Chennai River Restorations Trust (CRRT)	It has supported various initiatives implemented by various government Departments such as GCC, WRD, CMWSSB, and Other Departments	2010 - 2024

#	Title of the project	Name of the Executing Agency	Summary	Duration
4	Restoration of Adyar, Cooum River basins	Greater Chennai Corporation, Chennai	Maintenance of walkway and riverine plantation of Adyar and Cooum Rivers	2020 to 2024
5	Adyar River restoration project through public-private partnership (PPP) mode.	Chennai Metropolitan Water Supply and Sewerage Board	The proposed project aimed at comprehensive restoration wherein the concessionaire would carry out operation and management (O&M) of the projects under the 'One River, One Operator' model. Chennai Metro Water would lead the SPV comprising various government agencies and will take the step forward to form a new company as authority SPV as the project's nodal agency.	2023 to 2048
6	Integrating blue-green infrastructure (BGI) for flood disaster and risk reduction in urban planning and management in CMA	Chennai Metropolitan Development Agency (CMDA)	study is to capture the existing characteristics of the blue-green elements in CMA, analyze and identify the problems related to the blue-green elements, including climate change threats, identify the gaps and weaknesses, and develop suitable contextual BGI and recommendations on implementation strategy for climate resilient urban and regional development in CMA.	2023 to 2024
7	Impact of urban development on the coastal aquifer and measures for protection in the villages from Kottivakkam to Mahabalipuram between the Bay of Bengal and Buckingham Canal	Chennai Metropolitan Development Agency (CMDA)	The project seeks to conduct a comprehensive examination of aquifers within the coastal areas along with the Bay of Bengal in CMA. The central goal is to offer an encompassing view of historical and present aquifer statuses. The project unearths globally and nationally acclaimed practices, integrating established techniques for sustainable water management and preservation to ensure effective aquifer conservation.	2023 to 2024

Source: JICA Expert Team

8.7 Introduction to the Study Area

The introduction of the study area is provided in Chapter 1.

8.8 Scoping Analysis and TOR of the SEA Study

8.8.1 Scoping Analysis

For this project, the scope will be determined based on JICA GL for Social Environmental Considerations (April 2010). The results of the scoping analysis associated with the environmental items referred from the river and Sabo sector project are given in the following sector. The following structures will be taken into consideration as possible implementation of structural measures for the flood management project.

Construction of detention ponds, new discharge channels, levees, new stormwater storage (retention tank), drainage gates and drainage pump stations, training walls

Rehabilitation of river channels including widening, riverbed dredging, existing retention ponds/reservoirs, existing discharge channels, existing training walls at river mouths

Table 8-11: Scoping Analysis (P: Planning, C: Construction, O: Operation)

Category	#	Environmental items	Evaluation P/C Phase	 O Phase	Reason for evaluation
Measures against pollution	1	Air pollution	✓	-	P Phase: Before the work, there were no activities causing air pollution. C Phase: Deterioration of air quality is expected if vehicular traffic congestion is generated during the construction phase. The operation of heavy machinery and construction equipment may result in a temporary deterioration in air quality (including dust). O Phase: Air pollution is not related to the operation of flood management.
	2	Water pollution	✓	-	P Phase: There would be no activity polluting the river water. C Phase: There is the possibility of contamination/pollution of the river water resulting from the use of construction machines in the rivers to be rehabilitated. O Phase: There would be no activity resulting in contamination of the rivers. Depending on the mitigation measures, pollution of river surface water or groundwater would be improved.
	3	Waste	✓	-	P Phase: There would be no activity generating waste. C Phase: Generation of construction waste as well as general waste from workers is expected. O Phase: No additional waste due to the project will be generated.
	4	Soil pollution	✓	-	P Phase: There would be no activity causing contamination of soil. C Phase: There is a possibility of soil being contaminated from the use of construction machines. O Phase: There are no elements that may contaminate the soil.
	5	Noise and vibrations	✓	-	P Phase: There would be no activity, which may increase noise and vibrations. C Phase: Noise will be generated due to the operation of heavy machinery and building equipment. O Phase: Noise and vibration nuisance is not related to the operation of flood management.
	6	Subsidence of terrain	✓	✓	P Phase: There would be no activity causing subsidence of terrain.

Category	#	Environmental items	Evaluation P/C Phase	Evaluation O Phase	Reason for evaluation
					C Phase: A large volume of excavation could cause subsidence of terrain associated with declines in groundwater level. O Phase: Declines of groundwater level triggered by excavation would occur gradually and become conspicuous.
	7	Odors	✓	-	P Phase: There would be no activity that may create an odor nuisance. C Phase: An odor nuisance may be generated by waste from the workers' camp if wastewater is not adequately treated. O Phase: There would be no activity that may cause an odor nuisance.
	8	Sediments from riverbeds	✓	-	P Phase: There are no activities that may cause changes in the riverbed sediments. C Phase: There may be an impact on riverbed sediments due to construction works in the river. O Phase: There would be no elements that may cause changes in the riverbed sediments.
Natural environment	9	Protected areas	✓	✓	P, C Phases: The location of the protected area near the project site shall be clarified. O Phase: Some negative impacts would be involved depending on the location.
	10	Biodiversity	✓	✓	P Phase: The location of the area sensitive to biodiversity shall be clarified. C Phase: Some negative impacts on biodiversity are expected depending on the vulnerability of the natural environment. O Phase: Some negative impacts would be involved depending on the condition of the natural environment.
	11	Hydrological conditions	✓	✓	P Phase: There would be no activity that will affect the hydrological systems of the river. C Phase: Some impacts would be involved depending on the type of construction work. O Phase: Some impacts would be involved depending on the type of structures.
	12	Topography of terrain, geology of soils	✓	✓	P Phase: There would be no activity that may affect the topography of the land and soil. C Phase: Some negative impacts would be involved depending on whether the design required cuts and fills. O Phase: Some negative impacts would be involved depending on the type of structures.
Social environment	13	Resettlement and land acquisition	✓	-	P Phase: Involuntary resettlement and land acquisition for the structural measures would be included for most of the possible structural measures. C, O Phase: There are no activities that may require land acquisition and involuntary resettlement since the displacement of involuntary resettlement shall be completed before the construction.
	14	Living life and livelihood	✓	-	P, C Phase: There is no change in living life during the planning of flood management or construction of structural measures. O Phase: A significant positive impact will be expected from the aspect of social safety contributed by reducing flooding possibility.
	15	Socially vulnerable people (poverty)	✓	-	P Phase: Involuntary resettlement/land acquisition affects socially vulnerable people residing near/in the river to be rehabilitated. C Phase: If adequate considerations are taken, a negative impact may be avoided. O Phase: A positive impact on the safety of the vulnerable community could be contributed by the new flood management scheme.
	16	Ethnic minorities and Indigenous peoples	-	-	There are no ethnic minorities or indigenous peoples in the metropolitan area of Chennai.
	17	Local economy, such as	✓	-	P Phase: No impact on the local economy would be expected during the planning phase.

Category	#	Environmental items	Evaluation		Reason for evaluation
			P/C Phase	O Phase	
		employment and livelihood			C Phase: Employment of locals or a new business opportunity could be ensured for the construction works. O Phase: Some progress in the local economy could be expected based on the renewal of city planning associated with disaster risk management.
	18	Land use and local resources	✓	-	P Phase: Comprehensive thinking of the public could lead to recognition of the importance of natural environment. C Phase: Some negative impacts would be involved if significant local resources are located. O Phase: No impact is expected after the construction.
	19	Water use/rights	✓	-	P Phase: There are no activities that may generate an impact on the use of water. C Phase: In the agricultural area, some negative impact may be generated by the turbulence of water during the implementation of the construction works. O Phase: There are no activities that may generate an impact on the use of water. Depending on the mitigation measures, the shortage of water resources would be improved.
	20	Existing social infrastructures and social services	✓	✓	P Phase: Relocation of lifelines such as power, telecommunication, and drinking water lines could raise awareness of the residents' living conditions. C, O Phase: Depending on the structural measures, accessibility to the social infrastructures would be affected. Potential deterioration of accessibility to social infrastructures due to the inundation causing impassable roads will be improved.
	21	Social capital and social structure of regional decision-making organizations	-	-	P Phase: No negative impact on social capital (i.e., social connectivity) is expected. C, O Phase: No impact is foreseen regarding the social capital and social structure of regional decision-making organizations.
	22	Misdistribution of benefits and damage	✓	-	P Phase: If land acquisition and relocation are not managed correctly, this may lead to an unjust distribution of damages and benefits. C Phase: Since the compensation activity is completed before commencing the construction works, a potentially unjust balance of damages and benefits in the surrounding areas is not projected. O Phase: No misdistribution of benefits and damages in the region is expected. The natural disaster resilience of Chennai will be improved.
	23	Local conflict of interests	✓	-	P Phase: Depending on the ownership of the land to be acquired, there could be some conflict with the community in the region relevant to the proposed subprojects. C, O Phase: No negative impact is expected after commencing the construction works.
	24	Cultural Heritage	✓	-	P Phase: Since there are many religious objects, such as shrines or statues, regardless of their size around the city, relocation of the objects will be required based on the agreement of the owning communities. C, O Phase: There are no activities that may affect the local cultural heritage since displacement shall be completed before the construction.
	25	Landscape	✓	-	P Phase: There are no activities that may generate an impact on the landscape. C Phase: There would be some tree-cutting activity along the rivers, which could cause the regional landscape to deteriorate. O Phase: There are no activities that could generate an impact on the landscape.
	26	Gender	✓	-	P Phase: Problems regarding equality in women's rights to compensate for land expropriation and the resettling process may arise. C Phase: Potential negative impact on gender balance caused by neglect of job opportunities for the residents correlated with the construction operation. O Phase: No negative impacts regarding gender issues are foreseen in the present project.

Category	#	Environmental items	Evaluation		Reason for evaluation
			P/C Phase	O Phase	
	27	Children rights	✓	-	P Phase: Problems may arise regarding the rights of children concerning the reconstruction of living life. C Phase: Problems may arise with the rights of children when obtaining the necessary labor force to execute the works. O Phase: The project would not be related to any issues concerning children's rights.
	28	Infectious diseases such as HIV/AIDS (including hygiene conditions)	✓	-	P Phase: No impact is estimated for transmitted diseases such as HIV/AIDS during the planning phase. C Phase: Infectious diseases may spread due to the influx of workers for the construction. O Phase: No impact of infectious diseases resulting from the project, such as HIV/AIDS, is estimated. The potential spreading of infectious diseases caused by the inundation would be mitigated.
	29	Working conditions (including work safety)	✓	-	P Phase: There is no element related to the working environment before commencing the construction works. C Phase: Some negative impacts may be generated regarding safe labor conditions in case technically difficult tasks are carried out by local workers. O Phase: There are no activities that may involve a deterioration of work conditions.
Others	30	Accidents	✓	-	P Phase: No work that could cause accidents will be carried out during the planning phase. C Phase: There is an increased risk of workers or residents in the area having an accident due to the increase in work vehicles. O Phase: Depending on the design, the safety of the communities relevant to the water bodies in Chennai will be ensured.
	31	Impact of crossing borders and climate change	-	-	P Phase: No negative impact would be expected during the planning phase. C Phase: No negative impact would be expected, given the modest size of the project. O Phase: The new comprehensive master plan of the CMA integrated with the flood management plan could be a scope to reduce greenhouse gas emissions to control the expansion of the urban area as well as to secure greenery spaces by comparing current conditions.

Source: JICA Expert Team

8.8.2 Typical environmental and social issues/challenges in Chennai

Environmental and social issues or challenges in Chennai are summarised in the following items and tables.

Severe pollution of the six major waterways and drains, viz. Cooum, Adyar, Buckingham Canal, Captain Cotton Canal, Otteri Nallah, and Mambalam drain.

The sewage carried by them is of the order of 532 minimal liquid discharge (MLD), which is more than the quantity of sewage collected from the city for treatment by the Metro water treatment plants.

The major contributors to air pollution are the vehicular sector (71.28%), followed by the industrial sector (19.70%).

According to the Tamil Nadu Pollution Control Board (TNPCB), at major traffic intersections, the Total Suspended Particulate Matter (TSPM) and Respirable Suspended Particulate Matter

(RSPM) values exceed the standard values.

Pollution by industries is widely prevalent in the Manali industrial complex and surrounding areas.

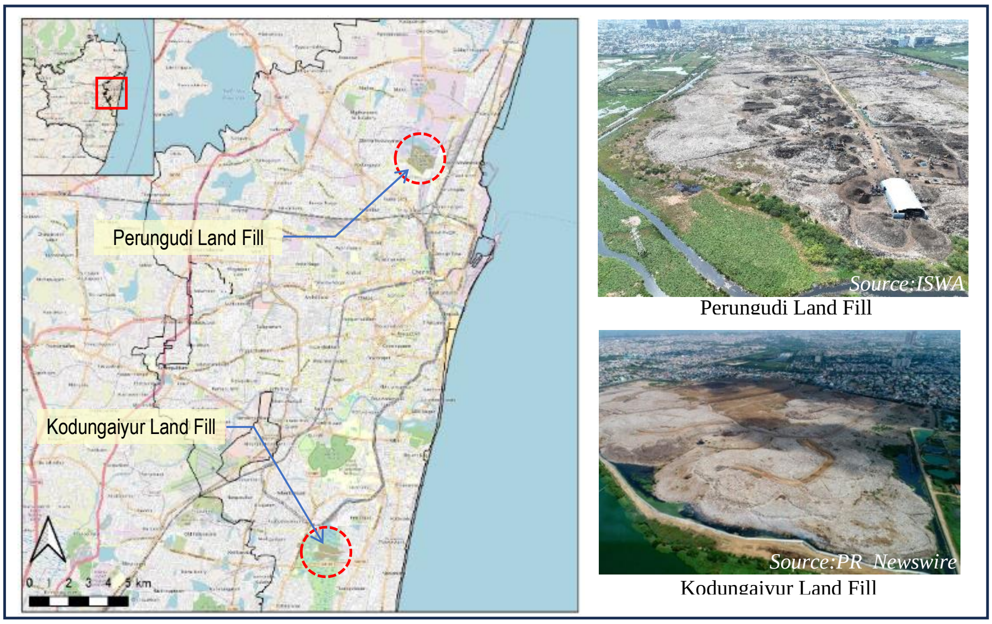
The noise level survey conducted by the TNPCB reveals that noise level exceeded the limits mostly in commercial areas, mainly due to vehicular movement.

During festive seasons in Chennai, the noise levels were noted to be high, particularly during Deepavali

The Corporation of Chennai is the largest generator of solid waste, estimated at 3000 tons per day.

It has a network of transfer stations and two landfill sites at Kodungaiyur and Perungudi.

The present system of collection, transfer, and dumping does not make any distinction between types of waste other than domestic and commercial waste and, to some extent, construction debris.



Source: JICA Expert Team

Figure 8-10: Location of the Land Fill sites in Chennai

Table 8-12: Typical Environmental Issues and Related Circumstances

Issues	Relationship
【Pollution】	
1. Air pollution	Derives from inappropriate urban planning, uncontrolled road and traffic network development, rapid & excessive urbanization
2. Noise and vibration	
3. Water pollution (river & sea)	Derives from inappropriate solid waste management, illegal dumping, lack of sewage & grey water drainage coverage Also affects landscape and living quality.
4. Sediment contamination	
5. Odour nuisance	
【Natural Environment】	
1. Biodiversity disappearance	Derives from river & seawater pollution, uncontrolled development, rapid & excessive urbanization, losing greenery area
2. Ecosystem deterioration	

Issues	Relationship
【Social Environment】	
1. Poverty	Related to involuntary resettlement, remaining slum areas, social discrimination, women's and children's rights Also affects water quality and landscape.
2. Public health deterioration	Floods could lead to the spread of infectious diseases and deteriorate public sanitary conditions, which is also associated with water pollution.
3. Deterioration of accessibility to social infrastructures	Flood with severe inundation makes roads impassable Also affects the living condition
4. Water resource shortage	Related to heat island phenomena, groundwater scarcity during draught, which is associated with uncontrolled development, rapid & excessive urbanization, loss of greenery areas
5. Living condition	
6. Cultural heritage damage	Floods could affect cultural heritage regardless of its size.
7. Landscape deterioration	Derives from waste management, illegal dumping, water pollution Floods may affect focal trees and greenery areas Also affects tourism quality in relationship with the regional economy
8. Misdistribution of benefit	Occasional flooding leads to lower land value.

Source: JICA Expert Team

8.8.3 Preliminary analysis of potential environmental impacts

Potential environmental impacts, including impact without the Project, are determined provisionally based on the baseline data collected during the initial study as follows.

8.8.3.1. Potential negative and positive impacts

The following table summarizes the impacts of implementation of the Project. It shows that there are many positive impacts on both the natural and social environment in Chennai, while most of the negative impacts would be remarkable depending on the details of the structural measures for the prioritized project.

Table 8-13: Summary of Potential Negative and Positive Impacts

Issues	Impacts	
	Positive	Negative (long-term period)
【Pollution】		
1. Air pollution	None	None
2. Noise and vibration	None	
3. Water pollution (river & sea)	Indirect positive impacts produced by the project are expected through the measures for reducing the risk to public health, avoiding deterioration of landscape and living quality, and greenery space conservation.	
4. Sediment contamination		
5. Odour nuisance		
【Natural Environment】		
1. Biodiversity disappearance	Indirect positive impacts produced by the project are expected through the measures for river water restoration.	Depending on the structural measures, part of ecologically sensitive areas in CMA would be degraded
2. Ecosystem deterioration		
【Social Environment】		

Issues	Impacts	
	Positive	Negative (long-term period)
1. Poverty	Public safety against natural disasters will be ensured by the project → socio-economic status will be improved.	Depending on the structural measures, a large volume of involuntary resettlement would be necessary
2. Public health deterioration	Public health deterioration could be avoided by reducing the risk of natural disasters. Indirect positive impacts produced by the project are expected through the measures for river water restoration.	None
3. Deterioration of accessibility to social infrastructures	The occurrence of impassable roads will be controlled by reducing the risk of natural disasters	None
4. Water resource shortage	Depending on the structural measures, water resources will be improved (development of detention/retention pond)	Depending on the structural measures, groundwater conditions could be affected (uncontrolled land excavation)
5. Living condition	Indirect positive impacts produced by the project are expected through the measures for reducing the risk to public health, avoiding deterioration of landscape and living quality, and greenery space conservation.	
6. Cultural heritage damage	The risk of cultural heritage damage will be mitigated	None
7. Landscape deterioration	Indirect positive impacts produced by the project are expected through the measures for river water restoration and greenery space conservation.	Depending on the structural measures, part of the greenery space/wetland in CMA would be degraded
8. Misdistribution of benefit	Reducing the natural disaster risk through the project will mitigate the misdistribution of benefits.	None

Source: JICA Expert Team

8.8.3.2. Impacts without the Project

The following table summarizes the impacts without the Project. It clarifies that both the natural and social environment in Chennai will be at severe risk without measures for flood control.

Table 8-14: Summary of Impact without the Project

Issues	Impacts without the Project
【Pollution】	
1. Air pollution	-
2. Noise and vibration	-
3. Water pollution (river & sea)	Existing pollution problems will be worsened unless issues of public health, landscape & living quality are raised through the project.
4. Sediment contamination	
5. Odour nuisance	
【Natural Environment】	
1. Biodiversity disappearance	Deterioration speed will be escalated without mitigating pollution problems.
2. Ecosystem deterioration	
【Social Environment】	
1. Poverty	Disaster risks to vulnerable people will remain without the project.

2. Public health deterioration	The risk to public health will not be relieved without appropriate flood management as well as mitigating pollution problems.
3. Deterioration in accessibility to social infrastructures	The risk of having impassable roads during floods will not be relieved without the project
4. Water resource shortage	-
5. Living condition	-
6. Cultural heritage damage	The risk of damage to the cultural heritage during floods will not be relieved.
7. Landscape deterioration	Landscape deterioration will not be stopped without pollution problems, which also affect economic stagnation.
8. Misdistribution of benefit	Misdistribution will be escalated without flood mitigation.

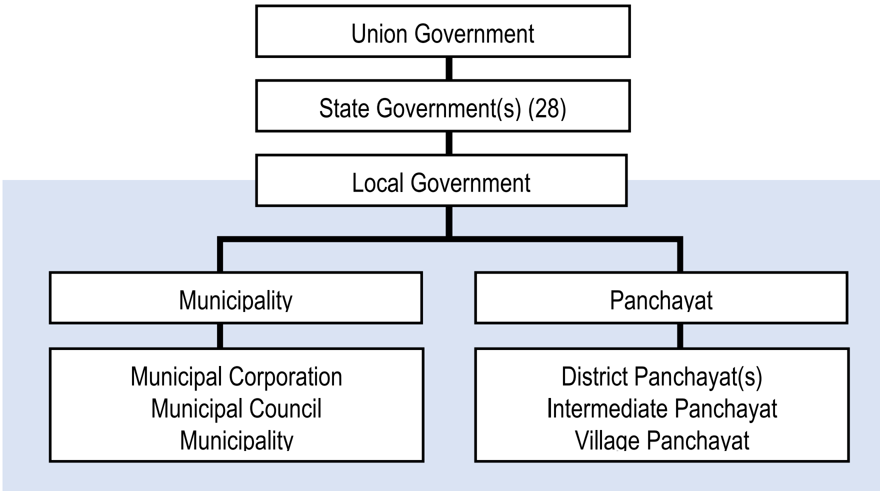
Source: JICA Expert Team

8.9 Environmental and Social Baseline

8.9.1 Physical Condition

8.9.1.1. Administrative condition

Indian administrative system is formed based on the Constitution for reinforcing structures for policymaking as well as policy enforcement. It consists of four main bodies: the Union Government of India, State Governments, Divisions, and Districts. Under these bodies, there are local governmental bodies, including Blocks, Municipal Corporations, Municipalities, and City councils, as shown in the following figure.



Source: Local Government in India, Council of Local Authorities for International Relations, 2007

Figure 8-11: Administrative Structure of India

Tamil Nadu State consists of 38 districts but no division as of August 2022. The study area encompasses Chennai District, administered by the Greater Chennai Corporation, Tiruvallur District in the north, Kanchipuram District in the West, and Chengalpattu District in the south of Chennai.

8.9.1.2. Introduction of the target river basins

Chennai is the capital of Tamil Nadu, located on the Coromandel Coast off the Bay of Bengal. It is located at 13°5’N Latitude and 80°16’E Longitude. It has an average elevation of 6 meters. Chennai's climate has a maximum average temperature of 45°C and a minimum average temperature of 14°C. Chennai has a tropical wet and dry climate. The city lies on the thermal equator and is on the coast, which prevents extreme variation in seasonal temperature. The mean annual rainfall of the region is about 1,400 mm, and the city gets most of its seasonal rainfall from the northeast monsoon wind from mid-October to mid-December. Cyclones in the Bay of Bengal sometimes hit the city. There are 17 river basins in Tamil Nadu, but Cauvery is the only major basin. Of the others, 13 basins are medium, and 3 are minor river basins. At 75 percent dependability, the annual surface water generated in the State is 692.78 TMC (19,619 MCM). The State depends on neighboring States for the considerable quantum of flows, which is about 261.70 TMC (7411 MCM) annually.

The Chennai metropolitan area is abounded with lakes and rivers, providing a habitat for a wide variety of flora and fauna. The Chennai City is drained by three east-flowing rivers, Kosasthalaiyar, Cooum, and Adyar, which flow between its north and south boundaries. After meandering through the city, these rivers finally flow into the Bay of Bengal. A major canal, Buckingham Canal, traverses parallel to the coast and has considerable importance in shaping the aquatic environment of Chennai City. The lakes and rivers within Chennai City have been neglected by people and government agencies for many years. Encroachment of rivers, river bunds, and lakes is not appropriately controlled, and illegal dumping of solid waste and disposal of untreated municipal wastewater industrial effluent has continued for many years without effective regulations. Due to severe impacts after successive flood events and interventions of Courts, the National Green Tribunal, and active citizen groups, these river basins have received the attention of the government in the last few years. Following are some of the rivers that flow through the Chennai Metropolitan Area.

(1) Cooum River

The river Cooum derives its name from the village Cooum, whose surplus lake water flows into this river. It starts near Sattarai village in Tiruvallur Taluk and flows through 65 km. Before it joins the Bay of Bengal, it enters the Chennai city near Thiruverkadu. The catchment of the river is about 290 km, studded with nearly 140 tanks. The Kesavaram dam diverts the river into the Chembarambakkam lake, which supplies drinking water to the city of Chennai. Therefore, the flow of water in the river is reduced. The second problem that affects the river stems from human activity, which began during the late 1800's. A large silt deposition to the river from stormwater drains is seen at several locations.

(2) Adyar River

The Adyar River shares Chennai, Chengalpattu, Kancheepuram, and Thiruvallur district boundaries. The Adyar River traverses about 42 km; it originates from Adhanur Lake, Guduvanchery, Kanchipuram district, and enters Chennai City near Nandambakkam. It flows in a west-east direction for 13.5 km before entering the Bay of Bengal. The Adyar River catchment area includes areas of Kancheepuram district, Thiruvallur district, Chennai, and its metropolitan periphery. Thirty-nine percent of its watershed lies within the Chennai Metropolitan area, with sixty-one percent in the neighboring districts of Kancheepuram and Tiruvallur. It collects surplus water from more than 200 tanks of the Chembarambakkam group and other irrigation tanks nearby, which have a combined catchment area of 857.2 km² (NRCD 2013). The estuary limit extends from the river mouth to the Saidapet bridge (7.5kms); when the river mouth is open, the normal tidal interaction extends 4.3 km, reaching the Kotturpuram bridge; and during the highest high tide, the saline water extends to the Saidapet bridge. There are nine islands between the river mouth and Thiru. Vi. Ka bridge. Despite the high pollution levels, boating and fishing take place in this river.

(3) Kosasthalaiyar River

The Kosasthalaiyar River Basin, with an area of 127.80 km2, is located in the northern part of Chennai. The Kosasthalaiyar River flows in the west-east direction, and it is one of the four rivers that flow into the Greater Chennai Corporation area. This river originates near the Kaveripakkam Lake, which is one of the Irrigation Tank fed by Palar Anicut in the Vellore District. The river flows in the northeast direction and confluences with the Bay of Bengal and the Kosasthalaiyar River basin, which extends over an area of 3,757 km2 in the northernmost part of Tamil Nadu. Its northern tributary, the Nagari River, originates in the Chittoor district of Andhra Pradesh and joins the main river in the backwaters of the Poondi reservoir.

(4) Buckingham Canal

Although not a river, the Buckingham Canal is an important waterway that flows through Chennai. It runs parallel to the Bay of Bengal and connects several lakes and rivers in the region.

8.9.1.3. Water resources

Tamil Nadu constitutes 4 percent of India’s land area and is inhabited by 6 percent of India’s population but has only 2.5 percent of India’s water resources. More than 95 percent of the surface water and 80 percent of the groundwater have already been put into use. Major uses of water include human/animal consumption, irrigation, and industrial use. The demand for water in Tamil Nadu is increasing at a fast rate both due to the increasing population and due to larger per capita needs triggered by economic growth. The per capita availability of water resources, however, is just 900 cubic meters when compared to the national average of 2,200 cubic meters. Agriculture is the largest consumer of water in the State, using 75 percent of the State’s water resources. The State is heavily dependent on monsoon rain. The annual average rainfall is around 930 mm (47 percent during the northeast monsoon, 35 percent during the southwest monsoon, 14 percent in the summer and 4 percent in the winter).

The Chennai city water supply is both via surface water and groundwater sources and is largely dependent on the annual rainfall. A good monsoon boosts the water sources of the city. The year 2019 recorded low rainfall, which affected the availability of water from these sources. Water from river basins and bore well water from the irrigation fields of Kancheepuram and Tiruvallur are the primary sources of groundwater procured by the Metro water department. This is useful to meet the water demand in localities such as Old Mahabalipuram Road and East Coast Road regions, where groundwater is hard due to their proximity to the sea. Subsurface water sources via the lakes and tanks from the rest of the Chennai regions also contribute to the city's water supply. The two desalination plants at Nemmeli and Minjur are additional sources for the city's water needs.

(1) Surface water resource

The total surface water potential of the state is 24,864 million cubic meters. There are 17 major river basins in the State, with 61 reservoirs and about 41,948 tanks. Of the annual water potential of 46,540 million cubic meters (MCM), surface flows account for about half. Most of the surface water has already been tapped, primarily for irrigation, which is the largest user. The area of 2.4 million hectares is irrigated by surface water through major, medium, and minor schemes. The utilization of surface water for irrigation is about 90 percent.

The surface water source of Chennai is the Poondi reservoir, the Redhills, Cholavaram, Chembarambakkam, and Veeranam lakes are the surface water sources situated around 200 km from Chennai. In addition, the city also relies on water from neighboring Andhra Pradesh (Telugu Ganga project), where water from the Krishna River in the Srisailam reservoir (400km away) is diverted to the Poondi reservoir. Also, Last year, Metro Water explored alternative sources, tapping water from the Porur Lake, the Retteri Lake, and the quarries of Erumaiyur and Sikarayapuram.

(2) Groundwater resource

The utilizable groundwater recharge is 22,423 MCM. The current level of utilization expressed as a net groundwater draft of 13,558 MCM is about 60 percent of the available recharge, while 8,875 MCM (40 percent) is the balance available for use. Over the last five years, the percentage of safe blocks has declined from 35.6 percent to 25.2 percent, while the semi-critical blocks have gone up by a similar percentage. Over-exploitation has already occurred in more than a third of the blocks (35.8 percent), while eight blocks (2 percent) have turned saline.

The water level data reveals that the depth of the wells ranges from an average of 0.93 meters in Pudukkottai District to 43.43 meters in Erode. According to the Central Groundwater Board, there was a general decline in groundwater level in 2003 due to the complete desaturation of shallow aquifers. There has been a considerable failure of irrigation wells in Coimbatore District.

Chennai city is mostly dependent on groundwater resources to meet its water needs. Groundwater resources in Chennai are recharged by rainwater, with the city's average rainfall being 1,276 mm, and any deficit in the rainfall impacts the water table. Groundwater occurs in all the geological formations of the city; the occurrence and quantity depend upon the percentage of granular zone available in the aquifers. The aquifers of Chennai city are phreatic. Groundwater resources play a vital role in additional demand by farmers and industries, and domestic usage leads to the rapid development of groundwater. About 63% of available groundwater resources are now being used. The resource use and development are not uniform all over the State, and in certain districts of Tamil Nadu, intensive groundwater development has led to declining water levels, an increasing trend of overexploitation, and saline water intrusion. Central Groundwater Board has reported that 80% of Chennai's groundwater has been depleted, and any further exploration could lead to saltwater ingress. The groundwater level declines between 0.037 and 0.798 m/year.

(3) Usage of water resources (drinking and irrigation)

The city's water resources and distribution for drinking or irrigation are managed by the Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB), which was constituted in 1978. The CMWSSB is responsible for promoting and securing the planned development of water supply and sewerage services, creation, operation, and maintenance of the needed infrastructure, and implementation of perspective plans to meet both current and future requirements in the areas of the Chennai Metropolitan Area. There are four reservoirs in the city, namely, Red Hills, Cholavaram, Poondi, and Chembarambakkam, with a combined capacity of 313.1 million m3 (11,057 mcft). The Red Hills Reservoir has a capacity of 93.4 million m3 (3,300 mcft), the Cholavaram Reservoir 24.9 million m3 (881 mcft), the Poondi Reservoir 91.4 million m3 (3,231 mcft), and the Chembarambakkam reservoir 103.2 million m3 (3,645 mcft). The reservoirs lose 141,585 m3 (5 mcft) daily due to evaporation. Chennai receives about 985 million liters per day (MLD) from various sources against the required amount of 1,200 mld. This demand is expected to rise to 2,100 mld by 2031. The Water Resources Department has identified 19 of the 29 major waterbodies along the city for restoration. Once the lakes are restored completely, the lakes will have a combined storage capacity of 28.3 million m3 (1,000 mcft). In addition, if the four primary reservoirs are desilted by a meter, an additional water volume of about 14.1 million m3 (500 mcf) can be stored.

(4) Geographic condition

Chennai is the capital of the southern Indian state of Tamil Nadu. Located in the northeast of the state, the city is the fourth largest city in India, with a population size of 7 million. Known as the "Gateway to South India," it is situated on the coastal plain of the Bay of Bengal in southeast India. The average level above sea level is about 6.7m, and the highest point is about 60m. These flat plains on which Chennai and adjacent areas are found extend from the Bay of Bengal to inland. In the target river basins, the elevation reaches only 100 m, even the inland 100 km from the sea.

(5) Meteorological conditions

Chennai has a tropical wet and dry climate. The coastal city lies in the thermal equator region and benefits from extreme variations in the temperature throughout the year. The hottest time of the year in Chennai starts from late May to early June, with maximum temperatures ranging from

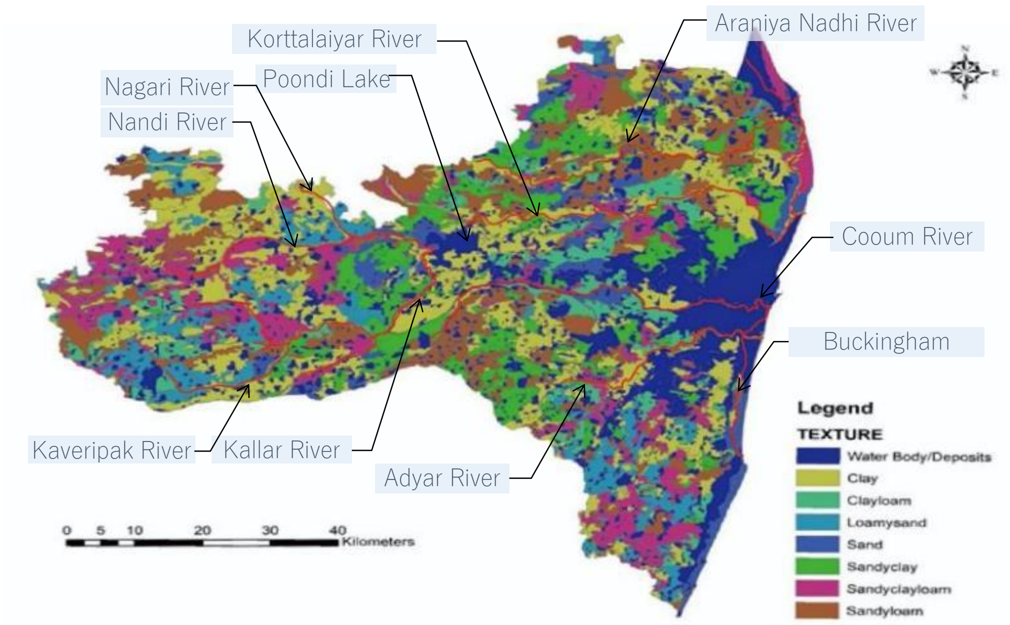
35°C to 40°C. The coolest part of the year is January for the city, with minimum temperatures ranging from 19°C to 25°C. The highest recorded temperature in the region was 45°C on May 31, 2003, while the lowest recorded temperature was 13.9°C on December 11, 1895, and January 29, 1905. Chennai receives its majority of rainfall twice a year, first from southwest monsoon winds between June and September and second from northeast monsoon winds between October and December. The average annual rainfall of the city is 1,400 mm. The highest annual rainfall recorded here is 2,570 mm in 2005. Sometimes, cyclones in the Bay of Bengal hit the region. Chennai is dependent on the yearly monsoon rains for its water reservoirs to be recharged, as there is no major river flowing through the city.

The Chennai basin has an area of 6,118.34 km2. Spread over four Districts, namely, Chennai, Thiruvallur, Vellore, and Kancheepuram. Considering the distribution of rain gauge stations and the availability of data, 24 rain gauge stations with long-term records in and around the basin are selected for the detailed analysis.

The Chennai basin lies within the tropical monsoon zone. Based on the hydrometeorological features of the basin, the year is divided into 1) a Monsoon period from June to December and 2) a non-monsoon period from January to May. The monsoon period is further subdivided into the Southwest monsoon period from June to September (4 months) and the Northeast monsoon period from October to December (3 months). Similarly, the non-monsoon period is further subdivided into the Winter period from January to February (2 months) and the summer period from March to May (3 months). As the monsoon period brings heavy rainfall, it improves the recharging of groundwater as well as the storage of surface water. Hence, the monsoon period is hydrologically significant for water resources analysis. In the case of the non-monsoon period, the rainfall is insignificant.

(6) Geological condition

The figure below is the soil map of river basins in and around Chennai. It shows most of the Chennai urban areas are composed of deposits. In the inland areas, deposits are distributed around the Cooum River and the Adyar River. In other areas, clay, clay loam, loamy sand, sand, sandy clay, and sandy clay loam are scattered. Sandy clay becomes less apparent in the inland areas 80km from the sea. In general, with widely distributed sand and clay, the soil of the area is considered well-drained and lacks water retention capacity.

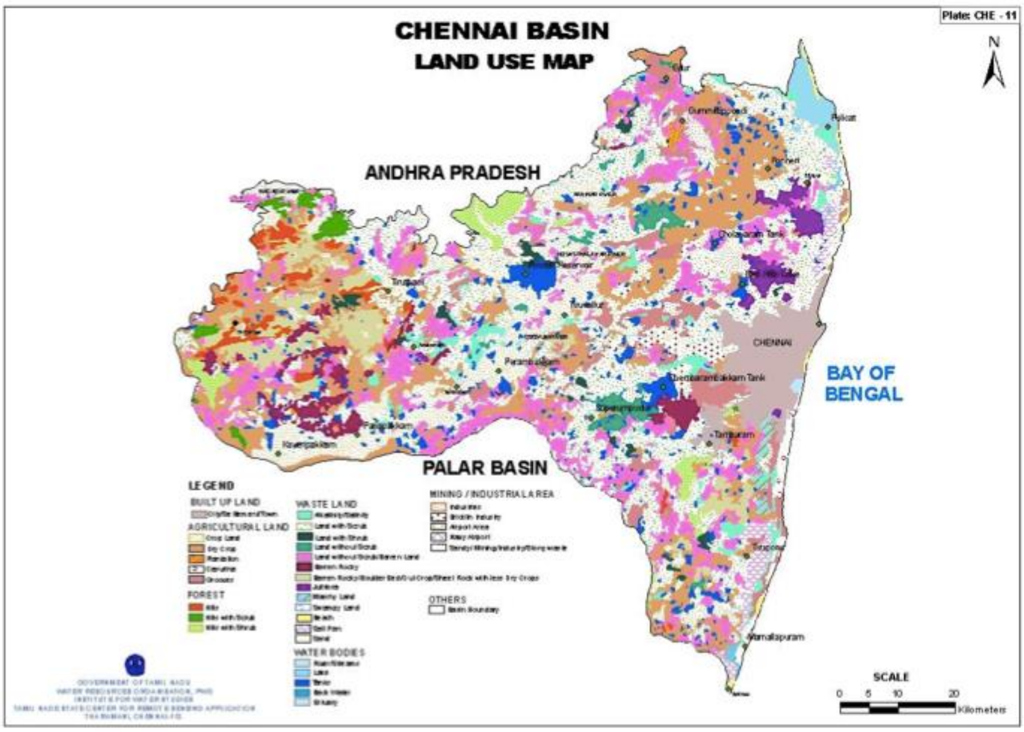


Source: TNPWD data modified by JICA Team

Figure 8-12: Soil Map of the River Basins around Chennai

(7) Land use condition

Most of Chennai Metropolitan Area is urbanized by construction and structures, while the suburbs are agricultural land comprising about 61% of 3,860 km2 of the total land area. Rivers and water bodies make up about 13% of the total land area and unused land 10%. Only 6% is forest, the majority of which is broad-leaved forest. This composition attests to the loss of the natural environment from urban development, population migration, and intensified land use.



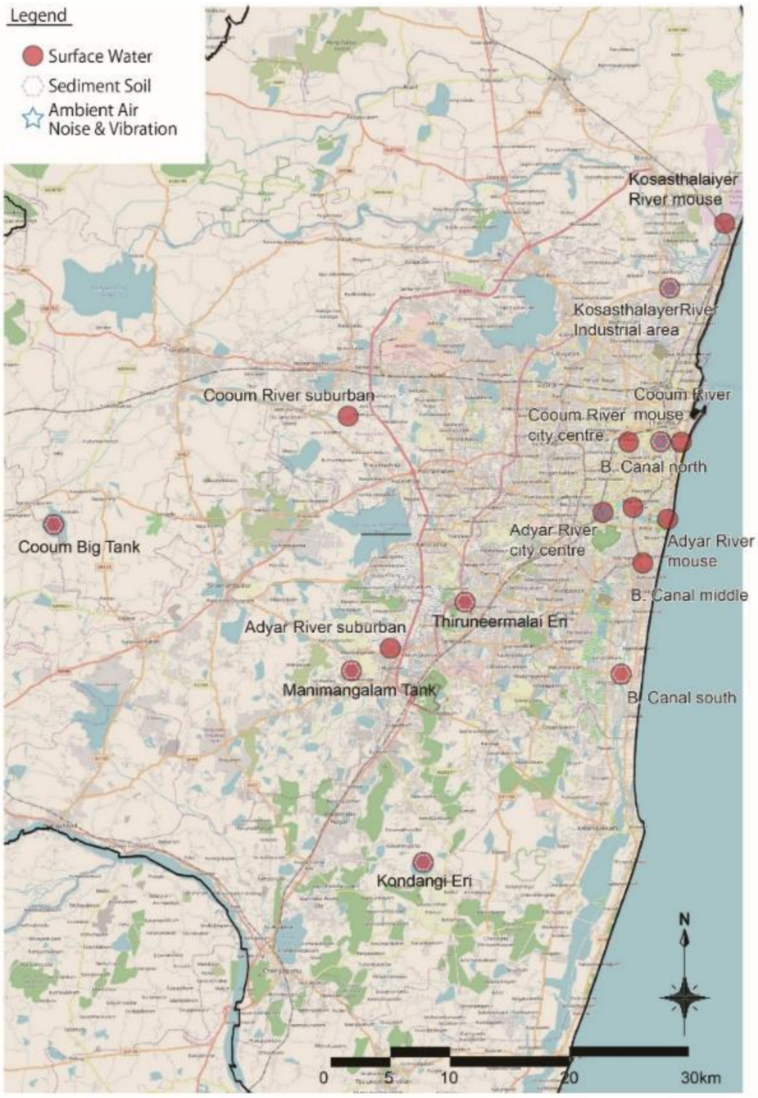
Source: Tamil Nadu Water Resources Department

Figure 8-13: Land Use Map of the River Basins around Chennai

8.9.2 Pollution Control

8.9.2.1. On-site survey

An on-site environmental survey was conducted in March 2023 to compare available data surveyed through the previous environmental study. This survey is carried out mainly to know the general environmental conditions of the targeted rivers so that the survey points are established in correspondence with those of the previous survey. Additionally, from another perspective, this survey will be carried out to assess the environment in the area related to the prioritized projects in the master plan, and the additional survey was conducted in April 2024. The target survey points related to the prioritized measures are determined based on the water tank rehabilitation. Four water tanks, Cooum Big Tank, Manimangalam Tank, Kondangi Eri, and Thruneemalai Eri, are selected from the list of 200 proposed water tanks. The former three are chosen as representatives in the Cooum, Adyar, and Kavalam River basins, respectively, while the last one is taken for one of the samples in the urbanized area. The following figure shows a summary of the survey points.



Source: JICA Expert Team

Figure 8-14: Summary Locations of Environmental Survey

8.9.2.2. Results of the Survey for General Baseline

(1) Air quality (General Baseline)

1) Survey Results

In the view of how the air quality will be improved by the relevant project-related construction components (such as road widening, construction of various types of flyovers, outer ring roads, bypass roads, river restoration, river beautification, construction of river promenade or parks), modification of zoning system are primarily aiming at decongesting city traffic and to maintain ambient air quality within the permissible levels. These locations are selected based on heavy traffic as these points act as key entry (Gateway of Chennai) or exit points. The following tables with photos show the location of sampling points, survey conditions, and survey results.

Table 8-15: Air Quality Survey Points (General Baseline)

Zone	Related to River Environment	Latitude	Longitude
I-1	Adyar Riverbank (City Centre)	13° 1'1.53"N	80°13'25.65"E
I-2	Cooum Riverbank (City Centre)	13° 4'5.73"N	80°16'6.74"E
I-3	Kosasthalaiyar Riverbank (Dense Residential Area)	13°10'37.24"N	80°12'6.45"E

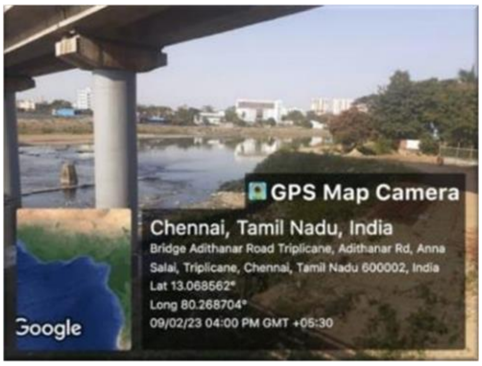


Photo 1 Adyar Riverbank (City Centre)

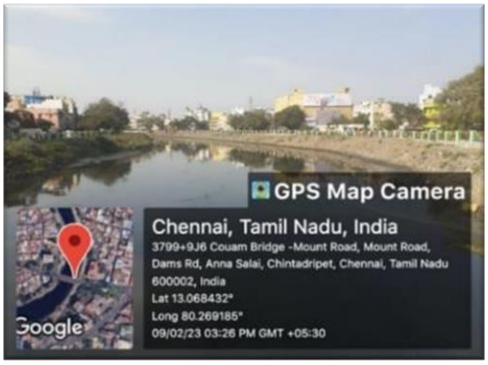


Photo 2 Cooum Riverbank (City Centre)

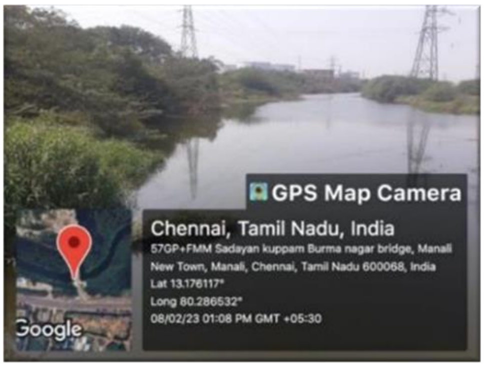


Photo 3 Kosasthalaiyar Riverbank (Dense Residential Area)

Source: JICA Expert Team

Table 8-16: Condition of the Air Quality Survey (24 April 2023) (General Baseline)

No	Location	Date of Sampling	Ambient Temperature		Relative Humidity	
			Max	Min	Max	Min
1	V.G.P Victory House Mount Road, Anna Salai	24.04.2023	28°C	36°C	45 %	80 %
2	Near Adyar River City Centre, Saidapet	24.04.2023	28°C	36°C	45 %	80 %
3	Kosasthalaiyar River Industrial Area, Manali	24.04.2023	28°C	36°C	45 %	80 %

		
Photo 1 V.G.P Victory House Mount Road, Anna Salai	Photo 2 Near Adyar River City Centre, Saidapet	Photo 3 Kosasthalaiyar River Industrial Area, Manali

Source: JICA Expert Team

Table 8-17: Survey Results of the Air Quality Survey (General Baseline)

No	Parameters	Unit	Results			Standards		
			AAQ1	AAQ2	AAQ3	CPCB	WHO	Japan
1	PM10	µg/m3	76.8	68.1	73.5	<100	<45	<100
2	PM2.5	µg/m3	42.1	35.7	40.9	<60	<15	<35
3	Sulfur dioxide (SO2)	µg/m3	10.6	11.9	14.1	<80	<20	<100 (0.04ppm)
4	Nitrogen Dioxide (NO2)	µg/m3	37.3	34.2	39.4	<80	<25	<110 (0.06ppm)
5	Ammonia (NH3)	µg/m3	BDL DL:20.0	BDL DL:20.0	22.7	<400	-	-
6	Ozone (O3)	µg/m3	BDL DL:20.0	BDL DL:20.0	BDL DL:20.0	<180	<100	<110 (0.06ppm)
7	Carbon Monoxide (CO)	mg/m3	BDL DL:1.0	BDL DL:1.0	BDL DL:1.0	<4.0	<4.0	<10.0
8	Benzene (C6H6)	µg/m3	BDL DL:1.0	BDL DL:1.0	BDL DL:1.0	<5.0	-	<3.0 (annual ave.)
9	Benzo (a) Pyrene (particulate phase only)	ng/m3	BDL DL:0.1	BDL DL:0.1	BDL DL:0.1	<1.0	-	-
10	Lead (Pb)	µg/m3	BDL DL:0.1	BDL DL:0.1	BDL DL:0.1	<1.0	-	-
11	Arsenic (As)	ng/m3	BDL DL:1.0	BDL DL:1.0	BDL DL:1.0	<6.0	-	-
12	Nickel (Ni)	ng/m3	BDL DL:1.0	BDL DL:1.0	BDL DL:1.0	<20	-	-

Note: BDL=Below Detection Limit, DL=Detection Limit

Source: JICA Expert Team

2) Analysis

The results of the air quality survey in the river environment in the Chennai city center were within the standards set by the CPCB for all parameters, although the results for PM10 did not meet the WHO and Japanese environmental standards. This indicates that the river environment away from the adjacent roads creates an environment that meets air quality standards even in the urban center. It is also important to carry out appropriate mitigation measures so as not to degrade the existing air quality environment when implementing future flood control-related measures in the river.

(2) Water quality (General Baseline)

1) Survey Results

Maintaining water quality parameters of rivers, lakes, and ponds is vital to having a healthy aquatic ecosystem to support flora and fauna and to enjoy ecosystem services. These points have been selected based on the length of the rivers and indicate the differences in quality between the rural and urban areas. Critical sections are also taken into account where there are stagnations due to untreated wastewater discharges and dumping of municipal solid waste, etc. The following tables with photos and figures show the location of sampling points, survey conditions, and results.

Table 8-18: Water Quality Survey Points (General Baseline)

Zone	Name of the area/location	Latitude	Longitude
I	Buckingham Canal		
I-1	B Canal Cooum River Outlet	13° 4'7.36"N	80°17'1.86"E
I-2	B Canal Adyar River Outlet	13° 1'4.24"N	80°14'54.57"E
I-3	B Canal Neelankarai	12°56'58.18"N	80°14'53.98"E
I-4	B Canal Near Pallikaranai	12°53'58.89"N	80°14'20.01"E
II	Riverine		
II-1	Adyar River Mouth	13° 0'54.05"N	80°16'14.20"E
II-2	Adyar River Suburban	12°54'56.67"N	80° 3'53.59"E
II-3	Cooum River Suburban	13° 5'16.08"N	80° 2'10.74"E
II-4	Cooum River Choolaimedu	13° 4'5.83"N	80°13'53.36"E
II-5	Kosasthalaiyar River Mouth	13°12'6.25"N	80°18'19.00"E
II-6	Adyar Riverbank (City Centre)	13° 1'1.53"N	80°13'25.65"E
II-7	Cooum Riverbank (City Centre)	13° 4'5.73"N	80°16'6.74"E
II-8	Kosasthalaiyar Riverbank (Dense Industrial Area)	13°22'23.03"N	80°31’90.84"E

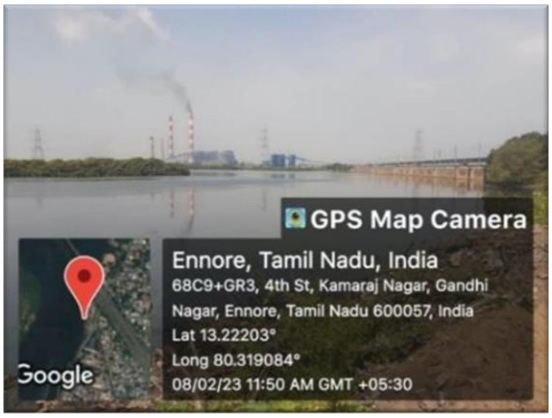


Photo 1 Kosasthalaiyar River mouth and industrial area (1)

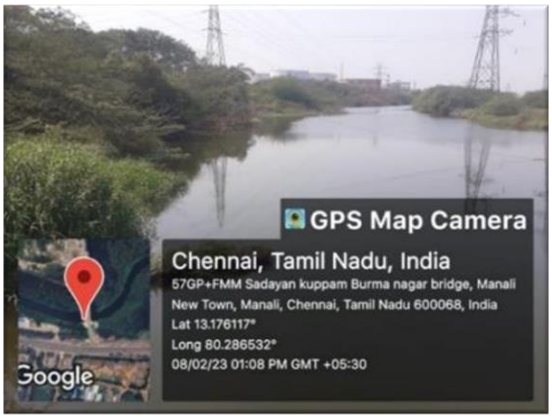


Photo 2 Kosasthalaiyar river mouth and industrial area (2)

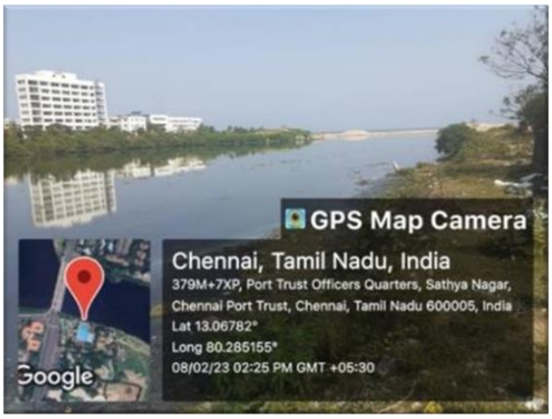


Photo 3 B Canal and Cooum confluence point and Cooum river mouth (1)

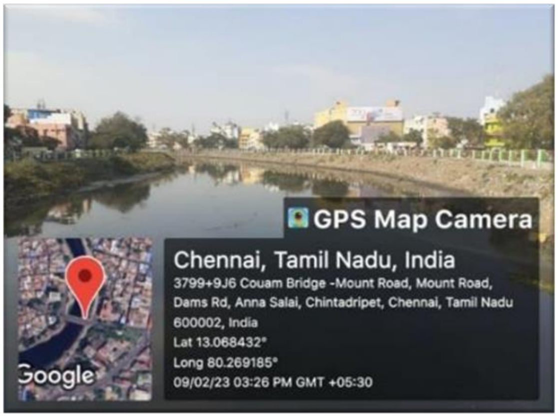


Photo 4 B Canal and Cooum confluence point and Cooum river mouth (2)

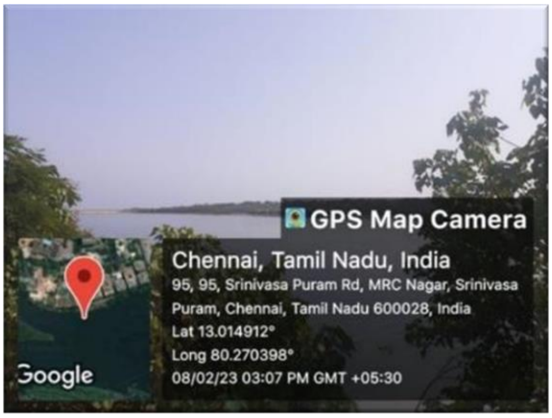


Photo 5 Adyar river mouth and Adyar river and B canal Confluence point (1)

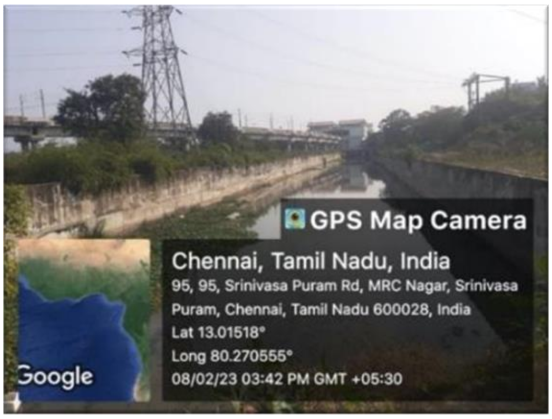


Photo 6 Adyar river mouth and Adyar river and B canal Confluence point (2)

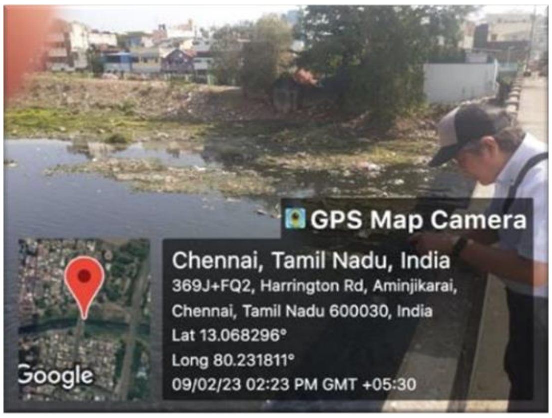


Photo 7 Cooum River city centre (1)

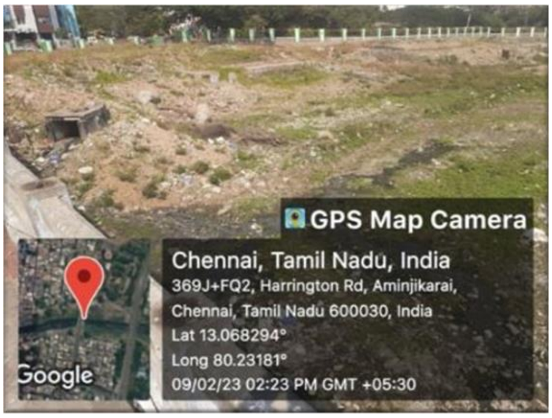
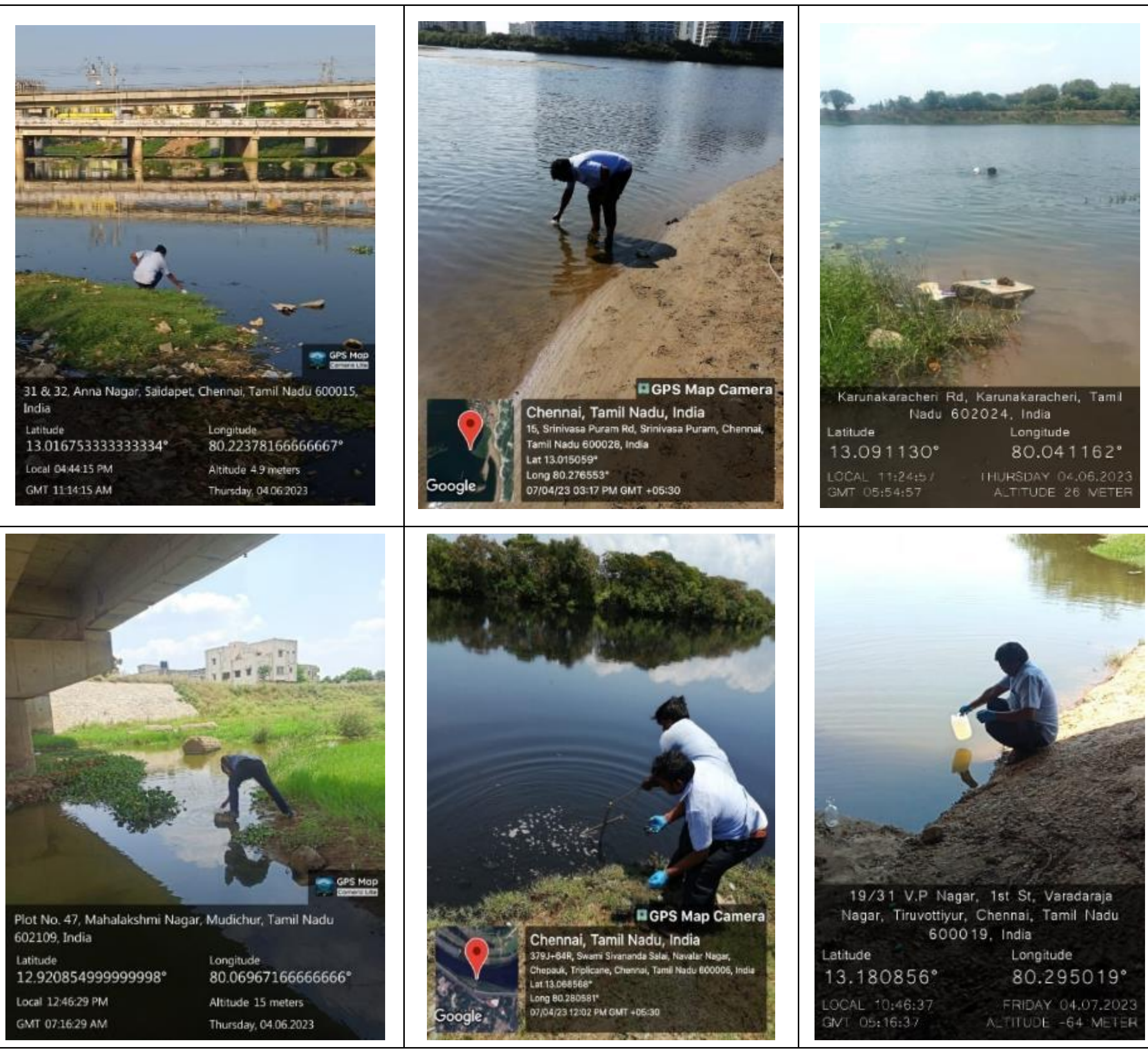


Photo 8 Cooum River city centre (2)

Source: JICA Expert Team



Source: JICA Expert Team

Figure 8-15: Condition of the Water Sampling (6 and 7 April 2023) (General Baseline)

Table 8-19: Survey Results of the Water Quality Survey (General Baseline)

#	Parameter	Unit	Results												Standards			
			I-1 (B)	I-2 (B)	I-3 (B)	I-4 (B)	II-1(A)	II -2(A)	II -3(C)	II -4(C)	II -5(K)	II -6(A)	II -7(C)	II -8(K)	Indian	EPA (US)	WHO	Japan
1	Colour	Hazen	20	25	25	35	5	10	25	20	35	5	30	10	5	-	-	-
2	Odor	-	Disagreeable	Agreeable	Agreeable	Agreeable	Agreeable	Agreeable	Agreeable	Disagreeable	Disagreeable	Agreeable	Agreeable	Agreeable	-	-	-	-
3	Turbidity	NTU	25	113	36.9	49.4	2	11	16	113	32.4	12.2	47.5	38.2	-	-		-
4	pH at 25°C	-	8.36	8.34	6.99	7.44	8.42	8.42	8.38	7.14	7.11	7.73	7.47	7.67	5.5-9.0	6.5-8.5	6.0-9.0	6.0-8.5
5	Temperature	°C	27	27	29	29	27	27	27	29	29	28	28	28	>5°C	-	-	-
6	Conductivity @ 25°C	mS/cm	2.53	2.46	10.30	2.71	0.89	1.43	1.76	2.17	6.91	64.30	39.95	71.70	-	-	-	-
7	Total Dissolved Solids (TDS)	mg/l	1428	1518	6564	1088	556	1106	1100	1140	4032	40604	23544	38926	-	<500	-	-
8	Total Suspended Solids (TSS)	mg/l	26	22	88	108	8	22	24	96	68	28	150	168	<100	-	<50	<50 Industrial
9	Total Solids	mg/l	1454	1540	6652	1196	564	1128	1124	1236	4100	40632	23694	39094	-	-	-	-
10	Total Alkalinity (CaCO3)	mg/l	366	467	447	469	185	298	431	475	469	109	258	126	-	-	-	-
11	Acidity (CaCO3)	mg/l	BDL (DL :1.0)	BDL (DL :1.0)	BDL (DL :1.0)	BDL (DL :1.0)	BDL (DL :1.0)	BDL (DL :1.0)	BDL (DL :1.0)	BDL (DL :1.0)	BDL (DL :1.0)	BDL (DL :1.0)	BDL (DL :1.0)	BDL (DL :1.0)	-	-	-	-
12	Total Hardness (CaCO3)	mg/l	496	484	1200	324	196	480	336	386	740	6250	4100	6700	<300	<200	<200	-
13	Calcium (Ca)	mg/l	72	87	160	87	40	96	79	99	132	521	401	441	-	-	-	-
14	Magnesium (Mg)	mg/l	77	65	194	26	23	58	34	34	100	1203	753	1361	-	-	-	-
15	Chloride (Cl)	mg/l	536	467	3040	304	133	238	247	334	2019	19524	10546	19334	-	<250	-	-
16	Fluoride (F)	mg/l	0.49	0.65	2.01	1.13	1.48	0.46	0.77	1.54	2.49	4.27	2.84	5.63	<2	<4	-	-
17	Nitrate (NO3)	mg/l	13.81	12.22	10.30	10.21	1.87	19.4	12.96	13.47	14.08	2.33	9.42	2.20	-	<10	-	-
18	Total Nitrogen	mg/l	43.92	47.45	26.61	31.10	8.34	11.54	33.02	23.72	28.53	2.88	21.80	3.20	-	-	-	-
19	Sulphate (SO4)	mg/l	33	28	429	89	24	0.36	51	77	259	1915	1309	1833	-	-	-	-
20	Total Phosphate (P)	mg/l	5.543	9.143	4.07	3.09	BDL (DL :1.0)	1.391	5.525	3.24	3.78	0.083	1.067	0.17	-	-	-	-

#	Parameter	Unit	Results												Standards			
			I-1 (B)	I-2 (B)	I-3 (B)	I-4 (B)	II-1(A)	II -2(A)	II -3(C)	II -4(C)	II -5(K)	II -6(A)	II -7(C)	II -8(K)	Indian	EPA (US)	WHO	Japan
21	Dissolved Oxygen (DO)	mg/l	BDL (DL:0.02)	BDL (DL:0.02)	BDL (DL:0.02)	BDL (DL:0.02)	5.26	6.9	BDL (DL :0.2)	BDL (DL :0.2)	BDL (DL :0.2)	6.2	BDL (DL :0.2)	6.7	>3	-	-	>5
22	BOD @ 27°C for 3 days	mg/l	23	17	23	15	6	7	12	35	20	4	5	3	<30	<5	<30	<8 Industrial
23	COD	mg/l	111	88	122	84	18	26.4	62	171	115	19	27	17	<250	<40	<125	-
24	Lead (Pb)	mg/l	BDL (DL:0.01)	BDL (DL:0.01)	BDL (DL:0.01)	BDL (DL:0.01)	BDL (DL :1.0)	BDL (DL :1.0)	BDL (DL :0.1)	BDL (DL :0.1)	BDL (DL :0.1)	BDL (DL :0.1)	BDL (DL :0.1)	BDL (DL :0.1)	<0.1	-	-	-
25	Total Chromium (Cr)	mg/l	0.081	0.068	0.019	0.022	0.055	0.031	0.101	0.031	0.022	BDL (DL :0.1)	0.016	BDL (DL :0.1)	<2	-	-	-
26	Iron (Fe)	mg/l	2.117	1.538	0.536	0.742	1.047	1.052	1.976	2.126	1.916	0.292	0.782	0.306	<3	<3	-	-
27	Manganese (Mn)	mg/l	0.340	0.416	0.231	0.118	0.074	0.216	0.202	0.415	0.257	0.012	0.149	0.029	-	0.5	-	-
28	Zinc (Zn)	mg/l	0.090	0.065	0.031	0.036	0.055	0.020	0.293	0.138	0.053	BDL (DL :0.1)	0.045	BDL (DL :0.1)	<5	<5	-	-
29	Aluminium (Al)	mg/l	0.760	0.611	0.266	0.436	0.547	0.841	1.364	1.023	0.446	0.574	0.364	0.355	-		-	-
30	Mercury (Hg)	mg/l	BDL (DL:0.0005)	BDL (DL:0.0005)	BDL (DL:0.0005)	BDL (DL:0.0005)	BDL (DL:0.0005)	BDL (DL:0.0005)	BDL (DL:0.0005)	BDL (DL:0.0005)	BDL (DL:0.0005)	BDL (DL:0.0005)	BDL (DL:0.0005)	BDL (DL :0.0005)	<0.01	<0.002	-	-
31	Total Arsenic (As)	mg/l	BDL (DL:0.01)	BDL (DL:0.01)	BDL (DL:0.01)	BDL (DL:0.01)	BDL (DL:0.01)	BDL (DL:0.01)	BDL (DL:0.01)	BDL (DL:0.01)	BDL (DL:0.01)	BDL (DL:0.01)	BDL (DL:0.01)	BDL (DL:0.01)	<0.2	<0.01	-	-
32	Escherichia coli	MPN /100ml	<1.8	<1.8	70	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	63	-	-	-	-
33	Total Coliform	MPN /100ml	280	240	430	170	210	210	170	280	220	220	170	220	<500	-	<400	-

Note: BDL=Below Detection Limit, DL=Detection Limit,
Red texts indicate the value of the standard water quality regulated by the CPCB, New Delhi, or international organizations.

Source: JICA Expert Team

2) Analysis

The results of the surface water quality studies of the Adyar, Cooum, and Kosasthalayer Rivers and the Buckingham Canal indicate that the value of calcium carbonate ($CaCO_3$), chloride (Cl), fluorine (F), and nitrate (NO_3) is very high in all surface water in the urban centers. From the results, it can be said that the water quality in the lower reaches of the three rivers and the Buckingham Canal is significantly degraded due to the inflow of untreated agricultural, industrial, and domestic wastewater. Additionally, the dissolved oxygen (DO) values are also below the standard values, indicating that the existing river environment in the city center is not suitable for a habitat of aquatic species and that it is difficult to ensure a biodiversity environment.

(3) Noise and vibration (General Baseline)

The basic concept of sampling locations is the same as an air quality survey. These locations are selected based on heavy traffic as these points act as key entry (Gateway of Chennai) or exit points. The following tables and figures with photos show the location of sampling points and survey results, respectively.

Table 8-20: Noise and Vibration Survey Points (General Baseline)

Zone	Related to River Environment	Latitude	Longitude
I-1	Adyar Riverbank (City Centre)	13° 1'1.53"N	80°13'25.65"E
I-2	Cooum Riverbank (City Centre)	13° 4'5.73"N	80°16'6.74"E
I-3	Kosasthalaiyar Riverbank (Dense Residential Area)	13°10'37.24"N	80°12'6.45"E

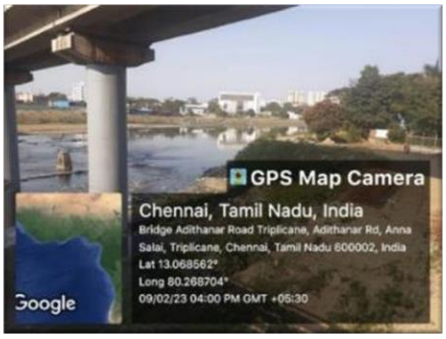


Photo 1 Adyar Riverbank (City Centre)

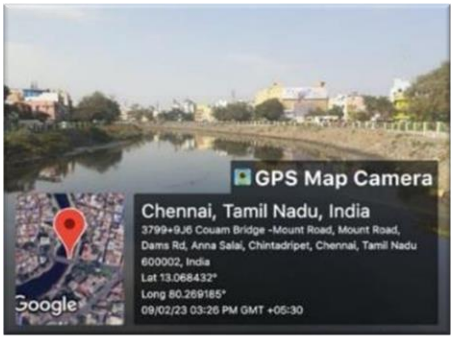


Photo 2 Cooum Riverbank (City Centre)

Photo 3 Kosasthalaiyar Riverbank (Dense Residential Area)

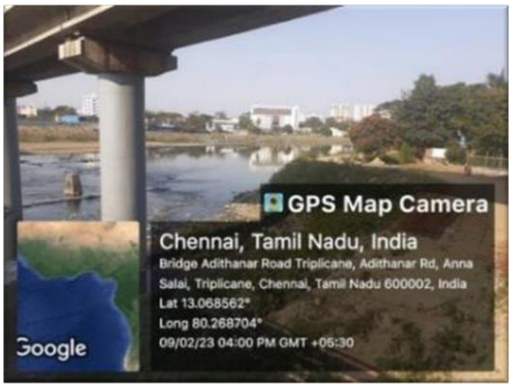


Photo 4 Kosasthalaiyar Riverbank (Dense Residential Area)

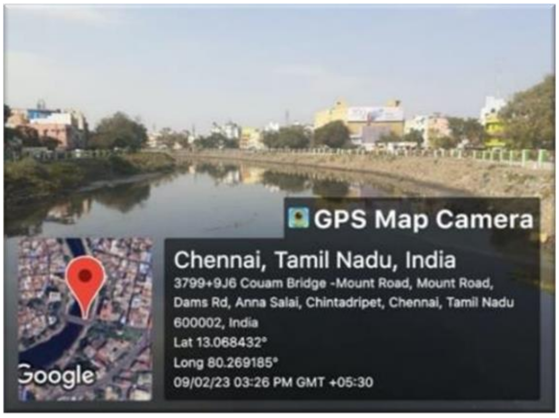


Photo 5 Cooum Riverbank (City Centre)

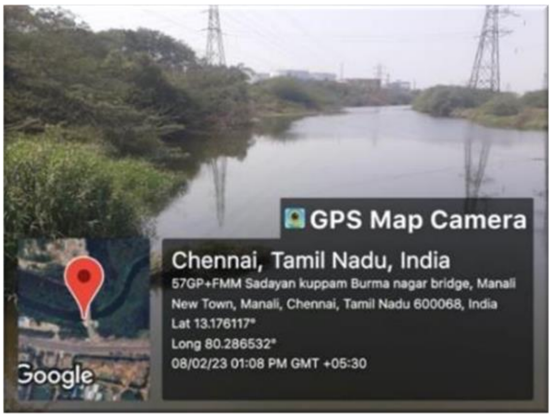
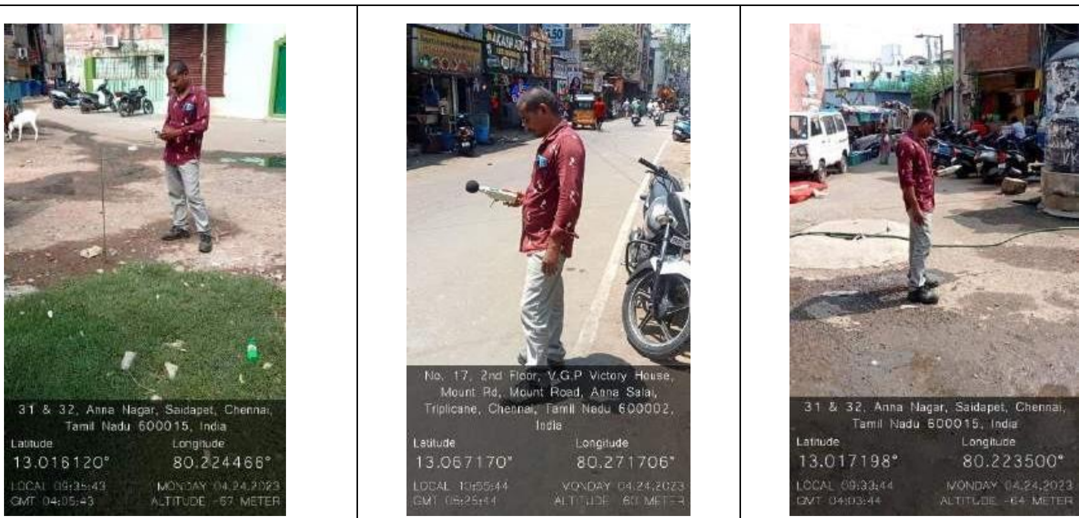


Photo 6 Kosasthalaiyar Riverbank (Residential Area)

Source: JICA Expert Team



Source: JICA Expert Team

Figure 8-16: Condition of the Noise and Vibration Survey (24 April 2023) (General Baseline)

Table 8-21: Noise and Vibration Survey Results (General Baseline)

#	Sampling Location	Results			Remarks
		Noise (dB(A) Leq)		Vibration (mm/s2)	
		Day6am-10 pm	Night10pm-6 am		
NV1	Adyar River (City Centre)	60.9	53.5	BDL, DL:0.5	
NV2	Mount Road, Anna Salai	63.7	55.2	BDL, DL:0.5	
NV3	Kosasthalaiyar River, Manali	62.5	47.9	BDL, DL:0.5	
	Standards				
1	India (commercial)	<65	<55	-	Residential noise standard: <55 (day), <45 (night)
2	WHO (industrial)	<70	<70	-	
3	Japan (industrial)	<60	<50	<56.2 (mm/s2) *=75 (dB)	

Note: BDL=Below Detection Limit, DL=Detection Limit,
Red texts indicate the value out of the standard from the CPCB

Source: JICA Expert Team

The noise levels observed in the sampling locations are primarily owing to vehicular traffic and other anthropogenic activities. At some locations, wind and bird chirping would contribute to the noise levels. The day equivalents during the study period ranged from 60.98dB (A) to 63.7dB (A). The maximum day equivalent value is under commercial area, and the night equivalents during the survey period ranged from 47.9dB (A) to 55.2dB (A). The maximum day equivalent value is under commercial area except for the noise level in Mound Road, Anna Salai, which is slightly higher than the limits. It may be traffic and other activities. From the results, day and night equivalents were within the ambient noise standards of commercial areas. The vibration values are below detection limits. Hence, no adverse impact was investigated.

(4) Sediment Soil quality (General Baseline)

1) Survey Results

To improve and maintain healthy sediment soil quality, the project analyses the soil quality at these locations and along the riverbed. During the time of flash floods and at the time of the release of large volumes of water during peak rainy seasons, huge quantities of soil silt are deposited all along the riverbeds and in some large lakes/ponds. Since all the rivers are seasonal, the deposited soil is not getting transferred during off-peak seasons and forms part of the benthic ecosystem and starts impacting aquatic flora and fauna with the heavy nutrients and toxic materials it carries. Maintaining the environmental standards of river-bed soil health is critical for the survival of parameters of rivers and lakes, and ponds are vital to have a healthy aquatic ecosystem to support flora and fauna and to enjoy ecosystem services. The following tables with photos and figures show the location of sampling points, survey conditions, and survey results.

Table 8-22: Sediment Soil Quality Survey Points (General Baseline)

Zone	Name of the area/location	Latitude	Longitude
I	Buckingham Canal		
I-1 (SQ1)	Buckingham Canal Near Pallikaranai	12°53'58.89"N	80°14'20.01"E
II	Riverine		
II-1 (SQ2)	Cooum River (City Centre)	13° 4'5.73"N	80°16'6.74"E
II-2 (SQ3)	Kosasthalaiyar River (Dense Industrial Area)	13°10'49.93"N	80°16'44.87"E

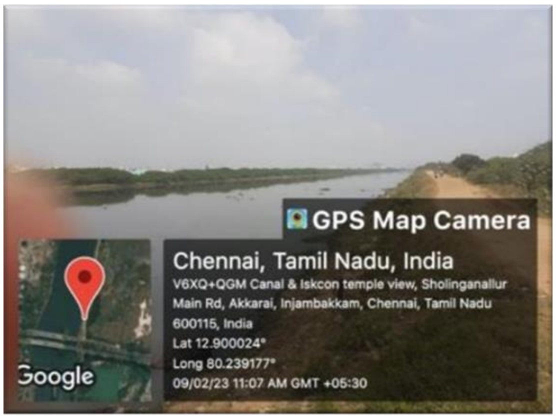


Photo 1 B Canal Near Pallikaranai

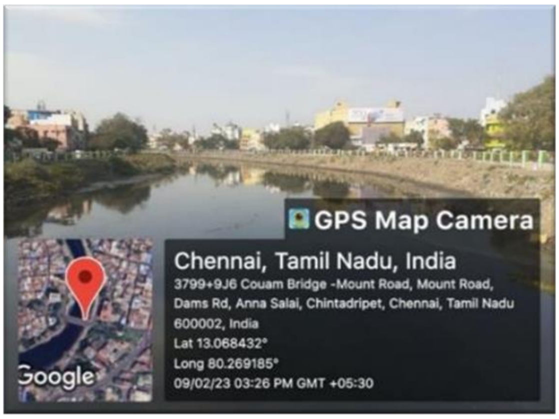


Photo 2 Cooum River (City Centre)

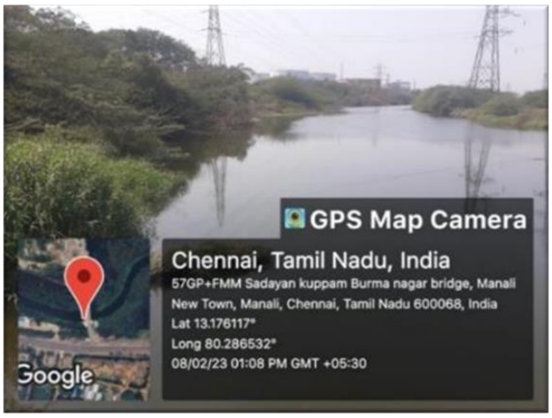
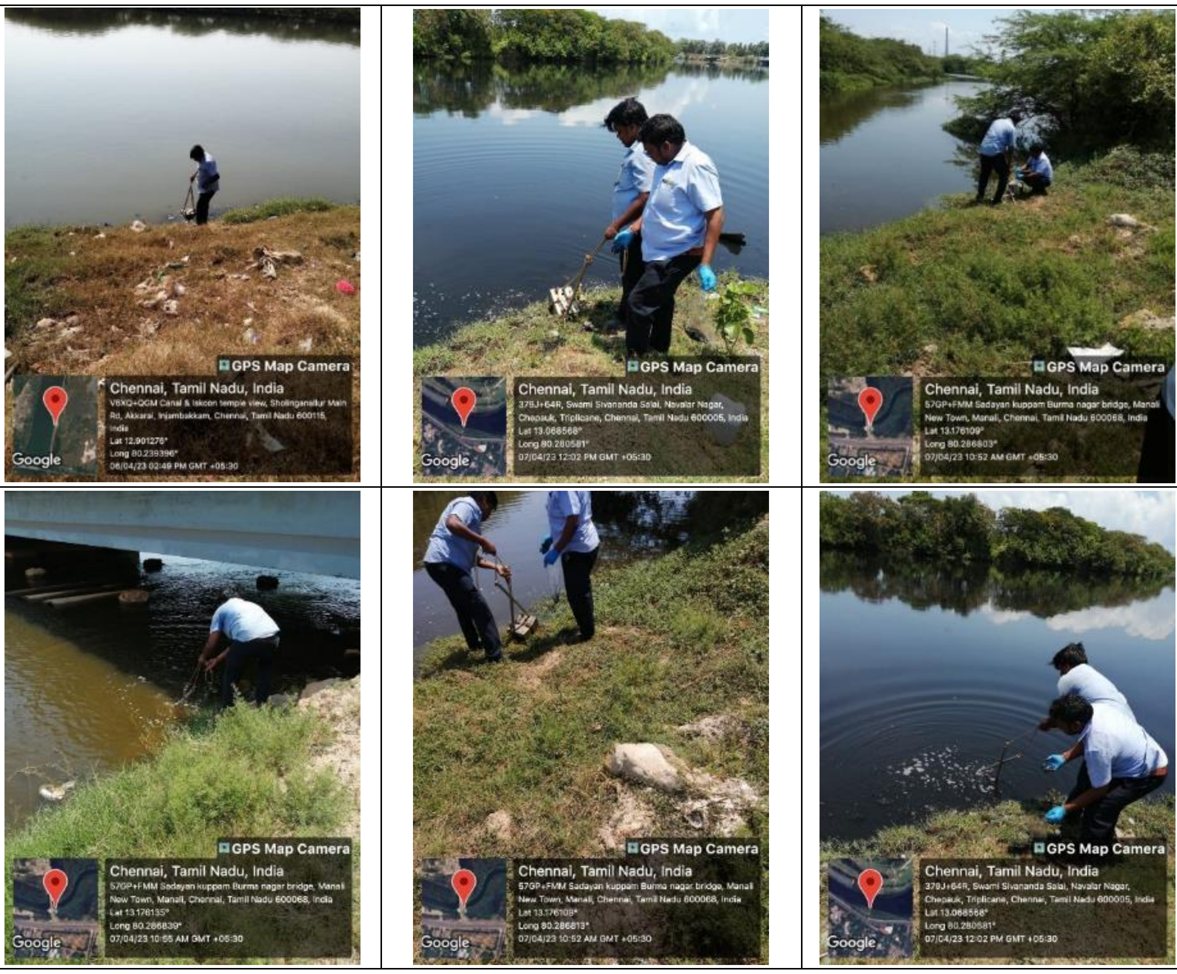


Photo 3 Kosasthalaiyar River (Dense Residential Area)

Source: JICA Expert Team



Source: JICA Expert Team

Figure 8-17: Condition of the Water Sampling (6 and 7 April 2023)

Table 8-23: Survey Results of the Sediment Soil Survey (General Baseline)

#	Parameters	Unit	Results			Targeted by DTIV	Moderate Value Classified by ICAR
			SQ1	SQ2	SQ3		
1	pH @ 25°C	-	7.80	7.59	8.04	-	5-8
2	Density	g/cc	1.2	1.18	1.24	-	-
3	Moisture Content	%	67.06	32.31	66.7	-	-
4	Electrical Conductivity @ 25°C	mS/cm	3.16	2.70	1.83	-	<4.0 for normal soil
5	Clay	%	25.49	23.42	44.62	-	-
6	Sand	%	64.52	74.18	54.48	-	-
7	Silt	%	9.99	2.4	0.9	-	-
8	Water Holding Capacity	%	65.42	54.89	53.58	-	-
9	Phosphorus as P	mg/kg	499	BDL DL:1.0	305	-	10-30
10	Sodium as Na	mg/kg	7768	2452	1597	-	200-500
11	Potassium as K	mg/kg	3947	2080	796	-	150-250
12	Calcium as Ca	mg/kg	7694	56266	2420	-	1000-2000
13	Magnesium as Mg	mg/kg	2733	7042	1631	-	100-300
14	Iron as Fe	mg/kg	13091	25	7849	-	-
15	Zinc as Zn	mg/kg	562	117	109	<140	-
16	Manganese as Mn	mg/kg	13829	221	65	-	-
17	Nickel as Ni	mg/kg	58.8	17	9	<35	-
18	Chromium as Cr	mg/kg	88.4	3	23	<100	-
19	Copper as Cu	mg/kg	1685	14	59	<36	-
20	Cadmium as Cd	mg/kg	10.4	BDL, DL:1.0	6	<0.8	-
21	Aluminium as Al	mg/kg	26.5	6195	3733	-	-
22	Organic Carbon	%	7.483	2.5	0.55	-	-
23	Organic Matter	%	12.90	4.31	0.95	-	-
24	Total Nitrogen as N	mg/kg	3633	1784	429	-	-

Note: Note: BDL=Below Detection Limit, DL=Detection Limit, DTIV=Dutch Target Intervention Value 2000, ICAR=Indian Council of Agricultural Research
Red texts indicate the value out of the standard from the Handbook of Agriculture, Indian Council of Agricultural Research, New Delhi, 2011, and international organizations.

Source: JICA Expert Team

Table 8-24: Standard Soil Classification

#	Parameters	Ranking				
		Very Low	Low	Moderate	High	Very High
1	pH	<4, very Strongly Acidic	4-5, Strongly Acidic	5-8, Ideal for Plant Growth	8-9, Strongly Basic	>9, Very Strongly Basic
2	Electrical conductivity (mS/cm)	<2.0, Non-saline	2.0-4.0, Saline	4.0-8.0, Moderately Saline	8.0-16.0, Highly Saline	>16.0, Extremely Saline
3	Total Nitrogen (%)	<0.05, Very Low	0.05-0.15, Low	0.15-0.25, Moderate	0.25-0.5, High	>0.5, Very High
4	Total Phosphorous (mg/kg)	<5, Very Low	5-10, Low	10-30, Moderate	30-60, High	>60, Very High
5	Sodium (mg/kg)	-	<200, non-Sodic	200-500, Moderate	>500, Sodic	-
6	Potassium (mg/kg)	-	<150, Low	150-250, Moderate	250-800, High	>800, Very High
7	Calcium (mg/kg)	-	<1000, Low	1000-2000, Moderate	>2000, High	-
8	Magnesium (mg/kg)	<40, Very Low	40-100, Low	100-300, Moderate	>300, High	-
9	Organic Matter (%)	0.5-1.0, Very Low	1.0-2.0, Low	2.0-3.0, Moderate	3.0-5.0, High	>5, Very High

Source: Handbook of Agriculture, Indian Council of Agricultural Research, New Delhi, 2011

2) Analysis

The results of the bed soils survey of the target rivers show that all the bed soils record high values of light metals, represented by Sodium (Na), Potassium (K), Calcium (Ca), and Magnesium (Mg). In addition, the bed soils in the industrial areas of the Kosasthalaiyar River and the Buckingham Canal record high values of heavy metals such as Copper (Cu) and Cadmium (Cd). The results indicate that the discharge of untreated domestic and industrial/agricultural effluents carries light and heavy metals into water bodies and causes the deposition of the metals in the bed soils in the long-term perspective. Such bed soils are not suitable for plant growth and may be harmful to human health when used for agriculture. In case the flood control mitigation measures involve dredging of the river or canal bed soils, environmental mitigation measures (e.g., bio-mining) should be taken to avoid secondary negative impacts caused by the soil contamination.

8.9.2.3. Results of the Survey for the Target Water Tanks

The following section shows the survey results of surface water quality and sediment soil quality of the target water tanks, Cooum Big Tank, Manimangalam Tank, Kondangi Eri, and Thruneemalai Eri. The locations of the target tanks are shown in the table below.

Table 8-25: Survey Points for Water and Sediment Soil Quality (Target Water Tanks)

#	Name of the tank/location	Date of Sampling	Latitude	Longitude
1	Cooum Gig Tank / Irulanjeri	April 6, 2024	13.019383°	79.820338°
2	Manimangalam Tank / Karasangal	April 6, 2024	12.896207°	80.037559°
3	Kondangi Eri / Kalvory R. F	April 6, 2024	12.752557°	80.090380°

<table>
<tr><td>4</td><td>Thrunee-malai Eri / Thiruneermalai</td><td>April 6, 2024</td><td>12.955868º</td><td>80.119963º</td></tr>
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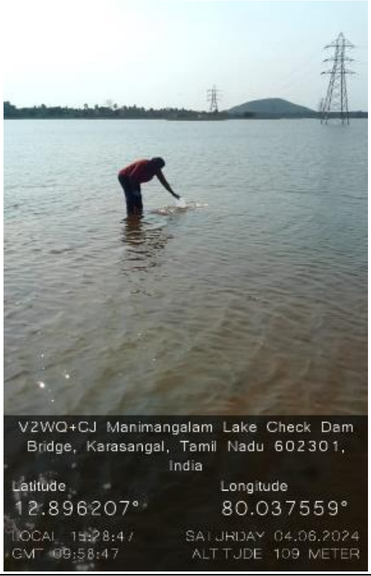
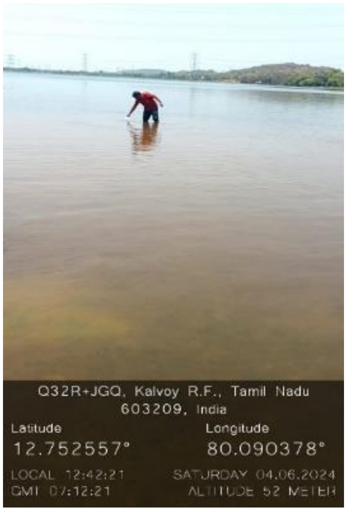
</td><td colspan="3">
</td></tr>
<tr><td colspan="2">Photo 1 Cooum Big Tank</td><td colspan="3">Photo 2 Manimangalam Tank</td></tr>
<tr><td colspan="2">
</td><td colspan="3">
</td></tr>
<tr><td colspan="2">Photo 3 Kondangi Eri</td><td colspan="3">Photo 4 Thrunee-malai Eri</td></tr>
</table>

Source: JICA Expert Team

(1) Surface Water Quality (Target Water Tanks)

Regarding the results, the water quality of the targeted proposed water tanks is much better than that of river water. Most of the values of the parameters are within the standards in India for the proposed water tanks. The results of the good water quality in Cooum Big Tank, Manimangalam Tank, and Kondangi Eri indicate that the water in the proposed tanks is not polluted, which is because the water is mostly used for irrigation of the regional agricultural fields. However, the water tank selected as a sample of those in an urbanized area, Thruneemalai Eri, has some parameter values, Total Dissolved Solids (TDS), Total Hardness (CaCO3), and Nitrate (NO3) out of the standards. An especially high value of TDS and Total Hardness directly affects biodiversity in aquatic environments related to the exacerbation of heavy metals in the tanks. Therefore, assuming that most of the water tanks in urbanized areas tend to have similar circumstances, it would be necessary to urgently implement restoration of those tanks.

Table 8-26: Survey Results of the Water Quality Survey (Target Water Tanks)

#	Parameter	Unit	Results of Surface Water Quality				Standards			
			Cooum Big Tank	Maniman-galam Tank	Kondangi Eri	Thrunee-malai Eri	Indian	EPA (US)	WHO	Japan
1	Colour	Hazen	20	15	10	50	5	-	-	-
2	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable	-	-	-	-
3	Turbidity	NTU	3.8	1.4	2.4	8.6	-	-		-
4	pH at 25°C	-	8.38	6.74	7.19	7.42	5.5-9.0	6.5-8.5	6.0-9.0	6.0-8.5
5	Temperature	°C	27	27	27	27	>5°C	-	-	-
6	Conductivity @ 25°C	mS/cm	0.68	0.37	0.27	0.94	-	-	-	-
7	Total Dissolved Solids (TDS)	mg/l	378	206	152	526	-	<500	-	-
8	Total Suspended Solids (TSS)	mg/l	9	4	6	22	<100	-	<50	<50 Industrial
9	Total Solids	mg/l	402	216	168	574	-	-	-	-
10	Total Alkalinity (CaCO3)	mg/l	177	103	89	191	-	-	-	-
11	Acidity (CaCO3)	mg/l	Nil	10.4	6.9	4.1	-	-	-	-
12	Total Hardness (CaCO3)	mg/l	125	115	100	215	<300	<200	<200	-
13	Calcium (Ca)	mg/l	38	36	13	46	-	-	-	-
14	Magnesium (Mg)	mg/l	7	6	11	24	-	-	-	-
15	Chloride (CI)	mg/l	119	61	44	165	-	<250	-	-
16	Fluoride (F)	mg/l	0.79	0.54	0.42	1.12	<2	<4	-	-
17	Nitrate (NO3)	mg/l	7.24	3	4	10.7	-	<10	-	-
18	Total Nitrogen	mg/l	BDL (DL: 1.0)	BDL (DL: 1.0)	BDL (DL: 1.0)	BDL (DL: 1.0)	-	-	-	-
19	Sulphate (SO4)	mg/l	4	8.4	BDL (DL: 1.0)	27	-	-	-	-
20	Total Phosphate (P)	mg/l	BDL (DL:0.01)	BDL (DL:0.01)	BDL (DL:0.01)	0.59	-	-	-	-
21	Dissolved Oxygen (DO)	mg/l	6.1	6.2	6.4	5.8	>3	-	-	>5
22	BOD @ 27°C for 3 days	mg/l	6	4	BDL (DL:2.0)	7	<30	<5	<30	<8 Industrial
23	COD	mg/l	31	19	13	38	<250	<40	<125	-
24	Lead (Pb)	mg/l	BDL (DL:0.01)	BDL (DL:0.01)	BDL (DL:0.01)	BDL (DL:0.01)	<0.1	-	-	-
25	Total Chromium (Cr)	mg/l	BDL (DL:0.01)	BDL (DL:0.01)	BDL (DL:0.01)	BDL (DL:0.01)	<2	-	-	-
26	Iron (Fe)	mg/l	0.573	0.419	0.365	0.871	<3	<3	-	-
27	Manganese (Mn)	mg/l	0.129	0.050	0.029	0.060	-	0.5	-	-
28	Zinc (Zn)	mg/l	0.043	0.031	0.033	0.036	<5	<5	-	-
29	Aluminium (Al)	mg/l	4.160	0.469	0.328	0.546	-		-	-
30	Mercury (Hg)	mg/l	BDL (DL:0.0005)	BDL (DL:0.0005)	BDL (DL:0.0005)	BDL (DL:0.0005)	<0.01	<0.002	-	-

#	Parameter	Unit	Results of Surface Water Quality				Standards			
			Cooum Big Tank	Maniman-galam Tank	Kondangi Eri	Thrunee-malai Eri	Indian	EPA (US)	WHO	Japan
31	Total Arsenic (As)	mg/l	BDL (DL:0.01)	BDL (DL:0.01)	BDL (DL:0.01)	BDL (DL:0.01)	<0.2	<0.01	-	-
32	Escherichia coli	MPN /100ml	280	<1.8	<1.8	<1.8	-	-	-	-
33	Total Coliform	MPN /100ml	1600	350	280	280	<500	-	<400	-

Note: BDL=Below Detection Limit, DL=Detection Limit,
Red texts indicate the value out of the standard water quality regulated by the CPCB, New Delhi, or international organizations.
Source: JICA Expert Team

(2) Sediment Soil Quality (Target Water Tanks)

The following results of sediment soil quality indicated that the soil contains high levels of heavy metal. If the excavated soil is used for agricultural purposes during the implementation of the prioritized measures, the excavated soil from the tank bed must be treated appropriately for plant growth and safer harvesting.

Sediment quality is of immense importance to maintain crops and human health, and any causality may lead to the slow poisoning of natural resources and human beings. Regular monitoring of the Sediment and water parameters is essential; therefore, we strongly recommend the regular monitoring of the capability, to be able to evaluate possible (negative) impacts on the surface water and Sediment, as they might become pollution-free over some time after completion of the restoration measures at river basin in Chennai.

Table 8-27: Survey Results of the Sediment Soil Quality (Target Water Tanks)

#	Parameters	Unit	Results				Targeted by DTIV	Moderate Value Classified by ICAR
			Cooum Big Tank	Maniman-galam Tank	Kondangi Eri	Thrunee-malai Eri		
1	pH @ 25°C	-	6.84	7.13	6.64	6.89	-	5-8
2	Density	g/cc	1.41	1.48	1.36	1.04	-	-
3	Moisture Content	%	35.30	17.88	34.30	56.50	-	-
4	Conductivity @ 25°C	mS/cm	0.31	0.52	0.33	0.80	-	<4.0 for normal soil
5	Clay	%	10.25	23.38	15.99	1.42	-	-
6	Sand	%	88.98	76.16	83.42	93.43	-	-
7	Silt	%	0.77	0.46	0.59	5.15	-	-
8	Water Holding Capacity	%	49.80	44.71	51 .67	68.07	-	-
9	Phosphorus as P	mg/kg	235	740	99.4	1,344	-	10-30
10	Sodium as Na	mg/kg	1198	1578	1384	2516	-	200-500
11	Potassium as K	mg/kg	1554	1738	1737	2613	-	150-250
12	Calcium as Ca	mg/kg	3595	4659	3929	19548	-	1000-2000
13	Magnesium as Mg	mg/kg	1954	2571	2925	3115	-	100-300
14	Iron as Fe	mg/kg	14151	43818	32685	34872	-	-
15	Zinc as Zn	mg/kg	30.7	45.7	62.0	100	<140	-
16	Manganese as Mn	mg/kg	133	331	238	223	-	-

#	Parameters	Unit	Results				Targeted by DTIV	Moderate Value Classified by ICAR
			Cooum Big Tank	Maniman-galam Tank	Kondangi Eri	Thrunee-malai Eri		
17	Nickel as Ni	mg/kg	10.9	30.5	21.6	15.8	<35	-
18	Chromium as Cr	mg/kg	21 .4	99.9	46.2	52.7	<100	-
19	Copper as Cu	mg/kg	14.4	38.7	27.5	81.4	<36	-
20	Cadmium as Cd	mg/kg	BDL (DL:1.0)	BDL (DL:1.0)	BDL (DL:1.0)	BDL (DL:1.0)	<0.8	-
21	Aluminium as Al	mg/kg	7297	29180	21763	8133	-	-
22	Organic Carbon	%	0.65	0.07	0.60	12.76	-	-
23	Organic Matter	%	1.12	0.12	1.03	22.0	-	-
24	Total Nitrogen as N	mg/kg	1920	962	1058	5682	-	-

Note: BDL=Below Detection Limit, DL=Detection Limit, DTIV=Dutch Target Intervention Value 2000, Red texts indicate the value out of the standard from the Handbook of Agriculture, Indian Council of Agricultural Research, New Delhi, 2011, and international organizations

Source: JICA Expert Team

8.9.3 Natural environment

Urban sprawl towards the peri-urban landscape is one of the major causes of strong ecological and environmental issues, including risks to ecosystem stability and biodiversity. Despite many advances, the process of interaction between cities and biodiversity is still not well understood. Decisions by key decision-makers affect biodiversity and put the city at changing climate risks such as flooding. The lack of understanding of city-biodiversity interaction hinders the development of effective governance mechanisms to manage the impacts of cities on biodiversity and vice-versa.

8.9.3.1. Flora

Classical Tamil literature (Sangam literature) has classified the Chennai city landscape representing the coast and associated coastal wetlands as *Neithal* and *Paalai*. The *Neithal* refers to coastal regions, the sea, and adjoining land, while *Paalai* is the arid region of Tamil Nadu with minimum vegetation, characterized by scattered secondary vegetation, often in the form of dense thickets, dominated by woody plants that bear latex, some of which are adorned with thorns. The cactus-like *Euphorbia antiquorum* also belongs to this vegetation type. Asian Palmyra palm (*Borassus flagelliform*) is the dominant tree species in both the *Neithal* and *Paalai* cultural landscapes, a keystone species, and the state tree of Tamil Nadu. The historical landscape of Chennai was dominated by Palmyra and Phoenix palms interspersed with thickets, the intervening spaces covered with a mixture of grasses and shrubs, and short herbs. The city is covered with wetlands and rivers like the Adyar River, the Cooum River, the Kosasthalaiyar River, the Buckingham Canal, the Pallikaranai Marshland, and the Kovalam wetlands. The *Paalai* landscape allowed surface water flows to move freely without flooding into the rivers and sea.

The existing greener vegetation, dominated by trees and shrubs locally, is the result of improvements made in the past 100 years in the Theosophical Society, the Indian Institute of Technology Madras (IIT-M) campus, the Guindy National Park, the Madras Christian College, and the Adyar Poonga. The river mouths of Adyar, Cooum, Kosasthalaiyar, parts of Buckingham Canal, and the Kovalam wetlands were once dominated by mangroves and associated species. Evidence and literature suggest that the Mylapore and Mandaveli regions had dense growth of mangroves 100 years back. The Luz Church at Mylapore was locally known as 'Kaattu Kovil' since it had dense mangroves around it.

Several researchers and botanists like Roxburgh (1795-1819), Gamble (1915-1936), and Mayuranathan (1929) studied the flora of Madras Coast, which also included all the wetlands and estuaries on the Chennai coast. Rao (1957) published an article entitled "The Flora of Adyar," which mostly dealt with the ornamental and other cultivated plants of the Theosophical Society and had very little reference to the estuarine flora. Livingstone and Henry (1994) revised Mayuranathan's "The Flowering Plants of Madras City and its immediate neighborhood" and made some significant additions to the flora. Chennai and its peri-urban regions have a terrestrial ecosystem, a freshwater ecosystem, an urban terrain system, a fragmented scrub jungle ecosystem, an estuarine ecosystem, and an intertidal and mangrove ecosystem.

The following table shows a list of floral species under the 'Threatened' category classified by IUCN in Chennai and surrounding areas.

Table 8-28: Threatened and Near Threatened Floral Species in Chennai and Around

#	Species	Common Name	Threatened category (IUCN Red List)
1	*Canthium dicoccum*	Ceylon boxwood	Vulnerable
2	*Chloroxylon swietenia*	Ceylon satinwood	Vulnerable
3	*Guaiacum officinale*	Roughbark lignum-vitae	Endangered
4	*Khaya senegalensis*	African mahogany	Vulnerable
5	*Pterocarpus marsupium*	Indian kino	Near Threatened
6	*Pterocarpus santalinus*	Red sanders	Endangered
7	*Saraca asoca*	Ashoka tree	Vulnerable
8	*Swietenia mahagoni*	American mahogany	Near Threatened
9	*Swietenia macrophylla*	Mahogany	Endangered

Source: JICA Expert Team

(1) Adyar River, Buckingham Canal, and Kovalam stretch:

Good vegetation cover was observed in the Theosophical Society campus, Indian Institute of Technology Madras (IIT-M) campus, Guindy National Park, Madras Christian College, and the Adyar Poonga Phase I and Phase II. In other regions, the vegetation was restricted to the river and lake bund area, with few tree species as fragmented patches. A total of 204 species belonging to 68 families were recorded. Interestingly, 26 families were represented by one species. A maximum of 13 species were of *Fabaceae,* followed by 13 of *Poaceae* and 8 of *Asteraceae*. *Euphorbiaceae* and *Cyperaceae* families are represented by seven species each. A good density of hydrophytes was observed. Species like *Spirodela polyrhiza*, *Aponogeton natans*, *Alternanthera sessilis*, *Hydrilla verticillata*, *Pistia stratiotes*, *Nymphaea nouchali*, *Nymphaea rubra* were identified, and good density of *Nelumbo nucifera*, *Nymphaea pubescent* and *Nymphaea nuchal* was observed throughout the water body along the thereunder malai stretch.

Water quality was good along this stretch, and the presence of a greater number of hydrophytes is a good indicator of it. Nearly 13% of the species recorded were represented by one or few numbers at scattered locations, and many non-woody species, such as herbs (31%) forming dense mat on the river and along the bund, Hydrophytes (20%) consist of submerged, emergent and floating habits, shrubs (13%) at scattered locations, climbers (10%) *Asclepiadaceae*, *Cucurbitaceae* and *Convoluvaceae* members running on trees and *Capparidaceae* on the ground and grasses (10%).

The floristic composition, as reported in 2013, shows that herbs dominate the flora of Adyar estuary with a total of 125 species (49%), followed by trees with 59 species (23%), climbers with 44 species (18%) and shrubs with 26 species representing 10% of the flora. A total of 252 species and two varieties of angiosperms belonging to 196 genera, distributed in 64 families, were recorded along the estuarine part of the Adyar River. During the summer, when the water level dries up on the water spread areas, it supports temporary habitat for herbs and grasses. Hardwood and thorny trees like *Prospis juliflora* and *Acacia nilotica* in the water spread were found, and these serve as nesting places for herons, especially purple heron, which breeds in these trees. They were more common along the freshwater zones of the river. Very few numbers of trees like *Azardiracta indica* and *Morinda* were identified along the bund in the urban region.

Guindy National Park Guindy National Park is a 2.70 km2 (1.04 sq ml) in Chennai, is the 8th-smallest National Park in India, and one of the very few national parks situated inside a city. The vegetation is mainly of the tropical dry evergreen type, and over 350 species of plants have been found, including trees, shrubs, climbers, herbs, and grasses. Guindy Park has rich floral diversity, and the habitats include thorn forests, dry evergreen scrub, water bodies, and grasslands. With shrubs, herbs, climbers, and grasses, there are more than 350 species of plants and over 24 varieties of trees, including the sugar apple, *Atlantia monophylla*, wood-apple, *Annona squamosa*, Feronia *limonia, Azadirachta indica,* and many others are found in this park. About one-sixth of the park has been left as open grassland to preserve that habitat for blackbucks.

The Theosophical Society campus is the second largest green patch in the city of Chennai, next to Guindy National Park. A total of 449 taxa have been recorded, comprising 161 trees, 84 shrubs, 179 herbs, and 25 climbers that are distributed in 353 genera, represented in 85 families. Superorder *Fabids* and *Lamids* account for about 49% of the taxa. Paleotropical elements (66%) dominate the TS campus, followed by Neotropical elements (31%). The Theosophical Society campus has a rich and diverse exotic flora.

(2) Cooum river

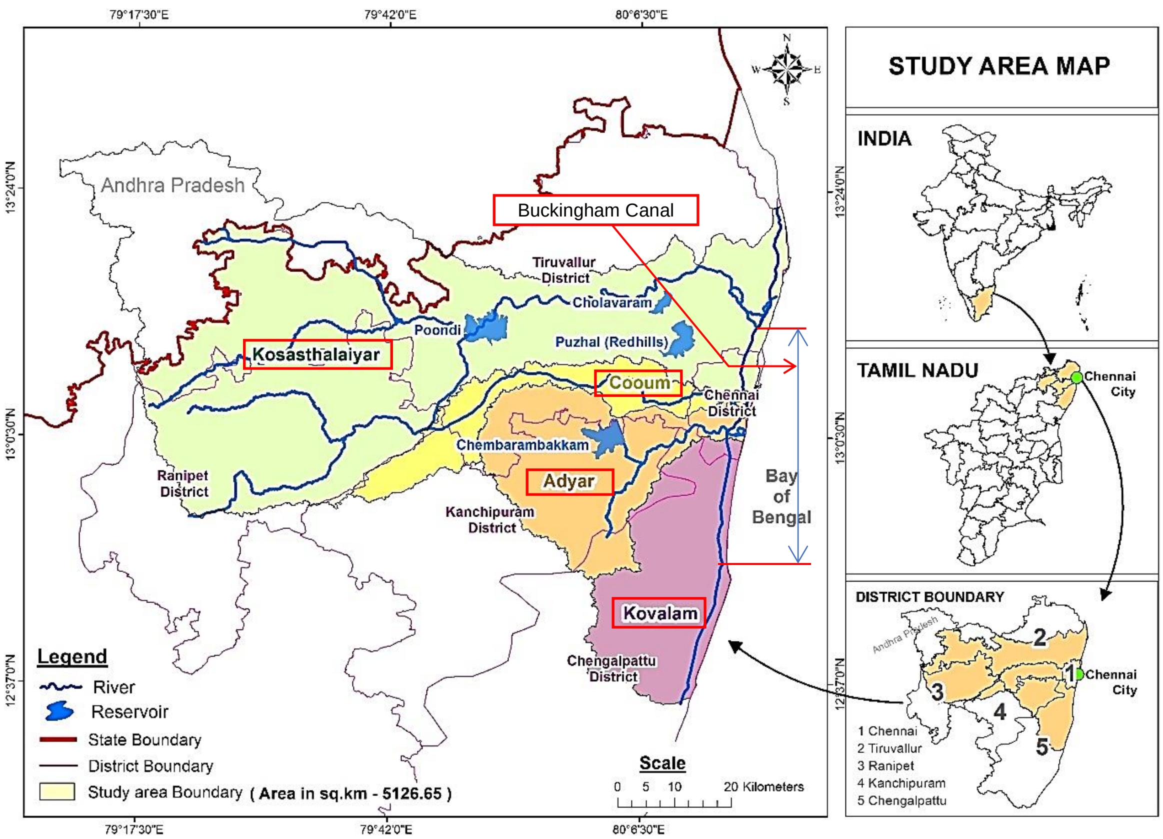
The floral diversity in the Cooum River was comparatively less than in the Adyar River since a major part of the Cooum River is influenced by urban development. The river site typically consists of small, fragmented pockets of vegetation and farmland and small plantations adjacent along the. Terrestrial plants are restricted to the Lake Bund area with few tree species. A total of

205 belonging to 64 families were recorded. Dominant species and composition, same as the ones in the Adyar River, are found in the Cooum River.

(3) Kosasthalaiyar Estuary

The Kosasthalaiyar River hosts diverse habitats, including freshwater systems, tidal mudflats, mangroves, salt marshes, and coastal wetlands. A single species of mangrove, Avicennia marina, dominates the area. Rhizophora species were introduced and are found in limited numbers, growing to less than 1 meter in height along the western side of the estuary, opposite the mouth near the flash pond. In total, 56 other species were recorded across the four ecosystems, including coastal wetlands. However, the mangrove patches are highly fragmented and disturbed, with stunted growth observed in most areas due to heavy siltation and high salinity.

Halophytes such as Arthrocnemum macrostachyum, Cyperus arenarius, Cyperus procerus, Fimbristylis cymosa, Fimbristylis ferruginea, Fimbristylis polytrichoides, Salicornia brachiata, Sesuvium portulacastrum, Suaeda maritima, and Suaeda monoica are present. Notably, Arthrocnemum macrostachyum and Salicornia brachiata, previously considered missing, were recently observed in good numbers at the tail end of the northern creek near Kattupalli. Reports suggest a significant decline in floral diversity, particularly in mangrove and saltmarsh species, which have shrunk in both area and diversity. No endemic or endangered species have been recorded in this region.



Source: JICA Expert Team

Figure 8-18: Locations of Adyar, Cooum, and Kosasthalayer River, Kovalam Basin, and Buckingham Canal

8.9.3.2. Fauna

The Chennai landscape was dominated by the Palmyra palm in the past and is supported by the persistence of animals like the Blackbuck, fan-throated lizard, saw-scaled viper, and a good of birds, including the laughing dove and the Indian stone curlew. These animals, best adapted to life in semi-desert-like habitats, are now surviving within small fragments of suitable habitats inside Chennai.

Irrespective of the degraded status of the Adyar, Cooum, Ennore, and Kovalam estuaries, good macrofauna diversity has been recorded. Macrofauna is a good indicator of the variability of environmental conditions. Benthic macrofauna reflects the ecological conditions prevailing at the sediment-water interface where a multiple effect of organic enrichment and pollutants occur. Thus, benthic macrofauna is considered one of the best biological tools for reflecting environmental change. Thirty crab species were reported in these estuaries; the most dominant crab species were the *Uca* species, followed by *Sesarma brocki*. *Scylla tranquebarica, Uca annulipes, Macrophthalmus depressus, Metapograpsus messor*, and *Sesarma plicatum* were almost found dominant throughout the southern region of the estuary. Commercially important *Scylla.spp* and *Portunus. spp* were caught in large numbers along the mouth region within a distance of 1,000m and near the mangroves in the Adyar, Enoore, and Kovalam estuaries.

A total of 65 genera and 84 species of macrofauna are identified in the Adyar, Enoore, and Kovalam estuaries, consisting of 2 species of *Schyphozoa*, 24 species of *Polychaetes*, 15 species of *Crustaceans*, 42 species of *Molluscs* and one species of *Echinodermata* in the Buckingham Canal region, which is a good indicator of species diversity in his region. Similar to crustaceans, molluscans were also more abundant in mangrove-rich sites than in poor sites. Thirty-six species of molluscan species were identified, of which 24 species were gastropods and 15 species were bivalves. The predominant species in all three sites were *Cerrithidea cingulata*, found throughout the Enoore and Kovalam estuaries until the tail end. *Cassidula nuclei* were found abundantly along the *Avicennia marina* patches in the Adyar, Enoore, and Kovalam estuaries. *Telescopium* was found along the muddy regions and was rarely found in the northern part of the estuary, where only a few mangrove patches exist. Bivalves were largely caught near the mouth of the Enoore and Kovalam estuaries. *Perna viridis* were identified below the crevices of the rocks near the mouth regions.

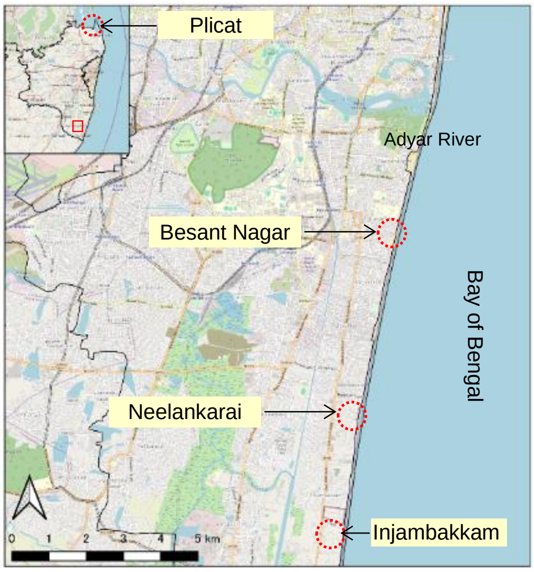
In the Adyar River stretch, fauna consists of both freshwater and estuarine faunal species. About 24 species of crabs and eight species of mollusk were recorded in the Adyar River. Twenty species of reptiles, 11 species of amphibians, and nine species of mammals were recorded. About 101 species of birds were recorded in the Adyar River based on habitat preference, which includes aquatic birds (33 Nos.), water department birds (9), and other birds (59 Nos.).

	
Uca annulipes	Metopograpsus spp
	
Common Sailer (*Neptis hylas*)	Common Crow (*Euploea core*)
	
Yellow-wattled lapwing (*Vanellus malabaricus*)	Birds roosting at Adyar Estuary

Source: JICA Expert Team

Figure 8-19: Sample Photos of the Faunal Environment

In the coastal area along the Bay of Bengal in Chennai, there are four locations for sea turtle nesting recognized, namely Besant Nagar, Injambakkam, Neelankarai, and Pulicat, as shown in the right figure. The species of the sea turtle that lays eggs has been identified as the Olive Ridley Turtle (*Lepidochelys olivacea),* which is classified 'Vulnerable (VU)' by the International Union for Conservation of Nature (IUCN) as a species in increasing danger of extinction. Therefore, during nesting seasons, normally from January to May, hatchery facilities will be prepared for safe hatching by the wildlife officials in Chennai.



Source: India Times

Figure 8-20: Location of Sa Tuttle Nesting Areas

The following table shows a list of faunal species under the 'Threatened' category classified by IUCN in Chennai and surrounding areas.

Table 8-29: Threatened or Near Threatened Faunal Species in Chennai and Around

#	Species	Common Name	Threatened category (IUCN Red List)
Mammals			
1	Antilope cervicapra	Blackbuck	Near Threatened
Avians			
1	*Calidris ferruginea*	Curlew sandpiper	Vulnerable
2	*Haematopus ostralegus*	Eurasian oystercatcher	Near Threatened
3	*Limosa lapponica*	Bar-tailed godwit	Near Threatened
4	*Limnodromus semipalmatus*	Asian dowitcher	Near Threatened
5	*Numenius arquata*	Eurasian curlew	Near Threatened
6	*Pelecanus philippensis*	Spot-billed pelican	Near Threatened
7	*Phoeniconaias minor*	lesser flamingo	Near Threatened
8	*Sterna aurantia*	Indian river tern	Vulnerable
Reptiles			
1	*Lepidochelys olivacea*	Olive Ridley Turtle	Vulnerable

Source: JICA Expert Team

8.9.3.3. Forest Coverage

Chennai city forest cover is about 7.24% (12.61 km2) of its geographical area, of which moderate dense forest is 6.17 km2, open forest is 6.5 km2, and no dense forest. In 2011, only 4% of the total city was covered by forests, and the green cover was largely because of the Theosophical Society campus, the Indian Institute of Technology Madras (IIT-M) campus, Guindy National Park, and Madras Christian College. With greenery efforts and the implementation of eco-restoration in Adyar Poonga Phase I and Phase II, the forest cover has increased to 7.24 % from 4% in 10 years.

8.9.3.4. Protected Areas

(1) Protected areas

The following tables summarize the protected areas in the Chennai metropolitan area and the wetlands/lakes identified by the Tamil Nadu government as requiring priority conservation. It shows that there are 15 priority conservation wetlands/lakes in Kancheepuram district, which is the highest number among the districts in Tamil Nadu. In addition, according to the wetland health index, the value of wetlands/lakes in Chennai district is lower than the others, and the ranking of the wetlands/lakes that require conservation is also higher.

Table 8-30: Protected Areas in the Chennai Metropolitan Area

Name	Category	Area(ha)	District	Certified Year
Karikili Birds Sanctuary	Bird Sanctuary Area	61.21	Kancheepuram	1989
Vedanthangal Birds Sanctuary	Bird Sanctuary Area	30.00	Kancheepuram	1998
Guindy National Park	National Park	270.57	Chennai	1978

Source: TNDoECC

Table 8-31: Prioritised Wetlands and Biodiversity in the Chennai Metropolitan Area

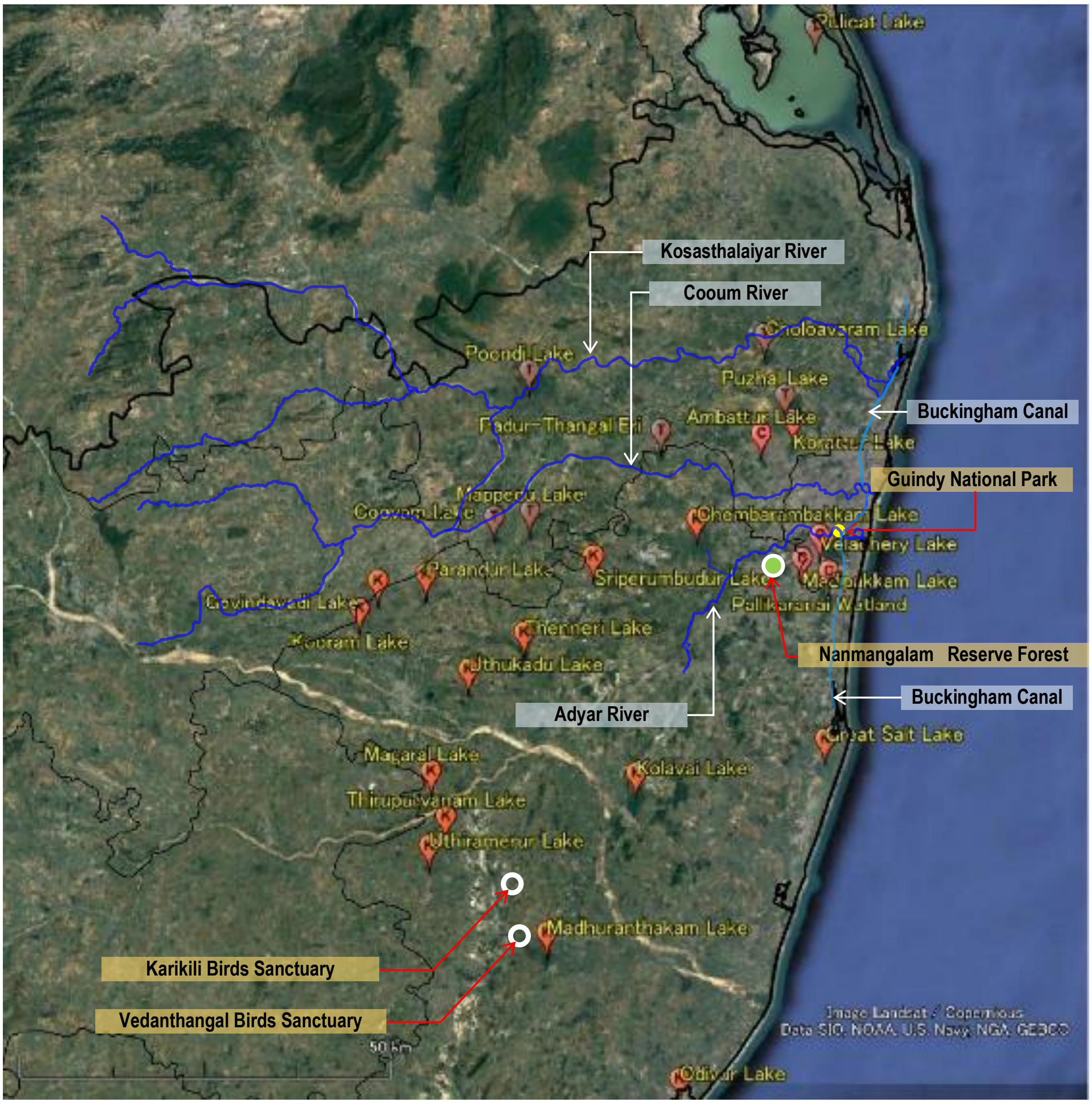
#	Name	Wetland Health Status Score[1]	Rank	Location
Chennai District				
1	Madipakkam Lake	-0.183	4	12°57'41.27"N/80°11'29.28"E
2	Pallikaranai Wetland	0.004	5	12°56'47.86"N/80°13'25.56"E
3	Korattur Lake	0.665	29	13°07'25.42"N/80°10'49.28"E
4	Velachery Lake	1.344	62	12°59'20.17"N/80°12'46.62"E
5	Ambattur Lake	0.636	108	13°06'27.94"N/80°08'29.45"E
Tiruvallur District				
1	Pulicat Lake	1.260	55	13°35'09.34"N/80°12'26.03"E
2	Padur-Thangal Eri	1.377	67	13°06'42.96"N/80°01'07.96"E
3	Mappedu Lake	1.413	76	13°01'02.08"N/79°51'37.10"E
4	Puzhal Lake	2.355	113	13°09'11.37"N/80°10'14.12"E
5	Poondi Lake	2.421	119	13°10'56.67"N/79°51'33.31"E
6	Coovam Lake	2.4344	120	13°00'36.13"N/79°48'59.24"E
7	Choloavaram Lake	4.347	140	13°13'30.21"N/80°08'44.77"E
Kanchipuram District				
1	Magaral Lake	0.305	16	12°42'35.79"N/79°44'23.37"E
2	Great Salt Lake	0.408	20	12°44'53.83"N/80°13'09.83"E
3	Sriperumbudur Lake	0.715	31	12°57'51.48"N/79°56'12.97"E
4	Sirudavoor Lake	1.164	50	12°41'01.69"N/80°08'42.14"E
5	Odiyur Lake	1.227	51	12°20'55.36"N/80°02'30.43"E
6	Parandur Lake	1.27	55	12°56'33.09"N/79°44'00.05"E
7	Chembarambakkam Lake	1.34	61	13°00'26.84"N/80°03'46.41"E
8	Uthukadu Lake	1.352	65	12°49'47.04"N/79°47'07.98"E
9	Kolavai Lake	1.404	73	12°42'29.30"N/ 79°59'20.94"E
10	Thenneri Lake	1.758	102	12°52'22.61"N/ 79°51'12.06"E

[1] Wetland Heath Status is scoring system in Tamil Nadu which involves creating "health cards" for selected wetlands. These cards evaluate ecological and hydrological characteristics, such as soil quality, carbon content, and emissions like methane and nitrous oxide.

#	Name	Wetland Health Status Score[1]	Rank	Location
11	Thirupulivanam Lake	1.867	109	12°39'24.32"N/ 79°45'27.45"E
12	Govindavadi Lake	2.322	111	12°56'5.15"N/ 79°40'26.09"E
13	Uthiramerur Lake	2.342	112	12°37'20.13"N/ 79°44'13.94"E
14	Madhuranthakam Lake	2.855	13	12°31'13.83"N/ 79°52'52.56"E
15	Kooram Lake	3.414	135	12°54'4.72"N/ 79°39'4.41"E

Source: Prioritized Wetlands and its Biodiversity in Tamil Nadu, DoE, Government of Tamil Nadu, 2019

The following figures show the location of protected areas and wetlands/lakes in need of priority conservation in the Chennai metropolitan area and a photograph of the current status of the wetlands.



Source: JICA Expert Team

Figure 8-21: Location of Protected Area and Prioritised Wetland and Biodiversity in the CMA


(Chennai District-1) Madipakkam Lake


(Chennai District-2) Pallikaranai Wetland


(Chennai District-3) Korattur Lake


(Chennai District-4) Velachery Lake


(Chennai District-5) Ambattur Lake


(Tiruvallur District-1) Padur-Thangal Eri


(Tiruvallur District-2) Mappedu Lake

Source: Prioritized Wetlands and its Biodiversity in Tamil Nadu, DoE, Government of Tamil Nadu, 2019

Figure 8-22: Location of Protected Area and Prioritized Wetland and Biodiversity in the CMA (1)

	
(Tiruvallur District-3) Puzhal Lake	(Tiruvallur District-4) Poondi Lake
	
(Tiruvallur District-5) Coovam Lake	(Tiruvallur District-6) Choloavaram Lake
	
(Kanchipuram District-1) Magaral Lake	(Kanchipuram District-2) Great Salt Lake
	
(Kanchipuram District-3) Sriperumbudur Lake	(Kanchipuram District-4) Sirudavoor Lake

Source: Prioritized Wetlands and its Biodiversity in Tamil Nadu, DoE, Government of Tamil Nadu, 2019

Figure 8-23: Location of Protected Area and Prioritized Wetland and Biodiversity in the CMA (2)

	
(Kanchipuram District-5) Odiyur Lake	(Kanchipuram District-6) Parandur Lake
	
(Kanchipuram District-7) Chembarambakkam Lake	(Kanchipuram District-8) Uthukadu Lake
	
(Kanchipuram District-9) Kolavai Lake	(Kanchipuram District-10) Thenneri Lake
	
(Kanchipuram District-11) Thirupulivanam Lake	(Kanchipuram District-12) Govindavadi Lake

Source: Prioritized Wetlands and its Biodiversity in Tamil Nadu, DoE, Government of Tamil Nadu, 2019

Figure 8-24: Location of Protected Area and Prioritized Wetland and Biodiversity in the CMA (3)

(Kanchipuram District-13) Uthiramerur Lake

(Kanchipuram District-14) Madhuranthakam Lake

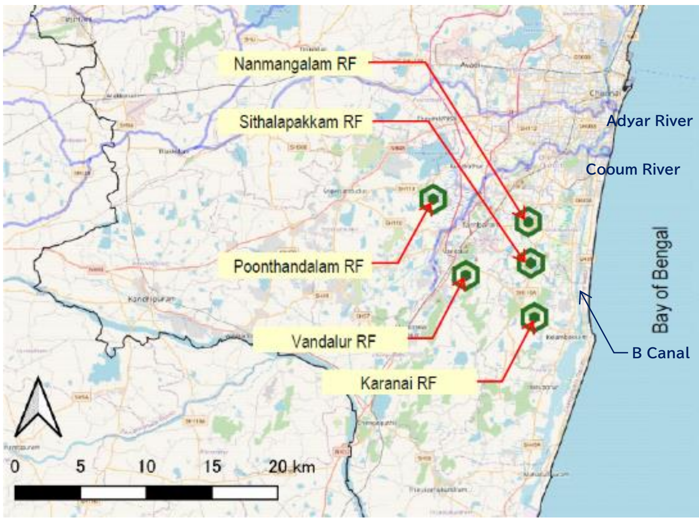
(Kanchipuram District-15) Kooram Lake

Source: Prioritized Wetlands and its Biodiversity in Tamil Nadu, DoE, Government of Tamil Nadu, 2019

Figure 8-25: Location of Protected Area and Prioritized Wetland and Biodiversity in the CMA (4)

8.9.3.5. Reserved Forests

There are five (5) reserved forests identified in the CMA shown in the following figure. These forests are defined as reserved forests under the Forest Conservation Act of 1980 and are managed by the respective districts.



Name of Reserve Forest	District	Size (ha)
Nanmangalam	Chengelpet	320
Sithalapakkam	Chengelpet	890
Poonthandalam	Kancheepuram	1641
Vandalur	Chengelpet	512
Karanai	Chengelpet	2389

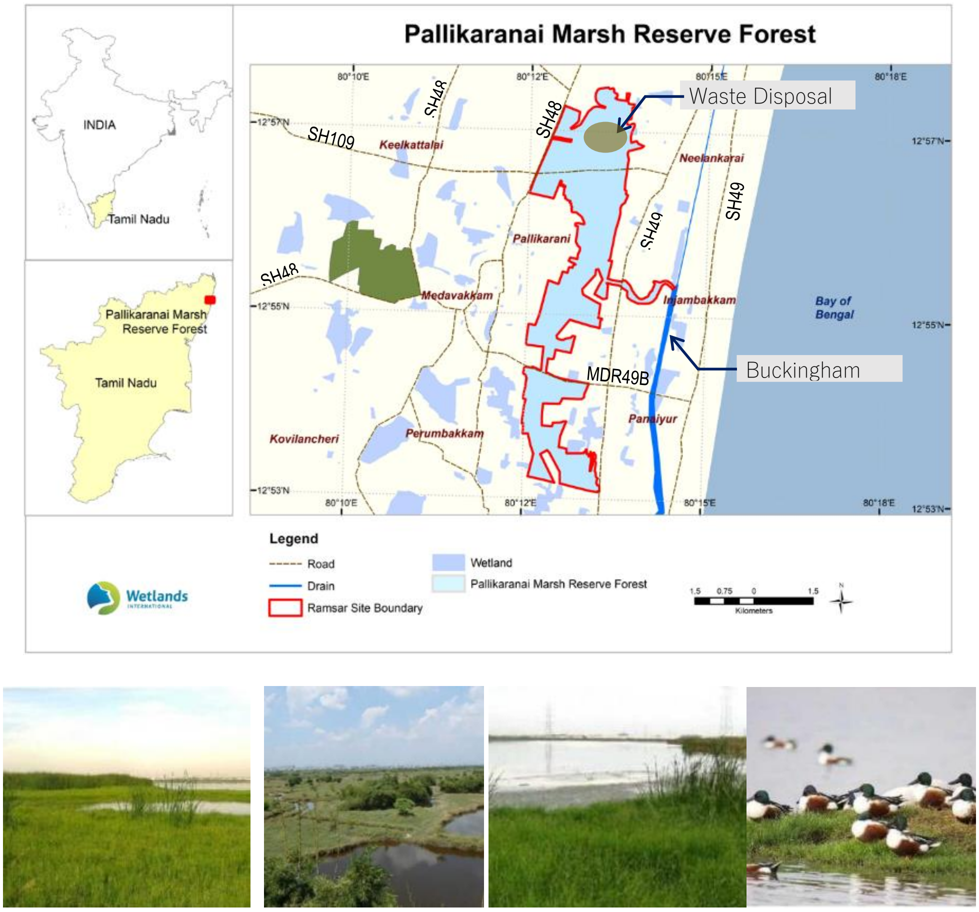
Source: JICA Expert Team

Figure 8-26: Location of Reserve Forest in Chennai

8.9.3.6. Ramsar site

Pallikaranai Marsh Reserve Forest, a freshwater marsh and partly saline wetland situated about 20 kilometers south of Chennai, was registered as a Ramsar site on 8 April 2022 for its biodiversity value and its importance in preventing flooding in the region. Although the site is threatened by invasive and non-native species, household sewage, urban wastewater, and droughts, based on the Convention on Wetland, the conservation of wetlands and waterfowl through the establishment of nature reserves on wetlands shall be promoted under the action plan to be formulated by the government of India. The following figure shows the boundary of the Ramsar Site.

The Greater Chennai Corporation prepared an eco-park plan and held a public hearing for an idea of the biodiversity park in the Pallikaranai Marsh as the next step after a process of biomining in the waste disposal area, Perungudi dump yard. However, when the idea of an eco-park started to appear in 2023, the question of having any of the construction works in the sensitive wetland or reinforcing water retention capacity was raised. Consequently, activation of the eco-park planning has been pending, and comprehensive study and discussion are underway.



Source: Ramsar Sites Information Service (https://rsis.ramsar.org/ris/2481)

Figure 8-27: Location of the Pallikaranai Marsh Reserve Forest

8.9.4 Social Environment

8.9.4.1. Demography

Chennai is one of the largest cities in South India. According to the 2011 Census, Chennai ranked sixth on the scale of most populated cities and fourth among the most populated urban agglomerations in India. The recorded population of Chennai Metropolitan region in 1971 was 35,05,502 lakh, which increased to 86,53,521 lakhs in 2011. CMA has witnessed a rapid increase in population since its formation in 1974 due to sporadic growth of the hardware manufacturing, automobile, healthcare, and IT sectors on the outskirts of the Chennai district, which has, in turn, resulted in a population influx in CMA. The population is estimated to increase in the future and reach 1,18,82,610 in 2025, considering the existing rate of decadal change in population (from 2001 to 2011). CMA has a combination of urban and rural areas. Out of the total CMA, Chennai district is completely urban. The rural population in CMA is found to be in parts of Chengalpattu, Kanchipuram, and Thiruvallur districts.

8.9.4.2. Socio-economic condition

Since India’s independence, Chennai has been a manufacturing-driven economy. This trend has slowly transformed with the growth of the tertiary sector, which includes the IT industry in the region. The tertiary sector in CMA, including transport, railways, communication, real estate, banking, and finance services, contributed significantly to the Gross District Domestic Product (GDDP) in the last two decades.

The GDDP of CMA is not available as it is a combination of several districts. As far as employment in CMA is concerned, the workers in primary activity constituted 6.52% in 1991, which dipped to 2.91% in 2001 and further to 1.3% in 2011. This indicates that the primary activities in the region are on a decline in the peripheral areas due to the emergence of manufacturing and new industries.

(1) Regional GDP

The following table shows the evolution of the GDP of Tamil Nadu and adjacent states and other states, including metropolitan cities, since 2011. It shows that Tamil Nadu, including the Chennai metropolitan area, has the highest GDP value in the South India region, indicating that the state is positioned as a key location of the Indian economy where diverse industries are active. In addition, Chennai is known as the fourth largest city in terms of population after Delhi, Mumbai, and Kolkata, but its state-level GDP is about 1.4 times that of West Bengal, which includes Kolkata, indicating the existence of a wider commercial and industrial area.

Table 8-32: Gross GDP of Tamil Nadu and adjoining states and provinces, including major cities (in ₹ Lakh)

Name	2012–13	2013–14	2014–15	2015–16	2016–17
India (National)	982,656,865	1,114,032,982	1,223,813,450	1,359,230,465	1,534,177,207
Tamil Nadu	85,482,535	96,853,045	107,267,797	117,650,003	130,263,858
Andhra Pradesh	41,140,371	46,427,201	52,497,564	60,422,862	68,441,587

Name	2012–13	2013–14	2014–15	2015–16	2016–17
Karnataka	69,541,305	81,666,615	91,392,303	104,516,810	120,760,772
Kerala	41,231,300	46,504,121	51,256,405	56,199,361	63,488,640
Telangana	40,159,361	45,158,040	50,584,879	57,790,206	65,832,534
Maharashtra（Mumbai）	145,962,863	164,964,663	177,913,793	196,622,458	219,818,515
West Bengal（Kolkata）	59,146,445	67,684,806	71,808,166	79,729,980	87,252,723
Delhi	39,138,764	44,395,989	49,480,302	55,080,370	61,608,506

Source: Ministry of Statistics and Programme Implementation

(2) Industry

Tamil Nadu is one of the most industrialized states in India. Chennai has been among the fastest-growing industrial regions in the country. The manufacturing sector has been at the forefront of CMA’s industrial growth, contributing to employment generation. In the past 10 years, Chennai has witnessed massive infrastructure development, resulting in a boom in the industrial sector, especially medium and large-scale industries in the peripheral areas and extended Chennai Metropolitan region.

Major industries in CMA are automobile and transport equipment manufacturers and their ancillary industries, railway coach building, petrochemicals and fertilizers, automotive tires, bicycles, electrical and other machinery, and leather products. Tamil Nadu accounts for 70% of leather tanning companies in India and 38% of leather footwear and components companies; most of the footwear industries are located within CMA. In the small-scale industrial sector, there were 56,913 units in Chennai District, 37,531 in Kancheepuram, and 17,843 in Thiruvallur District as of March 2007, which accounts for about 21.16% of the units in the state (530,552 units). The small-scale industrial sector in Chennai, Kancheepuram, and Thiruvallur districts is dominated by metals, rubber, and plastic products, electrical machinery, transport equipment, leather and fur products, and non-metallic mineral products. Chennai is perhaps the only city in India to have all the top 10 IT Indian multinational companies. Industries in the CMA receive water from both surface and groundwater sources. Around 40 million liters per day (MLD) of freshwater is being supplied to water-intensive industries in Manali, Minjur, and Ennore in North Chennai and Oragadam and Sriperumbudur in the city’s suburbs from Chembarambakkam reservoir (lake) and Minjur desalination plant.

(3) Agriculture

According to the statistical handbook 2020-2021 prepared by the government of Tamil Nadu, the total area of paddy fields in Chennai and surrounding districts is estimated to be about 202,077 ha, which accounts for about 85% of the agricultural fields in the areas. The following table shows crop yields in Chennai and surrounding districts, which indicates that most of the agricultural fields in the project area are paddy fields, and the existing water tank is mostly used for irrigation and rice harvesting.

Table 8-33: Areal Production and Productivity of Principal Crops

		District Name				Total
		Chennai	Kancheepuram	Chengalpattu	Thiruvallur	
District Area (ha)		42,600	144,800	294,500	342,300	824,200
Total Agricultural Fields (ha)		116	52,454	63,583	123,031	239,184
% of Agricultural Fields		0.27	36.23	21.59	35.94	29.02
The area under Principal Crops (ha)	Paddy	108	47,739	53,119	101,111	202,077
	Cumbu & other cereal	0	56	196	964	1,216
	Maize	0	0	0	3	3
	Pulses	1	1,228	1,333	7,667	10,229
	Sugar cane	0	634	808	3,824	5,266
	Cotton	0	0	0	0	0
	Ground nut	2	2,421	7,304	6,827	16,554
	Gingelly	5	376	822	2,635	3,838
	Castor	0	0	1	0	1
% of Paddy Area		93.10	91.01	83.54	82.18	84.49

Source: The Statistical Handbook 2020-2021

Regarding the paddy fields, double or triple cropping is practiced in Tamil Nadu, depending on the type of rice. The paddy fields harvesting Early Samba rice is typical in Tamil Nadu due to its shorter duration from sowing to harvest, allowing for earlier harvesting and potentially reducing the risk of crop damage from adverse weather conditions such as heavy rainfall or cyclones. For these paddy fields, the first sowing season is generally in March and April, and its harvest season is in July and August. The second sowing season comes after the first harvest season in September and October, and the harvest season is followed by the sowing in January and February, as shown in the following table. In this circumstance, when the proposed water tanks need a function of retaining runoff water during the rainy season, September to December, the water tanks where Early Samba rice is grown in the vicinity can be empty and be ready for its retaining function. Otherwise, it is necessary to ensure irrigation water for the paddy fields of other rice types, which requires appropriate consideration coordination during the basic design stage.

Table 8-34: Seasons of Rice Production in the Southern Region of India

#	Region/State	Autumn		Winter		Summer	
		Sowing	Harvesting	Sowing	Harvesting	Sowing	Harvesting
1	Andhra Pradesh	Mar.-Apr.	Jun.-Aug	May-Jun.	Nov.-Dec.	Dec.-Jan.	Apr.-May
2	Karnataka	May-Aug.	Sep.-Dec.	Jun.-Oct.	Nov.-Mar.	Dec.-Feb.	Apr.-Jul.
3	Kerala	Apr.-Jun.	Sep.-Oct	Sep.-Oct.	Dec.-Jan.	Dec.-Jan.	Mar.-Apr.
4	Tamil Nadu	Mar.-Apr. (Sornavari rice)	Jun.-Jul.	Jul.-Aug. (Erly Samba rice)	Jan.-Feb.	-	-
		Apr.-May (Kar rice)	Jun.-Aug.	Sep.-Oct. (Late samba rice)	Jan.-Feb.	Nov.-Dec. (Navarai rice)	Feb.-Mar.
		-	-	May-Jun (Kuruvai rice)	Aug.-Sep.	Sep.-Oct. (Thaladi/Pishanam rice)	Feb.-Mar.

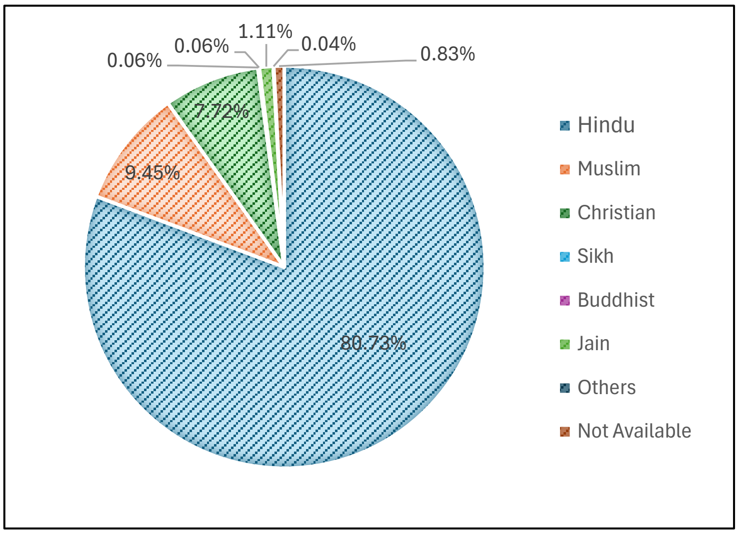
Source: All India Rice Exporters Association

8.9.4.3. Culture

(1) Religion

Being the birthplace of many of the world's major religions, India is characterized by a diversity of religious beliefs. Aside from Hinduism, Jainism, Buddhism, and Sikhism, which originated in India, Islam, Christianity, Zoroastrianism, and the Bahai Faith are also found. Similar to the national trend, over 80% of the population in Chennai practice Hinduism, according to the census 2011. Christianity forms 7.72% of the population in Chennai, while it is 2.3% in the entire nation. The following figure shows the population rate of religion in Chennai.

As indicated by the high percentage of Hindus in the population, there are a large number of Hindu temples throughout the districts of the CMA, ranging in size from the symbolic level as a tourist resource to the monumental level on a street corner. Therefore, it would be necessary if local religious structures would be affected by the prioritized projects, and appropriate mitigation measures such as relocation, if unavoidable, should be taken into consultation with the local people on time.



Source: Census of India, 2011

Figure 8-28: Religious Population Rate in Chennai

(2) Language

According to the Constitution, the official language of India is Hindi (Article 343 (1)). English is still being used as the official language, and official documents are all in English or translated into English. Many languages are spoken in various regions of India. The current 29 states were reorganized on a linguistic basis in 1956 after the end of colonialism. Officially recognized languages (22 scheduled languages) are recognized as official languages by each state. In Chennai, Tamil Nadu, the language of Tamil is spoken by over 75% of people, followed by Telugu and Urdu. Historically, English was the administrative language before independence, but English's official language status was contested and received opposition, having been the sole language for India, where multiple languages and linguistic cultures have developed. However, English is still being used in business communication in the globalized economy of India.

For the implementation of the project, to build consensus on the detailed development works, it is essential to consider stakeholders' accustomed language during the chance of discussions and decision-making.

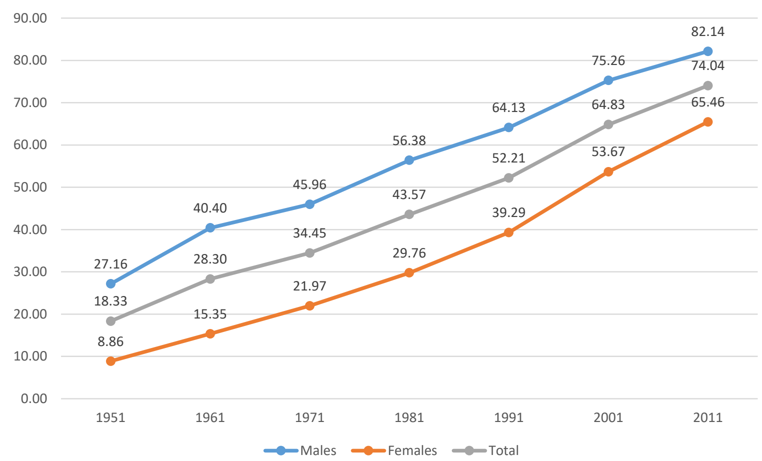
(3) Caste

The caste system in India today is not as prominent a social issue as before, given that Article 17 of the Constitution of India declared the practice of untouchability to be illegal, and presidential legislation, state laws, and regulations extended enforcement of affirmative actions in employment and education. Yet, the caste system itself is not banned, and in Hindu communities, the caste system is deeply embedded. In 2016, the "untouchable" group of Hindus (Scheduled Caste) of Tamil Nadu was denied access to a local temple. It was reported that they planned to convert to Islam in response to this denial, and the local Muslims were criticized for agitation.

During the planning phase of the project, it would be crucial to pay attention to the communities or people who might be discriminated against in the customary Caste system and to ensure social inclusion by collecting opinions from various residents.

(4) Education

The figure below shows the literacy rate in India by gender. Although the literacy rate in total has continued to improve since 1951, the gender gap in literacy is still evident. In 2011, the literacy rate of adult males was 82.14%, while that of adult females was 65.46%.



Source: Provisional Population Totals – India (Chapter 6: State of Literacy, p.102)

Figure 8-29: Literacy Rates of Adult Male and Female (1951-2011)

The gender gap in literacy in Chennai and Chennai Metropolitan Area is less prominent, with over 86% of adult female literacy rate, which is only 7 points lower than that of males.

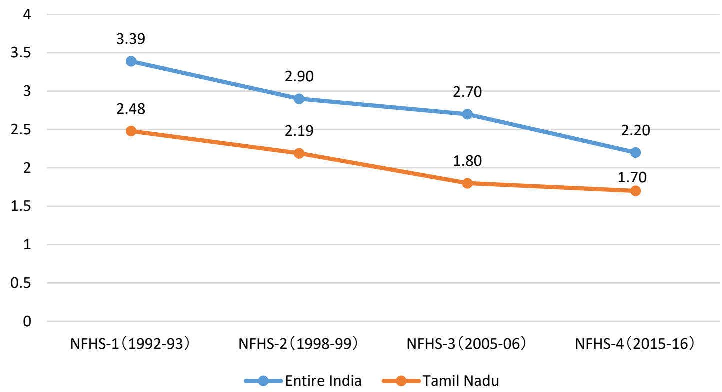
Table 8-35: Adult Literacy Rate in Chennai and Chennai Metropolitan Area (2011)

	Chennai City			CMA		
	Total	Male	Female	Total	Male	Female
Total Population	4,646,732	2,335,844	2,3108,88	8,653,521	4,538,612	4,294,909
Literate	3,776,276	1,968,079	1,808,197	7,000,270	3,660,527	3,339,743
Literacy Rate (%)	90.18	93.70	86.64	90.23	93.86	86.55

Source: Census, 2011

8.9.4.4. Public health

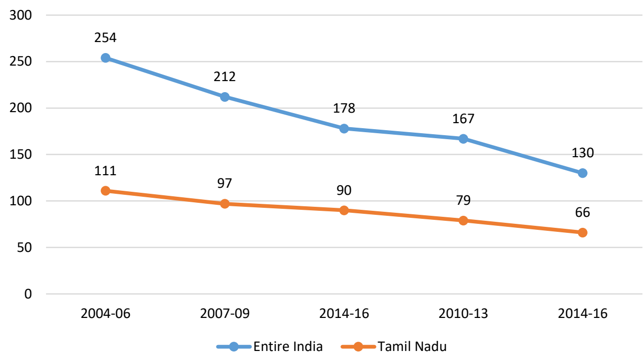
Compared to 1992-93, the birth rate in India in 2015-16 dropped from 3.39 births to 2.2 births per woman. The birth rate of Tamil Nadu is 0.5 points lower than the national average.



Source: NFHS-1, 2, 3, 4

Figure 8-30: Trend in Birth Rate in India and Tamil Nadu

The maternal mortality rate (MMR) per 100,000 live births in India was 254 in 2004-2006. It improved to 130 cases in 2014-2016. Similar to the national trend, the MMR in Tamil Nadu is showing improvement. High MMR in India is attributable to a large number of home births as opposed to births at medical facilities and limited prenatal and postnatal check-ups, among other reasons.



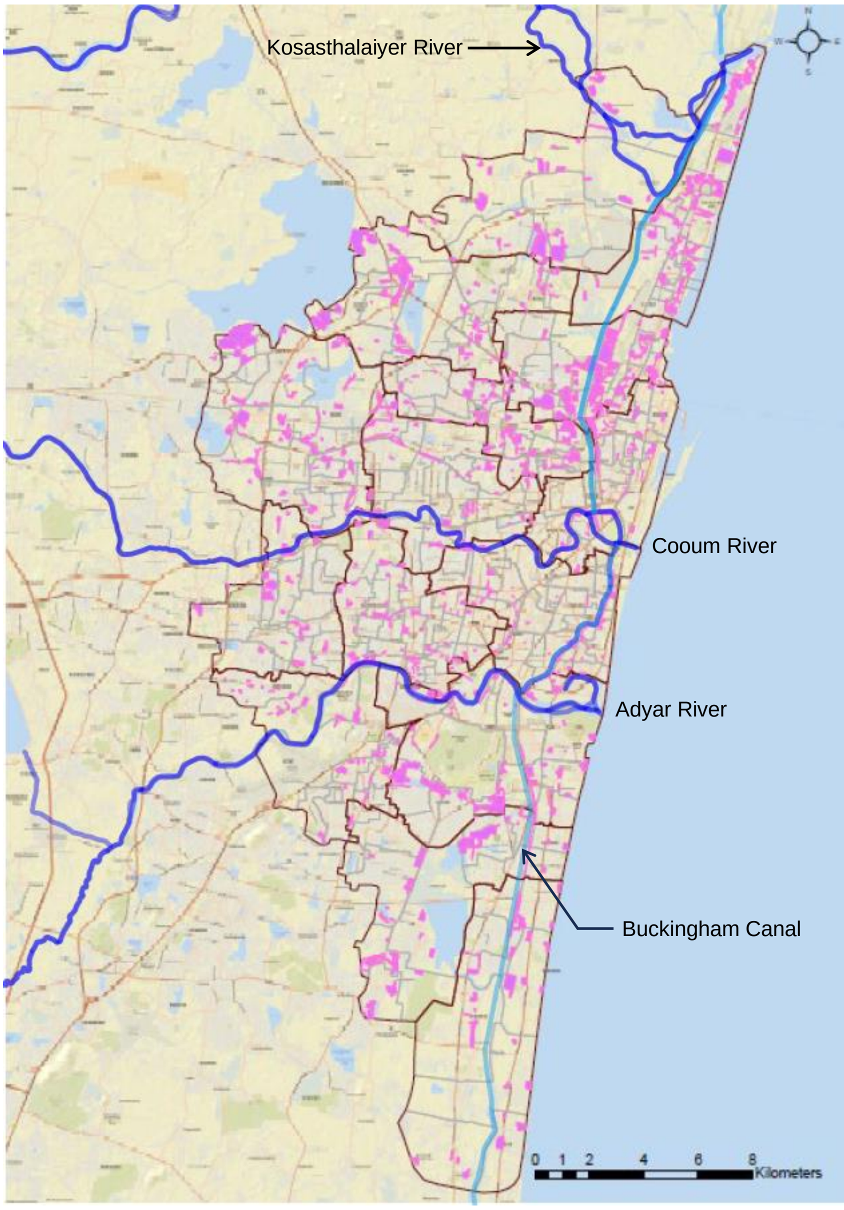
Source: NITI Aayog, http://niti.gov.in/content/maternal-mortality-ratio-mmr-100000-live-births

Figure 8-31: Maternal Mortality Rate in India and Tamil Nadu (2004-2016)

8.9.4.5. Poverty

Chennai (1.39M) is fourth on the list of total slum populations among Mumbai (5.21M), Hyderabad (2.29M) and Kolkata (1.41M). As of the provisional population totals of 2001, the slums in Chennai have 10,79,414 people, which constituted 25.6% of the total population of the city. Salem and Trichy had 23% and 19% of the population living in slums. Out of the totals in Chennai, 548,517 were males, and the rest were 530,897 females. The child sex ratio was 968 females to every 1,000 males compared to the non-slum sex ratio of 945. The literacy rate of the slum population was 80.09%, with 85.77% in males and 74.21% in females. A total of 125,725 households constitute 81,128 permanent (64.53%), 22,415 semi-permanent (17.83%), and 22,182 temporary households (17.64%). 66.96% of houses had single rooms, 24.19% had two, 5.85% had three, and 2.17% had more than three rooms. There was a total of 70,689 households (56.23%) that own houses, 50,764 (40.38%) with rented houses and 4,272 (3.39%) with other houses. Only 26% of the total population had access to water in their houses, while the majority traveled at least 500m to get drinking water. Handpumps and pipes are the major sources of water. There were 38,838 (30.89%) hand pumps, 53,556 (42.60%) water pipes, 3,162 (2.52%) tube wells, 4,665 wells, and 25,062 (19.93%) other sources of water. Only 79.41% of the slum dwellers had access to electricity, and 1,409 households had no access to lighting. Around 34% of the households had no latrines, resulting in the spread of diseases. Around 43.87% of households had a radio, while 60.07% of households had televisions.

Regarding the slum areas in GCC, many slum areas can be found along the water bodies, including the rivers and canals, as shown in the following figure.



Source: TNUHDB

Figure 8-32: Location of Slums in GCC

8.9.4.6. Landscape

Chennai is situated in a vast alluvial lowland plain, intersected by rivers running from the mountains in the west to the sea. During serious rainstorms, the urbanized area suffers not only from the large amounts of water dropping from the sky immediately on the city but also from the run-off of swelling rivers, discharging extra rainwater from upstream through the urbanized area to the sea. Urban Chennai has become the central drainage pit of the whole region. An effective solution for the retention and discharge of stormwater in Chennai is only possible when the urban area no longer plays a role as the drainage pit of the region. This is possible by creating a regional green-blue framework with a main role for watercourses and rivers, lakes, and ponds, combined with green slopes and parklands. These will be developed as robust green-blue corridors that provide ecosystem services: freshwater, ecology, recreation, urban climate control, etc. Together with parks and natural reserves, they form a continuous structure as a backbone for urban development and agriculture. Individual green-blue ponds are scattered throughout the region and form a complementary system for retaining water. The transportation structure will function as a second conditional tier for urban development.

The vision of a regional green-blue framework offers a comprehensive strategy to manage floods and increase water recharge and retention capacities in a multi-scalar manner. It addresses urban water management through strategies of reforestation, green-blue belts, restoration, and creation of lakes and also devises strategies for densification, creation of urban centers, and urban infrastructure. Together, these strategies envision the New Chennai Metropolitan Area as a water-rich, healthy, and sustainable urban region.

(1) Gender issues

The World Bank reports the female labor force participation rate in India and neighboring countries from 2009 to 2019. Since 2014, India has been in the last place for female participation in the labor force. In 2019, the rate dropped to 20.79%, over 15% lower than Bangladesh at the second place. Given that the male labor force participation rate of India in 2019 was 74.4%, significant gender inequality in labor participation is present.

In Tamil Nadu, female labor force participation in urban areas is comparable to the national trend. In rural areas, however, the female participation rate was 37.8% in 2011 and 29.4% in 2017, about 9 points higher than the national average. Women participating in agriculture in rural areas of Tamil Nadu is a likely contributing factor.

(2) Children’s rights

Indian National Commission for Protection of Child Rights (NCPCR) emphasizes the principle of universality and inviolability of child rights and recognizes the tone of urgency in all the child-related policies of the country. Protection of all children in the 0 to 18-year-old age group is of equal importance. This includes focusing on regions that are backward or on communities or children under certain circumstances, and so on. The task of reaching out to all children gets compromised, and a societal tolerance of violation of child rights continues. It considers that it is only in building a larger atmosphere in favor of the protection of children’s rights that children who are targeted become visible and gain confidence to access their entitlements.

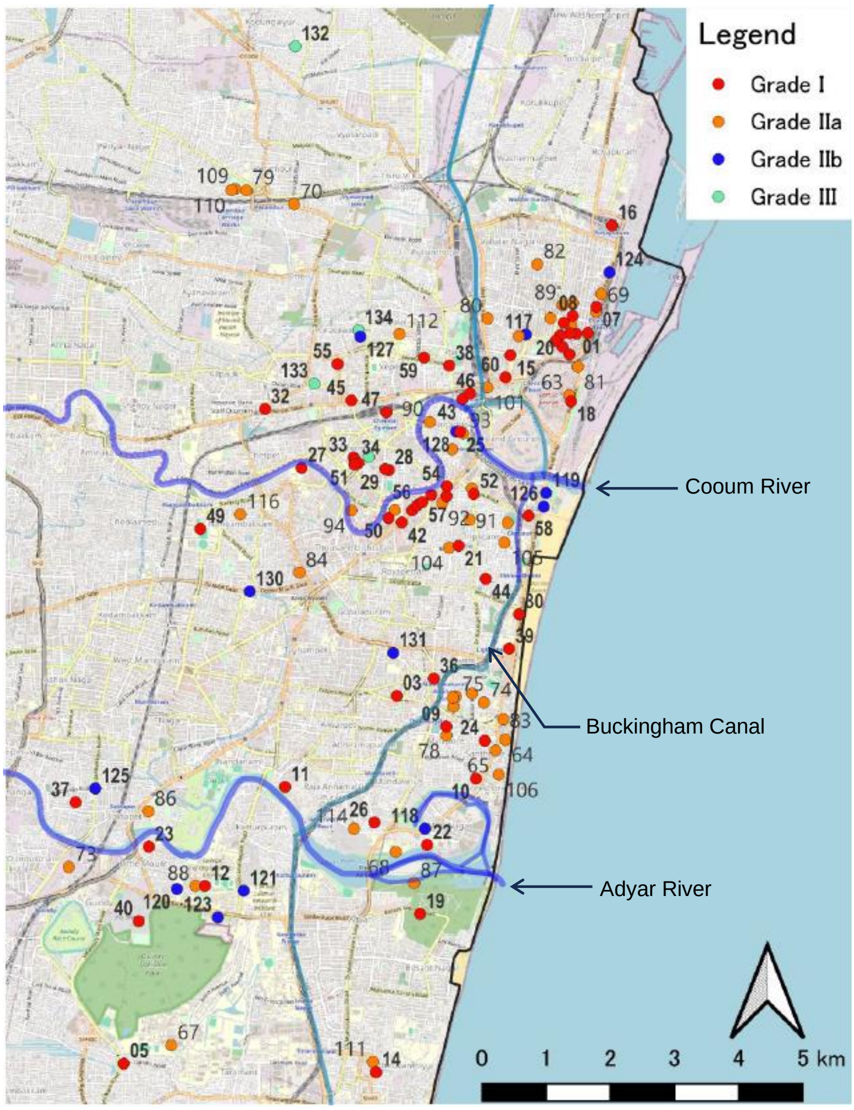
Tamil Nadu State Government is providing free and Compulsory Education to all Children of the age group from 6 to 14 years under the Right to Children for Free and Compulsory Education Act 2009 and preventing the employment of children below the age of 14 years in the factories, mines or hazardous occupations under the Child Labour (Prohibition and Regulation) Act 1986 and also ensuring the protection of constitutional and legal rights of the Children with a commitment to provide the opportunity and facilities to the development of Children in a healthy atmosphere with required freedom.

Subsequently, the Central Government enacted the Commissions for Protection of Child Rights Act 2005, thereby providing the constitution of NCPCR and SCPCRs. In the above context, the Tamil Nadu Commission for Protection of Child Rights (TNCPCR) has been formed vide G.O. (Ms) No.45, Social Welfare and Nutritious Meal Programme (SW8) Department, dated 28.03.2012, as per section 17 (1) of the Commissions for Protection of Child Rights Act 2005, and from 18.01.2013, the TNCPCR has been functioning effectively.

8.9.4.7. Cultural heritage

There are 136 heritage buildings/precincts identified by the CMDA, which are notified under the State Act in Chennai. The following figure shows the location of the heritage assets. The heritage structures are categorized into three grades, as shown in the following table: Grades I, II, and III. Grade I structure will be prime landmarks upon which no alternations will be permitted. Under Grade II, external changes in structures will be subject to scrutiny. Buildings under Grade III may be changed for 'adaptive reuse' with suitable internal and external changes. Regarding the distribution of the building heritages, all of them are located in the urbanized district of Chennai. Especially many are compacted in Georgetown, which is one of the historical areas in Chennai near the Chennai Port, where the colonial-era buildings, including the 17th century Fort St. George, were established. Moreover, it is also noteworthy that many of the heritage assets located in the historical areas around the Fort of George, including Vepery, Egmore, and Triplicane, are in the High Flood Prone (HFP) areas mentioned in the following section.

Although there is no doubt that the safety of citizens and the health of economic activity are the priorities for the development of the flood control master plan, preserving these heritage assets by protecting against damage caused by periodic flooding would be one of the controversial issues.



Source: CMDA

Figure 8-33: Location of Building Heritage Assets in the CMA

Table 8-36: List of Building Heritage in the CMA

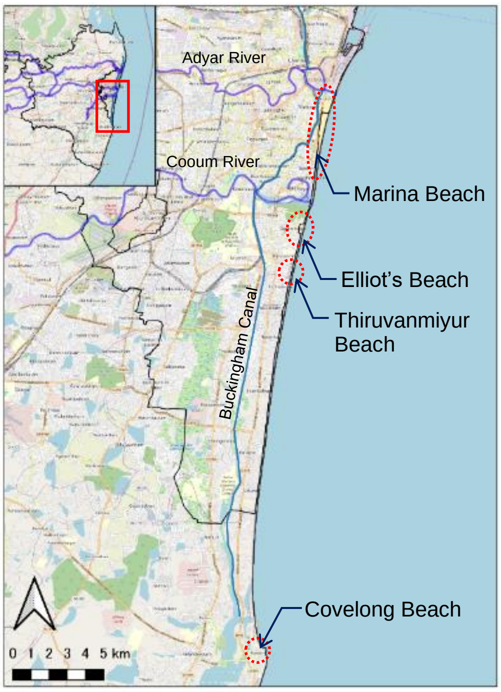
S.No.	Name of the Building	Grade	S.No.	Name of the Building	Grade	S.No.	Name of the Building	Grade
1	Anderson Church	I	46	Chennai Central Railway Station	I	91	Anwari Mosque	IIa
2	Armenian Church	I	47	Chennai Egmore Railway Station	I	92	Cosmopolitan Club	IIa
3	Luz Church	I	48	Christ Church	I	93	F1 Police Station	IIa
4	City Civil Court Building	I	49	Church of Christ the King	I	94	Freemasons Hall	IIa
5	Dandeeswara Temple	I	50	Connemara Hotel	I	95	Assistant Resident Medical Officer	IIa
6	Dare House, NSC Bose Road	I	51	Connemara Public Library	I	96	Female Ward	IIa
7	General Post Office	I	52	Curzon & Company	I	97	Gifford School	IIa
8	Gokhale Hall, Armenian Street	I	53	Durgah Hazareth Syed Moosa	I	98	Gynaecology 'G' Ward	IIa
9	Kapaleeshwar Temple	I	54	Electric Theatre	I	99	H Operation Theatre	IIa
10	Lazarus Church	I	55	Gangadhareeswarar Temple	I	100	Nurses Quarters	IIa
11	Madras Club	I	56	Gove Buildings	I	101	Outpatient Block	IIa
12	Madras Engineering College	I	57	Higginbotham	I	102	Resident Medical Officer Quarters	IIa
13	Madras High Court	I	58	HumayunMahal	I	103	Goschen Hall	IIa
14	Marundeeswarar Temple	I	59	Government Veterinary College	I	104	Jandha Mosque	IIa
15	Muthukumaraswami Temple	I	60	Memorial Hall	I	105	Kasturba Gandhi Hospital	IIa
16	Royapuram Railway Terminal	I	61	Binny Limited	IIa	106	Leith Castle	IIa
17	St. Columban's High School	I	62	Chenna Keshsava Perumal temples	IIa	107	Madras Cricket Club	IIa
18	State Bank of India	I	63	Cornwallis Cupola	IIa	108	Curator Residence	IIa
19	Theosophical Society – HQ Building	I	64	CSI St. Thomas English Church	IIa	109	Railway Higher Secondary School	IIa
20	Young Men's Christian Association	I	65	CSI St. Thomas Tamil Church	IIa	110	Railway Institute New Hall	IIa
21	Ameerunnisa Begum Sahib Mosque	I	66	Dharmaraja Temple	IIa	111	Saint Valmikinathar Temple	IIa

S.No.	Name of the Building	Grade	S.No.	Name of the Building	Grade	S.No.	Name of the Building	Grade
22	Chettinad Palace	I	67	Electrical Laboratory	IIa	112	St Paul's Church	IIa
23	Church Of Our Lady Health	I	68	Government Music College	IIa	113	Triplicane Police Station	IIa
24	Church Of the Holy Rosary	I	69	Hongkong and Shanghai Bank	IIa	114	Vasanta Vihar	IIa
25	CSI Zion Church	I	70	Jamalia Higher Secondary School	IIa	115	Madras – I –Azam	IIa
26	Director General of Police's Office	I	71	Karneesvarar Temple	IIa	116	Sterling Gardens	IIa
27	Doveton House	I	72	Katchleshwara Temple	IIa	117	Adams Building, NSC Bose Road	IIb
28	Government Ophthalmic Hospital	I	73	King's Institute of Preventive Medicine	IIa	118	Annal Ambedkar Ninaivakam	IIb
29	Government Ophthalmic Hospital	I	74	Kolavizhi Amman Temple	IIa	119	Anna Square	IIb
30	Icehouse (Vivekananda Illam)	I	75	Madhava Perumal Temple	IIa	120	Audio Visual Research Centre	IIb
31	Law College	I	76	Metropolitan Magistrates Court	IIa	121	Birla Planetarium	IIb
32	Kilpauk Medical College	I	77	Mundakanniamman Temple	IIa	122	Catholic Centre	IIb
33	Government Museum Main Building	I	78	Mylapore Hindu Permanent Fund Ltd.	IIa	123	Gandhi Mandapam	IIb
34	Government Museum Theatre	I	79	Our Lady of Lourdes Church	IIa	124	Gordon & Woodroffe Building	IIb
35	Centenary Exhibition Hall	I	80	Pachiappa's College Higher Secondary School	IIa	125	Kadumbadi Chinnaman Koil	IIb
36	Madras Sanskrit College	I	81	Reserve Bank of India	IIa	126	MGR Memorial	IIb
37	Prasanna Venkatesha Narasimha Temple	I	82	Seven Wells Market	IIa	127	Perumalpet 24 hrs Hospital	IIb
38	Periamet Mosque	I	83	St. Bede's Anglo Indian Higher S. School	IIa	128	CSI Zion Church Nursery	IIb
39	Queen Mary's College	I	84	St. Theresa Church	IIa	129	Museum Activity Centre	IIb
40	Raj Bhavan	I	85	St. Thomas Orthodox Cathedral	IIa	130	Valluvar Kottam	IIb
41	Addison's	I	86	Teacher's Training College	IIa	131	St Ebba's Girls Higher S. School	IIb
42	Agurchand Mansions	I	87	Theosophical Society	IIa	132	Lakshmi Narayana Prasanna Ramasamy Thirukoil	III
43	Anatomy Block	I	88	Traffic Engineering Building	IIa	133	Srinivasa Perumal Temple	III
44	Bharathiyar Illam	I	89	Tuckers church	IIa	134	Vempadi Vinayagar Temple	III
45	C.S.I Egmore Wesley Church	I	90	Adhipureeswarar Adhi Kesava Temple	IIa	135	Madras Museum Complex	-
		I	90	Adhipureeswarar Adhi Kesava Temple	IIa	136	Govt. Women Children Hospital Complex	-

Source: CMDA

(1) Tourism elements (coastal areas)

The tourism elements of the coastal area in Chennai are diverse and cater to various interests, ranging from natural beauty to cultural heritage. There are four famous and popular beaches along the Bay of Bengal, as shown in the following figure.



#	Name and Characteristics
1	Marina Beach: One of the longest urban beaches in the world, Marina Beach is Chennai's most famous coastal attraction, such as horse riding, beach volleyball, and a scenic walking promenade. It is a popular area with both locals and tourists.
2	Elliot's Beach (Besant Nagar Beach) Elliot's Beach is known for its serene atmosphere, clean surroundings, and religious sites like the Velankanni Church and the Ashtalakshmi Temple.
3	Thiruvanmiyur Beach Thiruvanmiyur beach is ideal for those looking for peace and solitude. It is also near the famous Marundeeswarar Temple.
4	Covelong Beach Located about 40 km from Chennai, Covelong Beach is popular for water sports like windsurfing and kite surfing. The nearby Fort and Church add historical interest.

Source: JICA Expert Team

Figure 8-34: Beaches as Tourism Elements in Chennai

8.9.5 Natural hazards

8.9.5.1. Earthquake-prone areas

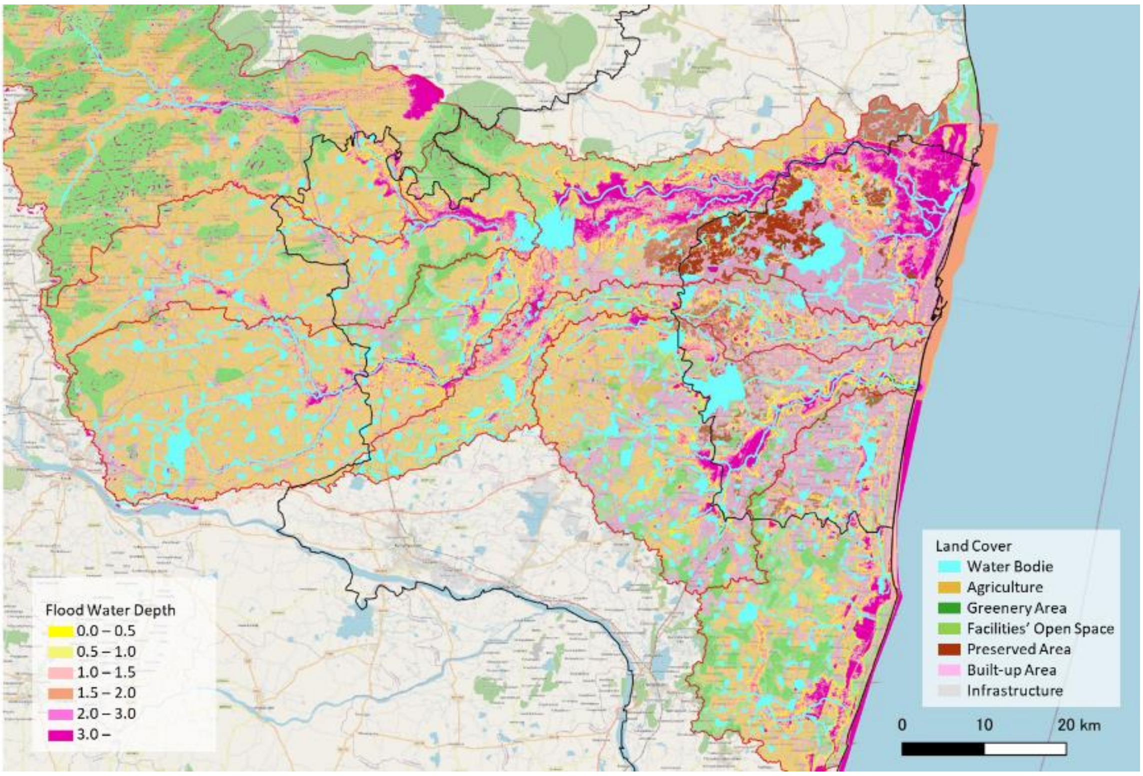
Chennai Metropolitan Area falls under Seismic Zone–III, classified as a Moderate Damage Risk Zone by the National Centre for Seismology in India. The whole of the Chennai Metropolitan Area falls in this zone.

8.9.5.2. Cyclone-prone areas

In the Chennai Metropolitan Area, it extends to a distance of 20 km from the coast. In these areas, the risk is due to (a) cyclonic wind velocities combined with heavy storms, (b) flooding by seawater due to high waves, and (c) flooding due to heavy storms.

8.9.5.3. Flood-Prone areas

In the Chennai Metropolitan Area, there are a few areas along the rivers and canals and low-lying areas that are susceptible to flooding/inundation during heavy storms. The following map shows the floodable areas [macro level] identified in the Madras Metro Flood Relief / Storm Water Drainage Master plan. The existence of macro and micro drainage networks in the Chennai Metropolitan Area facilitates the draining of these areas within a reasonable time. Developments in such low-lying areas are allowed only when a proposed development conforms to standards and after getting clearance from PWD on the measures to be taken to make it free from inundation.



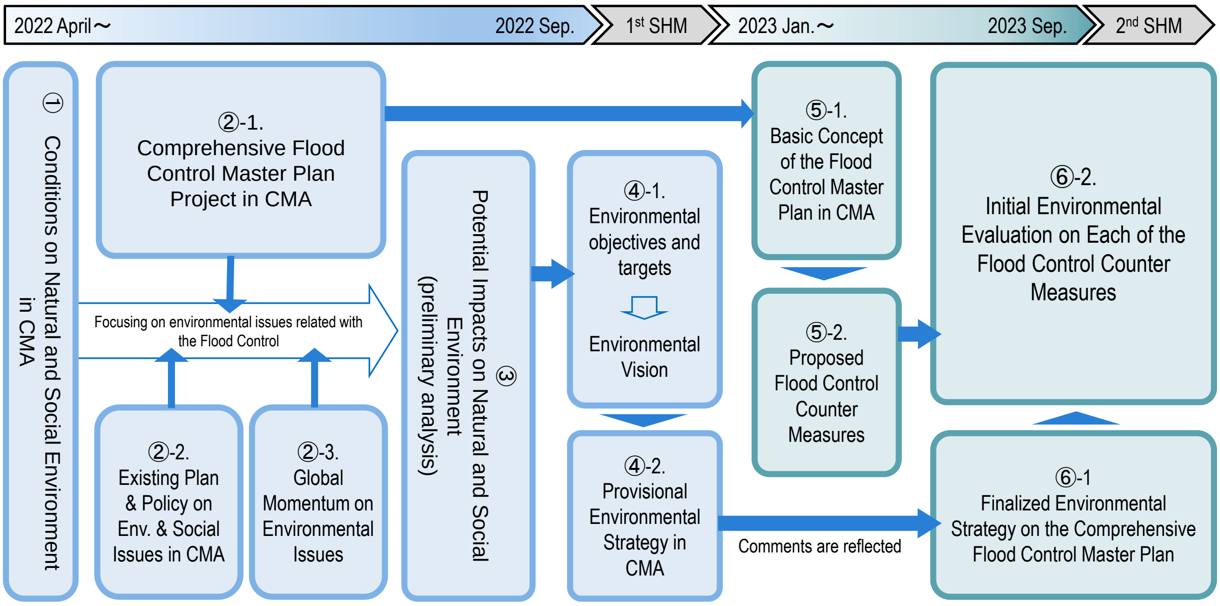
Source: JICA Expert Team

Figure 8-35: Flood Hazard Map (100-year probability)

8.10 Strategic Environmental Assessment (SEA)

8.10.1 Structure of the SEA

The SEA study will be carried out based on the following structure.



Source: JICA Expert Team

Figure 8-36: Structure of the SEA study

8.10.2 Environmental Impact Assessment

8.10.2.1. Overview of the physical measures

The evaluation of the impacts on the natural and social environment for the prioritized physical measures for the CFCMP mentioned above is summarized in the following table, comparing it to that in the scoping stage.

Regarding the mitigation measures to be examined in this section, 25 physical measures in 3 categories, namely Fluvial (River) Flood Control Measures as ‘A,’ Pluvial (Drainage) Flood Control Measures as ‘B,’ and Coastal Flood Control Measures as ‘C’ are chosen as shown in the following table.

Table 8-37: 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 the 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-layer 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 mauve Surplus Channelization-2 (Widening Riverbank)	Earthworks for widening riverbanks, construction of raised bank
	A5: All river basin	A5-①: Water tank 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 the connecting drains to Adyar and Cooum Rivers (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
C: Coastal Flood Control Measure		C-①: Training wall construction at Muttukadu	Earthworks in the river mouth, construction of training walls

Source: JICA Expert Team

8.10.2.2. Major negative impacts

(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, with high levels of Chloride (Cl) and Nitrate (NO3) and low levels of the Dissolved Oxygen (DO). Generally, it can be determined that the low water quality is caused by the untreated inflow of domestic, agricultural, and industrial wastewater into the rivers and canals, resulting from the extraordinary growth of phytoplankton and other algae and leading to eutrophication. 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. Therefore, when the physical measures involve the inflow of low-quality water by connecting the river/canal to the reservoirs or the Bay of Bengal, based on the detailed environmental examination considering especially accumulative negative impact in a long-term period, prudent correspondence and actions are required during the planning stage. Additionally, the sediment soil in the projected river and canal contains high levels of heavy metals such as Magnesium (Mg), Zinc (Zn), Nickel (Ni), Copper (Cu), and Cadmium (Cd). Since these heavy metals are generally toxic to human health, careful attention must be paid if the physical measures are carried out accompanied by utilization of the excavated sediment soil or movement of the contaminated soil. The following table shows a list of flood control measures possibly resulting in water pollution.

Table 8-38: List of measures possibly resulting in water pollution

Category #	Measure	Remark
A5-①	Water tanks rehabilitation	Due to the low quality of the existing river and canal water, the discharge of untreated water into the rehabilitated or developed ponds could raise the new water pollution issue.
B1-③, B4-③	Water tank rehabilitation and development	
A1, A2, A3, A4	River or Surplus Channelization	Because the existing sediment soil contains excessive heavy metals, utilization of the excavated sediment soil or movement of the contaminated soil could lead to secondary negative environmental impact on water or soil pollution.
A5	Water tank rehabilitation and development	
B1-③, B4-③	Water tank rehabilitation and development	

Source: JICA Expert Team

(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. However, from the perspective of retaining rainwater and having a natural environment with prudent biodiversity or ecosystem, it would be beneficial if the physical measures were implemented based on a development policy that includes the improvement of the natural environment, including the presence of abundant wetlands with sustainable management in the urban area.

In the list of the prioritized physical measures in the CFCMP, some are accompanied by the construction of a concrete structure at the coastal areas of the Bay of Bengal, such as ‘River Mouth Renovation,’ ‘Underground River Construction,’ and ‘Diversion Channel Construction.’ As shown in the previous section, most of the coastal areas in Chennai are designated as the Coastal Regulation Zone under the relevant Act. Therefore, the physical measures must be carried out based on the detailed environmental assessment of the aquatic ecosystem by the relevant national and state 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 wetland functions related to biodiversity should be given due attention. The following table shows a list of flood control measures possibly resulting in degradation of biodiversity.

Table 8-39: List of measures possibly resulting in the degradation of biodiversity

Category #	Measure	Remark
A1, A2, A3, A4	River or Surplus Channelization	Cutting a large volume of wood in the existing river environment and new detention pond areas could affect the existing biodiversity.
A5-②	New detention pond development	
A1-③	Underground River Construction	A discharge outlet structure connecting the existing beach could affect the aquatic environment in the Bay of Bengal by discharging untreated water into the sea.
B3-③	Diversion Channel Construction	

Source: JICA Expert Team

(3) Involuntary resettlement and land acquisition

Many residential and business buildings are settled along the rivers. Therefore, there is a large volume of involuntary resettlement and land acquisition required for the implementation of river widening. The following shows the approximate volume of both resettlement and land acquisition. In particular, many illegal residential areas have been identified along rivers and canals in the urbanized area in Chennai, and the implementation of flood control measures in these areas will have a significant negative social environment impact on socially vulnerable groups known as informal settlers, including the poor, related to involuntary resettlement. In the project phase, the preparation of resettlement plans requires careful consideration of not only appropriate relocation sites for these PAPs but also the implementation of livelihood restoration programs and reintegration efforts. The following table shows a list of flood control measures possibly resulting in involuntary resettlement.

1) Fluvial (river) flood control measures

- Adyar River Basin

Approximately 7,480 residential houses and 2,300 business buildings would be affected by the widening of the Adyar River, which would include at least 30,860 involuntary resettlement people in total. The amount of required land acquisition is approximately 493,000m2. The total displacement of houses and people amounts to 480 houses, with 1,880 people in the informal settlements and 7,480 houses, with 29,120 people in the formal settlements.

- Cooum River Basin

Approximately 6,855 residential houses and 3,200 business buildings would be affected by the widening of the Cooum River, which would include at least 26,000 involuntary resettlement people. The amount of required land acquisition is approximately 482,000m2. The total displacement of houses and people amounts to 445 houses, with 1,740 people in the informal settlements and 6,410 houses, with 24,260 people in the formal settlements.

- Kosasthalaiyar River Basin

Approximately 951 residential houses and 500 business buildings would be affected by the widening of the Kosasthalaiyar River, which would include at least 3,700 involuntary resettlement people. The amount of required land acquisition is approximately 70,000m2. The total displacement of houses and people amounts to 91 houses, with 360 people in the informal settlements, and 860 houses, with 3,340 people in the formal settlements.

- Kovalam Basin

There are neither affected buildings nor involuntary resettlement expected for Okkiyam Maduvu Channelization, including widening development of the new channel. However, approximately 160,000 m2 of land acquisition is required for the development.

2) Pluvial (drainage) flood control measures

No significant volume of resettlement and land acquisition is expected for the measures associated with the rehabilitation of the existing drainage channel, except for the channelization of the Central Buckingham Canal. Since Central Buckingham Canal is located in a densely urbanized area and the informal settlements live in partial sections along the canal, it would be necessary for land clearing for effective implementation of the measure, and approximately 340 houses with 1,320 involuntary resettlements in the informal resettlement would be required. In addition, a large volume of land acquisition will be required for Diversion Channel Construction connecting the Buckingham Canal and the Bay of Bengal, accounting for approximately 150,000m2. Especially the required land for the new diversion channel would pass through the leisure facility for citizens' recreational activities; careful consultations, including compensation policy and reformation planning of the facilities, would be required.

3) Coastal flood control measures

Neither involuntary resettlement nor land acquisition is expected for the construction of the training walls.

Table 8-40: List of measures possibly resulting in involuntary resettlement

Category #	Measure	Remark
A1, A2, A3, A4	River or Surplus Channelization	A large magnitude of involuntary resettlement, regardless of the formal or informal settlement, will be necessary for widening the existing waterway and
A1-③	Underground River Construction	

Category #	Measure	Remark
B2-①	Rehabilitation of the Central B. Canal	construction of an intake and construction of an outlet vertical shaft in the urbanized area.
B3-③	Diversion Channel Construction	A large amount of land acquisition will be necessary for the diversion channel construction.

Source: JICA Expert Team

(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. Therefore, implementation of the physical measures that involve a large volume of excavation, such as the measures 'River Channelization,' 'Underground River Construction,' and 'Water Tank Rehabilitation,' requires a detailed study of the geological conditions and groundwater table to confirm the magnitude of the impact and possible mitigation measures to be taken for the negative impact. Moreover, it is also necessary to monitor the groundwater level to avoid unexpected changes in the environment during the construction and operation phases.

There are many beaches for recreational use along with the Bay of Bengal, and these beaches are positioned as important tourism resources in Chennai. 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. In the list of the prioritized physical measures in the CFCMP, some involve the construction of concrete structures in the beach areas. Therefore, given the cumulative negative impact, it is very important to carry out a detailed analytical study to clarify the long-term movement of the sand on the beaches before the implementation of these measures. The following table shows a list of flood control measures possibly resulting in the deterioration of local resources.

Table 8-41: List of measures possibly resulting in the deterioration of local resources

Category #	Measure Name	Remark
A1, A2, A3, A4	River or surplus Channelization	A large volume of excavation could bring about a lowering groundwater level by undesirable movement of the existing groundwater. As a secondary impact, an excessive decrease of the groundwater could affect land subsidiary in the long-term perspective.
A1-③	Underground River Construction	
A5-①, ②	Water Tank rehabilitation and development	
B3-③	Diversion Channel Construction	
A1-③	Underground River Construction	A discharge outlet structure connecting the existing beach could affect sand movement in the long term.
B3-③	Diversion Channel Construction	

Source: JICA Expert Team

Table 8-42: Summary of Environmental Impact Assessment for Implementation of Fluvial (River) Flood Control Measures (1/5)

A. Fluvial (River) Flood Control Measures											
Category	#	Environmental items	Evaluation in Scoping Stage		A1: Adyar River Basin						Reason for evaluation
					①:River Channelization-1 (Deepening Riverbed)		②:River Channelization-2 (Widening Riverbank)		③:Underground River Construction		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
Pollution Control	1	Air pollution	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Deterioration of air quality is expected due to traffic congestion. The operation of heavy machinery and construction equipment may result in a temporary deterioration in air quality (including dust).
	2	Water pollution	✓	-	D/B-	D	D/B-	D	D/B-	B-	P: No major negative impact is expected. C: Deterioration of seawater and surface river water quality due to the bed soil excavation and oil leakage from construction machinery is expected. (①,②) O: No major negative impact is expected. (①,②) O: Deterioration of seawater quality by discharged water from the river is expected. (③)
	3	Waste	✓	-	D/A-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Generation of construction waste, including demolition debris, excavated soil, and general waste from the workers' camp, is expected. In particular, dredged soils would require appropriate treatment for their subsequent use.
	4	Soil pollution	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: The risk of soil contamination from the use of chemical substances or construction equipment is a concern during the construction works.
	5	Noise and vibrations	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Residential areas will be affected by noise from the operation of heavy machinery and construction equipment. C: Continuous vibration disturbance from the tunnel boring machine is a concern. (③)
	6	Subsidence of terrain	✓	✓	D/B-	B-	D/B-	B-	D/B-	D	P: No major negative impact is expected. C, O: Land subsidence may occur if a large amount of excavation or withdrawing water is required, resulting from a lowering of the groundwater table or soil layer movement.
	7	Odors	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: An odor nuisance may be generated by waste from workers' camps during the construction. C: Enlarging the river surface would increase the impact of odors if the river water condition were not improved. (②)
	8	Riverbeds Sediments	✓	-	D/D	D	D/D	D	D/D	D	P: Riverbed sediment will not be related to the measure. C: No significant negative impact is expected.

A. Fluvial (River) Flood Control Measures											
Category	#	Environmental items	Evaluation in Scoping Stage		A1: Adyar River Basin						Reason for evaluation
					①:River Channelization-1 (Deepening Riverbed)		②:River Channelization-2 (Widening Riverbank)		③:Underground River Construction		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
Natural Env.	9	Protected areas	✓	✓	D/D	D	D/D	D	B-/D	D	P: Special attention to the requirement of environmental laws for the development of the coastal zones near the south end of the B. Canal is necessary for the state environmental regulation. (③) C: No concern will be raised as long as the development is approved by the relevant agency before the commencement of construction. O: No major negative impact is expected.
	10	Biodiversity / Ecosystem	✓	✓	D/D	B-	D/B-	D	D/D	B-	P: No major negative impact is expected. C, O: Cutting many trees near the river could lead to deterioration of biodiversity. (②) O: Saline backwaters would cause deterioration of the existing ecosystem. (①) O: Discharging the polluted water from the Adyar River would affect the maritime ecosystem in the Bay of Bengal if the water were not treated or improved from the current condition. (③)
	11	Hydrological conditions/phenomena	✓	✓	D/B-	B-	D/B-	B-	D/B-	D	P: No major negative impact is expected. C, O: Large volumes of excavation could cause declines in groundwater levels.
	12	Topography of terrain, geology of soils	✓	✓	D/D	D	D/D	D	D/D	D	P, O: No major negative impact is expected. C: Dredging the river tanks would not affect the topography that is iconic to the local landscape.
Social Environment	13	Resettlement and land acquisition	✓	-	D/D	D	A-/D	D	B-/D	D	P: Widening the river and excavating a new underground river could be associated with involuntary relocation and land acquisition. Especially widening the river would necessitate a large volume of resettlement required in the urbanized area. (②) P: Some amount of involuntary relocation and land acquisition is expected for the deep shaft construction and the construction yard. (③) C, O: No resettlement and land acquisition are required after the commencement of the construction.
	14	Living life and livelihood	✓	-	D/D	B+	D/D	B+	D/D	D	P, C: No major negative impact is expected. O: The livelihood of the residents near the river would improve by decreasing concerns about chronic flooding. (①,②)
	15	Socially vulnerable people (poverty)	✓	-	B-/B-	D	B-/B-	D	B-/B-	D	P, C: In some parts of the river areas, some encroachers are suffering from poverty, and special measures should be considered for their lives if they are affected. O: No major negative impact is expected.
	16	Ethnic minorities and Indigenous people	-	-	D/D	D	D/D	D	D/D	D	P, C, O: There are no socially vulnerable ethnic minorities and indigenous people found in Chennai.

A. Fluvial (River) Flood Control Measures											
Category	#	Environmental items	Evaluation in Scoping Stage		A1: Adyar River Basin						Reason for evaluation
					①:River Channelization-1 (Deepening Riverbed)		②:River Channelization-2 (Widening Riverbank)		③:Underground River Construction		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
	17	Local economy, such as employment and livelihood	✓	-	D/B+	B+	D/B+	B+	D/B+	B+	P: No major negative impact is expected. C: New employment opportunities would be created during the construction work. O: Indirect positive impacts would be expected from the revitalization of the local economy if the problem of chronic flooding is solved.
	18	Land use and local resources	✓	-	D/D	B-	D/D	B-	D/D	D	P, C: No major negative impact is expected. O: A decrease in groundwater level if the measure involves a large amount of excavation is concerned. (①,②) O: It is expected that disruption of the shoreline, either in the beach around the mouse of the new diversion channel or the one far from the mouse, having relation with comprehensive sand movement, would result in the degradation of a tourist resource for the region. (②,③)
	19	Water use/rights	✓	-	D/D	D	D/D	D	D/D	D	P, C, O: No major negative impact is expected.
	20	Existing social infrastructures and social services	✓	✓	D/B-	D	B-/B-	D	D/B-	D	P: Widening rivers could affect existing roads and traffic accessing social infrastructure and services. (②) C: Construction of heavy machinery would affect local traffic operation, which is related to the accessibility of the social infrastructures. C: Vulnerable structures and underground facilities would be damaged by boring a tunnel. (③) O: No major negative impact is expected.
	21	Social capital and social structure of regional decision-making organizations	-	-	D/D	D	D/D	D	D/D	D	P, C, O: There is no social capital and structures of regional organization related to the measures.
	22	Misdistribution of benefits and damage	✓	-	D/D	D	D/D	D	D/D	D	P, C, O: No major negative impact is expected.
	23	Local conflict of interests	✓	-	D/D	D	D/D	D	D/D	D	P, C, O: There are no conflicts of interest within the community expected during and after. .
	24	Cultural Heritage	✓	-	D/B-	D	D/B-	D	D/D	D	P, O: No major negative impact is expected. C: Damage to local religious facilities or structures along the river is expected. (①, ②)
	25	Landscape	✓	-	D/D	D	D/D	D	D/D	B-	P, C: No major negative impact is expected. O: Disruption of the shoreline around the outlet in the beach would result in the degradation of a touristic landscape. (③)

A. Fluvial (River) Flood Control Measures											
Category	#	Environmental items	Evaluation in Scoping Stage		A1: Adyar River Basin						Reason for evaluation
					①:River Channelization-1 (Deepening Riverbed)		②:River Channelization-2 (Widening Riverbank)		③:Underground River Construction		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
	26	Gender	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Gender empowerment/equality issues shall be considered in the employment of construction workers. C: Social inclusion shall be taken into consideration during the consultation for involuntary resettlement activities. (②,③)
	27	Children rights	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: There will be a potential risk of violation of children's rights in the working environment of construction works.
	28	Infectious diseases such as HIV/AIDS (including hygiene conditions)	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: The Spread or pandemic of infectious diseases is expected due to the influx of workers from outside during the construction period.
	29	Working conditions (including work safety)	✓	-	D/B-	D	D/B-	D	D/B-	D	P: There is no element related to the working environment before commencing the work. C: Some negative impacts may be generated regarding safe labor conditions in case technically difficult tasks are carried out by local workers. O: There are no activities that may involve a deterioration of work conditions.
Others	30	Accidents	✓	-	D/B-	D	D/B-	D	D/B-	D	P: No work which could cause accidents will be carried out during the planning phase. C: There is a risk of accidents for workers and residents near the construction site due to the increase in construction vehicles. O: No accident triggered by the river rehabilitation would be expected.
	31	Impact of crossing borders and climate change	-	-	D/D	D	D/D	D	D/D	D	P, C, O: No significant impact on climate change is expected due to the scale and nature of the measure.

Note: A+/-: An important positive or negative impact is projected, B+/-: There may be some positive or negative impacts,
C+/-: The occurrence of a positive or negative impact has not been determined (a more detailed study must clarify the impact). D: No impact is projected.

Source: JICA Expert Team

Table 8-43: Summary of Environmental Impact Assessment for Implementation of Fluvial (River) Flood Control Measures (2/5)

Category	#	Environmental items	Evaluation in Scoping Stage		A2: Cooum River Basin				Reason for evaluation
A. Fluvial (River) Flood Control Measures									
					①:River Channelization-1 (Deepening Riverbed)		②:River Channelization-2 (Widening Riverbank)		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
Pollution Control	1	Air pollution	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Deterioration of air quality is expected due to the traffic congestion. The operation of heavy machinery and construction equipment may result in a temporary deterioration in air quality (including dust).
	2	Water pollution	✓	-	D/B-	D	D/B-	D	P: No major negative impact is expected. C: Deterioration of sea water and surface river water quality due to the bed soil excavation and oil leakage from construction machinery is expected. O: No major negative impact is expected.
	3	Waste	✓	-	D/A-	D	D/B-	D	P, O: No major negative impact is expected. C: Generation of construction waste including demolition debris, excavated soil and general waste from the workers' camp is expected. In particular, dredged soils would require appropriate treatment for their subsequent use.
	4	Soil pollution	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: The risk of soil contamination from the use of chemical substances or construction equipment is a concern during the construction works.
	5	Noise and vibrations	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Residential areas will be affected by noise from the operation of heavy machinery and construction equipment.
	6	Subsidence of terrain	✓	✓	D/B-	B-	D/B-	B-	P: No major negative impact is expected. C, O: Land subsidence may occur if a large amount of excavation or withdrawing water is required, resulting from a lowering of the ground water table or soil layer movement.
	7	Odours	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: An odour nuisance may be generated by waste from workers' camp during the construction. C: Enlarging the river surface would increase the impact of odours if the river water condition were not improved. (②)
	8	Riverbeds Sediments	✓	-	D/D	D	D/D	D	P: Riverbed sediment will not be related with the measure. C: No significant negative impact is expected.
Natural Env.	9	Protected areas	✓	✓	D/D	D	D/D	D	P: No protected area is found along the Cooum River. C: No concern will be raised as long as the development is approved by the relevant agency before commencement of construction. O: No major negative impact is expected.
	10	Biodiversity / Ecosystem	✓	✓	D/D	D	D/B-	B-	P: No major negative impact is expected. C, O: Cutting many trees near the river could lead to deterioration of biodiversity. (②)
	11	Hydrological conditions/phenomena	✓	✓	D/B-	B-	D/B-	B-	P: No major negative impact is expected. C, O: Large volumes of excavation could cause declines of ground water level.

A. Fluvial (River) Flood Control Measures										
Category	#	Environmental items	Evaluation in Scoping Stage		A2: Cooum River Basin				Reason for evaluation
					①:River Channelization-1 (Deepening Riverbed)		②:River Channelization-2 (Widening Riverbank)		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
	12	Topography of terrain, geology of soils	✓	✓	D/D	D	D/D	D	P, O: No major negative impact is expected. C: Dredging the rivers tanks would not affect the topography iconic to the local landscape.
Social Environment	13	Resettlement and land acquisition	✓	-	D/D	D	A-/D	D	P: Widening the river could be associated with involuntary relocation and land acquisition. Especially, widening the river would necessitate a large volume of resettlement required in the urbanized area. (②) C, O: No resettlement and land acquisition are required after commencement of the construction.
	14	Living life and livelihood	✓	-	D/D	B+	D/D	B+	P, C: No major negative impact is expected. O: Livelihood of the residents near the river would improve due to decreasing awareness of chronic floodings.
	15	Socially vulnerable people (poverty)	✓	-	B-/B-	D	B-/B-	D	P, C: In some parts of the river areas, there are some encroachers suffering from poverty, and special measures should be considered for their lives if they are affected. O: No major negative impact is expected.
	16	Ethnic minorities and indigenous people	-	-	D/D	D	D/D	D	P, C, O: There are no socially vulnerable ethnic minorities and indigenous people found in Chennai.
	17	Local economy such as employment and livelihood	✓	-	D/B+	B+	D/B+	B+	P: No major negative impact is expected. C: New employment opportunities would be created during the construction work. O: Indirect positive impacts would be expected from the revitalization of the local economy if the problem of chronic flooding is solved.
	18	Land use and local resources	✓	-	D/D	B-	D/D	B-	P, C: No major negative impact is expected. O: Decrease in groundwater level if the measure involves a large amount of excavation is concerned.
	19	Water use/rights	✓	-	D/D	D	D/D	D	P, C, O: No major negative impact is expected.
	20	Existing social infrastructures and social services	✓	✓	D/B-	D	B-/B-	D	P: Widening river could affect existing roads and traffic accessing social infrastructure and service. (②) C: Construction heavy machinery would affect local traffic operation, which is related with accessibility of the social infrastructures. O: No major negative impact is expected.
	21	Social capital and social structure of regional decision-making organizations	-	-	D/D	D	D/D	D	P, C, O: There is no relationship with social capital and structures of regional organization related with the measures.
	22	Misdistribution of benefits and damage	✓	-	D/D	D	D/D	D	P, C, O: No major negative impact is expected.
	23	Local conflict of interests	✓	-	D/D	D	D/D	D	P, C, O: There is no conflicts of interests within the community expected during and after

A. Fluvial (River) Flood Control Measures

Category	#	Environmental items	Evaluation in Scoping Stage		A2: Cooum River Basin				Reason for evaluation
					①:River Channelization-1 (Deepening Riverbed)		②:River Channelization-2 (Widening Riverbank)		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
	24	Cultural Heritage	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Damage to local religious facilities or structures along the river is expected.
	25	Landscape	✓	-	D/D	D	D/D	D	P, C, O: No major negative impact is expected.
	26	Gender	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Gender empowerment/equality issues shall be considered in the employment of construction workers.
	27	Children rights	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: There will be a potential risk of violation of children's rights in the working environment of construction works.
	28	Infectious diseases such as HIV/AIDS (including hygiene condition)	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Spread or pandemic of infectious diseases is expected due to influx of workers from outside during construction period.
	29	Working conditions (including work safety)	✓	-	D/B-	D	D/B-	D	P: There is no element related to the working environment before commencing the works. C: Some negative impacts may be generated regarding safe labour conditions in case that technically difficult tasks are carried out by local workers. O: There are no activities which may involve a deterioration of work conditions.
Others	30	Accidents	✓	-	D/B-	D	D/B-	D	P: No work which could cause accidents will be carried out during the planning phase. C: There is a risk of accidents for workers and residents near the construction site due to the increase in construction vehicles. O: No accident triggered by the river rehabilitation would be expected.
	31	Impact of crossing borders and climate change	-	-	D/D	D	D/D	D	P, C, O: No significant impact on climate change is expected due to the scale and nature of the measure.

Note: A+/-: An important positive or negative impact is projected, B+/-: There may be some positive or negative impacts,
C+/-: The occurrence of a positive or negative impact has not been determined (a more detailed study must clarify the impact). D: No impact is projected.

Source: JICA Expert Team

Table 8-44: Summary of Environmental Impact Assessment for Implementation of Fluvial (River) Flood Control Measures (3/5)

A. Fluvial (River) Flood Control Measures											
Category	#	Environmental items	Evaluation in Scoping Stage		A3: Kosasthalaiyar River Basin						Reason for evaluation
					①:River and Redhills Surplus Channelization-1 (Deepening Riverbed)		②: River and Redhills Surplus Channelization -2 (Widening Riverbank)		③: Looped waterway development with gate construction		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
Pollution Control	1	Air pollution	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Deterioration of air quality is expected due to traffic congestion. The operation of heavy machinery and construction equipment may result in a temporary deterioration in air quality (including dust).
	2	Water pollution	✓	-	D/B-	D	D/B-	D	D/B-	D	P: No major negative impact is expected. C: Deterioration of seawater and surface river water quality due to the bed soil excavation and oil leakage from construction machinery is expected. (①,②) O: No major negative impact is expected. (①,②)
	3	Waste	✓	-	D/A-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Generation of construction waste, including demolition debris, excavated soil, and general waste from the workers' camp, is expected. In particular, dredged soils would require appropriate treatment for their subsequent use.
	4	Soil pollution	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: The risk of soil contamination from the use of chemical substances or construction equipment is a concern during the construction works.
	5	Noise and vibrations	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Residential areas will be affected by noise from the operation of heavy machinery and construction equipment.
	6	Subsidence of terrain	✓	✓	D/B-	B-	D/B-	B-	D/D	D	P: No major negative impact is expected. C, O: Land subsidence may occur if a large amount of excavation or withdrawing water is required, resulting from a lowering of the groundwater table or soil layer movement.
	7	Odors	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: An odor nuisance may be generated by waste from workers' camps during the construction. C: Enlarging the river surface would increase the impact of odors if the river water condition were not improved. (②)
	8	Riverbeds Sediments	✓	-	D/D	D	D/D	D	D/D	D	P: Riverbed sediment will not be related with the measure. C: No significant negative impact is expected.

A. Fluvial (River) Flood Control Measures												
Category	#	Environmental items	Evaluation in Scoping Stage		A3: Kosasthalaiyar River Basin						Reason for evaluation
					①:River and Redhills Surplus Channelization-1 (Deepening Riverbed)		②: River and Redhills Surplus Channelization -2 (Widening Riverbank)		③: Looped waterway development with gate construction		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
Natural Env.	9	Protected areas	✓	✓	D/D	D	D/D	D	B-/B-	D	P: Special attention to the requirement of environmental laws for the development of the CRZ zones near the Ennore Creek is necessary for the state environmental regulation. (③) C: No concern will be raised as long as the development is approved by the relevant agency before commencement of construction. O: No major negative impact is expected.
	10	Biodiversity / Ecosystem	✓	✓	D/D	B-	D/B-	B-	D/B-	B-	P: No major negative impact is expected. O: Saline backwater would cause deterioration of the existing ecosystem. (①) C, O: Cutting many trees near the river could lead to deterioration of biodiversity. (②, ③)
	11	Hydrological conditions/phenomena	✓	✓	D/B-	B-	D/B-	B-	D/B-	B-	P: No major negative impact is expected. C, O: Large volumes of excavation could cause declines of ground water level.
	12	Topography of terrain, geology of soils	✓	✓	D/D	D	D/D	D	D/D	D	P, O: No major negative impact is expected. C: Dredging the rivers tanks would not affect the topography iconic to the local landscape.
Social Environment	13	Resettlement and land acquisition	✓	-	D/D	D	A-/D	D	B-/D	D	P: Widening the river could be associated with involuntary relocation and land acquisition. Especially, widening the river would necessitate a large volume of resettlement required in the urbanized area. (②,③) C, O: No resettlement and land acquisition are required after commencement of the construction.
	14	Living life and livelihood	✓	-	D/D	B+	D/D	B+	D/D	B+	P, C: No major negative impact is expected. O: Livelihood of the residents near the river would improve due to decreasing awareness of chronic floodings.
	15	Socially vulnerable people (poverty)	✓	-	B-/B-	D	B-/B-	D	D/D	D	P, C: In some parts of the river areas, there are some encroachers suffering from poverty, and special measures should be considered for their lives if they are affected. (①, ②) Otherwise there is no settlement of the vulnerable found in the looped waterway areas. (③) O: No major negative impact is expected.
	16	Ethnic minorities and indigenous people	-	-	D/D	D	D/D	D	D/D	D	P, C, O: There are no socially vulnerable ethnic minorities and indigenous people found in Chennai.
	17	Local economy such as employment and livelihood	✓	-	D/B+	B+	D/B+	B+	D/B+	B+	P: No major negative impact is expected. C: New employment opportunities would be created during the construction work. O: Indirect positive impacts would be expected from the revitalization of the local economy if the problem of chronic flooding is solved.

A. Fluvial (River) Flood Control Measures

Category	#	Environmental items	Evaluation in Scoping Stage		A3: Kosasthalaiyar River Basin						Reason for evaluation
					①:River and Redhills Surplus Channelization-1 (Deepening Riverbed)		②: River and Redhills Surplus Channelization -2 (Widening Riverbank)		③: Looped waterway development with gate construction		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
	18	Land use and local resources	✓	-	D/D	B-	D/D	B-	D/D	B-	P, C: No major negative impact is expected. O: Decrease in groundwater level if the measure involves a large amount of excavation is concerned.
	19	Water use/rights	✓	-	D/D	D	D/D	D	D/D	D	P, C, O: No major negative impact is expected.
	20	Existing social infrastructures and social services	✓	✓	D/B-	D	B-/B-	D	D/B-	D	P: Widening river could affect existing roads and traffic accessing social infrastructure and service. (②) C: Construction heavy machinery would affect local traffic operation, which is related with accessibility of the social infrastructures. O: No major negative impact is expected.
	21	Social capital and social structure of regional decision-making organizations	-	-	D/D	D	D/D	D	D/D	D	P, C, O: There is no relationship with social capital and structures of regional organization related with the measures.
	22	Misdistribution of benefits and damage	✓	-	D/D	D	D/D	D	D/D	D	P, C, O: No major negative impact is expected.
	23	Local conflict of interests	✓	-	D/D	D	D/D	D	D/D	D	P, C, O: There is no conflicts of interests within the community expected during and after
	24	Cultural Heritage	✓	-	D/B-	D	D/B-	D	D/D	D	P, O: No major negative impact is expected. C: Damage to local religious facilities or structures along the river is expected. (①, ②)
	25	Landscape	✓	-	D/D	D	D/D	D	D/D	D	P, C, O: No major negative impact is expected.
	26	Gender	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Gender empowerment/equality issues shall be considered in the employment of construction workers.
	27	Children rights	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: There will be a potential risk of violation of children's rights in the working environment of construction works.
	28	Infectious diseases such as HIV/AIDS (including hygiene conditions)	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: The Spread or pandemic of infectious diseases is expected due to the influx of workers from outside during the construction period.

A. Fluvial (River) Flood Control Measures											
Category	#	Environmental items	Evaluation in Scoping Stage		A3: Kosasthalaiyar River Basin						Reason for evaluation
					①:River and Redhills Surplus Channelization-1 (Deepening Riverbed)		②: River and Redhills Surplus Channelization -2 (Widening Riverbank)		③: Looped waterway development with gate construction		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
	29	Working conditions (including work safety)	✓	-	D/B-	D	D/B-	D	D/B-	D	P: There is no element related to the working environment before commencing the work. C: Some negative impacts may be generated regarding safe labor conditions in case technically difficult tasks are carried out by local workers. O: There are no activities that may involve a deterioration of work conditions.
Others	30	Accidents	✓	-	D/B-	D	D/B-	D	D/B-	D	P: No work which could cause accidents will be carried out during the planning phase. C: There is a risk of accidents for workers and residents near the construction site due to the increase in construction vehicles. O: No accident triggered by the river rehabilitation would be expected.
	31	Impact of crossing borders and climate change	-	-	D/D	D	D/D	D	D/D	D	P, C, O: No significant impact on climate change is expected due to the scale and nature of the measure.

Note: A+/-: An important positive or negative impact is projected, B+/-: There may be some positive or negative impacts,
C+/-: The occurrence of a positive or negative impact has not been determined (a more detailed study must clarify the impact). D: No impact is projected.

Source: JICA Expert Team

Table 8-45: Summary of Environmental Impact Assessment for Implementation of Fluvial (River) Flood Control Measures (4/5)

A. Fluvial (River) Flood Control Measures										
Category	#	Environmental items	Evaluation in Scoping Stage		A4: Kovalam Basin				Reason for evaluation
					①:Okkiyam Maduvu Surplus Channelization-1 (Deepening Riverbed)		②:Okkiyam maduvu Surplus Channelization-2 (Widening Riverbank)		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
Pollution Control	1	Air pollution	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Deterioration of air quality is expected due to traffic congestion. The operation of heavy machinery and construction equipment may result in a temporary deterioration in air quality (including dust).
	2	Water pollution	✓	-	D/B-	D	D/B-	D	P: No major negative impact is expected. C: Deterioration of seawater and surface river water quality due to the bed soil excavation and oil leakage from construction machinery is expected. O: No major negative impact is expected.
	3	Waste	✓	-	D/A-	D	D/B-	D	P, O: No major negative impact is expected. C: Generation of construction waste, including demolition debris, excavated soil, and general waste from the workers' camp, is expected. In particular, dredged soils would require appropriate treatment for their subsequent use.
	4	Soil pollution	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: The risk of soil contamination from the use of chemical substances or construction equipment is a concern during the construction works.
	5	Noise and vibrations	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Residential areas will be affected by noise from the operation of heavy machinery and construction equipment.
	6	Subsidence of terrain	✓	✓	D/B-	B-	D/B-	B-	P: No major negative impact is expected. C, O: Land subsidence may occur if a large amount of excavation or withdrawing water is required, resulting from a lowering of the ground water table or soil layer movement.
	7	Odours	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: An odour nuisance may be generated by waste from workers' camp during the construction. C: Enlarging the river surface would increase the impact of odours if the river water condition were not improved. (②)
	8	Riverbeds Sediments	✓	-	D/D	D	D/D	D	P: Riverbed sediment will not be related with the measure. C: No significant negative impact is expected.
Natural Environment	9	Protected areas	✓	✓	D/D	A-	B-/B-	A-	P, C: Special attention to the requirement of environmental laws for the development of the Pallikaranai Marsh Reserve Forest Area which is registered as a Ramsar site is necessary for the state environmental regulation. C: No concern will be raised as long as the development is approved by the relevant agency before commencement of construction. O: Decrease of water level in the Pallikaranai Marsh Reserve Forest is significant secondary negative impact on the existing ecosystem of the marsh area.

A. Fluvial (River) Flood Control Measures									
Category	#	Environmental items	Evaluation in Scoping Stage		A4: Kovalam Basin				Reason for evaluation
					①:Okkiyam Maduvu Surplus Channelization-1 (Deepening Riverbed)		②:Okkiyam maduvu Surplus Channelization-2 (Widening Riverbank)		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
	10	Biodiversity / Ecosystem	✓	✓	D/D	D	D/B-	B-	P: No major negative impact is expected. C, O: Cutting many trees near the river could lead to deterioration of biodiversity. (②)
	11	Hydrological conditions/phenomena	✓	✓	D/B-	B-	D/B-	B-	P: No major negative impact is expected. C, O: Large volumes of excavation could cause declines of ground water level.
	12	Topography of terrain, geology of soils	✓	✓	D/D	D	D/D	D	P, O: No major negative impact is expected. C: Dredging the river tanks would not affect the topography that is iconic to the local landscape.
Social Environment	13	Resettlement and land acquisition	✓	-	D/D	D	B-/D	D	P: Some volume of land acquisition would be expected. (②) C, O: No resettlement and land acquisition are required after the commencement of the construction.
	14	Living life and livelihood	✓	-	D/D	B+	D/D	B+	P, C: No major negative impact is expected. O: The livelihood of the residents near the river would improve due to decreasing awareness of chronic floodings.
	15	Socially vulnerable people (poverty)	✓	-	D/D	D	D/D	D	P, C: No settlement is found along the Okkiyam maduvu. O: No major negative impact is expected.
	16	Ethnic minorities and Indigenous people	-	-	D/D	D	D/D	D	P, C, O: There are no socially vulnerable ethnic minorities and indigenous people found in Chennai.
	17	Local economy, such as employment and livelihood	✓	-	D/B+	B+	D/B+	B+	P: No major negative impact is expected. C: New employment opportunities would be created during the construction work. O: Indirect positive impacts would be expected from the revitalization of the local economy if the problem of chronic flooding is solved.
	18	Land use and local resources	✓	-	D/D	B-	D/D	B-	P, C: No major negative impact is expected. O: A decrease in groundwater level if the measure involves a large amount of excavation is concerned.
	19	Water use/rights	✓	-	D/D	D	D/D	D	P, C, O: No major negative impact is expected.
	20	Existing social infrastructures and social services	✓	✓	D/B-	D	B-/B-	D	P: Widening rivers could affect existing roads and traffic accessing social infrastructure and services. (②) C: Construction of heavy machinery would affect local traffic operation, which is related to the accessibility of the social infrastructures. O: No major negative impact is expected.
	21	Social capital and social structure of regional decision-making organizations	-	-	D/D	D	D/D	D	P, C, O: There is no relationship between social capital and structures of regional organization related to the measures.

A. Fluvial (River) Flood Control Measures

Category	#	Environmental items	Evaluation in Scoping Stage		A4: Kovalam Basin				Reason for evaluation
					①:Okkiyam Maduvu Surplus Channelization-1 (Deepening Riverbed)		②:Okkiyam maduvu Surplus Channelization-2 (Widening Riverbank)		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
	22	Misdistribution of benefits and damage	✓	-	D/D	D	D/D	D	P, C, O: No major negative impact is expected.
	23	Local conflict of interests	✓	-	D/D	D	D/D	D	P, C, O: There are no conflicts of interest within the community expected during and after
	24	Cultural Heritage	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Damage to local religious facilities or structures along the river is expected.
	25	Landscape	✓	-	D/D	D	D/D	D	P, C, O: No major negative impact is expected.
	26	Gender	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Gender empowerment/equality issues shall be considered in the employment of construction workers.
	27	Children rights	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: There will be a potential risk of violation of children's rights in the working environment of construction works.
	28	Infectious diseases such as HIV/AIDS (including hygiene conditions)	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: The Spread or pandemic of infectious diseases is expected due to the influx of workers from outside during the construction period.
	29	Working conditions (including work safety)	✓	-	D/B-	D	D/B-	D	P: There is no element related to the working environment before commencing the work. C: Some negative impacts may be generated regarding safe labor conditions in case technically difficult tasks are carried out by local workers. O: There are no activities that may involve a deterioration of work conditions.
Others	30	Accidents	✓	-	D/B-	D	D/B-	D	P: No work which could cause accidents will be carried out during the planning phase. C: There is a risk of accidents for workers and residents near the construction site due to the increase in construction vehicles. O: No accident triggered by the river rehabilitation would be expected.
	31	Impact of crossing borders and climate change	-	-	D/D	D	D/D	D	P, C, O: No significant impact on climate change is expected due to the scale and nature of the measure.

Note: A+/-: An important positive or negative impact is projected, B+/-: There may be some positive or negative impacts,
C+/-: The occurrence of a positive or negative impact has not been determined (a more detailed study must clarify the impact). D: No impact is projected.

Source: JICA Expert Team

Table 8-46: Summary of Environmental Impact Assessment for Implementation of Fluvial (River) Flood Control Measures (5/5)

A. Fluvial (River) Flood Control Measures									
Category	#	Environmental items	Evaluation in Scoping Stage		A5: All river basins (including Kovalum Basin)				Reason for evaluation
					①: Water tank rehabilitation with gate construction		②: New water tank development with gate construction		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
Pollution Control	1	Air pollution	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Deterioration of air quality is expected due to traffic congestion. The operation of heavy machinery and construction equipment may result in a temporary deterioration in air quality (including dust).
	2	Water pollution	✓	-	D/B-	B-	D/B-	B-	P: No major negative impact is expected. C: There is a possibility of direct or indirect contamination of the existing water bodies resulting from the use of construction machinery and sewage from the construction site. C: Turbulence of existing water leading to water contamination caused by contaminated sediment is expected by excavation of bed soil. (①) O: Eutrophication would be problematic in terms of biodiversity due to inappropriate water management in the tanks.
	3	Waste	✓	-	D/B-	B-	D/B-	B-	P: No major negative impact is expected. C: Generation of construction waste, including excavated soil and general waste from the workers' camp, is expected. O: Littering of the new tank and channel would affect odor nuisance as well as a comfortable landscape.
	4	Soil pollution	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: The risk of soil contamination from the use of chemical substances or construction equipment is a concern. An indirect negative impact will be a concern if contaminated soil generated from the excavation works is utilized for other economic activities such as agricultural use or reclamation of land.
	5	Noise and vibrations	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Noise will be generated due to the operation of heavy machinery and construction equipment.
	6	Subsidence of terrain	✓	✓	D/B-	B-	D/B-	B-	P: No major negative impact is expected. C, O: Land subsidence may occur if a large amount of excavation is required, resulting in a lowering of the groundwater table. O: Gradual subsidence of terrain due to decreasing groundwater table could have occurred.
	7	Odors	✓	-	D/B-	B-	D/B-	B-	P: No major negative impact is expected. C: An odor nuisance may be generated by waste from the workers' camp as well as excavated soil. O: Improper maintenance could cause odor nuisance in the pond and surrounding areas.
	8	Riverbeds Sediments	✓	-	D/D	D	D/D	D	P: No major negative impact is expected. C, O: Riverbed sediment will not be related to the measures.

A. Fluvial (River) Flood Control Measures										
Category	#	Environmental items	Evaluation in Scoping Stage		A5: All river basins (including Kovalum Basin)				Reason for evaluation
					①: Water tank rehabilitation with gate construction		②: New water tank development with gate construction		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
Natural Environment	9	Protected areas	✓	✓	D/B-	B+	D/B-	B+	P: No major negative impact is expected. C: Careful attention must be paid to the water tanks designated as prioritized wetlands to conserve the natural environment. O: Conservation of the natural environment would be ensured, and uncontrolled development in the suburban area and the sprawling city could be controlled in the future.
	10	Biodiversity / Ecosystem	✓	✓	D/B-	D/B+	D/B-	D/B+	P: No major negative impact is expected. C: Deterioration of existing biodiversity caused by deepening tanks or cutting trees would be expected. O: Depending on the countermeasures for biodiversity, rich biodiversity would be ensured.
	11	Hydrological conditions/phenomena	✓	✓	D/B-	B-	D/B-	B-	P: No major negative impact is expected. C, O: Large volumes of excavation could cause declines in groundwater levels.
	12	Topography of terrain, geology of soils	✓	✓	D/D	D	D/D	D	P, O: No major negative impact is expected. C: Deepening the water tank or excavation for the new tanks would not affect the topography that is iconic to the local landscape.
Social Environment	13	Resettlement and land acquisition	✓	-	D/D	D	B-/D	D	P: Acquisition of some agricultural or residential land is expected for the development of new water tanks and network channels between the tanks. (②) C: No resettlement/land acquisition would be necessary after the commencement of the construction. O: No resettlement and land acquisition are considered during the operation phase.
	14	Living life and livelihood	✓	-	D/D	B+	D/B-	B-/B+	P: No major negative impact is expected. C, O: Decrease in quality of life is a concern for the one who loses his/her assets. (②) O: Concerns about chronic flooding would be alleviated.
	15	Socially vulnerable people (poverty)	✓	-	D/D	B+	D/D	B+	P, O: No major negative impact is expected. C: There are no vulnerable people affected in the area adjacent to the tanks for development. In the case of existence, it would be beneficial for them to alleviate flood awareness.
	16	Ethnic minorities and Indigenous people	-	-	D/D	D	D/D	D	P, C, O: There are no socially vulnerable ethnic minorities and indigenous people found in Chennai.
	17	Local economy, such as employment and livelihood	✓	-	D/B+	B+	D/B+	B+	P: No major negative impact is expected. C: New employment opportunities would be created during the construction work. O: A decrease in flood damage would bring about revitalization of the local economy.
	18	Land use and local resources	✓	-	D/D	B-	D/D	B-	P, C: No major negative impact is expected. O: A decrease in groundwater level if the measure involves a large amount of excavation is concerned.
	19	Water use/rights	✓	-	D/B-	B-	D/B-	B-	P: No major negative impact is expected. C, O: Ensuring adequate water in the tank and groundwater used for agriculture is a big concern.

A. Fluvial (River) Flood Control Measures

Category	#	Environmental items	Evaluation in Scoping Stage		A5: All river basins (including Kovalum Basin)				Reason for evaluation
					①: Water tank rehabilitation with gate construction		②: New water tank development with gate construction		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
	20	Existing social infrastructures and social services	✓	✓	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Construction of heavy machinery would affect local traffic operation, which is related to the accessibility of the social infrastructures.
	21	Social capital and social structure of regional decision-making organizations	-	-	D/D	D	D/D	D	P/C, O: There is no relationship between social capital and structures of regional organizations related to the measures.
	22	Misdistribution of benefits and damage	✓	-	B-/D	D	B-/D	D	P: Unbalanced implementation in regions would cause unfair distribution of flood protection areas. C, O: No negative impact is expected after the construction works.
	23	Local conflict of interests	✓	-	D/D	D	D/D	D	P, C, O: There are no conflicts of interest within the community expected during and after the construction.
	24	Cultural Heritage	✓	-	D/D	D	D/B-	D	P, O: No major negative impact is expected. C: Damage to local religious facilities or structures is expected, if any. (②)
	25	Landscape	✓	-	D/B-	B-	D/B-	B-	P: No major negative impact is expected. C, O: The natural landscape of the existing water tank will be degraded if covered with concrete.
	26	Gender	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Gender empowerment/equality issues shall be considered in the employment of construction workers.
	27	Children rights	✓	-	D/B-	D	D/B-	D	P, O: No impact is expected. C: There will be a potential risk of violation of children's rights in the working environment of construction works.
	28	Infectious diseases such as HIV/AIDS (including hygiene conditions)	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: The Spread or pandemic of infectious diseases is expected due to the influx of workers from outside during the construction period.
	29	Working conditions (including work safety)	✓	-	D/B-	D	D/B-	D	P: There is no element related to the working environment before commencing the work. C: Some negative impacts may be generated regarding safe labor conditions in case technically difficult tasks are carried out by local workers. O: There are no activities that may involve a deterioration of work conditions.
Others	30	Accidents	✓	-	D/B-	B-	D/B-	B-	P: No work which could cause accidents will be carried out during the planning phase. C: There is a risk of accidents for workers and residents near the construction site due to the increase in construction vehicles. O: An increase in water accidents associated with the new pond is expected unless appropriate safety measures are taken.

A. Fluvial (River) Flood Control Measures									
Category	#	Environmental items	Evaluation in Scoping Stage		A5: All river basins (including Kovalum Basin)				Reason for evaluation
					①: Water tank rehabilitation with gate construction		②: New water tank development with gate construction		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
	31	Impact of crossing borders and climate change	-	-	D/D	D	D/D	D	P, C, O: No significant impact on climate change is expected due to the scale and nature of the measure.

Note: A+/-: An important positive or negative impact is projected, B+/-: There may be some positive or negative impacts,
C+/-: The occurrence of a positive or negative impact has not been determined (a more detailed study must clarify the impact). D: No impact is projected.

Source: JICA Expert Team

Table 8-47: Summary of Environmental Impact Assessment for Implementation of Pluvial (Drainage) Flood Control Measures (1/4)

B. Pluvial (Drainage) Flood Control Measures

Category	#	Environmental items	Evaluation in Scoping Stage		B1: North Buckingham Canal (NBC)								Reason for evaluation
					①:Rehabili-station of the B. Canal		②:Retarding Pond construction adjacent to the Kodungaiyur Drain, Captain Cotton Canal, Otteri Nala Drain, and midstream of NBC		③:Bypass channel (Cut &Cover) construction connecting Otteri Nala Drain and the Cooum River		④ Construction of a gate at the junction of NBC and Cooum River		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
Pollution Control	1	Air pollution	✓	-	D/B-	D	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Deterioration of air quality is expected due to traffic congestion. The operation of heavy machinery and construction equipment may result in a temporary deterioration in air quality (including dust).
	2	Water pollution	✓	-	D/B-	D	D/D	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: There is a possibility of contamination of the existing drainage water resulting from the use of construction machinery and sewage from the construction site. C: Deterioration of surface river and sea water quality by discharged water from the drainage due to the bed soil excavation and oil leakage from construction machinery is expected. (①,③)
	3	Waste	✓	-	D/B-	D	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Generation of construction waste, including demolition debris, excavated soil, and general waste from the workers' camp, is expected.
	4	Soil pollution	✓	-	D/B-	D	D/B-	B-	D/B-	D	D/B-	D	P: No major negative impact is expected. C: The risk of soil contamination from the use of chemical substances or construction equipment is a concern. C: Indirect negative impact would be concerned if contaminated soil generated from the excavation works is utilized for other economic activities such as agricultural use or reclamation of land. (①, ②) O: Discharge of the contaminated drainage water from the canals to the new retarding ponds would affect bed soil contamination of the ponds. (②)
	5	Noise and vibrations	✓	-	D/B-	D	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Residential areas along with the B. Canal and commercial areas along 3rd Avenue will be affected by noise and vibration from the operation of heavy machinery and construction equipment.
	6	Subsidence of terrain	✓	✓	D/B-	B-	D/D	D	D/D	D	D/D	D	P: No major negative impact is expected.

B. Pluvial (Drainage) Flood Control Measures													
Category	#	Environmental items	Evaluation in Scoping Stage		B1: North Buckingham Canal (NBC)								Reason for evaluation
					①:Rehabili-station of the B. Canal		②:Retarding Pond construction adjacent to the Kodungaiyur Drain, Captain Cotton Canal, Otteri Nala Drain, and midstream of NBC		③:Bypass channel (Cut &Cover) construction connecting Otteri Nala Drain and the Cooum River		④ Construction of a gate at the junction of NBC and Cooum River		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
													C, O: Land subsidence may occur if a large amount of excavation is required, resulting from a lowering of the groundwater table. (①)
Natural Environment	7	Odors	✓	-	D/B-	D	D/B-	B-	D/B-	D	D/B-	D	P: No major negative impact is expected. C: An odor nuisance may be generated by waste from the workers' camps during the construction. O: Littering of the new retarding ponds would affect odor nuisance. (②)
	8	Riverbeds Sediments	✓	-	D/D	D	D/D	D	D/D	D	D/D	D	P, C: Riverbed sediment will not be related to the measures. O: No major negative impact is expected.
	9	Protected areas	✓	✓	D/D	D	D/D	D	D/D	D	D/D	D	P: No major negative impact is expected. C: No concern will be raised as long as the development is approved by the relevant agency before the commencement of construction. O: No major negative impact is expected.
	10	Biodiversity / Ecosystem	✓	✓	D/D	D	D/B-	B-/B+	D/D	D	D/D	D	P: No major negative impact is expected. C: Consideration of biodiversity would not be necessary for drainage facilities. (①, ③) C, O: Deterioration of the existing greenery space in the new retarding ponds is concerned, while biodiversity could be improved if the ponds are developed as urban wetland areas. (②)
	11	Hydrological conditions/phenomena	✓	✓	D/B-	B-	D/B-	B-	D/D	D	D/D	D	P: No major negative impact is expected. C, O: Large volumes of excavation could cause declines in groundwater levels. (①,②)
	12	Topography of terrain, geology of soils	✓	✓	D/D	D	D/D	D	D/D	D	D/D	D	P/O: No major negative impact is expected. C: Expanding drainage capacity or other related construction would not affect the topography iconic to the local landscape.
Social	13	Resettlement and land acquisition	✓	-	B-/D	D	B-/D	D	D/D	D	D/D	D	P: Some involuntary resettlements would be expected for channelization of B. Canal. (①) P: A large amount of land acquisition is expected for the construction of retarding ponds. (②) C, O: No resettlement and land acquisition are expected after the commencement of the construction.

B. Pluvial (Drainage) Flood Control Measures

Category	#	Environmental items	Evaluation in Scoping Stage		B1: North Buckingham Canal (NBC) ①:Rehabili-station of the B. Canal		②:Retarding Pond construction adjacent to the Kodungaiyur Drain, Captain Cotton Canal, Otteri Nala Drain, and midstream of NBC		③:Bypass channel (Cut &Cover) construction connecting Otteri Nala Drain and the Cooum River		④ Construction of a gate at the junction of NBC and Cooum River		Reason for evaluation
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
	14	Living life and livelihood	✓	-	D/D	B+	D/D	B+	D/D	B+	D/D	B+	P, C: No major negative impact is expected. O: The livelihood of the people living near the B. Canal would be improved if the awareness of chronic flooding is eliminated.
	15	Socially vulnerable people (poverty)	✓	-	B-/D	D	D/D	D	D/D	D	D/D	D	P: In some areas along the B. Canal, some encroachers are suffering from poverty, and special countermeasures should be considered for their lives if they are affected. (①) C, O: No major negative impact is expected.
	16	Ethnic minorities and Indigenous people	-	-	D/D	D	D/D	D	D/D	D	D/D	D	P, C, O: There are no socially vulnerable ethnic minorities and indigenous people found in Chennai.
	17	Local economy, such as employment and livelihood	✓	-	D/B+	B+	D/B+	B+	D/B+	B+	D/B+	B+	P: No major negative impact is expected. C: New employment opportunities would be created during the construction work. O: Indirect positive impacts would be expected from the revitalization of the local economy if the problem of chronic flooding is solved.
	18	Land use and local resources	✓	-	D/D	D	D/D	D	D/D	D	D/D	D	P: No major negative impact is expected. C, O: There is no land use and local resource issues related to the drainage facilities.
	19	Water use/rights	✓	-	D/D	D	D/D	D	D/D	D	D/D	D	P, C, O: No major negative impact is expected.
	20	Existing social infrastructures and social services	✓	✓	D/B-	D	D/D	D	D/B-	D	D/D	D	P, O: No major negative impact is expected. C: Construction of heavy machinery would affect local traffic operation, which is related to the accessibility of the social infrastructures. (①,③)
	21	Social capital and social structure of regional decision-making organizations	-	-	D/D	D	D/D	D	D/D	D	D/D	D	P, C, O: There is no relationship between social capital and structures of regional organization related to the measures.
	22	Misdistribution of benefits and damage	✓	-	D/D	D	D/D	D	D/D	D	D/D	D	P, C, O: There is no negative impact determined.
	23	Local conflict of interests	✓	-	D/D	D	D/D	D	D/D	D	D/D	D	P, C, O: There are no conflicts of interest within the community expected during and after the construction works.

B. Pluvial (Drainage) Flood Control Measures

Category	#	Environmental items	Evaluation in Scoping Stage		B1: North Buckingham Canal (NBC)								Reason for evaluation
					①:Rehabili-station of the B. Canal		②:Retarding Pond construction adjacent to the Kodungaiyur Drain, Captain Cotton Canal, Otteri Nala Drain, and midstream of NBC		③:Bypass channel (Cut &Cover) construction connecting Otteri Nala Drain and the Cooum River		④ Construction of a gate at the junction of NBC and Cooum River		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
	24	Cultural Heritage	✓	-	B-/B-	D	D/D	D	D/D	D	D/D	D	P: Relocation of religious structures would be coordinated with the local community. (①) C: Damage to local religious facilities or structures is expected, if any. (①) O: No major negative impact is expected.
	25	Landscape	✓	-	D/D	D	D/D	D	D/D	D	D/D	D	P, C, O: No major negative impact is expected.
	26	Gender	✓	-	D/B-	D	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Gender equality issues shall be considered in the employment of construction workers. C: Social inclusion shall be taken into consideration during the consultation for involuntary resettlement activities. (①)
	27	Children rights	✓	-	D/B-	D	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: There is a potential risk of violation of children's rights in the working environment of construction works.
	28	Infectious diseases such as HIV/AIDS (including hygiene conditions)	✓	-	D/B-	B-	D/B-	D	D/B-	D	D/B-	D	P: No major negative impact is expected. C: The Spread or pandemic of infectious diseases is expected due to the influx of workers from outside during the construction period. O: An increase in infectious diseases due to mosquitoes as vectors would continue if the condition of stagnant drainage/canal water is not improved. (①)
	29	Working conditions (including work safety)	✓	-	D/B-	D	D/B-	D	D/B-	D	D/B-	D	P: There is no element related to the working environment before commencing the work. C: Some negative impacts may be generated regarding safe labor conditions in case technically difficult tasks are carried out by local workers. O: There are no activities that may involve a deterioration of work conditions.

B. Pluvial (Drainage) Flood Control Measures														
Category	#	Environmental items	Evaluation in Scoping Stage		B1: North Buckingham Canal (NBC)								Reason for evaluation
					①:Rehabili-station of the B. Canal		②:Retarding Pond construction adjacent to the Kodungaiyur Drain, Captain Cotton Canal, Otteri Nala Drain, and midstream of NBC		③:Bypass channel (Cut &Cover) construction connecting Otteri Nala Drain and the Cooum River		④ Construction of a gate at the junction of NBC and Cooum River		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
Others	30	Accidents	✓	-	D/B-	B-	D/B-	D	D/B-	D	D/B-	D	P: No work which could cause accidents will be carried out during the planning phase. C: There is an increased risk of workers or residents in the area having an accident due to the increase in work vehicles. O: An increase in water accidents associated with the new pond is expected unless appropriate safety measures are taken.
	31	Impact of crossing borders and climate change	-	-	D/D	D	D/D	D	D/D	D	D/D	D	P, C, O: No significant impact on climate change is expected due to the scale and nature of the measure.

Note: A+/-: An important positive or negative impact is projected, B+/-: There may be some positive or negative impacts,
C+/-: The occurrence of a positive or negative impact has not been determined (a more detailed study must clarify the impact). D: No impact is projected.

Source: JICA Expert Team

Table 8-48: Summary of Environmental Impact Assessment for Implementation of Pluvial (Drainage) Flood Control Measures (2/4)

B. Pluvial (Drainage) Flood Control Measures									
Category	#	Environmental items	Evaluation in Scoping Stage		B2: Central Buckingham Canal (CBC)				Reason for evaluation
					①: Rehabilitation of the B. Canal		②:Gate construction with side walls at the junction of the Cooum and Adyar River		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
Pollution Control	1	Air pollution	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Deterioration of air quality is expected due to traffic congestion. The operation of heavy machinery and construction equipment may result in a temporary deterioration in air quality (including dust).
	2	Water pollution	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C, O: There is a possibility of contamination of the existing drainage water resulting from the use of construction machinery and sewage from the construction site.
	3	Waste	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Generation of construction waste, including demolition debris, excavated soil, and general waste from the workers' camp, is expected.
	4	Soil pollution	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: The risk of soil contamination from the use of chemical substances or construction equipment is a concern.
	5	Noise and vibrations	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Residential areas along with the B. Canal will be affected by noise and vibration from the operation of heavy machinery and construction equipment.
	6	Subsidence of terrain	✓	✓	D/B-	B-	D/D	D	P: No major negative impact is expected. C, O: Land subsidence may occur if a large amount of excavation is required, resulting from a lowering of the groundwater table. (①)
	7	Odors	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: An odor nuisance may be generated by waste from workers' camps during the construction.
	8	Riverbeds Sediments	✓	-	D/D	D	D/D	D	P: Riverbed sediment will not be related to the measure. C, O: No major negative impact is expected.
Natural Environment	9	Protected areas	✓	✓	D/D	D	D/D	D	P, C, O: No protected area found in the catch basin area of the Central B. Canal.
	10	Biodiversity / Ecosystem	✓	✓	D/D	D	D/D	D	P: No major negative impact is expected. C, O: Consideration of biodiversity would not be necessary for drainage facilities.
	11	Hydrological conditions/phenomena	✓	✓	D/D	D	D/D	D	P, C, O: No major negative impact is expected.
	12	Topography of terrain, geology of soils	✓	✓	D/D	D	D/D	D	P, O: No major negative impact is expected. C: Expanding drainage capacity or other related construction would not affect the topography iconic to the local landscape.

B. Pluvial (Drainage) Flood Control Measures										
Category	#	Environmental items	Evaluation in Scoping Stage		B2: Central Buckingham Canal (CBC)				Reason for evaluation
					①: Rehabilitation of the B. Canal		②:Gate construction with side walls at the junction of the Cooum and Adyar River		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
Social Env.	13	Resettlement and land acquisition	✓	-	B-/D	D	D/D	D	P: Some involuntary resettlements would be expected for channelization of B. Canal. (①) C, O: No resettlement and land acquisition are expected after the commencement of the construction.
	14	Living life and livelihood	✓	-	D/D	B+	D/D	B+	P, C: No major negative impact is expected. O: The livelihood of the people living near the drainage would be improved if the awareness of chronic flooding is eliminated.
	15	Socially vulnerable people (poverty)	✓	-	B-/D	D	D/D	D	P: In some parts of the drainage channel areas, there are some encroachers suffering from poverty, and special countermeasures should be considered for their lives if they are affected. (①) C, O: No major negative impact is expected.
	16	Ethnic minorities and indigenous people	-	-	D/D	D	D/D	D	P, C, O: There are no socially vulnerable ethnic minorities and indigenous people found in Chennai.
	17	Local economy such as employment and livelihood	✓	-	D/B+	B+	D/B+	B+	P: No major negative impact is expected. C: New employment opportunities would be created during the construction work. O: Indirect positive impacts would be expected from the revitalization of the local economy if the problem of chronic flooding is solved.
	18	Land use and local resources	✓	-	D/D	D	D/D	D	P: No major negative impact is expected. C, O: There is no land use and local resource issues related to the drainage facilities.
	19	Water use/rights	✓	-	D/D	D	D/D	D	P, C, O: No major negative impact is expected.
	20	Existing social infrastructures and social services	✓	✓	B-/B-	D	D/B-	D	P: Rehabilitation of the B. Canal could affect existing roads and traffic accessing social infrastructure and service. (①) C: Construction heavy machinery would affect local traffic operation, which is related with accessibility of the social infrastructures. O: No major negative impact is expected.
	21	Social capital and social structure of regional decision-making organizations	-	-	D/D	D	D/D	D	P, C, O: There is no relationship with social capital and structures of regional organization related with the measures.
	22	Misdistribution of benefits and damage	✓	-	D/D	D	D/D	D	P, C, O: There is no negative impact determined.
	23	Local conflict of interests	✓	-	D/D	D	D/D	D	P, C, O: There are no conflicts of interest within the community expected during and after the construction works.

B. Pluvial (Drainage) Flood Control Measures

Category	#	Environmental items	Evaluation in Scoping Stage		B2: Central Buckingham Canal (CBC)				Reason for evaluation
					①: Rehabilitation of the B. Canal		②:Gate construction with side walls at the junction of the Cooum and Adyar River		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
	24	Cultural Heritage	✓	-	B-/D	D	D/D	D	P: Relocation of religious structures would be coordinated with the local community. (①) C: Damage to local religious facilities or structures is expected, if any. (①) O: No major negative impact is expected.
	25	Landscape	✓	-	D/D	D	D/D	D	P, C, O: No major negative impact is expected.
	26	Gender	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Gender equality issues shall be considered in the employment of construction workers. C: Social inclusion shall be taken into consideration during the consultation for involuntary resettlement activities. (①)
	27	Children rights	✓	-	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: There will be a potential risk of violation of children's rights in the working environment of construction works.
	28	Infectious diseases such as HIV/AIDS (including hygiene condition)	✓	-	D/B-	B-	D/B-	D	P: No major negative impact is expected. C: Spread or pandemic of infectious diseases is expected due to influx of workers from outside during construction period. O: Increase in infectious diseases due to mosquitoes as vectors would continue if the condition of stagnant drainage water is not improved. (①)
	29	Working conditions (including work safety)	✓	-	D/B-	D	D/B-	D	P: There is no element related to the working environment before commencing the works. C: Some negative impacts may be generated regarding safe labour conditions in case technically difficult tasks are carried out by local workers. O: There are no activities which may involve a deterioration of work conditions.
Others	30	Accidents	✓	-	D/B-	B-	D/B-	D	P: No work which could cause accidents will be carried out during the planning phase. C: There is an increased risk of workers or residents in the area having an accident due to the increase in work vehicles. O: An increase in water accidents associated with the new pond is expected unless appropriate safety measures are taken.
	31	Impact of crossing borders and climate change	-	-	D/D	D	D/D	D	P, C, O: No significant impact on climate change is expected due to the scale and nature of the measure.

Note: A+/-: An important positive or negative impact is projected, B+/-: There may be some positive or negative impacts,
C+/-: The occurrence of a positive or negative impact has not been determined (a more detailed study must clarify the impact). D: No impact is projected.

Source: JICA Expert Team

Table 8-49: Summery of Environmental Impact Assessment for Implementation of Pluvial (Drainage) Flood Control Measures (3/4)

B. Pluvial (Drainage) Flood Control Measures												
Category	#	Environmental items	Evaluation in Scoping Stage		B3: South Buckingham Canal (SBC)						Reason for evaluation
					①: Rehabilitation of the B. Canal		②:Gate and Pump construction at the north end and the area near Pallikaranai Marsh		③: Construction diversion channel connecting B. Canal and the Bay of Bengal at Injambakkam area and shortcut channel from Okkiyam Maduvu to B. Canal		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
Pollution Control	1	Air pollution	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Deterioration of air quality is expected due to the traffic congestion. The operation of heavy machinery and construction equipment may result in a temporary deterioration in air quality (including dust).
	2	Water pollution	✓	-	D/B-	D	D/B-	D	D/B-	B-	P, O: No major negative impact is expected. C, O: There is a possibility of contamination of the existing drainage water resulting from the use of construction machinery and sewage from the construction site. C, O: Deterioration of sea water quality by discharged water from the drainage due to the bed soil excavation and oil leakage from construction machinery is expected. (③)
	3	Waste	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Generation of construction waste including demolition debris, excavated soil and general waste from the workers' camp is expected.
	4	Soil pollution	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: The risk of soil contamination from the use of chemical substances or construction equipment is a concern.
	5	Noise and vibrations	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Residential areas along with the B. Canal and the adjacent areas will be affected by noise and vibration from the operation of heavy machinery and construction equipment.
	6	Subsidence of terrain	✓	✓	D/B-	B-	D/D	D	D/B-	B-	P: No major negative impact is expected. C, O: Land subsidence may occur if a large amount of excavation is required, resulting from a lowering of the ground water table. (①,③)
	7	Odours	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: An odour nuisance may be generated by waste from workers' camp during the construction.
	8	Riverbeds Sediments	✓	-	D/D	D	D/D	D	D/D	D	P: Riverbed sediment will not be related to the measure. C, O: No major negative impact is expected.

B. Pluvial (Drainage) Flood Control Measures

Category	#	Environmental items	Evaluation in Scoping Stage		B3: South Buckingham Canal (SBC)						Reason for evaluation
					①: Rehabilitation of the B. Canal		②:Gate and Pump construction at the north end and the area near Pallikaranai Marsh		③: Construction diversion channel connecting B. Canal and the Bay of Bengal at Injambakkam area and shortcut channel from Okkiyam Maduvu to B. Canal		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
Natural Environment	9	Protected areas	✓	✓	D/D	D	D/D	D	B-/D	D	P: Special attention to the requirement of environmental laws for the development of the coastal zones and Pallikaranai Marsh Reserve Forest is necessary in compliance with the state environmental regulation. (③) C: No concern will be raised as long as the development is approved by the relevant agency before commencement of construction. O: No major negative impact is expected.
	10	Biodiversity / Ecosystem	✓	✓	D/D	D	D/D	D	D/A-	A-	P: No major negative impact is expected. C, O: Consideration on biodiversity would not be necessary for drainage facilities. (①, ②) C, O: Discharge the contaminated water from the B. Canal would affect the maritime ecosystem in the Bay of Bengal if the water is not treated or improved from the current condition. (③)
	11	Hydrological conditions/phenomena	✓	✓	D/D	D	D/D	D	D/B-	B-	P: No major negative impact is expected. C, O: Large volumes of excavation could cause declines of ground water level. (③)
	12	Topography of terrain, geology of soils	✓	✓	D/D	D	D/D	D	D/D	D	P, O: No major negative impact is expected. C: Expanding drainage capacity or other related construction would not affect to the topography iconic to the local landscape.
Social Environment	13	Resettlement and land acquisition	✓	-	B-/D	D	D/D	D	B-/D	D	P: Some involuntary resettlements would be expected for channelization of B. Canal. (①) P: A large amount of land acquisition is expected for the construction of a diversion channel connecting B. Canal and the Bay of Bengal. (③) C, O: No resettlement and land acquisition are expected after commencement of the construction.
	14	Living life and livelihood	✓	-	D/D	B+	D/D	B+	D/D	B+	P, C: No major negative impact is expected. O: The livelihood of the people living near the drainage would be improved by the awareness of chronic flooding is eliminated.
	15	Socially vulnerable people (poverty)	✓	-	B-/D	D	D/D	D	D/D	D	P: In some parts of the drainage channel areas, there are some encroachers suffering from poverty, and special countermeasures should be considered for their lives if they are affected. (①) C, O: No major negative impact is expected.

B. Pluvial (Drainage) Flood Control Measures

Category	#	Environmental items	Evaluation in Scoping Stage		B3: South Buckingham Canal (SBC) ①: Rehabilitation of the B. Canal		②:Gate and Pump construction at the north end and the area near Pallikaranai Marsh		③: Construction diversion channel connecting B. Canal and the Bay of Bengal at Injambakkam area and shortcut channel from Okkiyam Maduvu to B. Canal		Reason for evaluation
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
	16	Ethnic minorities and indigenous people	-	-	D/D	D	D/D	D	D/D	D	P, C, O: There are no socially vulnerable ethnic minorities and indigenous people found in Chennai.
	17	Local economy such as employment and livelihood	✓	-	D/B+	B+	D/B+	B+	D/B+	B+	P: No major negative impact is expected. C: New employment opportunities would be created during the construction work. O: Indirect positive impacts would be expected from the revitalization of the local economy if the problem of chronic flooding is solved.
	18	Land use and local resources	✓	-	D/D	D	D/D	D	D/D	B-	P: No major negative impact is expected. C, O: There is no land use and local resource issues related to the drainage facilities. (①, ②) O: It is expected that disruption of the shoreline either in the beach around the mouse of new diversion channel or the one far from the mouse having relation with comprehensive sand movement, which would result in the degradation of a tourist resource for the region. (③)
	19	Water use/rights	✓	-	D/D	D	D/D	D	D/D	D	P, C, O: No major negative impact is expected.
	20	Existing social infrastructures and social services	✓	✓	B-/B-	D	D/D	D	B-/B-	D	P: Drainage improvement and new diversion channel could affect existing roads and traffic accessing social infrastructure and service. C: Construction heavy machinery would affect local traffic operation, which is related with accessibility of the social infrastructures. O: No major negative impact is expected.
	21	Social capital and social structure of regional decision-making organizations	-	-	D/D	D	D/D	D	D/D	D	P, C, O: There is no relationship with social capital and structures of regional organization related with the measures.
	22	Misdistribution of benefits and damage	✓	-	D/D	D	D/D	D	D/D	D	P, C, O: There is no negative impact determined.
	23	Local conflict of interests	✓	-	D/D	D	D/D	D	D/D	D	P, C, O: There are no conflicts of interest within the community expected during and after the construction works.

B. Pluvial (Drainage) Flood Control Measures												
Category	#	Environmental items	Evaluation in Scoping Stage		B3: South Buckingham Canal (SBC)						Reason for evaluation
					①: Rehabilitation of the B. Canal		②:Gate and Pump construction at the north end and the area near Pallikaranai Marsh		③: Construction diversion channel connecting B. Canal and the Bay of Bengal at Injambakkam area and shortcut channel from Okkiyam Maduvu to B. Canal		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
	24	Cultural Heritage	✓	-	B-/D	D	D/D	D	D/D	D	P: Relocation of religious structures would be coordinated with the local community. (①) C: Damage to local religious facilities or structures is expected, if any. (①) O: No major negative impact is expected.
	25	Landscape	✓	-	D/D	D	D/D	D	D/D	B-	P, C: No major negative impact is expected. O: Disruption of the shoreline around the outlet in the beach would result in the degradation of a touristic landscape. (③)
	26	Gender	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Gender equality issues shall be considered in the employment of construction workers. C: Social inclusion shall be taken into consideration during the consultation for involuntary resettlement activities. (①)
	27	Children rights	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: There will be a potential risk of violation of children's rights in the working environment of construction works.
	28	Infectious diseases such as HIV/AIDS (including hygiene condition)	✓	-	D/B-	B-	D/B-	D	D/B-	D	P: No major negative impact is expected. C: Spread or pandemic of infectious diseases is expected due to influx of workers from outside during construction period. O: Increase in infectious diseases due to mosquitoes as vectors would continue if the condition of stagnant drainage water is not improved. (①)
	29	Working conditions (including work safety)	✓	-	D/B-	D	D/B-	D	D/B-	D	P: There is no element related to the working environment before commencing the works. C: Some negative impacts may be generated regarding safe labour conditions in case technically difficult tasks are carried out by local workers. O: There are no activities which may involve a deterioration of work conditions.

B. Pluvial (Drainage) Flood Control Measures											
Category	#	Environmental items	Evaluation in Scoping Stage		B3: South Buckingham Canal (SBC)						Reason for evaluation
					①: Rehabilitation of the B. Canal		②:Gate and Pump construction at the north end and the area near Pallikaranai Marsh		③: Construction diversion channel connecting B. Canal and the Bay of Bengal at Injambakkam area and shortcut channel from Okkiyam Maduvu to B. Canal		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
Others	30	Accidents	✓	-	D/B-	B-	D/B-	D	D/B-	D	P: No work which could cause accidents will be carried out during the planning phase. C: There is an increased risk of workers or residents in the area having an accident due to the increase in work vehicles. O: An increase in water accidents associated with the new pond is expected unless appropriate safety measures are taken.
	31	Impact of crossing borders and climate change	-	-	D/D	D	D/D	D	D/D	D	P, C, O: No significant impact on climate change is expected due to the scale and nature of the measure.

Note: A+/-: An important positive or negative impact is projected, B+/-: There may be some positive or negative impacts,
C+/-: The occurrence of a positive or negative impact has not been determined (a more detailed study must clarify the impact). D: No impact is projected.

Source: JICA Expert Team

Table 8-50: Summery of Environmental Impact Assessment for Implementation of Pluvial (Drainage) Flood Control Measures (4/4)

B. Pluvial (Drainage) Flood Control Measures											
Category	#	Environmental items	Evaluation in Scoping Stage		B4: Connecting Drains to Adyar and Cooum Rivers						Reason for evaluation
					①:Drainage rehabilitation by deepening and widening of the connecting drains to Adyar and Cooum River		②:Gate construction at the drainage outlet and reorientation of the outlet discharge to align river flow		③: Water tank rehabilitation and development with gate construction (midstream of Kundrathur Drain, upstream of Palmmar Drain		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
Pollution Control	1	Air pollution	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Deterioration of air quality is expected due to the traffic congestion. The operation of heavy machinery and construction equipment may result in a temporary deterioration in air quality (including dust).
	2	Water pollution	✓	-	D/B-	D	D/B-	D	D/B-	B-	P, O: No major negative impact is expected. C, O: There is a possibility of contamination of the existing drainage water resulting from the use of construction machinery and sewage from the construction site. C: Turbulence of existing water in the projected retaining tanks is expected by excavation of bed soil, which leads to water contamination. (③)
	3	Waste	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Generation of construction waste including demolition debris, excavated soil and general waste from the workers' camp is expected.
	4	Soil pollution	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: The risk of soil contamination from the use of chemical substances or construction equipment is a concern.
	5	Noise and vibrations	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Residential areas along with the projected drains will be affected by noise and vibration from the operation of heavy machinery and construction equipment.
	6	Subsidence of terrain	✓	✓	D/B-	B-	D/D	D	D/B-	B-	P: No major negative impact is expected. C, O: Land subsidence may occur if a large amount of excavation is required, resulting from a lowering of the ground water table. (①, ③)
	7	Odours	✓	-	D/B-	D	D/B-	D	D/B-	B-	P, O: No major negative impact is expected. C: An odour nuisance may be generated by waste from workers' camp during the construction.
	8	Riverbeds Sediments	✓	-	D/D	D	D/D	D	D/D	D	P: Riverbed sediment will not be related to the measure. C, O: No major negative impact is expected.
Na	9	Protected areas	✓	✓	D/D	D	D/D	D	D/B-	B+	P, C, O: No protected area found in the projected area of.

B. Pluvial (Drainage) Flood Control Measures

Category	#	Environmental items	Evaluation in Scoping Stage		B4: Connecting Drains to Adyar and Cooum Rivers ①:Drainage rehabilitation by deepening and widening of the connecting drains to Adyar and Cooum River		②:Gate construction at the drainage outlet and reorientation of the outlet discharge to align river flow		③: Water tank rehabilitation and development with gate construction (midstream of Kundrathur Drain, upstream of Palmmar Drain		Reason for evaluation
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
	10	Biodiversity / Ecosystem	✓	✓	D/D	D	D/D	D	D/B-	D/B+	P: No major negative impact is expected. C, O: Consideration on biodiversity would not be necessary for drainage facilities.
	11	Hydrological conditions/phenomena	✓	✓	D/D	D	D/D	D	D/B-	B-	P: No major negative impact is expected. C, O: Large volumes of excavation could cause declines of ground water level. (③)
	12	Topography of terrain, geology of soils	✓	✓	D/D	D	D/D	D	D/D	D	P, O: No major negative impact is expected. C: Expanding drainage capacity or other related construction would not affect to the topography iconic to the local landscape.
Social Environment	13	Resettlement and land acquisition	✓	-	B-/D	D	D/D	D	D/D	D	P: Some involuntary resettlements would be expected for channelization of the drains. (①) C, O: No resettlement and land acquisition are expected after commencement of the construction.
	14	Living life and livelihood	✓	-	D/D	B+	D/D	B+	D/D	B+	P, C: No major negative impact is expected. O: The livelihood of the people living near the drainage would be improved by the awareness of chronic flooding is eliminated.
	15	Socially vulnerable people (poverty)	✓	-	B-/D	D	D/D	D	D/D	B+	P: In some parts of the drainage channel areas, there are some encroachers suffering from poverty, and special countermeasures should be considered for their lives if they are affected. (①) C, O: No major negative impact is expected.
	16	Ethnic minorities and indigenous people	-	-	D/D	D	D/D	D	D/D	D	P, C, O: There are no socially vulnerable ethnic minorities and indigenous people found in Chennai.
	17	Local economy such as employment and livelihood	✓	-	D/B+	B+	D/B+	B+	D/B+	B+	P: No major negative impact is expected. C: New employment opportunities would be created during the construction work. O: Indirect positive impacts would be expected from the revitalization of the local economy if the problem of chronic flooding is solved.

B. Pluvial (Drainage) Flood Control Measures

Category	#	Environmental items	Evaluation in Scoping Stage		B4: Connecting Drains to Adyar and Cooum Rivers						Reason for evaluation
					①:Drainage rehabilitation by deepening and widening of the connecting drains to Adyar and Cooum River		②:Gate construction at the drainage outlet and reorientation of the outlet discharge to align river flow		③: Water tank rehabilitation and development with gate construction (midstream of Kundrathur Drain, upstream of Palmmar Drain		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
	18	Land use and local resources	✓	-	D/D	D	D/D	D	D/D	B-	P: No major negative impact is expected. C: There is no land use and local resource issues related to the drainage facilities. O: Decrease in groundwater level if the measure involves a large amount of excavation is concerned. (③)
	19	Water use/rights	✓	-	D/D	D	D/D	D	D/D	D	P, C, O: No major negative impact is expected.
	20	Existing social infrastructures and social services	✓	✓	B-/B-	D	D/B-	D	D/B-	D	P: Drainage improvement could affect existing roads and traffic accessing social infrastructure and service. (①) C: Construction heavy machinery would affect local traffic operation, which is related with accessibility of the social infrastructures. O: No major negative impact is expected.
	21	Social capital and social structure of regional decision-making organizations	-	-	D/D	D	D/D	D	D/D	D	P, C, O: There is no relationship with social capital and structures of regional organization related with the measures.
	22	Misdistribution of benefits and damage	✓	-	D/D	D	D/D	D	D/D	D	P, C, O: There is no negative impact determined.
	23	Local conflict of interests	✓	-	D/D	D	D/D	D	D/D	D	P, C, O: There are no conflicts of interest within the community expected during and after the construction works.
	24	Cultural Heritage	✓	-	B-/B-	D	D/D	D	B-/B-	D	P: Relocation of religious structures would be coordinated with the local community. C: Damage to local religious facilities or structures is expected, if any. O: No major negative impact is expected.
	25	Landscape	✓	-	D/D	D	D/D	D	D/D	D	P, C: No major negative impact is expected. O: No major negative impact is expected.
	26	Gender	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: Gender equality issues shall be considered in the employment of construction workers. C: Social inclusion shall be taken into consideration during the consultation for involuntary resettlement activities. (①)

B. Pluvial (Drainage) Flood Control Measures											
Category	#	Environmental items	Evaluation in Scoping Stage		B4: Connecting Drains to Adyar and Cooum Rivers						Reason for evaluation
					①:Drainage rehabilitation by deepening and widening of the connecting drains to Adyar and Cooum River		②:Gate construction at the drainage outlet and reorientation of the outlet discharge to align river flow		③: Water tank rehabilitation and development with gate construction (midstream of Kundrathur Drain, upstream of Palmmar Drain		
			P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	P/C Phase	O Phase	
	27	Children rights	✓	-	D/B-	D	D/B-	D	D/B-	D	P, O: No major negative impact is expected. C: There will be a potential risk of violation of children's rights in the working environment of construction works.
	28	Infectious diseases such as HIV/AIDS (including hygiene condition)	✓	-	D/B-	B-	D/B-	D	D/B-	D	P: No major negative impact is expected. C: Spread or pandemic of infectious diseases is expected due to influx of workers from outside during construction period. O: Increase in infectious diseases due to mosquitoes as vectors would continue if the condition of stagnant drainage water is not improved. (①)
	29	Working conditions (including work safety)	✓	-	D/B-	D	D/B-	D	D/B-	D	P: There is no element related to the working environment before commencing the works. C: Some negative impacts may be generated regarding safe labour conditions in case technically difficult tasks are carried out by local workers. O: There are no activities which may involve a deterioration of work conditions.
Others	30	Accidents	✓	-	D/B-	B-	D/B-	D	D/B-	B-	P: No work which could cause accidents will be carried out during the planning phase. C: There is an increased risk of workers or residents in the area having an accident due to the increase in work vehicles. O: An increase in water accidents associated with the new pond is expected unless appropriate safety measures are taken.
	31	Impact of crossing borders and climate change	-	-	D/D	D	D/D	D	D/D	D	P, C, O: No significant impact on climate change is expected due to the scale and nature of the measure.

Note: A+/-: An important positive or negative impact is projected, B+/-: There may be some positive or negative impacts,
C+/-: The occurrence of a positive or negative impact has not been determined (a more detailed study must clarify the impact). D: No impact is projected.

Source: JICA Expert Team

Table 8-51: Summery of Environmental Impact Assessment for Implementation of Coastal Flood Control Measure

Category	#	Environmental items	Evaluation in Scoping Stage P/C Phase	Evaluation in Scoping Stage O Phase	①: Construction of training wall at Muttukadu P/C Phase	①: Construction of training wall at Muttukadu O Phase	Reason for evaluation
C. Coastal Flood Control Measure							
Pollution Control	1	Air pollution	✓	-	D/B-	D	P, O: No major negative impact is expected. C: Deterioration of air quality is expected due to the traffic congestion. The operation of heavy machinery and construction equipment may result in a temporary deterioration in air quality (including dust).
	2	Water pollution	✓	-	D/B-	D	P, O: No major negative impact is expected. C: Deterioration of sea water and surface river water quality due to the bed soil excavation and oil leakage from construction machinery is expected.
	3	Waste	✓	-	D/B-	D	P, O: No major negative impact is expected. C: Generation of construction waste including demolition debris, excavated soil and general waste from the workers' camp is expected.
	4	Soil pollution	✓	-	D/B-	D	P, O: No major negative impact is expected. C: The risk of soil contamination from the use of chemical substances or construction equipment is a concern during the construction works.
	5	Noise and vibrations	✓	-	D/D	D	P, O: No major negative impact is expected. C: Beach areas will be affected by noise from the operation of heavy machinery and construction equipment.
	6	Subsidence of terrain	✓	✓	D/D	D	P, C, O: No major negative impact is expected.
	7	Odours	✓	-	D/B-	D	P, O: No major negative impact is expected. C: An odour nuisance may be generated by waste from workers' camp during the construction.
	8	Riverbeds Sediments	✓	-	D/D	B-	P: Riverbed sediment will not be related with the measure. C: No significant negative impact is expected. O: Accumulation of sediment soil would affect sand movement on the related beaches.
Natural Environment	9	Protected areas	✓	✓	B-/D	D	P: Special attention to the requirement of environmental laws for the development of the coastal zones near the south end of the B. Canal is necessary for the state environmental regulation. C: No concern will be raised as long as the development is approved by the relevant agency before commencement of construction. O: No major negative impact is expected.
	10	Biodiversity / Ecosystem	✓	✓	D/B-	B-	P: No major negative impact is expected. C, O: Negative impact on the habitat of sea turtles on the beach near the south end of the Buckingham Canal is a big concern. (③)
	11	Hydrological conditions/phenomena	✓	✓	D/D	D	P, C, O: No major negative impact is expected.
	12	Topography of terrain, geology of soils	✓	✓	D/D	D	P, O: No major negative impact is expected. C: Dredging the rivers tanks would not affect the topography iconic to the local landscape.
S	13	Resettlement and land acquisition	✓	-	D/D	D	P, C, O: No resettlement and land acquisition are required after commencement of the construction.

C. Coastal Flood Control Measure							
Category	#	Environmental items	Evaluation in Scoping Stage		①: Construction of training wall at Muttukadu		Reason for evaluation
			P/C Phase	O Phase	P/C Phase	O Phase	
	14	Living life and livelihood	✓	-	D/D	D	P, C, O: No major negative impact is expected.
	15	Socially vulnerable people (poverty)	✓	-	D/D	D	P, C, O: No major negative impact is expected.
	16	Ethnic minorities and indigenous people	-	-	D/D	D	P, C, O: There are no socially vulnerable ethnic minorities and indigenous people found in Chennai.
	17	Local economy such as employment and livelihood	✓	-	D/B+	B+	P: No major negative impact is expected. C: New employment opportunities would be created during the construction work. O: Indirect positive impacts would be expected from the revitalization of the local economy if the problem of chronic flooding is solved.
	18	Land use and local resources	✓	-	D/D	B-	P, C: No major negative impact is expected. O: It is expected that disruption of the shoreline either in the beach around the mouse or the one far from the mouse having relation with comprehensive sand movement, which would result in the degradation of a tourist resource for the region.
	19	Water use/rights	✓	-	D/D	D	P, C, O: No major negative impact is expected.
	20	Existing social infrastructures and social services	✓	✓	D/B-	D	P, O: No major negative impact is expected. C: Construction heavy machinery would affect local traffic operation, which is related to accessibility of the social infrastructures.
	21	Social capital and social structure of regional decision-making organizations	-	-	D/D	D	P, C, O: There is no relationship with social capital and structures of regional organization related with the measures.
	22	Misdistribution of benefits and damage	✓	-	D/D	D	P, C, O: No major negative impact is expected.
	23	Local conflict of interests	✓	-	D/D	D	P, C, O: There is no conflicts of interests within the community expected during and after
	24	Cultural Heritage	✓	-	D/D	D	P, C, O: No major negative impact is expected.
	25	Landscape	✓	-	D/D	B-	P, C: No major negative impact is expected. O: Disruption of the shoreline around the outlet in the beach would result in the degradation of a touristic landscape.
	26	Gender	✓	-	D/B-	D	P, O: No major negative impact is expected. C: Gender empowerment/equality issues shall be considered in the employment of construction workers.
	27	Children rights	✓	-	D/B-	D	P, O: No major negative impact is expected. C: There will be a potential risk of violation of children's rights in the working environment of construction works.

C. Coastal Flood Control Measure							
Category	#	Environmental items	Evaluation in Scoping Stage		①: Construction of training wall at Muttukadu		Reason for evaluation
			P/C Phase	O Phase	P/C Phase	O Phase	
Others	28	Infectious diseases such as HIV/AIDS (including hygiene condition)	✓	-	D/B-	D	P, O: No major negative impact is expected. C: Spread or pandemic of infectious diseases is expected due to influx of workers from outside during construction period.
	29	Working conditions (including work safety)	✓	-	D/B-	D	P: There is no element related to the working environment before commencing the works. C: Some negative impacts may be generated regarding safe labour conditions in case that technically difficult tasks are carried out by local workers. O: There are no activities which may involve a deterioration of work conditions.
	30	Accidents	✓	-	D/B-	D	P: No work which could cause accidents will be carried out during the planning phase. C: There is a risk of accidents for workers and residents near the construction site due to the increase in construction vehicles. O: An increase in water accidents associated with the new pond is expected unless appropriate safety measures are taken.
	31	Impact of crossing borders and climate change	-	-	D/D	D	P, C, O: No significant impact on climate change is expected due to the scale and nature of the measure.

Note: A+/-: An important positive or negative impact is projected, B+/-: There may be some positive or negative impacts,
C+/-: The occurrence of a positive or negative impact has not been determined (a more detailed study must clarify the impact). D: No impact is projected.

Source: JICA Expert Team

8.10.3 Alternative analysis

The following table shows a summary of alternative analysis for the proposed counter measures 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.

Table 8-52: 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 Channelization-1 (Deepening Riverbed)	Okkiyam maduvu Surplus Channelization-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 Cooum R.	Construction of gate at the junction of NBC and Cooum River to prevent backwater	Rehabilitation of the B. Canal	Gate construction with side walls at the junction of the Cooum 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

According to the summary table above, it is examined that there are three groups distinguishable in the evaluation level, namely as high, moderate, and low. The high evaluation group includes the measures with around 30 points, while the measures with less than 21 points are considered as the low evaluation group. Additionally, those with points ranging from 22 to 28 can be determined as the moderate evaluation group. On the other hand, each category of the measures has characteristics as mentioned in the following table.

Table 8-53: Characteristics of Category of Measures

Category	Characteristics
A: Fluvial (River) Flood Control Measures Average Point: 24.83	
A1 Adyar River Basin Average Point: 23.00	All measures are evaluated as moderate except for the measure 'Underground River construction'. Evaluation of the item 'Beneficial to local economy' is comparatively high, because the river channelization including river deepening and widening, would contribute to comprehensive areas along the Adyar River suffering from the chronic floodings. On the other hand, the mitigation 'Underground River Construction' has the lowest score in this category due to the item 'Impact on natural environment' and 'Local resource'. Concerns about biodiversity in coastal and maritime environment including beach condition as tourism resources shall be eliminated and clarified in detail if incorporating this measure. Additionally, issues of pollution control would be controversial including a large volume of waste soil generated by excavation of the riverbed soil.
A2 Cooum River Basin Average Point: 24.50	All measures are evaluated as moderate category. River channelization including deepening and widening belongs to the moderate evaluation group due to the low scores of the items, 'Pollution control', 'Impact on natural environment' and 'Involuntary Resettlement'. The item 'Involuntary Resettlement' is the most controversial issue on this physical measure, and it shall be carefully taken into consideration based on the relevant laws as well as an appropriate safeguard policy. However, it can be said that the measures in this category could be highly applicable if these negative elements are resolved and mitigated during the project phase.
A3 Kosasthalaiyar River Basin Average Point: 25.67	All measures are evaluated as moderate category. Characteristics of this category is similar to the ones for the Adyar and Cooum River Basin. Regarding the 'Looped waterway development', instead of its high potential cost of the measure, since the projected area is located not compacted residential/business district, it would give less negative impact on 'Involuntary Resettlement' than the others. However, it is necessary to consider about degradation of biodiversity because the area is close to the Ennore Creek where some areas are partially designated as the CRZ.
A4 Kovalam Basin Average Point: 26.00	The average point of the measures in this category is the highest in the river flood control measures. Especially, the items 'Beneficial to local economy' and 'Living condition of the citizens' are highly evaluated because the flood-prone districts are included in this area. On the other hand, there are two big concerns left for these measures. One is the item 'Impact on natural environment', because the projected site, part of the Okkiyam maduvu and adjacent area, the Pallikaranai Marsh Reserve Forest, are registered as Ramsar site. And the other is 'Land acquisition', because a large volume of land acquisition will be required for Okkiyam maduvu Surplus Channelization. For the former issue, an impact assessment based on a detailed environmental study on environmental impacts on the Ramsar area is required prior to the implementation of the construction works, and it is also important to proceed with the project in accordance with environmental laws and regulations in Tamil Nadu. For the latter issue, in order to obtain the landowner's consent for land acquisition, careful action is required regarding discussions, including compensation policies.
A5 All basin Average Point: 23.50	All measures are evaluated as moderate category. The projected existing tanks have been utilized for irrigation of the rice field and support agricultural activity for farmers. Therefore, Implementation of development associated with existing tanks carries potential risks including ensuring adequate water in timely manner or water pollution control, which could hinder economic activity by farmers. Additionally, the item 'Impact on natural environment' relates to the loss of points due to the potential degradation of biodiversity mainly caused by the dynamic tree cutting or vegetation clearing. However, given that the new retarding ponds will be developed based on environmental considerations and will end up with regional marshland in the future, the evaluation of the measure could be reviewed and modified as one of the effective measures for the flood mitigation in Chennai.
B: Pluvial (Drainage) Flood Control Measures Average Point: 27.92	

Category	Characteristics
B1 North Buckingham Canal (NBC) Average Point: 28.50	Total evaluation point of this category is the highest of all. Since most of the measures in this category will be carried out in the existing drainage facilities, the construction works will not be associated with new development areas. Therefore, no significant negative impact on both natural and social environment is expected. However, impacts of natural environment to the retarding pond construction is one of the big concerns because it could lead to deterioration of existing biodiversity due to a large volume of tree cutting and excavation of bed soil.
B2 Central Buckingham Canal (CBC) Average Point: 28.50	Total average evaluation point of this category is the highest of all. Because the Buckingham Canal in the central section is located in the city centre and the canal functioned as a drainage channel collecting untreated discharged water from the residential and business buildings. Under these circumstances, there is less natural environment left for conservation along the canal. Instead of the protective actions, it would be necessary to have a positive action to create a comfortable canal environment for the future. On the other hand, there are citizens living along the section and suffering from poverty, who can be acknowledged as the socially vulnerable. Therefore, careful handling to involuntary resettlement before implementation of the measures would be required.
B3 South Buckingham Canal (SBC) Average Point: 26.00	Two of the three measures are classified as high, while the other is classified as low. Since the projected site for the measures scoring high evaluation is located in the suburbs rather than in the centre of the city, the impact on the natural and social environment is expected to be minimized. On the other hand, the measure, ‘Construction of Diversion Channel connecting the B. Canal and the Bay of Bengal’ has the lower score than others due to the impact on pollution control and necessity of land acquisition. There is a significant environmental risk of discharging the water, which is likely to be contaminated in its present condition, into the sea. Therefore, this action should be controlled by setting a condition that the treated water is to be discharged into the Bay of Bengal.
B4 Connecting Drains to Adyar and Cooum Rivers Average Point: 28.67	Total average evaluation point of this category is the second highest of all. It is expected that the measures in this category are required small-scaled construction, therefore the impacts either on natural or social environment would be relatively small. However, it would be necessary to pay attention to pollution control in the rehabilitation of the existing water tanks because there are some citizens who use the resource from the tanks by fishing for their livelihood.
C: Coastal Flood Control Measure Average Point: 21.00	
The evaluation point of this measure is in the low level due to the item ‘Impact on natural environment’, ‘Pollution control’ and Impact on local resource’. The projected site is located in Muttucadu district which includes beaches in the coastal area, and part of the coastal area is designated as CRZ. One of the big concerns is sand movement change after carrying out the measure which would result in changing the existing beach shape. Gradual changes of existing shape of the beach would affect to the tourism industry because there are some tourism elements in the district including viewpoints.	

Source: JICA Expert Team

Furthermore, paying attention to the category of measures, “Pluvial (Drainage) Flood Control Measures (B1, B2, B3, B4)” has seven highly evaluated measures in total, which could be identified as the most applicable category of all in short period of time. The category, ‘River Flood Control Measures (A)” could be applicable and remarkably effective for flood control if the controversial issues, such as involuntary resettlement and pollution control, can be resolved.

However, it would be recommended that combination of the proposed measures would be able to seek the best way of the flood prevention in Chennai, therefore, prioritized mitigation measures for the flood control have to be determined in anticipation of areas requiring immediate actions and coordinated based on a long-term project implementation schedule.

The following table is a source of the aforementioned ‘Summary of Alternatives Analysis’, which provides rationale or comments on the assessment.

Table 8-54: Alternative Analysis (1) (Evaluation: 1←Negative Positive→5)

#	Evaluation Item	Without Project Option	A: Fluvial (River) Flood Control Measures				
			A1：Adyar River Basin			A2：Cooum River Basin	
			①	②	③	①	②
			River Channelization-1 (Deepening Riverbed)	River Channelization-2 (Widening Riverbank)	Underground River construction	River Channelization-1 (Deepening Riverbed)	River Channelization-2 (Widening Riverbank)
1	Cost for flood mitigation	Very high for long-term perspective	Moderately high	Moderately high	Very high	High	High
		1	3	3	1	2	2
2	Beneficial to local economy	Local economy will continuously suffer from the periodic flooding.	Very effective by eliminating the awareness of flooding when water capacity of the target rivers is dramatically improved.	Very effective by eliminating the awareness of flooding when water capacity of the target rivers is dramatically improved.	Effectiveness to the local economy is moderate since the location of the implementation area is limited.	Very effective by eliminating the awareness of flooding when water capacity of the target rivers is dramatically improved.	Very effective by eliminating the awareness of flooding when water capacity of the target rivers is dramatically improved.
		1	5	5	4	5	5
3	Pollution control	Worsening pollution of river water is expected without any measures or mindset of river environment.	The magnitude of the impact on water quality during the construction is very high. Treatment of polluted dredged soil is one of the concerns.	Magnitude of the impacts on water quality during the construction is not significant.	The magnitude of the impacts on sea water quality during the construction and operation period is high.	The magnitude of the impacts on water quality during the construction is very high.	The magnitude of the impacts on water quality during the construction is not significant.
		1	2	4	2	2	4
4	Impact on natural environment	No change	Potential saline backwater would affect the existing ecosystem.	Some amounts of tree-cutting are expected when widening river is carried out.	Possible changes in coastal lines would affect the aquatic ecosystem.	No significant negative impact is expected.	Some amounts of tree-cutting are expected when widening river is carried out.
		3	3	3	2	4	2
5	Involuntary Resettlement and land acquisition	No involuntary resettlement and land acquisition is expected.	Neither involuntary resettlement nor land acquisition is expected.	Large amounts of involuntary resettlements and land acquisition are expected when widening river is carried out.	Some magnitude of resettlement and land acquisition is expected for the deep shaft construction.	Neither involuntary resettlement nor land acquisition is expected.	Large amounts of involuntary resettlements and land acquisition are expected when widening river is carried out.
		5	5	2	3	5	2
6	Impact related to living conditions of the citizens	Living conditions would deteriorate due to the periodic flooding.	Living conditions of the implemented area would be improved significantly without a dynamic change of social environment.	Significant improvement would be ensured if accessibility to the social infrastructure is controlled.	Living conditions of the implemented area would be improved significantly without a dynamic change of social environment.	Living conditions of the implemented area would be improved significantly without a dynamic change of social environment.	Significant improvement would be ensured if accessibility to the social infrastructure is controlled.
		1	5	4	5	5	4
7	Impact on local resources (groundwater and beach etc.)	No change	Potential negative impact on lowering groundwater table is a big concern for the neighbours.	Potential negative impact on lowering groundwater table is a big concern for the neighbours.	Potential negative impact on lowering groundwater table and changing coastal line are big concerns.	Potential negative impact on lowering groundwater table is a big concern for the neighbours.	Potential negative impact on lowering groundwater table is a big concern for the neighbours. Many cultural heritages in the urbanized area will be protected from the chronic floodings.
		3	3	3	2	3	4

#	Evaluation Item	Without Project Option	A: Fluvial (River) Flood Control Measures				
			A1：Adyar River Basin			A2：Cooum River Basin	
			①	②	③	①	②
			River Channelization-1 (Deepening Riverbed)	River Channelization-2 (Widening Riverbank)	Underground River construction	River Channelization-1 (Deepening Riverbed)	River Channelization-2 (Widening Riverbank)
	Total	No advantage due to the evaluation of continuous cost for flood mitigation and local economy.	If magnitude of resettlement and tree cutting, impact on pollution control are controlled, it would get higher evaluation.	If magnitude of resettlement and tree cutting are controlled, it would get higher evaluation.	The cost of measure is the big bottleneck for rating. If the impact on the natural environment can be resolved, the applicability would be increased.	If magnitude of resettlement and tree cutting, impact on pollution control are controlled, it would get higher evaluation.	If magnitude of resettlement and tree cutting are controlled, it would get higher evaluation.
		15	26	24	19	26	23

Source: JICA Expert Team

Table 8-55: Alternative Analysis (2) (Evaluation: 1←Negative Positive→5)

#	Evaluation Item	Without Project Option	A: Fluvial (River) Flood Control Measures						
			A3: Kosasthalaiyar River Basin			A4: Kovalam Basin		A5: All river basin (including Kovalum Basin)	
			①	②	③	①	②	①	②
			River and Redhills Surplus Channelization-1 (Deepening Riverbed)	River and Redhills Surplus Channelization -2 (Widening Riverbank)	Looped waterway development with gate construction	Okkiyam Maduvu Surplus Channelization-1 (Deepening Riverbed)	Okkiyam maduvu Surplus Channelization-2 (Widening Riverbank)	Water tank rehabilitation with gate construction	New water tank development with gate construction
1	Cost for flood mitigation	Very high for long-term perspective	Moderately high	Moderately high	High	Moderate	Moderate	Moderate	Moderate
		1	3	3	2	4	4	4	4
2	Beneficial to local economy	Local economy will continuously suffer from the periodic flooding.	Very effective by eliminating the awareness of flooding when water capacity of the target rivers is dramatically improved.	Very effective by eliminating the awareness of flooding when water capacity of the target rivers is dramatically improved.	Effectiveness of the local economy is moderate since beneficial areas for flood protection are limited.	Very effective by eliminating the awareness of flooding when water capacity of the target rivers is dramatically improved.	Very effective by eliminating the awareness of flooding when water capacity of the target rivers is dramatically improved.	Very effective by eliminating the awareness of flooding when many existing tanks are applied for the improvement.	Effectiveness to the local economy is moderate since available lands for the new tanks are limited.
		1	5	5	4	5	5	5	4
3	Pollution control	Worsening pollution of river water is expected without any measures or mindset of river environment.	The magnitude of the impact on water quality is very high. Treatment of polluted dredged soil is one of the concerns.	The magnitude of the impact on water quality during the construction is not significant.	Building walls and gate construction have relatively less negative impact on water quality of drainage channels.	The magnitude of the impact on water quality is very high. Treatment of polluted dredged soil is one of the concerns.	The magnitude of the impacts on water quality during the construction is not significant.	The magnitude of the impacts on water quality during the construction is very high.	Constructing stormwater tanks has less negative impact than other countermeasures.
		1	2	4	4	2	4	2	3
4	Impact on natural environment	No change	Potential saline backwater would affect the existing ecosystem.	Some amounts of tree-cutting are expected when widening river is carried out.	Some amounts of tree-cutting are expected when widening river is carried out.	Secondary negative impact on the decreasing water level of the marsh is a significant concern.	Some amounts of tree-cutting are expected when widening river is carried out. Same as left.	Cutting trees and aquatic vegetation is expected. Cutting large specimen trees is a big concern.	Some amounts of tree-cutting are expected when the applicable land is covered by trees.
		3	3	3	3	2	2	2	2
5	Involuntary Resettlement and land acquisition	No involuntary resettlement and land acquisition is expected.	Neither involuntary resettlement nor land acquisition is expected.	Large amounts of involuntary resettlements and land acquisition are expected.	Resettlement and land acquisition would be limited.	Neither involuntary resettlement nor land acquisition is expected.	The amounts of resettlements and land acquisition are limited.	Small amounts of involuntary resettlement would be expected. No land acquisition is expected	Small amounts of involuntary resettlement and land acquisition would be expected.
		5	5	2	4	5	4	4	3
6	Impact related to living condition of the citizens	Living conditions would deteriorate due to the periodic flooding.	Living conditions of the implemented area would be improved significantly without a dynamic change of social environment.	Significant improvement would be ensured if accessibility to the social infrastructure is controlled.	Business and industrial areas would be improved significantly due to decrease in flood occurrence.	Living conditions of the implemented area would be improved significantly without a dynamic change of social environment.	Significant improvement would be ensured if accessibility to the social infrastructure is controlled.	Living conditions would be improved significantly without a dynamic change of social environment.	Living conditions would be moderately improved because quantities of the applicable tanks are limited.
		1	5	4	5	5	4	5	3
7	Impact on local resources (groundwater and beach etc.)	No change	Potential negative impact on lowering groundwater table is a big concern for the neighbours.	Potential negative impact on lowering groundwater table is a big concern for the neighbours.	No impact on local resource is expected because there is no relationship with local resource in the	Potential negative impact on lowering groundwater table is a big concern for the neighbours.	Potential negative impact on lowering groundwater table is a big concern for the neighbours.	Ensuring adequate water resources in the tanks and ground water in the surrounding area is required especially for	Potential negative impact on lowering groundwater table is a big concern for the neighbours.

#	Evaluation Item	Without Project Option	A: Fluvial (River) Flood Control Measures						
			A3: Kosasthalaiyar River Basin			A4: Kovalam Basin		A5: All river basin (including Kovalum Basin)	
			①	②	③	①	②	①	②
			River and Redhills Surplus Channelization-1 (Deepening Riverbed)	River and Redhills Surplus Channelization -2 (Widening Riverbank)	Looped waterway development with gate construction	Okkiyam Maduvu Surplus Channelization-1 (Deepening Riverbed)	Okkiyam maduvu Surplus Channelization-2 (Widening Riverbank)	Water tank rehabilitation with gate construction	New water tank development with gate construction
					intersection area b/w drainage and river.			existing agricultural activities.	
		3	3	3	5	3	3	3	3
	Total	No advantage due to the evaluation of continuous cost for flood mitigation and local economy.	If magnitude of resettlement and tree cutting, impact on pollution control are controlled, it would get higher evaluation.	If magnitude of resettlement and tree cutting are controlled, it would get higher evaluation.	Remarkable for high evaluation despite higher construction cost.	Low impact in social environment ended up with higher evaluation. Deterioration of water quality is only the issue.	Remarkable for a high rating due to the less challenging issues in comparison to the other measures.	Utilization of existing tanks ends moderately high evaluation; however, some items require appropriate mitigations	The number of applicable tanks reflects its evaluation; however, it is possible to achieve a higher evaluation if each item can be properly mitigated.
		15	26	24	27	26	26	25	22

Source: JICA Expert Team

Table 8-56: Alternative Analysis (3) (Evaluation: 1←Negative Positive→5)

#	Evaluation Item	Without Project Option	B: Pluvial (Drainage) Flood Control Measures					
			B1: North Buckingham Canal (NBC)				B2: Central Buckingham Canal (CBC)	
			①	②	③	④	①	②
			Rehabilitation of the North B. Canal	Retarding Pond construction adjacent to the Kodungaiyur Drain, Captain Cotton Canal, Otteri Nala Drain, etc.	Bypass channel (Cut &Cover) construction connecting Otteri Nala Drain and the Cooum River	Construction of gate at the junction of NBC and Cooum River	Rehabilitation of the Central B. Canal	Gate construction with side walls at the junction of the Cooum and Adyar River
1	Cost for flood mitigation	Very high for long-term perspective	Moderate	Moderate	Moderately high	Moderate	Moderate	High
		1	4	4	3	4	4	2
2	Beneficial to local economy	The local economy will continuously suffer from the periodic flooding.	Very effective by eliminating the awareness of flooding when many sections of the B. Canal in the CBD are improved.	Effectiveness of the local economy is moderate since beneficial areas for flood protection are limited.	Effectiveness of the local economy is moderate since beneficial areas for flood protection are limited.	Effectiveness of the local economy is moderate since beneficial areas for flood protection are limited.	Very effective by eliminating the awareness of flooding when many sections of the B. Canal along with the Metro line are applied.	Effectiveness of the local economy is moderate since beneficial areas for flood protection are limited.
		1	5	4	4	4	5	4
3	Pollution control	Worsening pollution of river water is expected without any measures or mindset of river environment.	Discharging or leaking polluted water from the drainage into the river is only a big concern.	An inflow of polluted water in the canal to the new retarding pond is expected.	Inflow of polluted water in the drains to the Cooum River is expected.	Building walls and installing pumps has relatively less negative impact on water quality of drainage channels.	Discharging or leaking polluted water from the drainage into the river is only a big concern.	Building walls and installing pumps has relatively less negative impact on water quality of drainage channels.
		1	3	3	3	4	3	4
4	Impact on natural environment	No change	Deterioration of existing vegetation would be limited unless accompanied by dynamic change of existing drainage channels.	Some amounts of tree-cutting are expected when the applicable land is covered by trees.	No deterioration of existing vegetation would be considered because the projected sites are mostly urbanized or built areas.	No deterioration of existing vegetation would be considered because the projected sites are mostly urbanized or built areas.	Deterioration of existing vegetation would be limited unless accompanied by dynamic change of existing drainage channels.	No deterioration of existing vegetation would be considered because the projected sites are mostly urbanized or built areas.
		3	4	2	5	5	4	5
5	Involuntary Resettlement and land acquisition	No involuntary resettlement and land acquisition is expected.	Almost no involuntary resettlement and land acquisition would be expected because it is just modification of the existing drainage channels.	Small amounts of land acquisition from private sectors would be expected.	No involuntary resettlement and land acquisition would be expected because the new culvert is installed under the existing road.	Small amounts of land acquisition from private sectors would be expected.	Almost no involuntary resettlement and land acquisition would be expected because it is just modification of the existing drainage channels.	Some amounts of involuntary resettlement would be expected. Some amount of land acquisition is required for dike construction.
		5	5	4	5	4	3	3
6	Impact related to living conditions of the citizens	Living conditions would deteriorate due to the periodic flooding.	Living conditions in the large residential areas would be improved significantly due to decrease in flood occurrence.	Living conditions would be moderately improved because most of the applicable areas are currently unutilized.	Living conditions would be improved due to a decrease of flood occurrence but it is limited to the proposed areas.	Living conditions in the large residential areas would be improved significantly due to decrease in flood occurrence.	Living conditions in the large residential areas would be improved significantly due to decrease in flood occurrence.	Living conditions in the large residential areas would be improved significantly due to decrease in flood occurrence.
		1	5	4	4	5	5	5
7	Impact on local resources (groundwater and beach etc.)	No change	No impact on local resources is expected, while beautification of drainage channel would rather be	Potential negative impact on lowering groundwater table is a big concern for the neighbours.	No impact on local resources is anticipated due to the small-scale drainage channel development	No impact on local resource is expected because there is no relationship with local resource in the	No impact on local resources is expected, while beautification of drainage channel would rather be	No impact on local resources is expected because there is no relationship with local

#	Evaluation Item	Without Project Option	B: Pluvial (Drainage) Flood Control Measures					
			B1: North Buckingham Canal (NBC)				B2: Central Buckingham Canal (CBC)	
			①	②	③	④	①	②
			Rehabilitation of the North B. Canal	Retarding Pond construction adjacent to the Kodungaiyur Drain, Captain Cotton Canal, Otteri Nala Drain, etc.	Bypass channel (Cut &Cover) construction connecting Otteri Nala Drain and the Cooum River	Construction of gate at the junction of NBC and Cooum River	Rehabilitation of the Central B. Canal	Gate construction with side walls at the junction of the Cooum and Adyar River
			expected through people's environmental mindset.			intersection area b/w drainage and river.	expected through people's environmental mindset.	resources in the intersection area b/w the canal and river.
		3	5	3	4	5	5	5
	Total	No advantages due to the evaluation of continuous cost for flood mitigation and local economy.	Utilization of the existing drainage channels marked the highest evaluation, however there would be appropriate pollution control mitigation.	The number of applicable areas reflects its evaluation, yet it is capable to get higher evaluation if each item can be mitigated properly.	Utilization of the existing road marked the highest evaluation, but there would be appropriate pollution control mitigation during construction and operation phases.	Remarkable for high evaluation despite higher construction cost.	Utilization of the existing drainage marked highest evaluation, but there would be appropriate pollution control mitigation during construction and operation phases.	Remarkable for high evaluation despite higher construction cost.
		15	31	24	28	31	29	28

Source: JICA Expert Team

Table 8-57: Alternative Analysis (4) (Evaluation: 1←Negative Positive→5)

#	Evaluation Item	Without Project Option	B: Pluvial (Drainage) Flood Control Measures						C: Coastal Flood Control Measure
			B3: South Buckingham Canal (SBC)			B4: Drainages in Urban Area			
			①	②	③	①	②	③	①
			Rehabilitation of the South B. Canal	Gate and Pump construction at the north end and the area near Pallikaranai Marsh	Diversion channel construction connecting B. Canal and the Bay of Bengal	Drainage rehabilitation by deepening and widening of the connecting drains to Adyar and Cooum	Gate construction at the drainage outlet and reorientation of the outlet discharge to align river flow	Water tank rehabilitation and development with gate construction	Construction of training wall at Muttukadu
1	Cost for flood mitigation	Very high for long-term perspective	Moderate	High	High	Moderate	Moderate	Moderate	Moderately high
		1	4	2	2	4	4	4	3
2	Beneficial to local economy	Local economy will continuously suffer from the periodic flooding.	Very effective by eliminating the awareness of flooding when many sections of the B. Canal are applied for the improvement.	Effectiveness of the local economy is moderate since beneficial areas for flood protection are limited.	Effectiveness of the local economy is moderate since beneficial areas for flood protection are limited.	Very effective by eliminating the awareness of flooding when many sections of the drains are applied for the improvement.	Effectiveness of the local economy is moderate since beneficial areas for flood protection are limited.	Very effective by eliminating the awareness of flooding when many existing tanks are applied for the improvement.	Fairly effective to the local economy since this measure should be corresponded with the river rehabilitation.
		1	4	4	4	4	4	5	4
3	Pollution control	Worsening pollution of river water is expected without any measures or mindset of river environment.	Discharging or leaking polluted water from the drainage into the river is only a big concern.	Building walls and installing pumps has relatively less negative impact on water quality of drainage channels.	Coastal pollution caused by contaminated water from B. Canal to the Bay of Bengal is a big concern.	Discharging or leaking polluted water from the drainage into the river is only a big concern.	Building walls and installing pumps has relatively less negative impact on water quality of drainage channels.	The magnitude of the impact on water quality during the construction is very high.	The magnitude of the impact on water quality during the construction is very high.
		1	3	4	2	3	4	2	2
4	Impact on natural environment	No change	Deterioration of existing vegetation would be limited unless accompanied by dynamic change of the canal.	No deterioration of existing vegetation would be considered because the projected sites are mostly urbanized or built areas.	Deterioration of the maritime ecosystem would be concerned because the new channel will directly connect to the Bay.	Deterioration of existing vegetation would be limited unless accompanied by dynamic change of existing drainage channels.	No deterioration of existing vegetation would be considered because the projected sites are mostly urbanized or built areas.	Cutting some amounts of trees is expected. Cutting large specimen trees is a big concern for local ecosystem.	Possible changes in coastal lines would affect the aquatic ecosystem such as nesting of sea turtles.
		3	4	5	2	4	5	2	2
5	Involuntary Resettlement and land acquisition	No involuntary resettlement and land acquisition is expected.	Almost no involuntary resettlement and land acquisition would be expected because it is just modification of the existing drainage channels.	Small amounts of involuntary resettlement would be expected. Some amount of land acquisition is required for dike construction.	Large amounts of land acquisition and some resettlements are expected for the construction of the new diversion channel.	Almost no involuntary resettlement and land acquisition would be expected because it is just modification of the existing drainage channels.	Small amounts of involuntary resettlement would be expected. Some amount of land acquisition is required for dike construction.	Small amounts of involuntary resettlement would be expected. No land acquisition is expected	No involuntary resettlement and land acquisition is expected.
		5	5	4	3	5	4	4	5
6	Impact related to living conditions of the citizens	Living conditions would deteriorate due to the periodic flooding.	Living conditions in the large residential areas would improve significantly due to decrease in flood occurrence.	Living conditions in the residential areas would improve significantly due to decrease in flood occurrence.	Living conditions would improve due to a decrease in flood occurrence but it is limited to the proposed areas.	Living conditions in the large residential areas would be improved significantly due to decrease in flood occurrence.	Living conditions in the large residential areas would improve significantly due to decrease of flood occurrence.	Living conditions would improve significantly without a dynamic change of social environment.	Moderate improvement would be ensured since the applied areas are limited to river mouth areas.
		1	5	5	4	5	5	5	3
7	Impact on local resource (groundwater and beach etc.)	No change	No impact on local resource is expected, while beautification of drainage channel would rather be expected	No impact on local resource is expected.	Potential negative impact on lowering groundwater table is a big concern for the residents around the	No impact on local resource is expected, while beautification of drainage channel would rather be expected	No impact on local resource is expected because there is no relationship with local resource in the	Ensuring adequate water resource in the tanks and ground water in the surrounding area is required especially for	Gradual change of the beach shape is a big concern if it is significant aquatic

#	Evaluation Item	Without Project Option	B: Pluvial (Drainage) Flood Control Measures						C: Coastal Flood Control Measure
			B3: South Buckingham Canal (SBC)			B4: Drainages in Urban Area			
			①	②	③	①	②	③	①
			Rehabilitation of the South B. Canal	Gate and Pump construction at the north end and the area near Pallikaranai Marsh	Diversion channel construction connecting B. Canal and the Bay of Bengal	Drainage rehabilitation by deepening and widening of the connecting drains to Adyar and Cooum	Gate construction at the drainage outlet and reorientation of the outlet discharge to align river flow	Water tank rehabilitation and development with gate construction	Construction of training wall at Muttukadu
			through people's environmental mindset.		proposed the diversion channel.	through people's environmental mindset.	intersection area b/w drainage and river.	existing agricultural activities.	resource and attracts many tourists.
		3	5	5	2	5	5	3	2
Total		No advantages due to the evaluation of continuous cost for flood mitigation and local economy.	Utilization of the existing drainage channels marked highest evaluation, however there would be appropriate pollution control mitigation during and operation phases.	Remarkable for high evaluation despite higher construction cost.	Impacts on natural environment are the reason for lower rating. Mitigation for water treatment could bring up the viability.	Utilization of the existing drainage channels marked highest evaluation, however there would be appropriate pollution control mitigation during and operation phases.	Remarkable for high evaluation despite higher construction cost.	Utilization of existing tanks ends moderately high evaluation; however some items require appropriate mitigations	Potential negative impacts on the marine environment for long-term perspective resulted in relatively low evaluation.
		15	30	29	19	30	31	25	21

Source: JICA Expert Team

8.10.4 Mitigation measures

The following table shows mitigation measures for environmental items evaluated with respect to the negative impact in the previous section.

Table 8-58: Summary of Mitigation Measures

Categ.	#	Items	Mitigation Measure	A: Fluvial (River) Flood Control Measures												B: Pluvial (Drainage) Flood Control Measures												Coastal
				A1 Adyar R. B.			A2 Cooum R. B.		A3 Kosastha-laiyar R. B.			A4 Kovalam B.		A5 All river b.		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
				Depening Riverbed	Widening Riverbank	Underground river construction	Depening Riverbed	Widening Riverbank	Depening Riverbed	Widening Riverbank	Looped waterway development	Depening Riverbed	Widening Riverbank	Water tanks rehabilitation	New detention ponds	Rehabilitation of the B. Canal	Retarding Pond construction	Bypass channel (Cut &Cover)	Construction of gate	Rehabilitation of the B. Canal	Gate construction w/ side walls	Rehabilitation of the B. Canal	Gate & Pump construction	Construction diversion channel	Drainage rehabilitation	Gate construction	Water tank rehabilitation	Training wall construction
Planning and Construction Stage																												
Pollution	1	Air pollution	[Dust] - Sprinkle water for dust nuisance.		✓	✓		✓		✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			[Exhaust gas] - Use low emission construction machinery to avoid high exhaust gas emissions.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			- Thorough management of construction machines to avoid inappropriate gas emissions.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			- Prepare a traffic management plan for a diversion route to avoid traffic congestion based on traffic analysis that covers both intensive and extensive areas.		✓	✓		✓		✓	✓		✓		✓	✓		✓		✓	✓	✓	✓	✓	✓			
	2	Water pollution	[Turbid water and other items] - Discharge turbid water through a sedimentation pond and silt fence.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			- Install a portable toilet for workers.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			- Appropriate management of waste and construction machines to prevent oil spillage / discharge of untreated wastewater from the work site.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			- Provide an appropriate explanation and response to the community and fishermen residing along the river, if necessary.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓									✓				✓
			[Polluted water] - Applying emerged and aquatic vegetation area near the inlet of the tanks for future water purification by the vegetation.											✓	✓		✓										✓	

Categ.	#	Items	Mitigation Measure	A: Fluvial (River) Flood Control Measures												B: Pluvial (Drainage) Flood Control Measures												Coastal
				A1 Adyar R. B.			A2 Cooum R. B.		A3 Kosastha-laiyar R. B.			A4 Kovalam B.		A5 All river b.		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
				Depening Riverbed	Widening Riverbank	Underground river construction	Depening Riverbed	Widening Riverbank	Depening Riverbed	Widening Riverbank	Looped waterway development	Depening Riverbed	Widening Riverbank	Water tanks rehabilitation	New detention ponds	Rehabilitation of the B. Canal	Retarding Pond construction	Bypass channel (Cut &Cover)	Construction of gate	Rehabilitation of the B. Canal	Gate construction w/ side walls	Rehabilitation of the B. Canal	Gate & Pump construction	Construction diversion channel	Drainage rehabilitation	Gate construction	Water tank rehabilitation	Training wall construction
			- Analyse bed soil quality to ensure impact on surface water quality during the excavation.	✓			✓		✓			✓		✓	✓	✓	✓			✓		✓					✓	✓
	3	Waste	[Construction waste] - Waste shall not be dumped into the existing water body and a temporary dump area shall be prepared.		✓	✓		✓		✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			- Dispose construction waste, including concrete debris at the designated disposal site after determination of a scope for reuse.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			- Hazardous waste material shall be stored properly until final treatment.		✓	✓		✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			[Garbage from base camp] - Garbage at the workers' camp and waste oil shall be brought to a disposal site or treatment facility.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			[Night soil] - Temporary sanitation facilities such as septic tanks shall be introduced to the workers' camp.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	4	Soil pollution	- Prepare a facility management plan for waste collection and dumping facility in the construction yard and working camp.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			- Analyse the quality of the bed soil for pollution control for secondary use such as agricultural use or reclamation.	✓			✓			✓		✓		✓		✓	✓			✓		✓			✓		✓	
			- Prepare a treatment method in case of soil contamination.	✓			✓			✓		✓		✓		✓	✓			✓		✓			✓		✓	
	5	Noise and vibrations	[Construction noise and vibrations] - Install a noise barrier; use low-noise equipment if necessary	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Categ.	#	Items	Mitigation Measure	A: Fluvial (River) Flood Control Measures												B: Pluvial (Drainage) Flood Control Measures												Coastal
				A1 Adyar R. B.			A2 Cooum R. B.		A3 Kosasthalaiyar R. B.			A4 Kovalam B.		A5 All river b.		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
				Depening Riverbed	Widening Riverbank	Underground river construction	Depening Riverbed	Widening Riverbank	Depening Riverbed	Widening Riverbank	Looped waterway development	Depening Riverbed	Widening Riverbank	Water tanks rehabilitation	New detention ponds	Rehabilitation of the B. Canal	Retarding Pond construction	Bypass channel (Cut &Cover)	Construction of gate	Rehabilitation of the B. Canal	Gate construction w/ side walls	Rehabilitation of the B. Canal	Gate & Pump construction	Construction diversion channel	Drainage rehabilitation	Gate construction	Water tank rehabilitation	Training wall construction
			- Avoid works involving heavy equipment at night.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			- Inform the surrounding communities of the construction schedule.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	6	Subsidence of terrain	- Analyse seasonal condition of the groundwater table to avoid interference of the existing groundwater movement in CMA.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		✓		✓			✓	
			- Avoid taking a large amount of groundwater for construction use.			✓												✓			✓		✓	✓		✓		✓
			- Prepare detailed construction management when using chemical and hardware materials that could affect the surrounding soil.			✓																						
	7	Odours	[Garbage from base camp] - Garbage at the workers' camp shall be collected by the local authority.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			[Night soil] - Temporary sanitation facilities such as septic tanks shall be introduced to the workers' camp.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			[Other] - Implement proper maintenance and control of odorous construction materials in the construction yard.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Natural	9	Protected areas	- Avoid interfering with the prioritized wetlands designated by the competent authority or minimize a part of applying the flood control measures for conservation of existing ecosystem.											✓			✓							✓			✓	

Categ.	#	Items	Mitigation Measure	A: Fluvial (River) Flood Control Measures												B: Pluvial (Drainage) Flood Control Measures												Coastal
				A1 Adyar R. B.			A2 Cooum R. B.		A3 Kosastha-laiyar R. B.			A4 Kovalam B.		A5 All river b.		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
				Depening Riverbed	Widening Riverbank	Underground river construction	Depening Riverbed	Widening Riverbank	Depening Riverbed	Widening Riverbank	Looped waterway development	Depening Riverbed	Widening Riverbank	Water tanks rehabilitation	New detention ponds	Rehabilitation of the B. Canal	Retarding Pond construction	Bypass channel (Cut &Cover)	Construction of gate	Rehabilitation of the B. Canal	Gate construction w/ side walls	Rehabilitation of the B. Canal	Gate & Pump construction	Construction diversion channel	Drainage rehabilitation	Gate construction	Water tank rehabilitation	Training wall construction
			- Determine the existing ecosystem condition and regulatory requirements for development before selecting the area for flood mitigation.											✓			✓										✓	✓
	10	Biodiversity / Ecosystem	- Install ropes and fences on construction site boundaries to prevent wildlife from entering from the surrounding areas.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			- Plant additional trees shall be carried out for substitution of the cutting trees. The area for replanting is designated based on discussion with the relevant authorities.		✓			✓		✓	✓		✓		✓	✓	✓					✓		✓			✓	
	11	Hydrological conditions/ phenomena	- Analyse seasonal condition of the groundwater table to avoid interference of the existing groundwater movement in CMA.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		✓		✓			✓	
			- Periodically monitor the condition of the groundwater table in the area near the construction site.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		✓		✓			✓	
	12	Topography of terrain, geology of soils	- Confirm the erosion control condition at the planned quarry site that will provide aggregates for the construction and carry out counter measure for drainage improvement around the site.			✓										✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Social	13	Resettlement and land acquisition	- Hold a consultation meeting to convey the compensation policy agreeable to the Project Affected Persons (PAPs).		✓	✓		✓		✓	✓		✓		✓	✓				✓		✓		✓			✓	
			- Offer appropriate compensation and social assistance in accordance with the Resettlement Action Plan (RAP).		✓	✓		✓		✓	✓		✓		✓	✓				✓		✓		✓			✓	

Categ.	#	Items	Mitigation Measure	A: Fluvial (River) Flood Control Measures												B: Pluvial (Drainage) Flood Control Measures												Coastal
				A1 Adyar R. B.			A2 Cooum R. B.		A3 Kosastha-laiyar R. B.			A4 Kovalam B.		A5 All river b.		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
				Depening Riverbed	Widening Riverbank	Underground river construction	Depening Riverbed	Widening Riverbank	Depening Riverbed	Widening Riverbank	Looped waterway development	Depening Riverbed	Widening Riverbank	Water tanks rehabilitation	New detention ponds	Rehabilitation of the B. Canal	Retarding Pond construction	Bypass channel (Cut &Cover)	Construction of gate	Rehabilitation of the B. Canal	Gate construction w/ side walls	Rehabilitation of the B. Canal	Gate & Pump construction	Construction diversion channel	Drainage rehabilitation	Gate construction	Water tank rehabilitation	Training wall construction
	14	Living life and livelihood	- Prepare a livelihood reconstruction plan and clarify programs and process of the support for the PAPs.		✓	✓		✓		✓	✓		✓		✓	✓				✓		✓		✓			✓	
	15	Socially vulnerable people (poverty)	- Apply economic assistance to restore the livelihood for PAPs under the poverty line and PAPs with the socially vulnerable.		✓	✓		✓		✓	✓		✓		✓	✓				✓		✓		✓			✓	
			- Conduct a focus group meeting to clarify the needs of the vulnerable people to reflect them to the economic assistance.		✓	✓		✓		✓	✓		✓		✓	✓				✓		✓		✓			✓	
	19	Water usage/ rights	- Apply mitigation measures for water pollution.											✓	✓	✓	✓			✓		✓					✓	✓
			- Ensure adequate water in the existing and additional tanks for agricultural use.											✓	✓													
	20	Existing social infrastructures and services	- Hold a stakeholder meeting with the authorities relevant to utility lines.		✓	✓		✓		✓	✓		✓			✓		✓		✓		✓		✓			✓	✓
			- Construct diverted roads for vehicles and pedestrians appropriately to ensure accessibility to the social infrastructure such as hospitals and schools.		✓	✓		✓		✓	✓		✓			✓		✓		✓		✓		✓			✓	
			- Provide traffic control information to the residents in an appropriate manner.		✓	✓		✓		✓	✓		✓			✓		✓		✓		✓		✓			✓	
	22	Misdistribution of benefits and damage	- Prepare a reasonable schedule for implementation of flood control measures and present it to the affected community for public approval.											✓	✓													
			- Hold a public hearing to share information about the implementation of flood control measures.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Categ.	#	Items	Mitigation Measure	A: Fluvial (River) Flood Control Measures												B: Pluvial (Drainage) Flood Control Measures												Coastal
				A1 Adyar R. B.			A2 Cooum R. B.		A3 Kosastha-laiyar R. B.			A4 Kovalam B.		A5 All river b.		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
				Depening Riverbed	Widening Riverbank	Underground river construction	Depening Riverbed	Widening Riverbank	Depening Riverbed	Widening Riverbank	Looped waterway development	Depening Riverbed	Widening Riverbank	Water tanks rehabilitation	New detention ponds	Rehabilitation of the B. Canal	Retarding Pond construction	Bypass channel (Cut &Cover)	Construction of gate	Rehabilitation of the B. Canal	Gate construction w/ side walls	Rehabilitation of the B. Canal	Gate & Pump construction	Construction diversion channel	Drainage rehabilitation	Gate construction	Water tank rehabilitation	Training wall construction
	24	Cultural Heritage	- Avoid damaging the existing religious facilities during the detailed planning or design stage.		✓			✓		✓		✓	✓	✓		✓				✓		✓		✓			✓	
			- Hold a focus group meeting with the affected community to discuss a problem to be solved, including relocation.		✓			✓		✓		✓	✓	✓		✓				✓		✓		✓			✓	
	25	Landscape	- Avoid cutting large trees, mass of wood, street trees as much as possible for preserve the local landscape.		✓			✓		✓	✓		✓	✓	✓		✓							✓			✓	
			- Hold a focus group meeting with the affected community to discuss alternatives of losing greenery in town including replanting trees.		✓			✓		✓	✓		✓	✓	✓		✓							✓			✓	
	26	Gender	- Share the information about compensation policy or livelihood restructure plan to the women PAPs to follow the policy of the gender equality and reflect their pinions to RAP.		✓	✓		✓		✓	✓		✓		✓	✓				✓		✓		✓			✓	
			- Ensure women's employment rate for utilizing women's empowerment during the construction period.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	27	Children's rights	- Avoid children's employment by thorough monitoring in supervision during the construction.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	28	Infectious diseases such as dengue and HIV/AIDS	- Install sufficient drainage facilities to discourage breeding of vector mosquitoes in the construction yard.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			- Conducting regular seminars and health checks for the prevention of infectious diseases, including blood tests and providing contraceptives to construction workers.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Categ.	#	Items	Mitigation Measure	A: Fluvial (River) Flood Control Measures												B: Pluvial (Drainage) Flood Control Measures												Coastal
				A1 Adyar R. B.			A2 Cooum R. B.		A3 Kosastha-laiyar R. B.			A4 Kovalam B.		A5 All river b.		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
				Deepening Riverbed	Widening Riverbank	Underground river construction	Deepening Riverbed	Widening Riverbank	Deepening Riverbed	Widening Riverbank	Looped waterway development	Deepening Riverbed	Widening Riverbank	Water tanks rehabilitation	New detention ponds	Rehabilitation of the B. Canal	Retarding Pond construction	Bypass channel (Cut &Cover)	Construction of gate	Rehabilitation of the B. Canal	Gate construction w/ side walls	Rehabilitation of the B. Canal	Gate & Pump construction	Construction diversion channel	Drainage rehabilitation	Gate construction	Water tank rehabilitation	Training wall construction
Others	29	Working conditions (including work safety)	- Reinforce medical screening and periodic medical check-ups	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			- Promote awareness of infectious diseases among workers to prevent the spread of such diseases.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			- Periodic guidance and supervision of safety during construction works shall be ensured.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	30	Accidents	- Proper occupational safety management and records of the same are recommended.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			- Deploy flagmen at the gate and crossing points of the construction vehicles.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			- Install safety facilities including safety signboards, lighting for nighttime traffic control, and fences around the construction site to keep out local people such as children.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			- Install adequate parking areas for idling construction machines.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			- Restrict mobilization speed in the construction site.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			- Conduct periodic safety training for construction workers and safety patrol by supervisors.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Operation Stage																												
Pollution	2	Water Pollution	- Establish a monitoring or surveillance system for the water quality of the tanks and ponds shall be structured to respond quickly in case of deterioration of the water quality, such as eutrophication and increase of oxygen demand.											✓	✓		✓										✓	

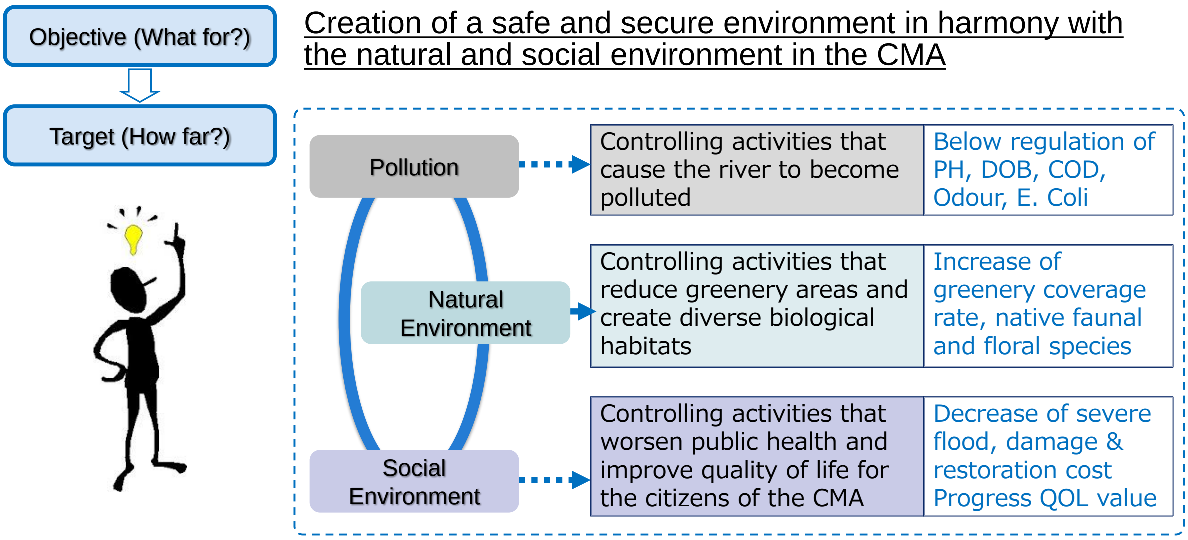
Categ.	#	Items	Mitigation Measure	A: Fluvial (River) Flood Control Measures												B: Pluvial (Drainage) Flood Control Measures												Coastal
				A1 Adyar R. B.			A2 Cooum R. B.		A3 Kosastha-laiyar R. B.			A4 Kovalam B.		A5 All river b.		B1 NBC				B2 CBC		B3 SBC			B4 Connecting Drains			C
				① Depening Riverbed	② Widening Riverbank	③ Underground river construction	① Deepening Riverbed	② Widening Riverbank	① Deepening Riverbed	② Widening Riverbank	③ Looped waterway development	① Deepening Riverbed	② Widening Riverbank	① Water tanks rehabilitation	② New detention ponds	① Rehabilitation of the B. Canal	② Retarding Pond construction	③ Bypass channel (Cut &Cover)	④ Construction of gate	① Rehabilitation of the B. Canal	② Gate construction w/ side walls	① Rehabilitation of the B. Canal	② Gate & Pump construction	③ Construction diversion channel	① Drainage rehabilitation	② Gate construction	③ Water tank rehabilitation	① Training wall construction
			- Develop a water quality management plan including applying water purification system and desilting periods.			✓								✓	✓									✓			✓	
	3	Waste	- Reinforce the littering regulation in the area of tanks, river, canal, and drainage in CMA.		✓			✓		✓	✓		✓	✓	✓	✓	✓			✓		✓		✓	✓		✓	✓
			- Promote a community-based beautification activity by picking up litter in the neighbourhoods.		✓			✓		✓	✓		✓	✓	✓	✓	✓			✓		✓		✓	✓		✓	✓
	6	Subsidence of terrain	- Monitor the condition of terrain to check if the ground elevation around the construction sites is subsidized.	✓		✓	✓		✓			✓		✓	✓	✓	✓			✓		✓		✓			✓	
	7	Odours	- The same measures should be taken as for 'waste'.		✓			✓		✓	✓		✓	✓	✓	✓	✓			✓		✓		✓	✓		✓	✓
	8	Riverbeds Sediments	- Monitor sand in the beach near the river mouth to check if the sand moves unexpected way.	✓			✓		✓			✓						✓						✓				✓
Natural Env.	10	Biodiversity / Ecosystem	- Carry out periodic study of natural environment in the developed area for flood control measures, especially in the tank, river and beach area near the river mouth for natural conservation.	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓			✓									✓	✓
	11	Hydrological conditions/phenomena	- Carry out periodic study of groundwater table in the area near the improved tank and river to confirm no significant decrease of groundwater table. The study includes interview surveys to the ones who use the water for their economic activity such as farmers.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		✓		✓			✓	

Categ.	#	Items	Mitigation Measure	A: Fluvial (River) Flood Control Measures												B: Pluvial (Drainage) Flood Control Measures												Coastal
				A1 Adyar R. B.			A2 Cooum R. B.		A3 Kosastha-laiyar R. B.			A4 Kovalam B.		A5 All river b.		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
				Depening Riverbed	Widening Riverbank	Underground river construction	Depening Riverbed	Widening Riverbank	Depening Riverbed	Widening Riverbank	Looped waterway development	Depening Riverbed	Widening Riverbank	Water tanks rehabilitation	New detention ponds	Rehabilitation of the B. Canal	Retarding Pond construction	Bypass channel (Cut &Cover)	Construction of gate	Rehabilitation of the B. Canal	Gate construction w/ side walls	Rehabilitation of the B. Canal	Gate & Pump construction	Construction diversion channel	Drainage rehabilitation	Gate construction	Water tank rehabilitation	Training wall construction
	12	Topography of terrain, geology of soils	- Establish a monitoring system for embankment erosion and a procedure for maintaining the reinforcement of river, canal, drainage channel embankment.		✓			✓		✓			✓	✓	✓		✓					✓		✓			✓	
Social Environment	13	Resettlement and land acquisition	- Evaluating the implementation of resettlement activities, particularly for restoring livelihood in accordance with the RAP.		✓	✓		✓		✓	✓		✓		✓	✓				✓		✓		✓			✓	
	14	Living life and livelihood	- Carry out socio-economic study for PAPs after relocation and land acquisition as well as land regulation.		✓	✓		✓		✓	✓		✓		✓	✓				✓		✓		✓			✓	
	18	Land use and local resources	- The same measures should be taken as for 'Biodiversity / Ecosystem'.	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓			✓									✓	✓
			- Carry out interview surveys to the PAPs after land acquisition or land regulation in the retarding area.		✓	✓		✓		✓	✓		✓		✓	✓				✓		✓		✓			✓	
			- The same measures should be taken as for 'Riverbed sediment'.	✓			✓		✓			✓						✓						✓				✓
	19	Water use/rights	- Carry out interview surveys to the farmers who have agricultural land near the improved tanks and rivers if they have a problem with water resources for their agricultural activity.											✓	✓	✓	✓			✓		✓					✓	✓
	25	Landscape	- The same measures should be taken as for 'Riverbed sediment'.	✓			✓		✓			✓						✓						✓				✓

Source: JICA Expert Team

8.10.5 Environmental objective and target

The following figure summarise the environmental objective and target for the SEA.

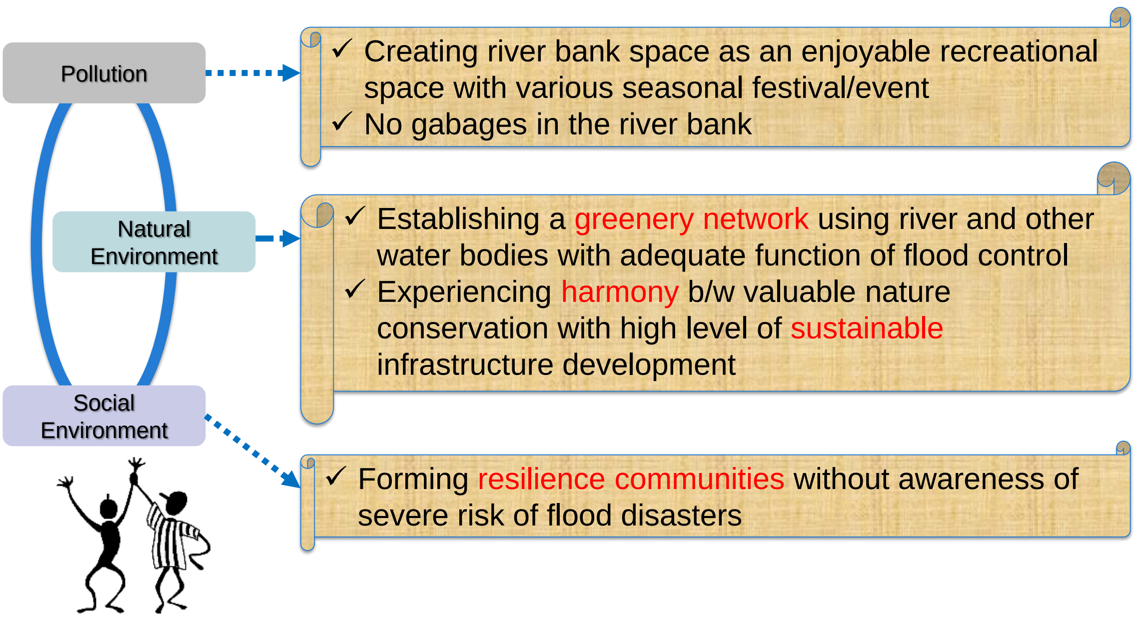


Source: JICA Expert Team

Figure 8-37: Environmental Objective and Target (Provisional)

8.10.6 Environmental vision

The following figure was initially proposed to the Chennai citizens as environmental vision in Chennai during the Stakeholder Consultation Meeting. The vision is determined based on the forementioned environmental objective and target.

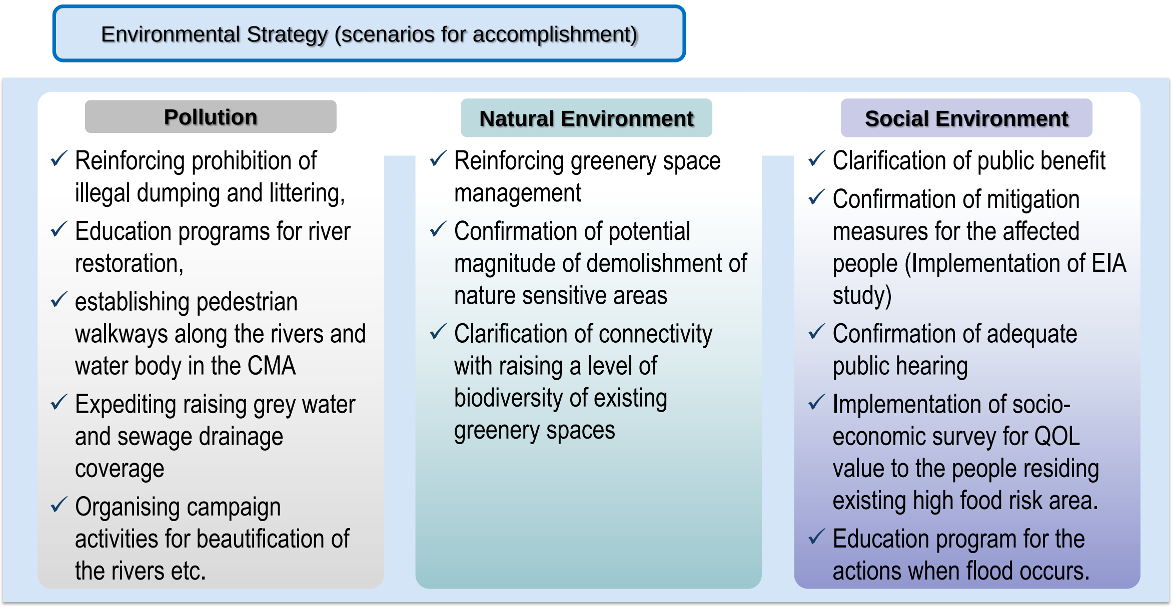


Source: JICA Expert Team

Figure 8-38: Environmental Vision

8.10.7 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 8-39: Environmental Strategy (Provisional)

8.11 Stakeholder Consultation Meetings (SHCM)

8.11.1 Scoping stage

Stakeholder consultation meetings were held for the SEA for the CFCMP during the scoping stage of the study. Objectives of the SHCM are summarized in the following items.

To know the views and perceptions of affected parties in the development project.

To validate and verify data obtained elsewhere and improve the quality of SEA.

To enable people to understand their rights and responsibilities about the project.

To enhance transparency and involvement of stakeholders, thus enhancing trust, project acceptance, and local ownership, which are key to project sustainability and development outcomes.

Complying with state/national policies on projects that have the potential to cause harm to people or the environment is also essential to comply with the JICA guidelines.

The following table shows profiles of the SHCM, including the date, venue, and number of participants.

Table 8-59: Profiles of the SHCM in the Scoping Stage

Date of Consultation	Venue	No of Participants	Affiliations of participants
29 September 2022	Avadi Municipal Corporation Council Hall	110	Ward Councillors elected by the people, Chairman of different Committees appointed by the Council of members, Deputy Mayor, Mayor, Commissioner, Municipal Engineers, Office Manager, and key staff members of the Municipal Corporation participated. In addition to that, Journalists from Print and Electronic Media also participated.
30 December 2023	Tambaram Municipal Corporation	120	Ward Councillors elected by the people, Chairman of different Committees appointed by the Council of members, Deputy Mayor, Mayor, Commissioner, Municipal Engineers, Office Manager, and key staff members of the Municipal Corporation participated. In addition to that, Journalists from Print and Electronic Media also participated.
6 May 2023	Greater Chennai Corporation	4	Ward Councillors elected and appointed as the members of the City Town Planning Committee at Greater Chennai Corporation were consulted. They were appraised about the SEA study in person and requested their opinions on different dates in Chennai. One of the reputed civil contractors who is doing river cleaning, dredging, and encroachment removal was also consulted.

Source: JICA Expert Team

As part of the proceedings, Municipal Engineers introduced the topic and invited the JICA team members to make a brief presentation about the CFCMP project objectives of the consultation meeting. The team made a brief presentation that covered the following aspects.

Project overview of CFCMP

Strategic Environment Assessment (SEA) and its objectives

Benefits of SEA

Structure of SEA

Potential environmental and social impacts of the CMA with or without the CFCMP project

Scope for stakeholders to make suggestions and propose amendments on the selection of study areas.

Some of the important feedback received from the stakeholders and photos of the meeting are as follows.

Table 8-60: Major Feedback from the Participants of the SHCM

Avadi Corporation
1) Avadi Municipal Corporation, a newly upgraded Municipal Corporation, has insufficient coverage of micro-irrigation facilities (more than 75% of areas yet to be covered). As a result, many areas are getting inundated during the peak of the northeast monsoon season from November to January every year. 2) Many critical stretches that get flooding every year are Thendral Nagar, Cholan Nagar, Sekkadu, and Sriram Nagar in the Paruthipattu area. 3) Avadi Corporation has many lakes, such as Avadi Lake, Paruthipattu Lake, Tamarai Kulam, Vilinjiyambakkam Lake, Poompozhily Nagar Lake, and others. For a long time, the feeder channels to carry water to these lakes have not been de-silted or maintained. As a result, the excess water during cyclonic rains cannot reach the lakes and often inundates the residential and commercial areas. The water level sometimes rises to 6 to 7 feet in height, which is impossible and blocks all kinds of transportation. Often, houses and apartments will get inundated up to 7-8 feet of water. According to them, all the channels leading towards lakes must be de-silted and maintained properly throughout the year. 4) Councillors have unanimously agreed that encroachments have to be strictly dealt with to have flood-free streets and roads. 5) Some of them have voiced the opinion that more schemes and investments are needed to fund many flood-control measures, such as complete coverage of stormwater drainages, underground sewage collection and treatment systems, and Municipal Solid waste management infrastructures.
Tambaram Corporation
1) Tambaram also recently upgraded as Municipal Corporation. It has fair coverage of micro-irrigation facilities, and the newly annexed areas are yet to be covered. As a result, many suburban areas are getting inundated during the peak season of the Northeast Monsoon from November to January every year. 2) Tambaram Corporation has 70 wards. It has many lakes and ponds. Adyar River flows just along the boundary areas of the Corporation. At the time of peak flow during monsoon, many areas get flooded. Members of the opinion that the bund of the river needs to be strengthened. 3) For a long time, the feeder channels to carry water to these lakes and rivers have not been de-silted or maintained. Also, the city expansion and creation of new roads block the natural flow of water. As a result, the excess water during cyclonic rains cannot reach the lakes and rivers and inundate the residential and commercial areas. Hence, many councilors insist that the channels leading towards lakes must be de-silted and maintained properly throughout the year. 4) Councillors have unanimously agreed that solid waste dumping along the river and encroachments have to be strictly dealt with to have flood-free streets and roads. 5) Some of them have voiced the opinion that more schemes and investments are needed to fund many flood-control measures, such as complete coverage of stormwater drainages, underground sewage collection and treatment systems, and Municipal Solid waste management infrastructures. 6) A few councilors informed that the Tambaram area has many granite stone quarrying activities, and many abandoned quarries with huge water storing capacities are left unutilized. They think that these quarries can be used to store excess rainfall and can act as reservoirs to store water and can be retrieved to meet the water shortage during summer months.
Greater Chennai Corporation
1) Greater Chennai Corporation is the oldest Municipal Corporation in India, established in 1688. It shows that the oldest institution has been through a lot of transformation over the years. It is comprised of 200 wards and covers an area of 426 km2.

2) All rivers (Adyar, Cooum, Kosasthalaiyar, Buckingham Canal, Kovalam) are highly polluted and facing multiple problems such as pollution of water, weed infestation, dumping of municipal solid wastes, encroachments of riverbanks, etc. This poor management of rivers is a major reason for the choking of water and causes flooding.

3) Wetlands such as Pallikaranai marsh and many water bodies in the city were misused for dumping municipal solid wastes used for constructing buildings. Hence, they were unable to drain excess water during heavy flooding.

4) Due to the rapid growth of the city and demand for space to construct buildings, roads, bridges, and bus stations. Therefore, all the open spaces were either fully utilized or cemented. Hence, the percolation of water is not happening, thus creating flooding.

5) Strom water drains built many years ago were inadequate and unable to cater to the present requirements of drainage of flood waters.

6) Installation of wastewater treatment facilities to cover 100% of wastewater generated by the city is paramount to keep the city waterways clean at all times.

7) Regular desilting of river courses and removal of encroachments helps in the easy drainage of flood water into the sea. Thus, flooding can be avoided.

8) Open spaces rooftops could be used to install sewage treatment plants as there is a severe shortage of space for the installation of treatment plants.

9) Commercial buildings and vertical structures should be mandated to set up sewage treatment plants and waste treatment facilities to reduce pressure on the existing systems.

Source: JICA Expert Team

Source: JICA Expert Team

Figure 8-40: Stakeholder consultations in Avadi Municipal Corporation (29 September 2022)

Source: JICA Expert Team

Figure 8-41: Stakeholder consultations in Tambaram Municipal Corporation (30 December 2022)

Figure 8-42: Stakeholder consultations in Greater Chennai Corporation (6 May 2023)

8.11.2 Draft final stage

Stakeholder consultation meetings were held for the SEA for the CFCMP during the draft final stage of the study with the same objectives as the one in the scoping stage in the previous section.

The following table shows profiles of the SHCM, including the date, venue, and number of participants.

Table 8-61: Profiles of the SHCM in Draft Final Stage

Date of Consultation	Venue	No of Participants	Affiliations of participants
14 March 2024	JICA Expert Team Office in CMDA	4	Engineer (Hydrologist, climate and environmental analyst, environmental planner, planning analyst)
14 March 2024	Mayers Chamber, Avady Municipal Corporation Office	5	Commissioner, Mayer, Councillor, Team of Engineers
15 March 2024	Mayors Chamber, Tambaram Municipal Corporation Office	2	Commissioner, Mayer
24 May 2024	Local villages in the Kothasthalaiyar Basin	8	Farmers
24 & 27 May 2024	Local villages in the Adyar River Basin	5	Farmers
From 3 to 6 June 2024	Executive Office in GCC	4	Joint Commissioner, Superintending Engineer, Executive Engineer

Source: JICA Expert Team

As part of the proceedings, the JICA team members will make a brief presentation about the progress of the CFCMP project, including briefs of the proposed prioritized physical measures. The team made a brief presentation that covered the following aspects:

Project overview of CFCMP

Strategic Environment Assessment (SEA) and its objectives

Structure of SEA

Prioritized physical measures to be proposed in the CFCMP project

Potential negative impacts on the natural and social environment in CMA triggered by the implementation of the proposed physical measures

Subsequently, the floor was open for discussion. The following questions were asked to guide them to provide an adequate understanding of stakeholders, the project, and the process of SEA.

1. Are there any other negative impacts on the natural and social environment identified from the local's perspective?
2. What measures do you think should be given the highest priority to mitigate the flood risk in your area? Where is the most important area where the flood risk needs to be mitigated? What is the reason?

Some of the important feedback received from the stakeholders and photos of the meeting are as follows.

Table 8-62: Major Feedback from the Participants of the SHCM

CMDA
1) Since the people residing near the existing tank derive some benefits from the existing tank by fishing or harvesting aquatic plants for their daily food, drastic change in the topography of the tank by excavating the bed soil would lead to a significant negative impact on their living conditions.

2) River water pollution triggered by excavating riverbed soil, such as increasing BOD value, especially near the river mouth, is one of the big concerns. 3) Deterioration of the riverine ecosystem due to salinization of the river water as a result of changing the river gradient would have a significant negative impact on the implementation of the project. 4) Resettlement of encroachers in the river or existing tanks would be a big problem if required. The practical cares for the involuntary resettlement have to be taken into consideration. 5) The relocation of religious facilities requires the consent of the affected community. It would be possible if the distance of the relocation is not too far. 6) Dumping garbage into the river and littering is the current problem in Chennai. Deterioration of the river landscape will not solve any problem if citizens do not change their attitudes. 7) There should be dissemination of information to the public regarding the environmental impact and mitigation measures as well as disaster prevention issues.
Tambaram Municipal Corporation
Discussion with Mr. Thangadurai AEsq and Anandhavelu AEsq on the availability of the councilor and the nature of the lakes shortlisted by the team, and call with Puzhanthi Perengalarthur Councillor, who has a wide knowledge of all the lakes and environmental issues in the Tambaram municipality. 1) The mayor acknowledged that all five lakes, Madambakkam Lake, Perungalathur Lake, Thiruneermalai Lake, Peerkankaranai Lake, and Nanmangalam Lake, mentioned by the commissioner and chief engineer, should preferably be designed. She also added that the Mungial from West Tambaram is also one of the affected areas due to the flood. She further mentioned that the Perungalathur Lake and the surrounding regions were the most affected by all the floods, she was personally involved in the flood relief activities during the recent floods in 2023. 2) The mayor shared her experience about the Perugalathur being well placed in altitude compared to other lakes, but the drainage systems are poor, and thus, major flooding happens in the region. 3) She added that nearly 10 panchayats share the boundary with the Tambaram municipality, the drainage projects in Tambaram end along the border of the 10 panchayats, and no further development beyond during the rainfall though the water drains from Tambaram, and it gets flooded along the boundaries. 4) She further said that they had made a resolution to take control of all the panchayats sharing the boundary of Tambaram, and she wanted to recommend us in our report 5) She said that they have an administrative difference with the GCC, since they have major control over the city, they face issues in getting clearances and approvals for many projects. 6) Environment/ecology, its interlinkages, and the impacts were described by the Environmental Expert from the JET, the municipal engineers and the mayor were not aware of the issues, they were concerned about the trees cutting along their project areas.
Avady Municipal Corporation
1) The commissioner mentioned that it would be difficult to detailly examine the negative impacts on the natural and social environment at this stage. Therefore, a detailed analysis of environmental impact assessment in the project stage for the local stakeholders would be necessary. 2) He further mentioned that there are four locations in and around the Avadi Corporation which has regular flooding problems. These are namely Vasanthan Nagar, Thirumullaivoyal, Sriram Nagar, and Kannan Theatre. In addition to that, Ambattur and Oragadam areas are also sensitive to flooding every season. 3) He further said that five lakes need immediate desolation and bund strengthening. Lakes such as Aarabath Lake, Sekkadu Lake, Paruthipattu Lake, Ayan Lake, and Villianjiampakkam Eri. 4) The mayor also mentioned that there are issues such as connecting their stormwater lines/canals with the Cooum River, especially in the areas adjacent to Greater Chennai Corporation (GCC) areas. Due to flow direction and gradient, those canals can only be connected with the Cooum River portion that falls under the administrative control of the GCC. However, GCC officials are not providing clearance to go ahead with the connection. So, these kinds of administrative clearances /approvals are critical to ensure easy flow of water. 5) Mayer expresses the difficulty of relocation of encroachment in the vicinity of the tank area if involuntary resettlement would be required and recommends avoidance or minimization of the involuntary resettlement for the project.
Villages in the Kosasthalayer River Basin
Name of the villages SHCM held with stakeholders

Village	Taluk Name	District
Nerkundram	Ponneri	Thiruvallur
Periya Madiyur	Ponneri	Thiruvallur
Chinna madiyur	Ponneri	Thiruvallur
Pasuvan Palayam	Ponneri	Thiruvallur
Sadayankuppam	Tiruvottiyur	Chennai
Seemavaram	Ponneri	Thiruvallur
Goundarpalayam	Ponneri	Thiruvallur
Vannipakkam	Ponneri	Thiruvallur

The outcome of the discussion with respondents

1) Most of the respondents said that flooding occurs every year during the monsoon season. In most areas, the river bund is weak, and during heavy flooding, rainwater enters the villages.

2) Therefore, they demanded that permanent solutions have to be made. But for many years, nothing has been done by the government except some temporary measures during the flooding time or post-flooding to strengthen the river bund (sandbags). Hence, an old earthen bund needs to be replaced with concrete, at least in critical places to begin with.

3) The locals are well aware of the importance of plants on the bund. Most of them want to remove the Prosopis, an exotic species, from the bund and the middle of the river. They also understand that Prosopis contributes to flooding by obstructing the river's flow, which causes water to enter the villages.

4) Additionally, they want to increase the height of the check dams that have been built in a few places along the Kosasthalaiyar River. The local people believe that raising the height of these check dams will improve water quality and enhance the groundwater table.

5) The local people are also ready to remove encroachments near the river bunds if they are given alternative land and buildings in the same village.

6) They think that for creating such long-term measures, there will be few disturbances such as construction activities, and removal of encroachments is necessary, and they are willing to accept them for long-term benefits.

7) Some were skeptical about flood control interventions as they thought that many consultations had happened in the past, but nothing had transformed on the ground. Hence, they wanted some real interventions that are urgently needed.

Villages in the Adyar River Basin

Name of the villages SHCM held with stakeholders

Village	Taluk Name	District
Muduchur	Tambaram	Chengalpattu
Anakaputhur	Tambaram	Chengalpattu
Thiruneer malai	Tambaram	Chengalpattu
Mani Mangalam	Kundrathur	Kancheepuram
Varadharajapuram	Kundrathur	Kancheepuram

The outcome of the discussion with respondents

1) Respondents of the village were a mixed group of farmers as well as residents that stayed in very close proximity to the Adyar River. Every one of them experienced flooding in the past few years consecutively.

2) According to a few senior citizens, flooding is a recent phenomenon as there was not much of a problem some 20 or 30 years ago. They blame it on the sudden surge in the population and city development in the downstream areas without paying much attention to the free flow of rivers during monsoons.

3) They showed that their villages are also now becoming suburban areas, and people started to settle in the lands that were largely used for cultivation 10 to 15 years ago. According to them, the sudden surge in the settlements, even in and around their villages without any provision for drainages, has resulted in recurring flooding in their villages.

4) They also reported that encroachments along the riverbanks, narrow canals, lack of desilting, and proliferation of exotic weeds are other reasons for the flooding.

5) With regards to the need for flood control projects, they are appreciative of any effort because they are strongly of the opinion that it will save them from future flooding and safeguard their agricultural lands.

6) Respondents were apprehensive that the government is not doing much for their areas, and according to them, the city gets a lot of attention for any new projects such as river restoration, etc. Hence, they are demanding that any new project intervention in river restoration has to be implemented simultaneously both in the city areas as well as in the suburban areas.

Greater Chennai Corporation

1) There is no second opinion about the measures proposed for flood control in CMA. All of them have strongly endorsed the hard and soft measures proposed

2) The deepening of water tanks in the CMA area rests with the WRD Department, and for small tanks, the responsibility lies with the Local Self Governments or Panchayats.

3) The opinion that under river channel improvements, one of the challenges will be the relocation of people occupying the riverbanks. It requires full support from the government by providing them with alternative places to live. Shifting them to new locations may have initial trouble. But once they settled into the new locations, which will be a modern building with better facilities, there will be problems for them in the long term.

4) In the stormwater drain improvement program, there is no hurdle faced by them in the implementation as most of them are below ground. However, they cautioned that the facility should not be misused by the people, and there could be chances that people may divert the sewage and dump solid wastes into the facility. If not monitored, the purpose may get defeated as it may get choked, and it may not function to its designed capacity during flood times, etc. Therefore, for any future drains, they wanted all the precautions to be considered.

5) Though 80% of the stormwater drains are completed, there are still many missing links that need to be studied and connected properly to have the full benefit of flood control. Or else people may lose faith in the flood control measures due to improper management of new measures.

6) New initiatives for Tank improvements within the city are welcome measures, and the CMDA has initiated work on 12 major lakes within the GCC areas. Once they get completed in the next year, additional space could be created to store more water, and not only that, they may help in groundwater recharge.

7) The opinion that the land acquisition for flood control measures may be costly and need more resources. Sometimes, people may resist allowing the lands to be acquired.

8) The environmental impacts are very limited and temporary. Only during the construction phase, it may appear that some level of impact, however, once completed, they will yield long-term benefits as nature can rectify itself.

9) People need to be made more aware of the cost and implications of the absence of these flood control measures so that they will provide full support for the long-term flood control measures.

10) They also emphasized that a coordinated approach is required in the execution of these measures as multiple departments are involved. To realize full success in the mission, the coordination of WRD, GCC, CMDA, environment department, and pollution control departments is a must. Or else the public will not cooperate with such measures and blame one or two departments for inconveniences faced by them during the implementation/construction and maintenance phases.

Source: JICA Expert Team

Photo 1: SHCM to CMDA on 12 March 2024

Photo 2: SHCM to GCC on 3 June 2024

Photo 3: SHCM to Avady Municipal Corporation on 14 March 2024

Photo 4: SHCM to Tambaram Municipal Corporation on 15 March 2024

	
Photo 5: SHCM to the Villagers in the Kosastharayer River on 24 May 2024	Photo 6: SHCM to the Villagers in the Kosastharayer River on 24 May 2024
	
Photo 7: SHCM to the Villagers in the Adyar River on 24 and 27 May 2024	Photo 7: SHCM to the Villagers in the Adyar River on 24 and 27 May 2024

Source: JICA Expert Team

Figure 8-43: Stakeholder consultations in the Draft Final Stage

8.12 Environmental Monitoring Plan

8.12.1 Construction phase

Environmental monitoring will be carried out to assess whether mitigation measures are being correctly applied against negative environmental impacts during the construction stage. The monitoring activity associated with pollution control during the construction will be initiated mainly by the contractor at its own expense, with monitoring reports submitted periodically to the project proponent.

Table 8-63: Summary of Monitoring Activity during the Planning/Construction Phase

Category	#	Items	Parameter	Method	Location	Frequency	Implement. Agency	Standard
Pollution Control	1	Air pollution	1) SO2, 2) NO2, 3) PM10	1) Ultraviolet fluorescence (UVF) 2) Modified Jacob & Hochheiser (Na-Arsenite) 3) Beta attenuation	At least 2 in each proposed site (adjacent to the construction site and residential site)	Biannual	Contractor	SO2: <80μg/m³ (24hr.) NO2: <80μg/m³ (24hr.) PM10: <100μg/m³ (24hr.) *No.B-29016/20/90/PCI-I, CPCB
	2	Water pollution	pH, BOD, COD, SS, Coliform	Laboratory test by an expertized institution	At least 2 in each proposed site	Biannual	Contractor	pH 5.5 – 9.0 BOD <30 mg/l COD <250 mg/l SS <100 mg/l COL <500 (MPN)/100ml
	3	Waste	Volume of waste soil, cutting tree and domestic garbage. Waste from demolition works	Record volume of generated waste, Record of disposal method	Construction yard and camp site	Monthly	Contractor	Generated waste shall be disposed at a designated site. The method shall be followed by the final Env. Management Plan
	4	Soil pollution	Surveillance of polluted soil and source of contamination	Ocular inspection, Record of the monitoring activity	Construction yard and camp site	Monthly	Contractor	Soil polluted by oil or another chemical substance shall be monitored.
	5	Noise	Ambient and roadside noise (LAeq (dB (A))	Measured by a noise level meter. dB(A) denotes the time weighted average of the level of sound in decibels on scale A.	At least 2 in each proposed site (adjacent to the construction site and residential site)	Biannual	Contractor	(Commercial area) Daytime: 65 dB (A) Nighttime: 55 dB (A) (Residential area) Daytime: 55 dB (A) Nighttime: 45 dB (A)
		Vibration	Vibration (dB)	Measured by a vibration level meter.	Same as above	Biannual	Contractor	75 dB
	6	Subsidence of terrain	Depth of groundwater level Confirmation of a detailed construction management	Measurement at the selected bore holes near the proposed site. Reviewing report	At least 2 boring sites in each proposed site Before implementation of excavation	Biannual Timely manner	Contractor Proponent (Supervisor)	The survey shall be also carried out before the construction to determine its differences.
	7	Odours	Condition of garbage and septic tank maintenance	Measured by an odour meter	Construction yard and base camp	Monthly	Contractor	It can be estimated in the item 'Waste' above.
Natural Environment	9	Protected areas	Whether or not the proposed sites are designated by the government or the relevant institutions	Collection of updated study data and review the proposed sites during the planning stage	-	Before decision of the proposed sites	Proponent (Supervisor)	"Prioritised Wetlands and its Biodiversity in TN (2019)" Ramsar Convention etc.
	10	Biodiversity/ Ecosystem	Status of tree cutting and	Ocular inspection, Analysis of the study report (inventory of flora	Existing vegetation areas	(Tree cutting)	Proponent (Supervisor)	Impact of the ecologically disturbed area based on a

Category	#	Items	Parameter	Method	Location	Frequency	Implement. Agency	Standard
			replanting trees or seedlings Biodiversity study	and fauna including aquatic fauna)	Ecologically sensitive area, water tank or coastal areas	Before carrying out tree cutting (Study) Annual		before and after comparison is analysed.
	11	Hydrological conditions/ phenomena	Groundwater quality: Arsenic, Cadmium, Chromium, Copper etc.	Laboratory test by an expertized institution for water quality	Existing wells or bore holes at least 2 in each proposed site	Biannual	Contractor	"Criteria for water quality monitoring" in the Solid Waste Management Rules, 2016
	12	Topography of terrain, geology of soils	Status of riverbank and embankment of tanks or any fills of soil	Ocular inspection	Riverbank, water tank embankment etc.	Monthly	Proponent (Supervisor)	Can be covered in the regular supervision activity.
Social Environment	13	Resettlement and land acquisition	Economic status of relocated PAHs and records of grievance redress	Interview survey to the PAPs	Displaced PAHs	Biannual	Proponent (Supervisor)	Shall be completed during the construction stage.
	14	Living life and livelihood	Economic status of stakeholders including the poverty and farmers correlated with the project	Interview survey to the stakeholders residing or managing economic activities adjacent to the projected site	Areas adjacent to the projected site	Biannual	Proponent (Supervisor)	The survey shall be also carried out before commencement of the construction to determine its differences.
	15	Socially vulnerable people (poverty)						
	19	Water usage/ rights	Condition of fishing ground	Interview survey to stakeholders engaging with fishery activities in the projected sites.	Subjected water body including water tanks and rivers	Biannual	Proponent (Supervisor)	
	20	Existing social infrastructure and services	Status of accessibility to existing social infrastructures	Ocular inspection, Interview survey to relevant residents and commercial buildings	All the access roads	Biannual	Proponent (Supervisor)	This can be counted as regular supervision activities.
	22	Misdistribu-tion of benefits and damage	Status of implementation coordination	Review of implementation schedule	Implementation area of flood mitigation measures	Before decision of the proposed sites	Proponent (Supervisor)	Public hearings will be carried out to share information about implementation schedule if necessary.
	24	Cultural Heritage	Status of affected cultural heritages	Ocular inspection, Interview survey to the relevant person	All the affected cultural heritages	Biannual	Proponent (Supervisor)	Adequate communications with the residents will be required.
	25	Landscape	Status of affected landscape including coastal area	Ocular inspection, Interview survey to the relevant residents	Area with the affected landscape	Biannual	Proponent (Supervisor)	Survey before the construction will be required to determine its differences.
	26	Gender	Employment rate of women	Review of an employment record	All construction workers	Monthly	Contractor	Target rate will be discussed with the proponent
	27	Children's rights	Prohibition of child labour	Ocular inspection, Interview survey to the workers	All construction workers	Monthly	Contractor	Child Labour (Prohibition & Regulation) Act, 1986
	28	Infectious diseases such as HIV/AIDS	Numbers of infected patients	Periodic health check list	All construction workers	Monthly	Contractor	Holding seminars for infectious diseases prevention will be recommended.
	29	Working conditions (including work safety)	Record of work environment	Review of a work employment record and safety instruction record	Construction site, yard and worker's base camp	Monthly	Contractor and Proponent (Supervisor)	This can be counted as regular supervision activities.

Category	#	Items	Parameter	Method	Location	Frequency	Implement. Agency	Standard
Others	30	Accident	Numbers of accidents	Review of an accident record	Construction site, yard and worker's base camp	Monthly	Contractor and Proponent (Supervisor)	This can be counted as regular supervision activities.

Source: JICA Expert Team

8.12.2 Operational phase

The monitoring activity during the operation period will be carried out mostly by the proponent, with appropriate collaboration with the relevant institution in accordance with the fields of the environmental items for two years on an ongoing basis after completion of construction. It is preferable to obtain basic information to determine environmental changes in local communities once all inhabitants have been displaced.

Table 8-64: Summary of Monitoring Activity during the Operation Phase

Category	#	Items	Parameter	Method	Location	Frequency	Implement. Agency	Standard
Pollution Control	1	Air pollution	1) SO2, 2) NO2, 3) PM10	1) Ultraviolet fluorescence (UVF) 2) Modified Jacob & Hochheiser (Na-Arsenite) 3) Beta attenuation	At least 2 in each implemented site (adjacent to the construction site and residential site)	Biannual	Proponent	SO2: <80μg/m³ (24hr.) NO2: <80μg/m³ (24hr.) PM10: <100μg/m³ (24hr.) *No.B-29016/20/90/PCI-I, CPCB
	2	Water pollution	pH, BOD, COD, SS, Coliform	Laboratory test by an expertized institution	At least 2 in each implemented site	Biannual	Proponent	pH 5.5 – 9.0 BOD <30 mg/l COD <250 mg/l SS <100 mg/l COL <500 (MPN)/100ml
	3	Waste	Volume of garbage, condition of littering	Ocular inspection, Record of the waste volume during beautification activities	At implemented riverbank and embankment of implemented tanks	Biannual	Proponent or local government	Results and corrective actions can be shared with the local resident.
	5	Noise and vibration	-	-	-	-	-	-
	6	Subsidence of terrain	Depth of groundwater level	Measurement at the selected bore holes near the proposed site.	At least 2 boring sites in each implemented site	Biannual	Proponent	Trend of the results shall be recorded.
	7	Odours	Odour condition Perception of odour annoyance	Measured by an odour meter	At least 2 in each implemented site especially river and tanks	Biannual	Proponent	Results and corrective actions can be shared with the local resident.
	8	Riverbeds Sediments	pH, EC, TN, TP, Sodium, Potassium, Calcium, Mg. Organic Matter	Laboratory test by an expertized institution	At least 2 in each implemented site	Biannual	Proponent	Handbook of Agriculture, Indian Council of Agricultural Research, New Delhi, 2011
Natural Environment	10	Biodiversity / Ecosystem	Biodiversity study	Analysis of the study report (inventory of flora and fauna including aquatic fauna)	Ecologically sensitive area, water tank or coastal areas	Annual	Proponent	Impact of the ecologically disturbed area based on a before and after comparison is analysed.
	11	Hydrological conditions/ phenomena	Groundwater quality: Arsenic, Cadmium, Chromium, Copper etc.	Laboratory test by an expertized institution for water quality	Existing wells at least 2 in each implemented site	Biannual	Proponent	"Criteria for water quality monitoring" in the Solid Waste Management Rules, 2016

Category	#	Items	Parameter	Method	Location	Frequency	Implement. Agency	Standard
	12	Topography of terrain, geology of soils	Status of riverbank and embankment of tanks or any fills of soil	Ocular inspection	Riverbank, water tank embankment etc.	Biannual	Proponent	The results shall be shared with the relevant authorities to determine corrective actions.
Social Environment	13	Resettlement and land acquisition	Economic status of relocated PAHs and records of grievance redress	Interview survey to the PAPs	Displaced PAHs	Annual	Proponent	Comprehensive analysis will be required, and an additional support would be arranged if necessary.
	14	Living life and livelihood	Economic status of stakeholders including the poverty and farmers	Interview survey to the stakeholders residing or managing economic activities adjacent to the implemented site	Areas adjacent to the projected site	Biannual	Proponent	
	18	Land use and local resources	Land use condition	Interview survey to the stakeholders holding the implemented retarding area.	Implemented the new retarding areas	Biannual	Proponent	Necessary counter measures will be prepared.
	19	Water use/rights	Condition of fishing ground	Interview survey to stakeholders engaging with fishery activities in the implemented sites.	Subjected water body including water tanks and rivers	Biannual	Proponent	Necessary counter measures will be prepared.
	25	Landscape	Status of affected landscape including coastal area	Ocular inspection, Interview survey to the relevant residents	Area with the affected landscape	Biannual	Proponent	Comprehensive analysis by an expert will be required, and counter measures will be prepared if necessary.

Source: JICA Expert Team

Chapter 9. Synthesis, Prioritization and Implementation Plan

9.1 Proposed Project Components of the 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.

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 chapter, the prioritization of components is outlined by basin and by type of countermeasure, taking into account technical and socio-economic considerations. This chapter serves as a roadmap, offering a structured approach to addressing flood risks by summarizing and scaling the measures into actionable components.

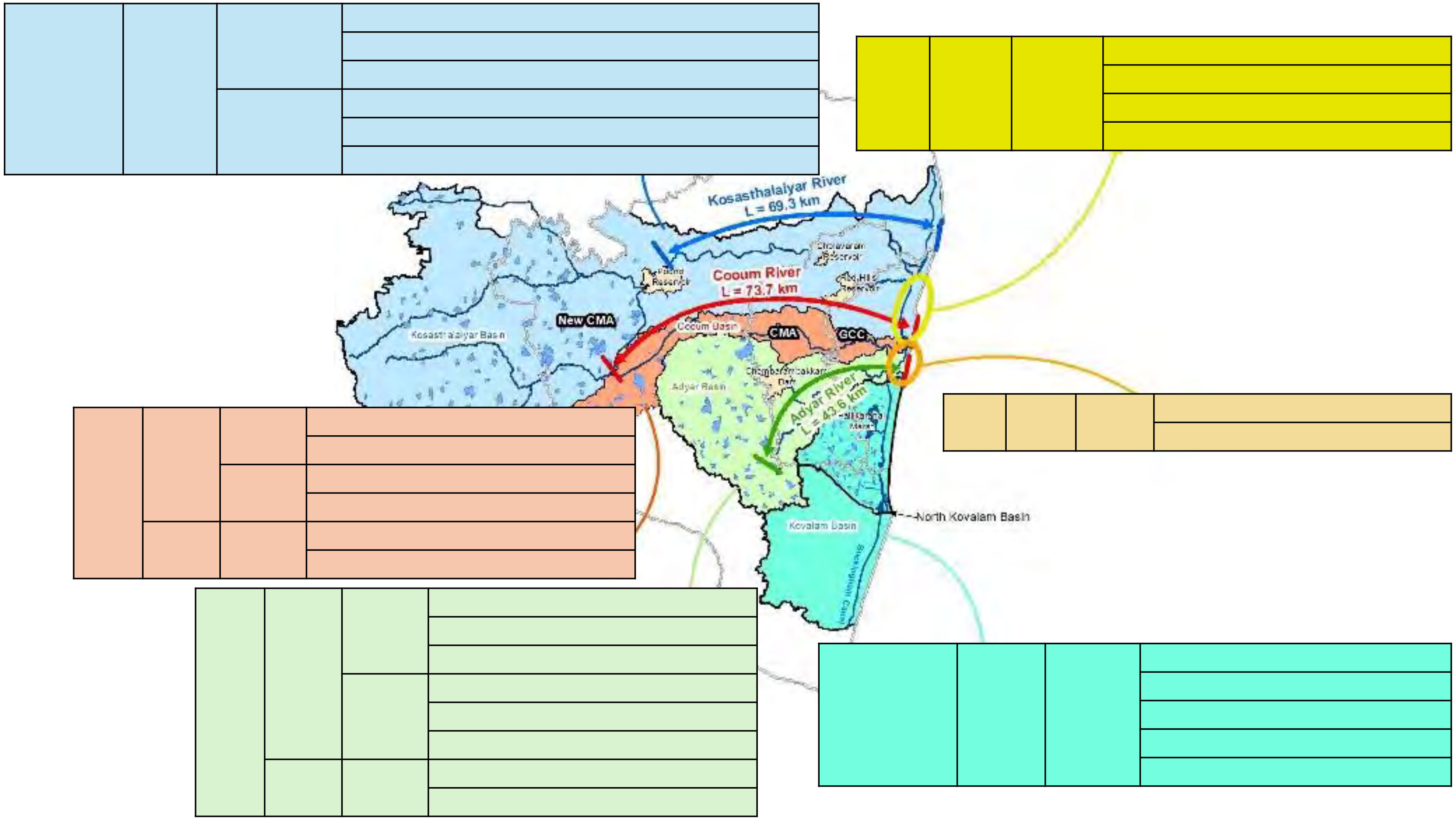
A detailed list of the proposed components for flood control is shown in **Table 9-1** and **Figure 9-1**, addressing both fluvial and pluvial measures. The chapter not only consolidates the interventions but also evaluates their importance and urgency to guide resource allocation effectively. This prioritization 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.

Table 9-1: Project Components

countermeasure			
Adyar River	Flood control	Using Existing Waterbodies	50 tanks
		Dam Operation Improvement	under verification
		River Channelization (Deepning and local widening)	43.6km
		Underground river	12.0km
	Strom Water	Gates in Connecting Drainages to Rivers	3 Gates
		River Channelization	8 river
Centrl B Canal	Strom Water	Gates in Connecting Drainages to Rivers	1 Gates
		River Channelization	Centrl B Canal
Cooum River	Flood control	Using Existing Waterbodies	31 tanks
		River Channelization (Deepning and local widening)	34.2km
	Strom Water	Gates in Connecting Drainages to Rivers	Gates（1place）
		River Channelization	4 place
North B Canal	Strom Water	Gates in Connecting Drainages to Rivers	1 Gates
		River Channelization	North B Canal , 3 river
		Diversion Channel	1 Channel
		New Flood Storage	5 storages
Kosasthalaiyar River	Flood control	Using Existing Waterbodies	112 tanks
		Dam Operation Improvement	Under verification
		River Channelization (Deepning and local widening)	69.3km
Kovalam	Strom Water	Using Existing Waterbodies	2 tanks
		River Channelization	okaymado
		Gates in B Canal	3 Gates
		Pumps	2 pumps
		Bypass	1 bypass

Source: JICA Expert Team



Source: JICA ExpertTeam

Figure 9-1：Location of and Details of Structural Components

9.2 Development of the Implementation Schedule

9.2.1 Basin-Wise Prioritization

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 km^2) of the basins. **Table 9-2** presents the total potential damage across the basin-wide areas and **Table 9-3** Details the potential damage per square kilometer.

Table 9-2: Basin-wide Potential Flood Damage

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

Source: JICA Expert Team

Table 9-3: Potential Flood Damage per km2

Potential Damage per Km^2 (INR Cr.)	Flood RPs	Adyar (854 km^2)	Cooum (435 km^2)	Kosasthaliyar (4082 km^2)	Kovalam (782 km^2)
	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 9-4 Summarizes the prioritization results based on these factors. As shown, the Adyar Basin ranks the highest, followed by the Kovalam Basin.

Table 9-4: 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 ExpertTeam

9.2.2 Prioritization of Countermeasures for Each Basin

The implementation schedule is structured into two phases:

- Phase 1 (Immediate Measures): Expected to be completed within 10 years (e.g., 2026–2035).
- Phase 2 (Long-Term Measures): Planned to proceed after 2036 for approximately 20 years, though the timeline may be extended based on evolving asset and economic conditions.

While the processes initially start simultaneously in each basin, the Adyar River basin will be prioritized first, followed by the Kovalam, Cooum, and Kosasthalaiyar basins, as summarized in the previous section.

9.2.2.1. Prioritization of River Flood Control Countermeasures

River channel improvement will be executed in a phased manner due to the land acquisition challenges associated with widening efforts, which necessitate the relocation of numerous residential and commercial properties as in the Table 9-5 Includes:

Adyar River: 19 Ha of Residential Area and 11 Ha of farmland, Cooum River: 15 Ha of Residential Area and 10 Ha of farmland, and Kosasthalaiyar River: 22 Ha of Residential Area and 70 Ha of farmland.

Given these constraints, the river channelization process will follow a two-phase approach, as in **Figure 9-2**.

- Phase 1: Excavation and deepening within the existing river channel, with limited localized widening where feasible. This phase is expected to take 10 years and aims to enhance immediate flood conveyance capacity.
- Phase 2: Full-scale river channel widening, involving extensive land acquisition and

relocation. This phase will commence after Phase 1 and is expected to span 20+ years due to its complexity.

This phased strategy ensures that critical flood mitigation measures can be implemented in the short term.

Figure 9-2: River Channelization Priority and Phases

Table 9-5: Estimated Impact of River Widening on Households and Businesses

Adyar River

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

Cooum River

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

Kosasthalaiyar River

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

Total Number of Properties in Basins			
Type	**Adyar**	**Coourn**	**Kossathalaiyar**
Residential	7800	6100	830
Bussiness	500	2800	420
Total	12800	8900	1250

Source: JICA ExpertTeam

9.2.2.2. Prioritization of Enhancing Flood Storage in Tanks and Waterbodies

The restoration and functional enhancement of reservoirs and waterbodies are currently being carried out by TNWRD and other counterparts using internal resources and external funding. Given this, the JICA Flood Control Master Plan recommends a phased approach to improving tank functionality for flood storage through relevant agencies.

Priority for maintenance is given to tanks with larger capacities and those closer to the reservoir's downstream side, as they have a greater impact on flood control. However, priorities may be adjusted based on stakeholder coordination.

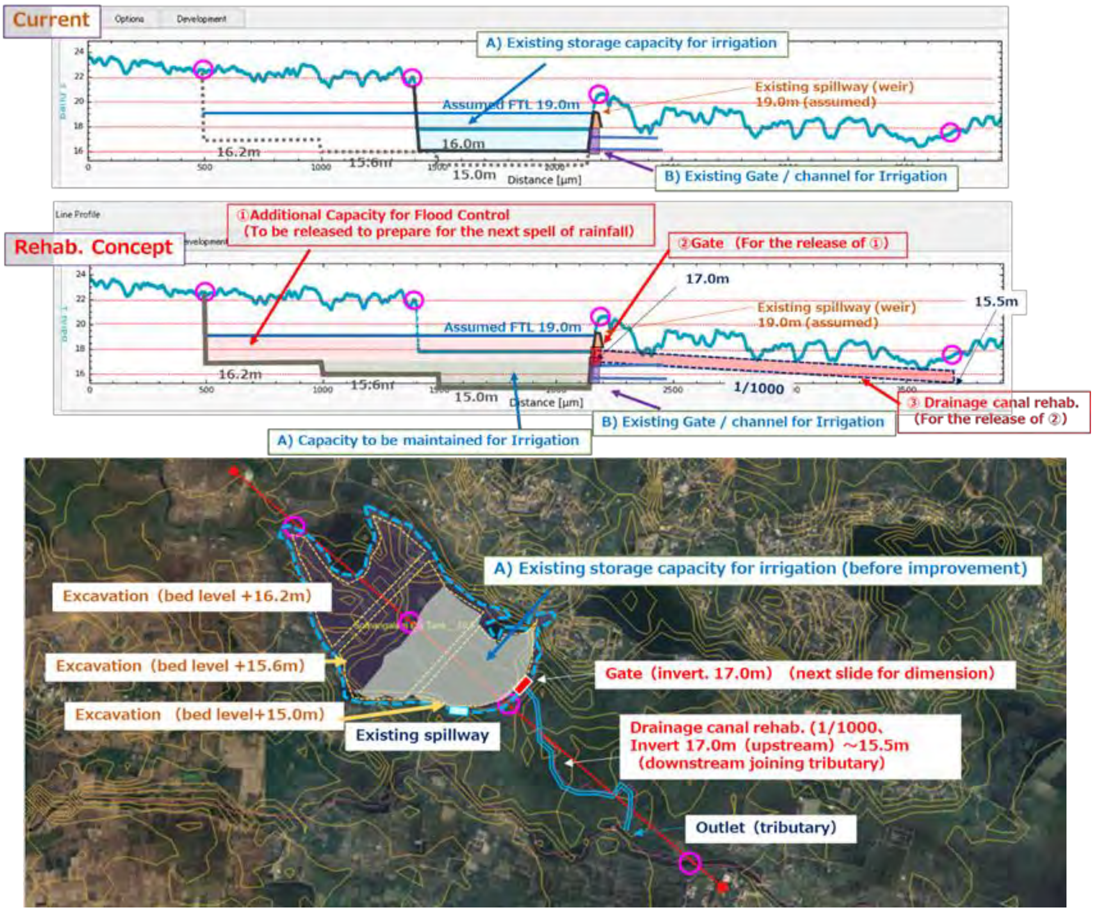
The engineering works for improving flood storage capacity in the selected tanks and waterbodies involve three major actions, each with its technical complexities:

1. Desilting and Deepening: Desilting the bottom of tanks and waterbodies to increase their storage capacity is a primary solution. However, deepening cannot extend below the outlet gates, as this would create dead storage, preventing drainage after heavy rainfall and reducing readiness for the next flood. Accurate topographic and bathymetric maps are essential for this solution to ensure precise execution.

2. Expansion in Foreshore Areas: Expanding tanks and waterbodies in their foreshore areas can enhance flood storage capacity. This also requires detailed topographic and bathymetric data. Additionally, any encroachments or illegal settlements around these waterbodies must be addressed. Fortunately, since most of these waterbodies are located upstream and under the jurisdiction of TNWRD, encroachments are minimal and primarily involve farmers, with land prices and resettlement costs being relatively low.

3. Elevation of Bunds: Increasing the elevation of tank bunds by constructing embankments around selected waterbodies is another solution. This approach also relies on accurate topographic and bathymetric data. The soil required for embankment construction can be sourced from the excavation of deepened waterbodies or other tanks, creating a synergistic benefit.

These three measures are shown in **Figure 9-3**. The most significant technical challenge is Operational and Maintenance Challenges. While the construction phase presents technical difficulties, the most significant challenges arise during the operational and maintenance phases. Coordinated operation of the several tanks and waterbodies during heavy rainfall and monsoon seasons requires automated electromechanical facilities, such as a SCADA system (control room), to monitor and control water levels effectively. Additionally, TNWRD will need dedicated personnel with strong technical capacity to continuously monitor the tanks and waterbodies during monsoon seasons, ensuring water levels are reduced after each flood event to prepare for the next.



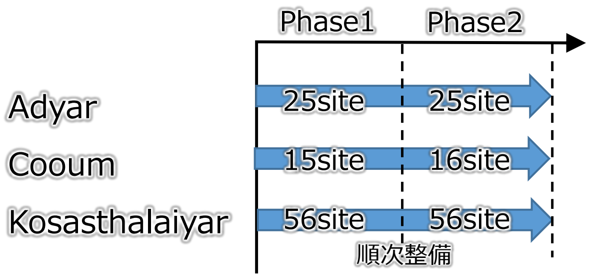
Spirce: JICA Expert Team

Figure 9-3: Concept for Improving Flood Storage Capacity (Somangalam Tank)

Furthermore, in addition to increasing the storage capacity of the waterbodies and tanks, it is essential to improve the connecting drainage systems downstream. This ensures the efficient release of stored floodwater to the next river or the Chembarambakkam Dam. Improving existing drainage systems, restoring missing links, and maintaining these connecting drains are critical for the project's overall success.

In summary, while the construction phase involves moderate technical complexity, the operational and maintenance phases require advanced systems like SCADA, skilled personnel, and continuous improvements to drainage infrastructure. Addressing these challenges will ensure the project's effectiveness in flood mitigation and long-term water management.

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.



Source: JICA ExpertTeam

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

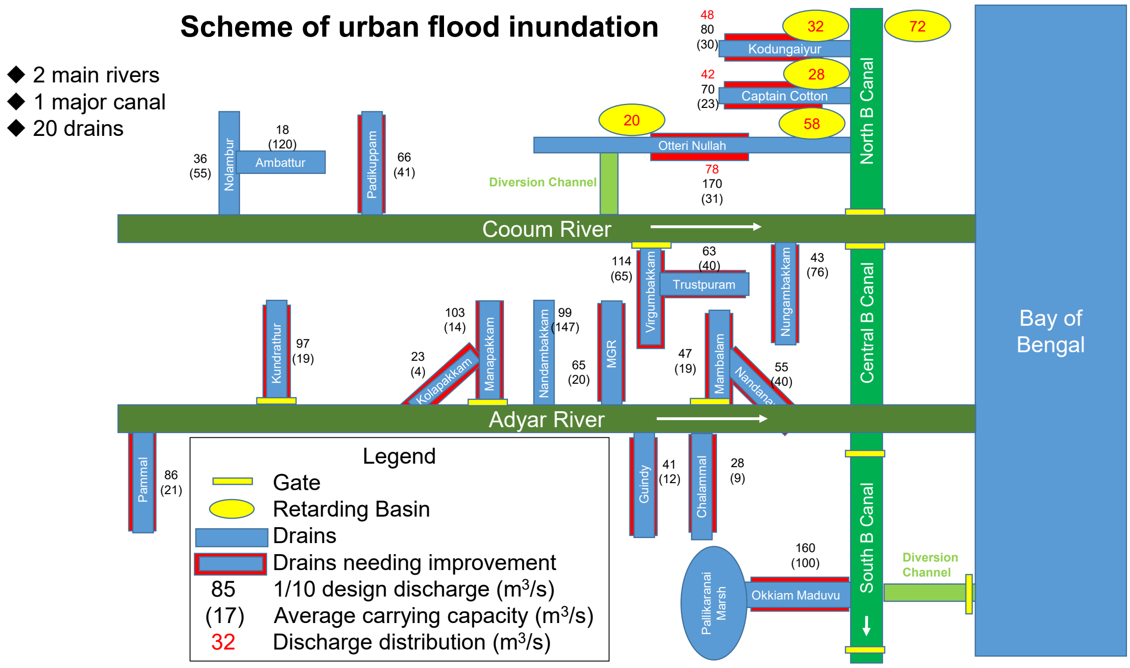
9.2.2.3. Prioritization of Urban Flood Control Countermeasures

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, improvements to the flow capacity of the drainage canals connected to the B Canal, and the installation of a regulating pond.

- **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

Figure 9-5 Shows the location of the several drainage systems, their current discharge capacity, the improved discharge capacity, and the location of detention ponds, etc.

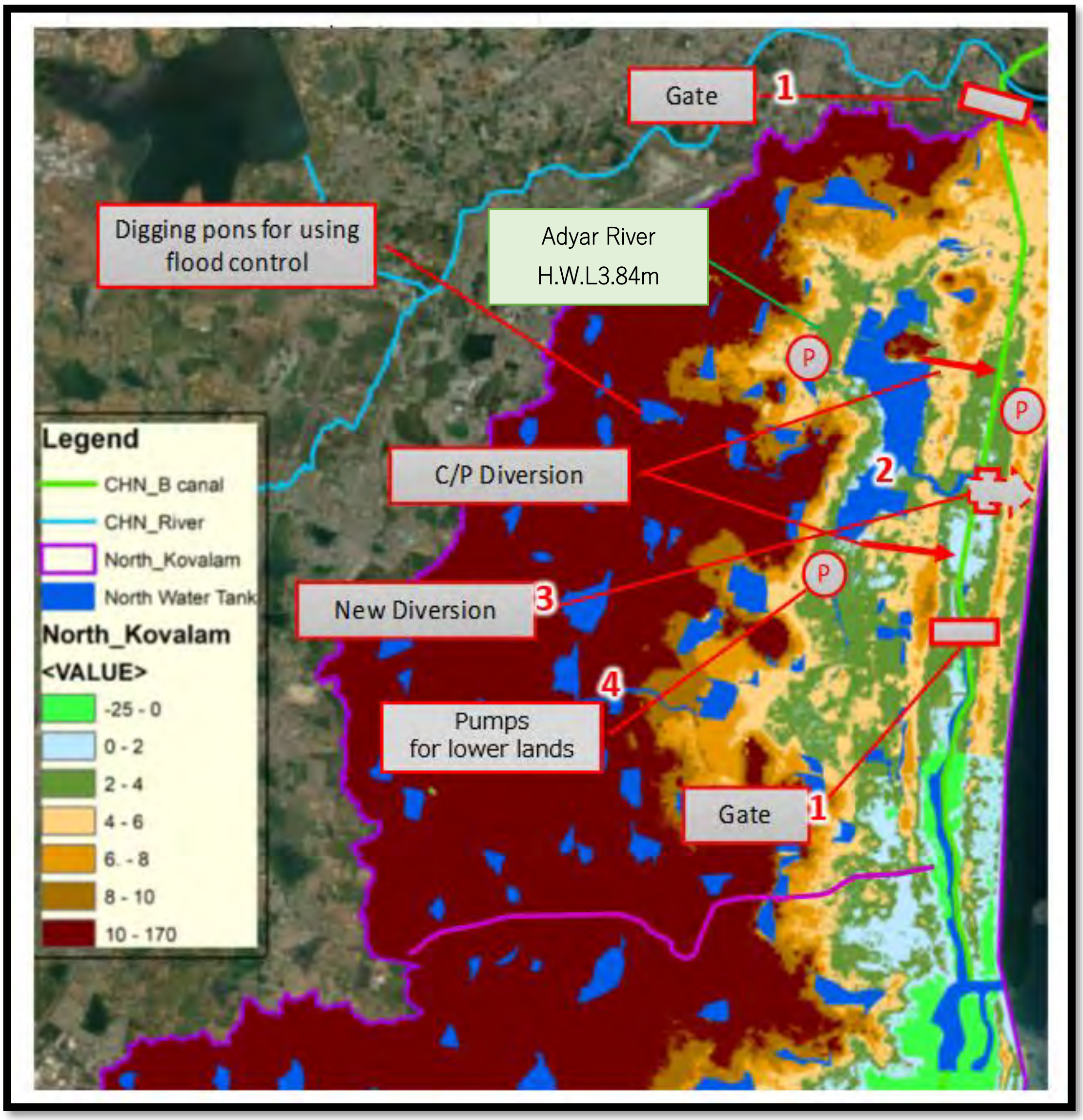


Source: JICA ExpertTeam

Figure 9-5: Overview of Urban Flood Control 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, and installing backwater prevention gates. Phase 2 will cover the channelization of Okkiyam Maduvu and the installation of pumps in low-lying areas.

Figure 9-6 Shows the areas to be improved, with the order of improvement indicated by the numbers.



Source: JICA Expert Team

Figure 9-6: Location of Proposed Countermeasures for the Kovalam Basin

9.2.3 Implementation Schedule

The project schedule is outlined 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 9-6: 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	Priority1		0.0～43.6k		
		Underground River						
	Strom Water	Gates in Connecting Drains to River	3 Gates			Extended (depend on circumstances)		
		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	Priority 3				
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					
Kosasthalaiyar River	Flood Control	Using Existing Waterbodies	112 Tanks	28 tanks Priority 4	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	Priority2				
		Bypass and Shortcut	One Bypass and One Short cut					

Source: JICA ExpertTeam

9.3 Selection of Priority Projects

In this section, the adequacy of the measures selected in the previous section is validated using the results of the inundation analysis.

9.3.1 Evaluation Criteria for Selecting Priority Projects

The priority evaluation was conducted by performing flood analysis for the following four scenarios and then examining the priority projects based on the flood reduction effects of river channel improvements, storage, and costs.

Case 1: Evaluation of the existing situation (Evaluation at existing)

Case 2: Evaluation after the Master Plan (MP) (Evaluation at MP Complete)

Case 3: Effects of river channel rehabilitation alone (Evaluation of excavation-only scenario)

Case 4: Effects of storage in tanks and other reservoirs (Effects of tank and other storage)

Case 5: Effect of improvements in Phase 1

9.3.2 Proposal of Priority Projects

9.3.2.1. Adyar River

- Effectiveness of river channel improvement through excavation alone

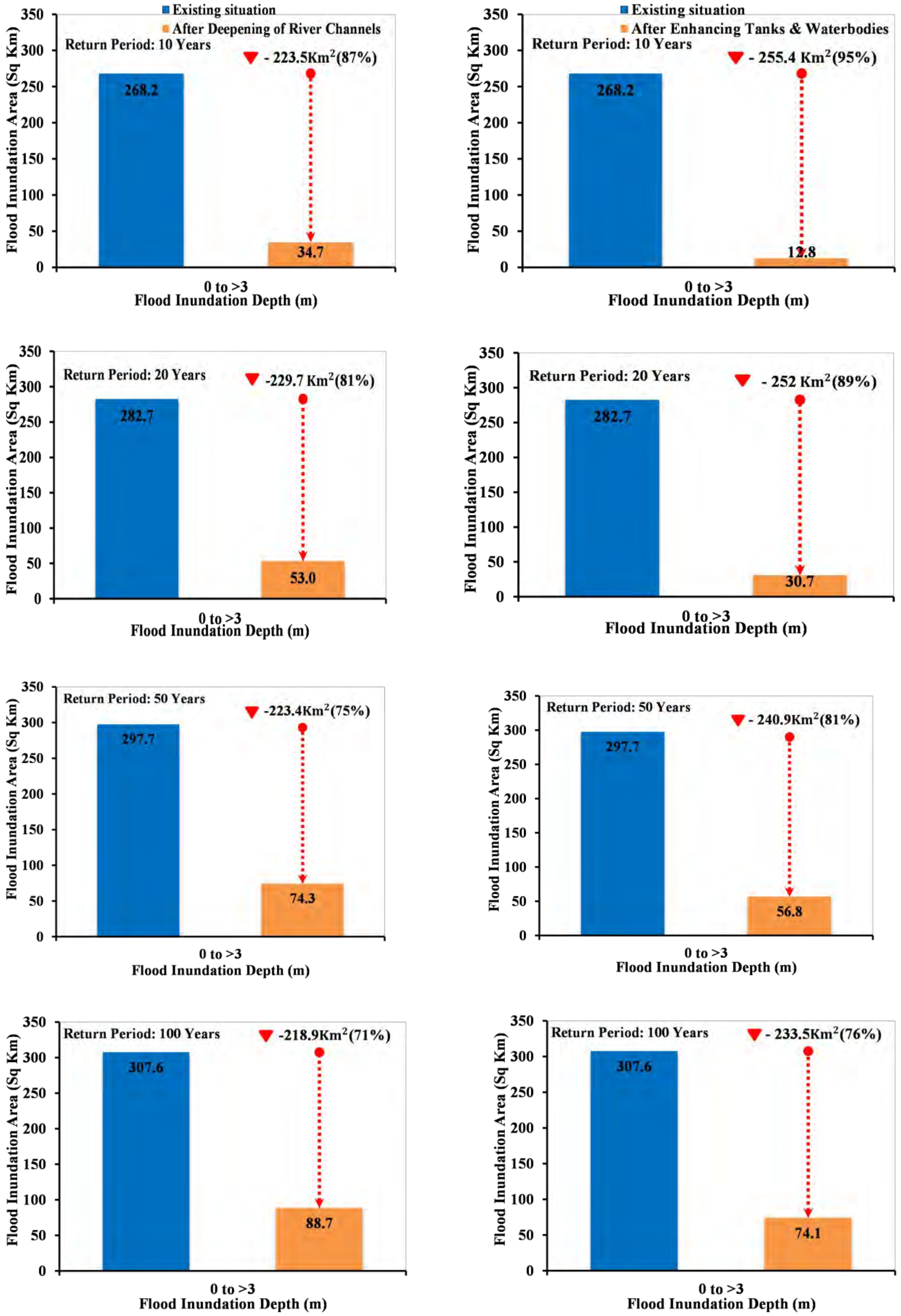
Figure 9-7 Illustrates the results of flood analysis for river channel improvements in the Adyar River, focusing on excavation alone (without widening) as part of Phase 1 improvements while also considering storage in tanks. The analysis covers probability scales from 1/10 (for immediate improvements) to 1/20, 1/50, and 1/100 (for plans). The figure reveals the following trends:

- Excavation alone provides a flood reduction effect comparable to that of utilizing all storage facilities, including tanks.
- Even in the 1/100 scale plan, a flood reduction effect exceeding 70% is expected, demonstrating the effectiveness of excavation as a standalone measure.

Given these findings and considering that 50 tank modifications would require coordination with the local community, along with the varying flood control effects depending on rainfall patterns, prioritizing river channel improvements through excavation alone seems to be the most feasible option. This approach ensures reliable management of floodwater. Additionally, as shown in **Figure 9-7**, river channel excavation without widening effectively mitigates fluvial flooding at the 1/10 scale; however, some flood inundation persists even after the improvements.

Effect of river channel improvement (without widening)

Effect of flood storage in tanks



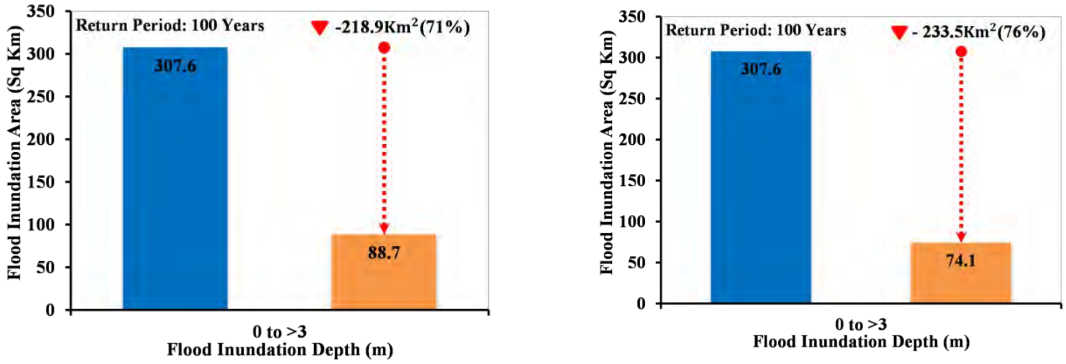
Source: JICA Expert team

Figure 9-7: Comparison of Adyar River Channelization vs Flood Storage in Tanks

- Effectiveness of preliminary river channel improvements

Figure 9-8 Presents the effects of river channel improvements only, without considering the operation of tanks and dams or the development of discharge channels, for the 1/100 scale planned scenario. The left side of the figure shows Phase 1 with excavation alone, while the right side shows the case where widening is also implemented. The figure illustrates that excavation alone provides a flood damage reduction effect in the basin comparable to that achieved by widening, indicating that river channel excavation alone is highly effective as a priority project.

Phase 1 Phase2



Source: JICA Expert team

Figure 9-8：Effect of River Channelization (Deepening and Widening)

- Priority projects for each combination

Table 9-7 Shows the flood reduction effects for each combination of measures. The table indicates that, at the 1/100 scale of the planned scenario, Phase 2 achieves approximately 86% flood reduction, while Phase 1, as part of the phased implementation, covers about 85%, demonstrating that Phase 1 is an effective phased improvement option.

Furthermore, the flood reduction effect of upgrading all the tanks as planned in Case 4 is equivalent to that of Phase 1. However, due to the time required for coordination with local communities and considerations of reliability, the combination in Phase 1 has been determined to be the most appropriate.

Table 9-7: Adyar River Flood Reduction Effects for the 1/100 RP

Modeling Scenarios	Countermeasures			Flood situation	
	River Channelization	Enhanced Flood Storage in Tanks	Others	Inundation Area (km2)	Reduction of Inundation Area (km2) and %
Existing situation (Case1 Model)	None	None	None	307.6	—
Case3 Model	Only Deepening	None	None	88.7	218.9(71%)
Phase1: Case5 Model	**Only Deepening**	**50% of Tanks**	**Underground Bypass**	**47.1**	**260.1(85%)**
Phase2: Case2 Model	**Deepening and widening**	**All Tanks**	**Underground Bypass**	**44.4**	**263.2(86%)**
Case4 Model	None	All Tanks	None	74.1	233.5(76%)

Source: JICA ExpertTeam

9.3.2.2. Cooum River

- Effectiveness of river channel improvements through excavation alone

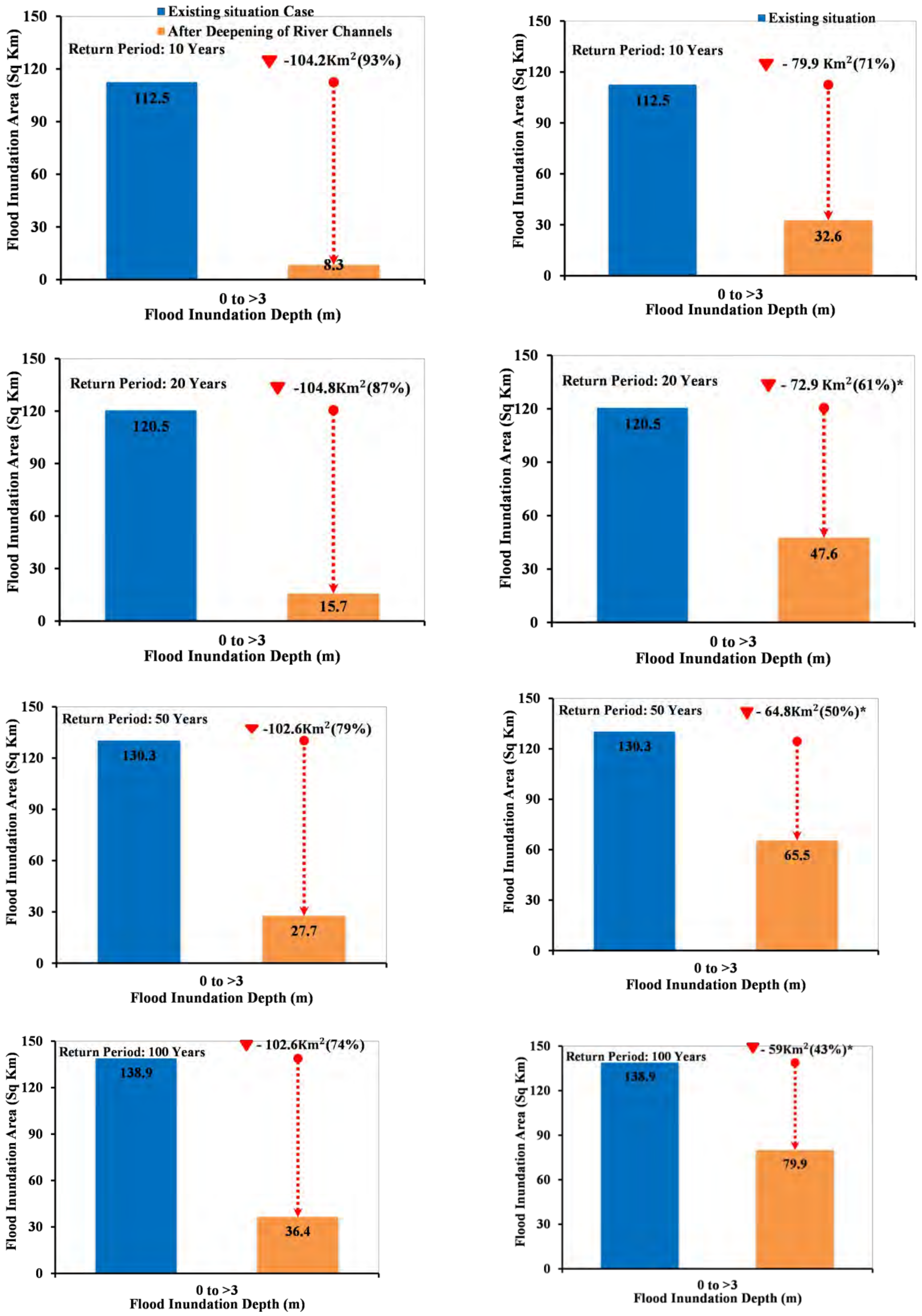
Figure 9-9 Presents the flood analysis results for the Cooum River, comparing the effects of river channel improvement through excavation alone (Phase 1 works) without widening, along with the effects of storage provided by tanks. The analysis covers probability scales ranging from 1/10 (for immediate improvements) to 1/20, 1/50, and 1/100 (for plans).

The figure shows that both cases exhibit similar trends to those observed in the Adyar River, as summarized below:

- The excavation-only improvement yields a flood reduction effect nearly equivalent to that of utilizing all storage facilities, including tanks.
- In the plan (1/100 scale), a flood reduction effect of over 50% is expected, demonstrating the effectiveness of the improvement even when implemented alone. A similar flood reduction effect of over 40% is also anticipated when the improvement is implemented as a standalone measure.

Based on these findings, river channel improvement through excavation alone is proposed as the priority project for the Cooum River, as it can reliably manage a certain volume of water, similar to the Adyar River.

Effect of Deepening (without widening) | Effect of Flood Storage in Tanks

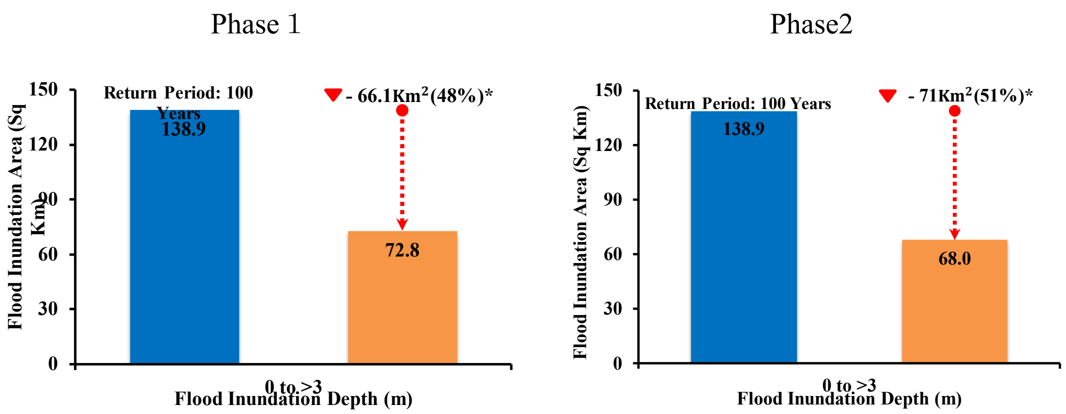


Source: JICA Expert team

Figure 9-9: Comparison of Cooum River Deepening vs Flood Storage in Tanks

- Effectiveness of preliminary river channel improvement

Figure 9-10 Presents the effects of river channel improvements alone, without considering the operation of tanks and dams or the development of discharge channels, for the 1/100 scale planned scenario. The left side of the figure shows Phase 1 with excavation alone, while the right side shows the case where widening is also implemented. The figure shows that excavation alone provides a flood damage reduction effect in the basin comparable to that achieved by widening, indicating that river channel excavation alone is highly effective as a priority project.



Source: JICA Expert team

Figure 9-10：Effect of River Channel Improvements

- Priority projects for each combination

Table 9-8 Shows the flood reduction effects for each combination of measures, similar to those of the Adyar River. From the table, at the 1/100 design scale, Phase 2 achieves approximately 60% flood reduction, while Phase 1, as a phased approach, covers about 53%. This indicates that Phase 1 is an effective phased implementation strategy.

Additionally, for the Cooum River, the flood reduction effect of improving all the tanks in Case 4 of the table is similar to that of Phase 1. However, considering the time required for coordination with local communities and the need for certainty, the combination of Phase 1 measures is considered the most reasonable option.

Table 9-8：Cooum River Flood Reduction Effects for the 1/100 RP

Modeling Scenarios	Countermeasures			Flood situation	
	River Channelization	Enhanced Flood Storage in Tanks	Others	Inundation Area (km2)	Reduction of Inundation Area (km2) and %
Existing situation (Case1 Model)	None	None	None	138.6	—
Case3 Model	Only Deepening	None	None	72.8	66.1(48%)
Phase1: Case5 Model	**Only Deepening**	**50% of Tanks**	**Underground Bypass**	**65.0**	**73.9(53%)**
Phase2: Case2 Model	**Deepening and widening**	**All Tanks**	**Underground Bypass**	**55.5**	**83.4(60%)**
Case4 Model	None	All Tanks	None	67.4	71.5(52%)

Source: JICA ExpertTeam

9.3.2.3. Kosasthalaiyar River

- Effectiveness of river channel improvements through excavation alone

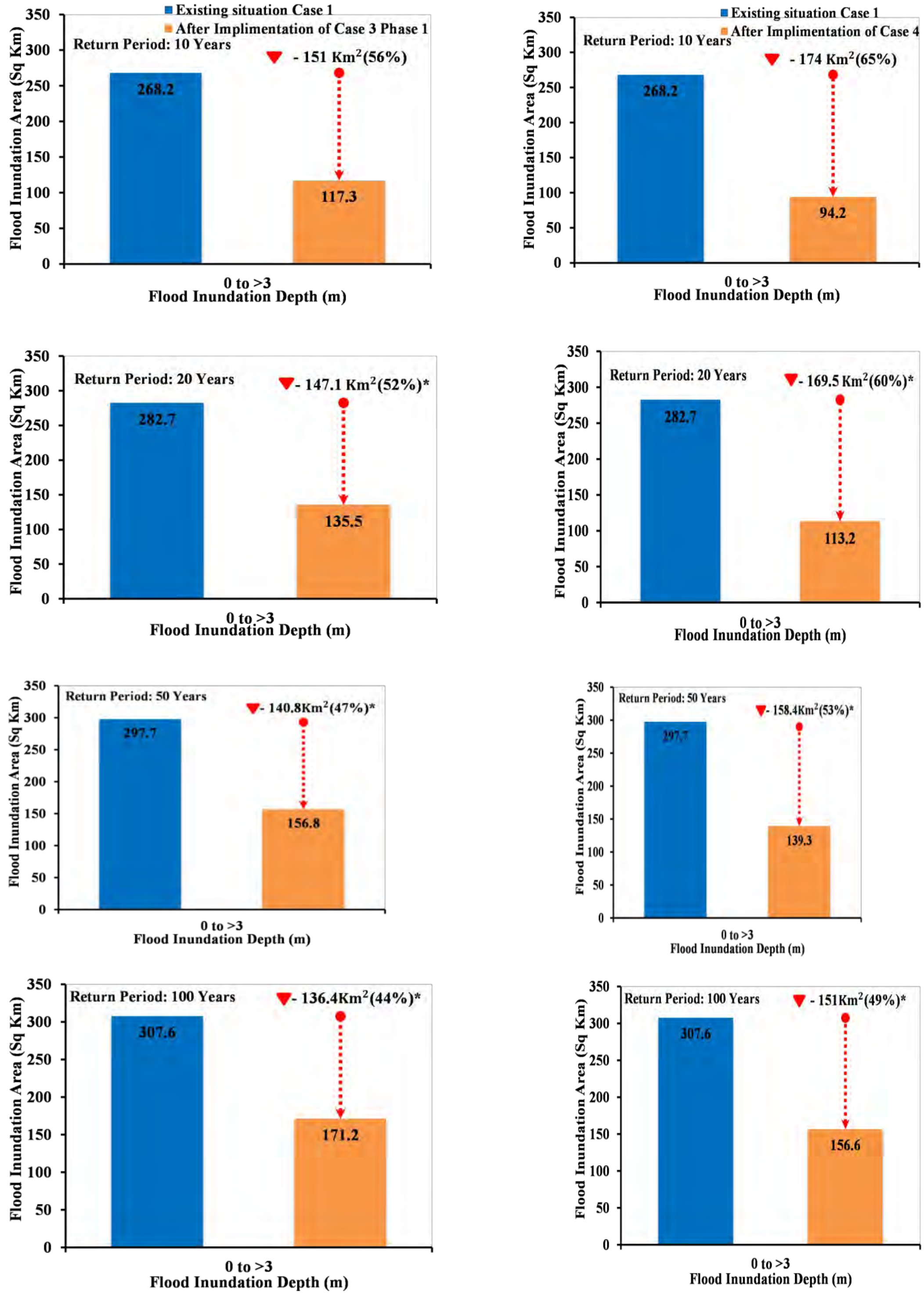
Figure 9-11 Presents the flood analysis results for the Kosasthalaiyar River, comparing the effects of river channel improvement through excavation alone (Phase 1 works) without widening, along with the effects of storage provided by tanks. The analysis includes probability scales ranging from 1/10 (for immediate improvements) to 1/20, 1/50, and 1/100 (for plans).

The figure demonstrates that both cases follow similar trends to those observed in the Adyar River, as outlined below:

- The excavation-only improvement provides a flood reduction effect comparable to that achieved by fully utilizing all storage facilities, such as tanks.
- In the plan (1/100 scale), a flood reduction effect of over 50% is expected, indicating that the improvement is effective even when implemented as a standalone measure. A similar effect of over 40% is anticipated when the improvement is implemented alone.

Based on these results, river channel improvement through excavation alone is proposed as the priority project for the Kosasthalaiyar River, as it can reliably manage a certain volume of water, similar to the Adyar River.

Effect of Deepening (without widening) | Effect of Flood Storage in Tanks

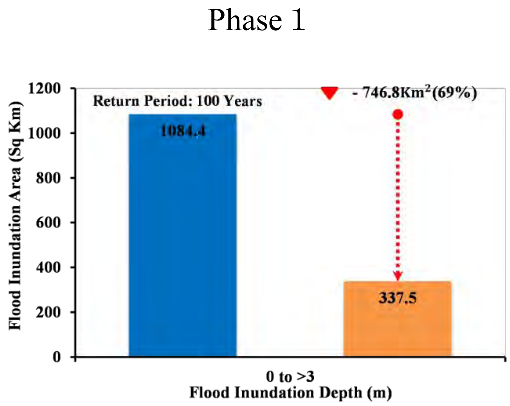


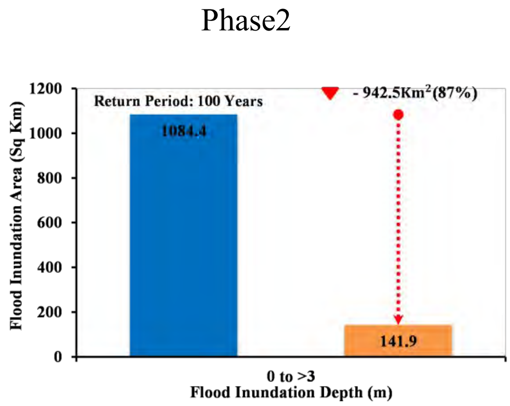
Source: JICA Expert team

Figure 9-11: Comparison of Kosasthaliyar River Deepening vs. Flood Storage in Tanks

- Effectiveness of preliminary river channel improvement

The figure summarises the effects of river channel rehabilitation alone, without tank and dam discharge operations and channel maintenance in the basin at the 1/100th planning scale. The left-hand side of the figure shows Phase 1 with excavation only, while the right-hand side shows the case with widening. The figure shows that the damage reduction effect in Phase 1 is 68%, which is almost the same as Phase 2, indicating that the maintenance effect in Phase 1 is high.





Source: JICA Expert team

Figure 9-12: Effect of River Channel Improvements

- Priority projects for each combination

Table 9-9 shows the flood reduction effects for each combination of measures, similar to those of the Adyar River. From the table, at the 1/100 design scale, Phase 2 achieves approximately 87% flood reduction, while Phase 1, as a phased approach, covers about 69%. This indicates that Phase 1 is an effective phased implementation strategy.

Additionally, for the Kosasthalaiyar River, the flood reduction effect of improving all the tanks in Case 4 of the table is similar to that of Phase 1. However, considering the time required for coordination with local communities and the need for certainty, the combination of Phase 1 measures is considered the most reasonable option.

Table 9-9：Kosasthaliyar River Flood reduction effects at the 1/100 scale

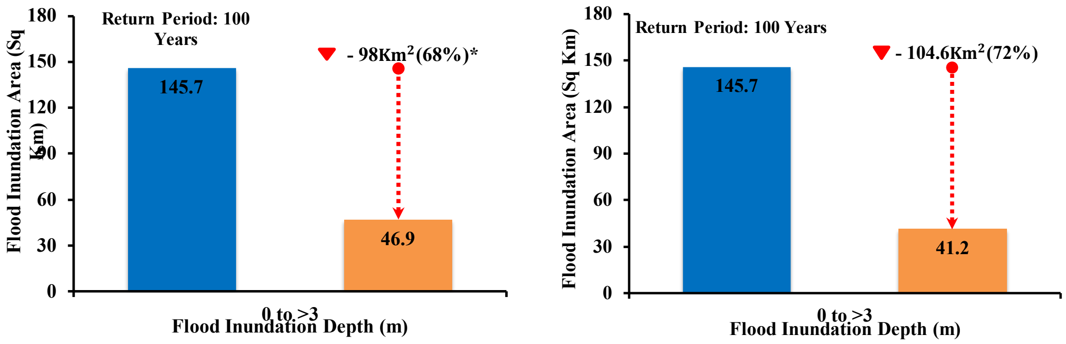
Modeling Scenarios	Countermeasures			Flood situation	
	River Channelization	Enhanced Flood Storage in Tanks	Others	Inundation Area (km2)	Reduction of Inundation Area (km2) and %
Existing situation (Case1 Model)	None	None	None	1084.4	—
Case3 Model	Only Deepening	None	None	171.2	136.4(44%)
Phase1: Case5 Model	**Only Deepening**	**50% of Tanks**	**Underground Bypass**	**337.5**	**746.8(69%)**
Phase2: Case2 Model	**Deepening and widening**	**All Tanks**	**Underground Bypass**	**141.9**	**042.5(87%)**
Case4 Model	None	All Tanks	None	156.6	151(49%)

Source: JICA ExpertTeam

9.3.2.4. Kovalam Basin

Figure 9-13 shows the improvement effects of Phase 1 and Phase 2 at the 1/100 design scale for the Kovalam area. The figure clearly shows that implementing Phase 1 significantly reduces the overall flood extent, making it an effective phased improvement strategy.

Phase1 Phase2



Source: JICA Expert team

Figure 9-13：Phased Improvement Effects for the Kovalam Basin

9.3.3 Evaluation based on project costs

Table 9-10 shows the costs associated with river channel improvements and tank reservoir enhancements. From the table, the cost of river channel improvements for the three rivers is approximately 11 billion INR, which is about one-seventh of the cost of tank improvements, estimated at approximately 82 billion INR. Therefore, while the improvement effects of river channel improvements and reservoir enhancements are similar, river channel improvements are considered more cost-effective.

Moreover, although the cost of underground rivers is high, without discharge channels, the need for river widening would increase, requiring the relocation of many houses. Therefore, it has been decided to prioritize this approach.

Table 9-10: Project Costs for Riverine Flood Control Structural Measures (Cr. INR)

River		Phase-1	Phase-2	Total (Phase-1 and Phase-2)		
		CPC (INR Crores)	CPC (INR Crores)	Reduction in Inundation (km^2)	Direct Beneficiary Population (Lakhs)	CPC (INR Crores)
River Channelization	Adyar River	530	1,700	437	20	2,230
	Cooum River	420	560	200	9	980
	Kosasthalaiyar and Redhills	330	300	1139	21	630
	Sub Total	**1,280**	**2,560**	**1776**	**50**	**3,840**
Improvement of Reservoirs	Adyar River (25 tanks)	160	160	218	15	320
	Cooum River (15 tanks)	130	130	66	5	260
	Kosasthalaiyar and Redhills (59 tanks)	280	280	845	26	560
	Sub Total	**570**	**570**	**1129**	**46**	**1,140**
Underground River (L=12.3 km, Φ = 11 m)		**7,970**	**0**	**176**	**20**	**7,970**
Grand Total CPC (INR Crores)		**9,820**	**3,130**	**12,950**		
*CPC: Construction Procurement Cost, excluded land acquisition and administrative cost.						

Source: JICA ExpertTeam

9.4 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.

9.4.1 Adyar River

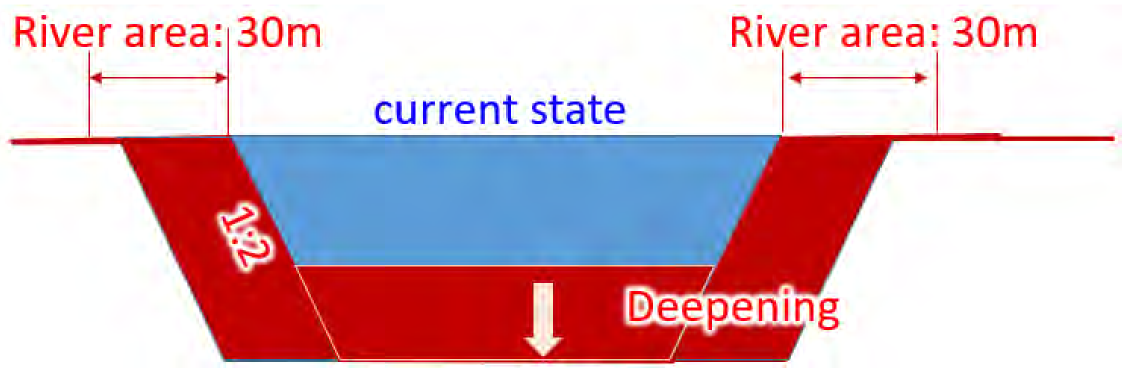
9.4.1.1. River channel improvement

Figure 9-14 shows the standard cross-section for the river channelization of the Adyar River. **Figure 9-15** provides an aerial view of the implementation phases and the locations of the proposed river channelization countermeasures. **Figure 9-17** 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 (15.2 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.

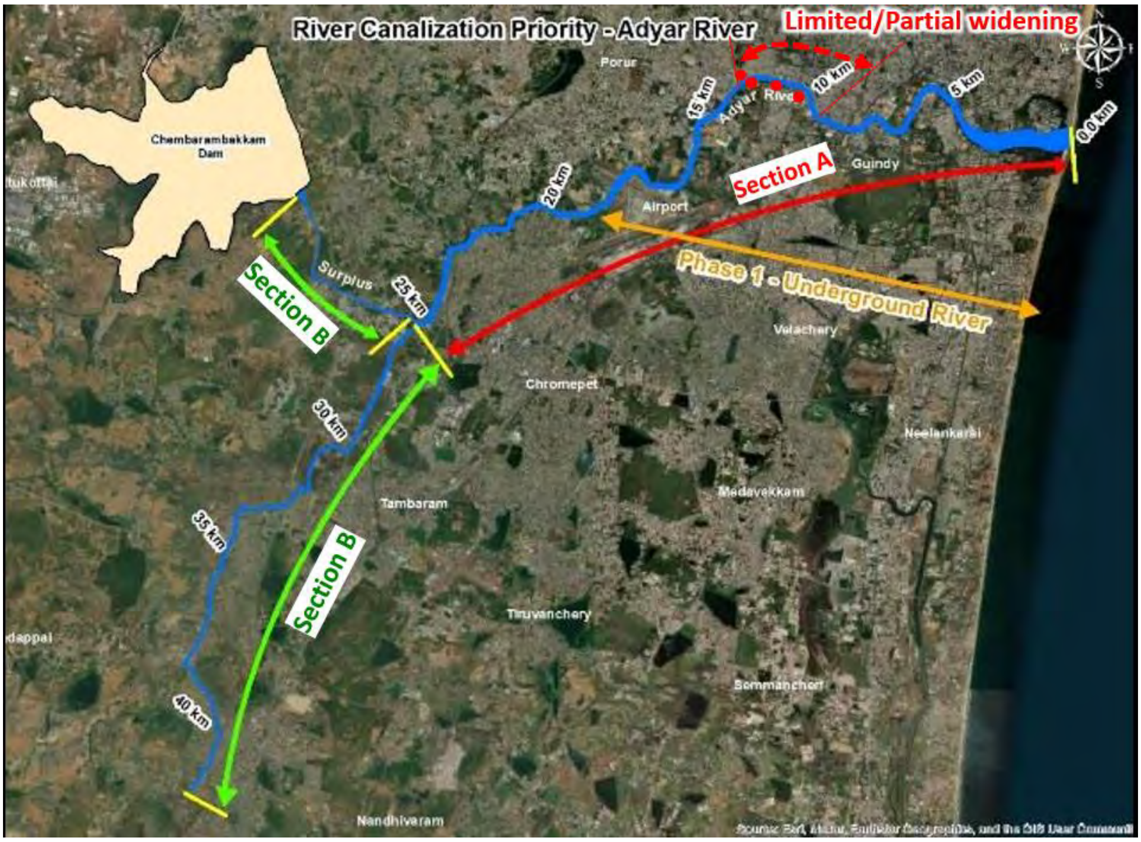
Phase 2 includes the continuation of the river deepening upstream (from 25.0 km to 43.7 km), as well as river widening along the entire river and improvements to the flood storage capacity in the remaining tanks.



Source: JICA ExpertTeam

Figure 9-14: Standard Cross-section for River Channelization

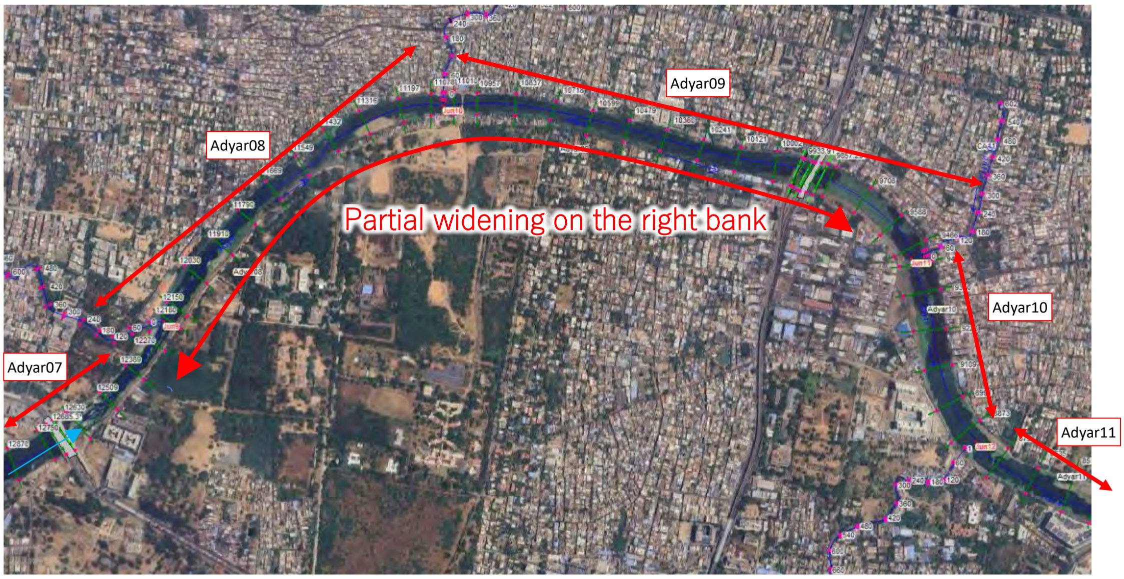
Based on the effects discussed in the previous section, the overviews of each project are as follows.



Source: JICA ExpertTeam

Figure 9-15: Aerial View of Phases and Countermeasures in Adyar River

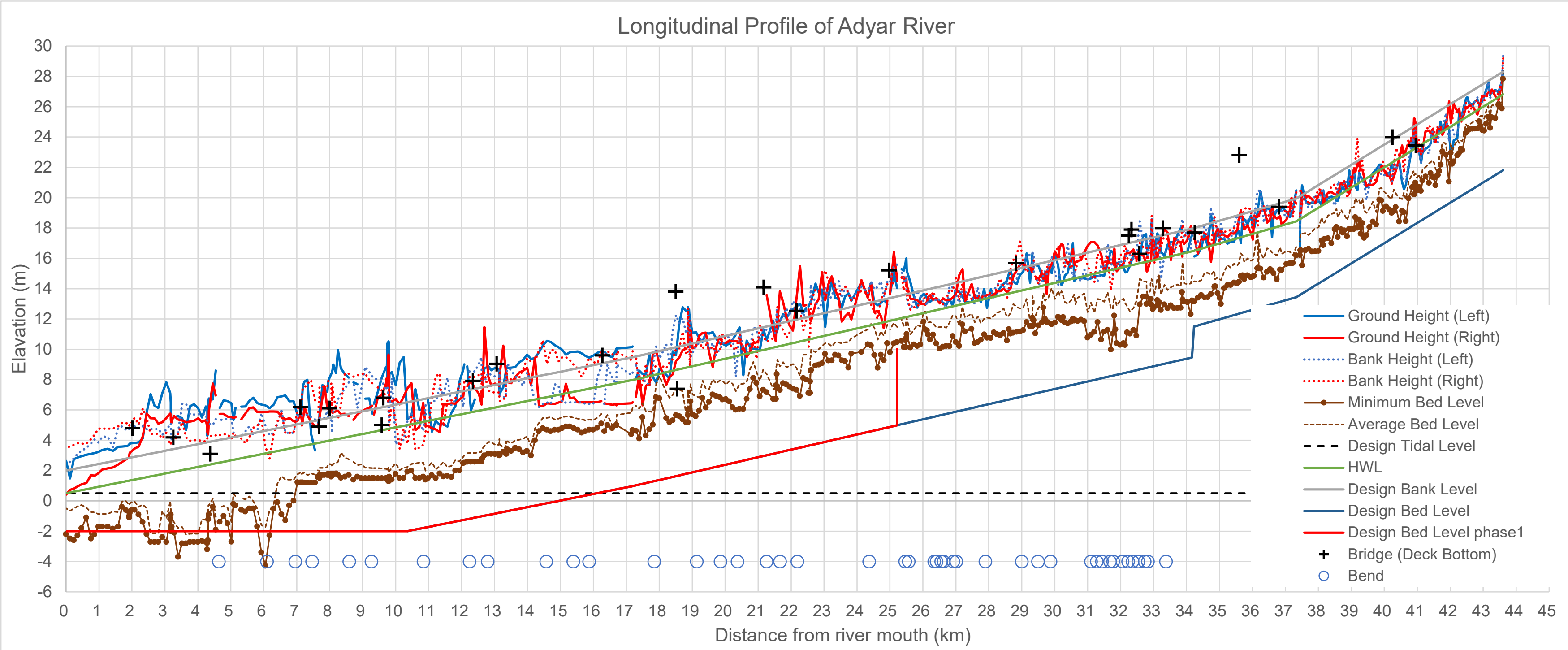
The sections that require partial widening are Adyar 8 and Adyar 9 in Figure 9-16. These sections will be partially widened mainly on the right bank because the right bank is not urbanized.



Source: JICA ExpertTeam

Figure 9-16: Plan View of Areas Requiring Limited/Partial Widening

The river will be excavated from the mouth (0.0 km) to the confluence with the Chembarambakkam River (15.2 km). However, from the river mouth to 10.0 km, excavation will be carried out to a depth of -2 meters, as required to maintain the river mouth.



Source: JICA ExpertTeam

Figure 9-17: Longitudinal Profile of the Plan (Adyar River)

9.4.1.2. Underground Bypass

The facility specifications for the underground bypass tunnel are as follows.

(1) Facility Overview

The scale of the underground bypass tunnel facility is as described in Section 2.3.4, where water is led from the Adyar River to the underground tunnel through the intake facility and inlet shaft. Drainage from the underground tunnel is based on natural drainage in the form of siphons into Bengal Bay. The longitudinal gradient of the underground bypass tunnel is i=1/2000, and the inner diameter is 11 m.

Table 9.11：Preliminary Underground Bypass Tunnel Specification

		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 ExpertTeam

Table 9.12：Relationship of Tunnel Inner Diameter and Discharge at Route 1

Route1											
Diameter	Area	10% Reduction Area	Conversion Diameter	Conversion Area	Roughness Coefficient	Gradient	Wetted Perimeter	Hydroulic Radius	Velocity	Discharge	Volume
管径	断面積	断面積(10%ロス)	換算直径	換算面積	粗度係数	勾配	潤辺	径深	流速	流量	管路体積
m	m2	m2	m	m2			m	m	m/s	m3/s	m3
15	176.715	159.043	14.230	159.043	0.015	1928	44.71	3.56	3.538	563	2,208,932
14	153.938	138.544	13.282	138.544	0.015	1928	41.73	3.32	3.379	468	1,924,226
13	132.732	119.459	12.333	119.459	0.015	1928	38.74	3.08	3.216	384	1,659,154
12	113.097	101.788	11.384	101.788	0.015	1928	35.76	2.85	3.049	310	1,413,717
11	95.033	85.530	10.436	85.530	0.015	1928	32.78	2.61	2.877	246	1,187,915
10	78.540	70.686	9.487	70.686	0.015	1928	29.80	2.37	2.700	191	981,748
9	63.617	57.256	8.538	57.256	0.015	1928	26.82	2.13	2.517	144	795,216

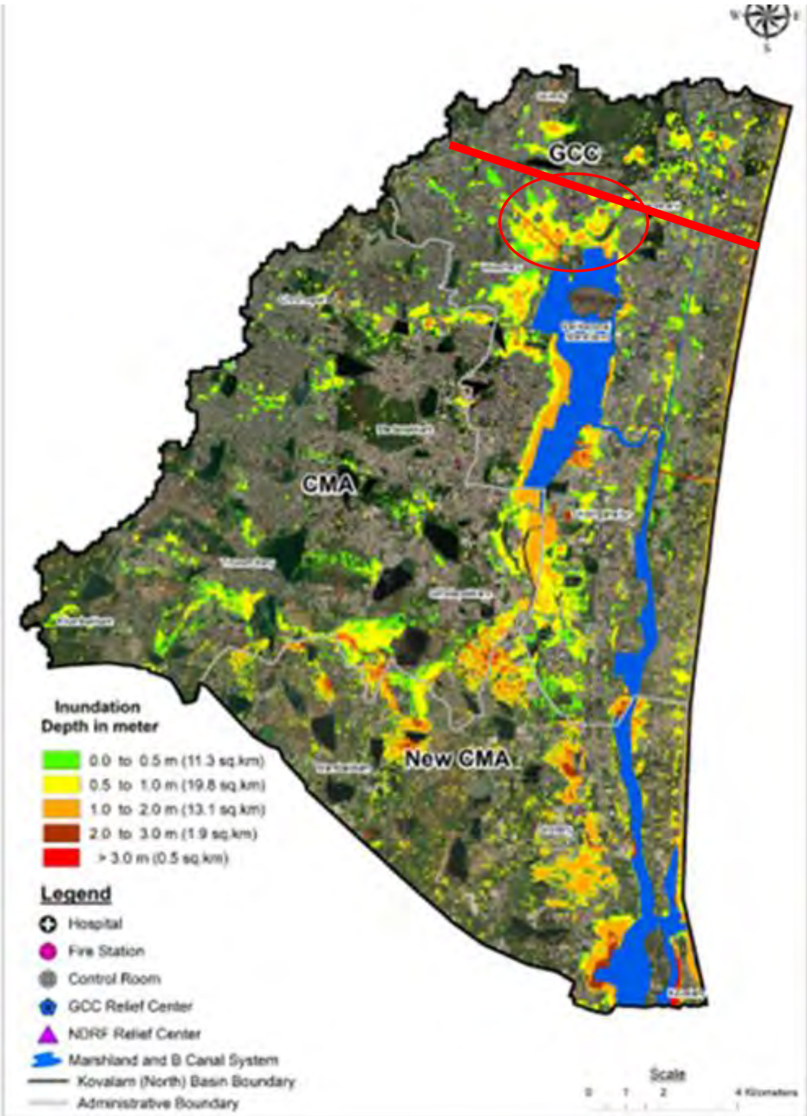
Source: JICA ExpertTeam

(2) Priority improvement section

Figure 9-18 Shows the route of the underground river on a 1/100 flood scale inundation map in the Kovalam basin after the MP measures.

The figure shows that there is an inland water zone in the Kovalam catchment on the route.
Therefore, the underground bypass tunnel will be completed in Phase 1, but to achieve the flood

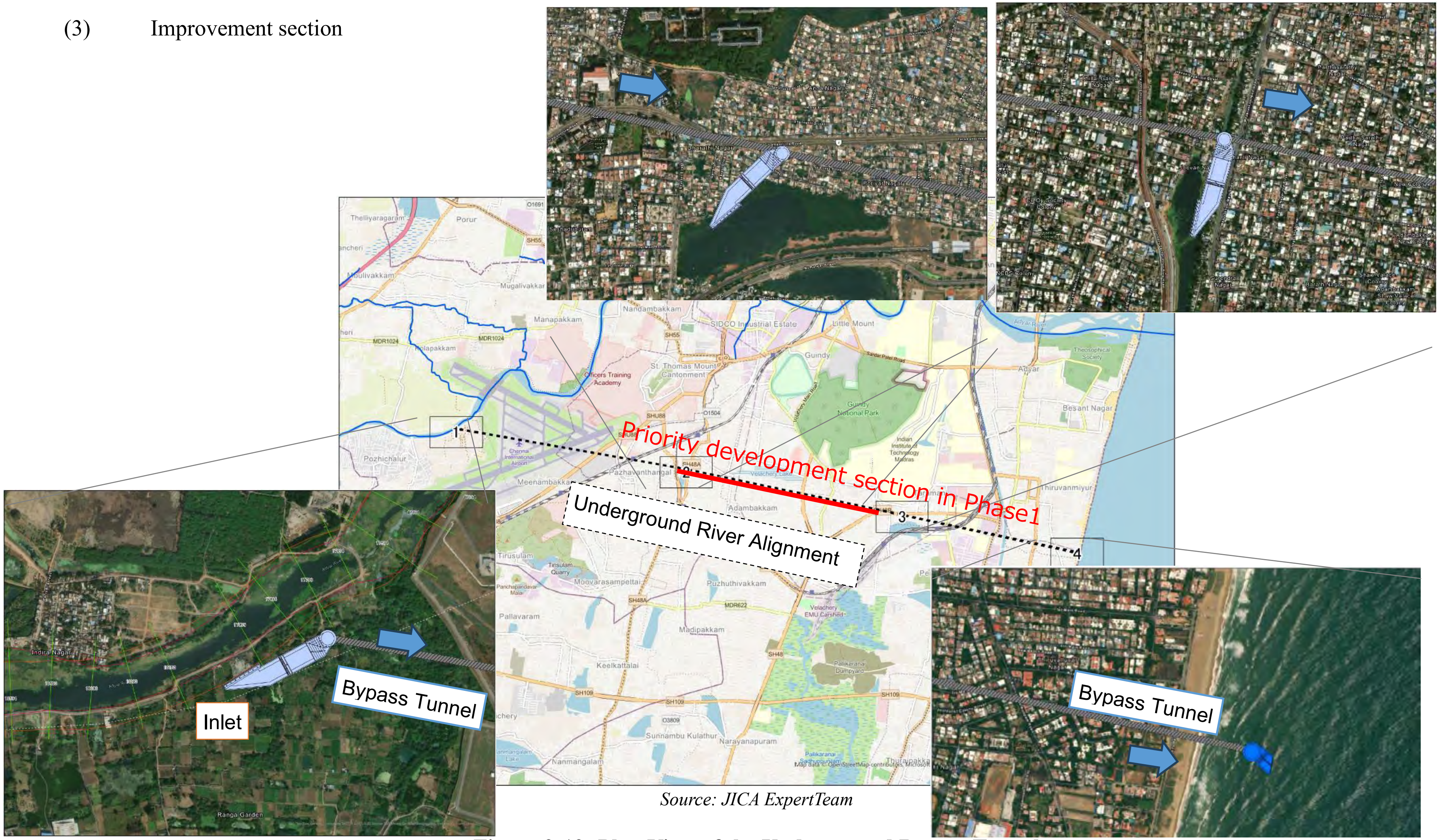
control effect of the underground bypass tunnel earlier, it may be possible to start construction from the section in this inland water area and use it as an underground control basin until the entire section is completed.



Source: JICA ExpertTeam

Figure 9-18 Proposed Direction for Underground Bypass in the Kovalam Basin

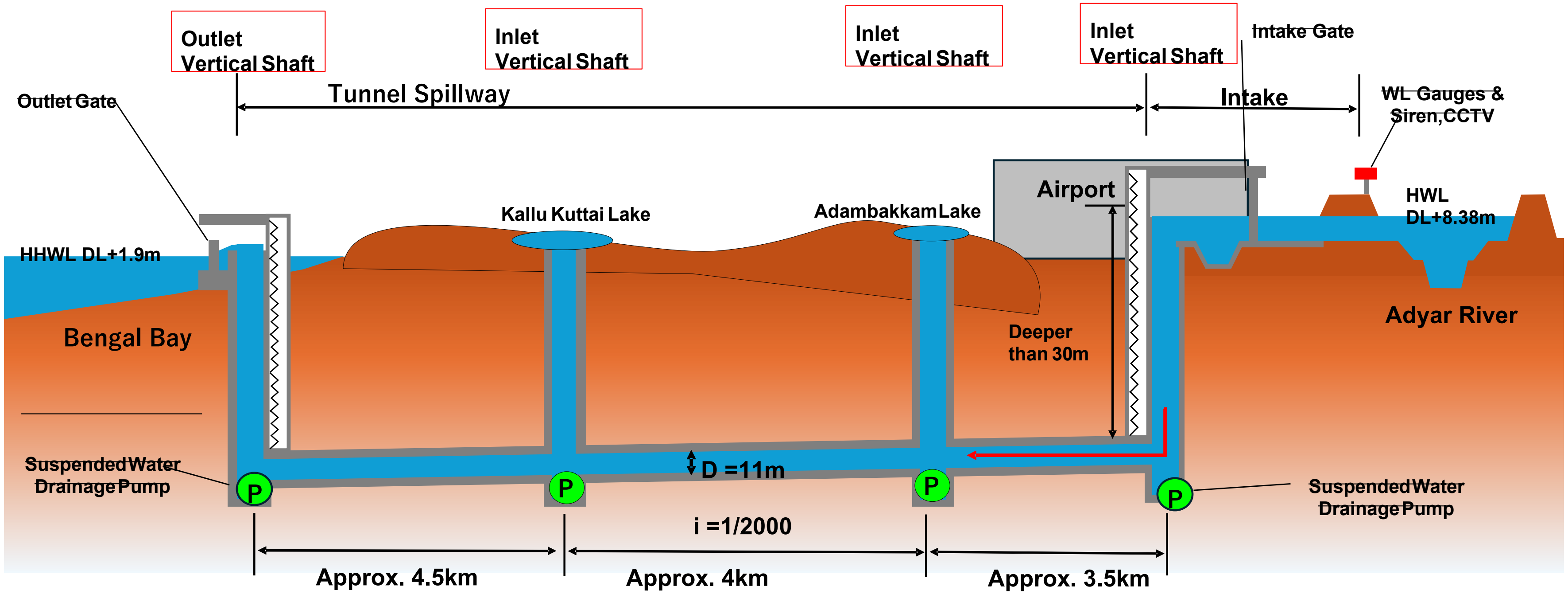
(3) Improvement section



Source: JICA ExpertTeam

Figure 9-19: Plan View of the Underground Bypass Tunnel

(4) Underground Bypass Longitudinal Profile Plan



Source: JICA ExpertTeam

Figure 9-20: Schematic Plan of Underground Bypass

9.4.2 Cooum River

9.4.2.1. River channel excavation

The standard cross-section for river channel excavation, sections that require partial widening, and the excavation profile are as follows.

(1) Standard Cross-section

The slope of the excavation area will be set at a 1:2 ratio as the standard, and excavation will be carried out accordingly.

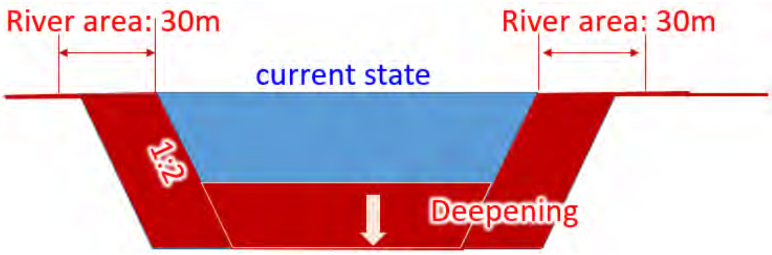


Figure 9-21: Concept of Standard Excavation Cross-section

(2) Plan View

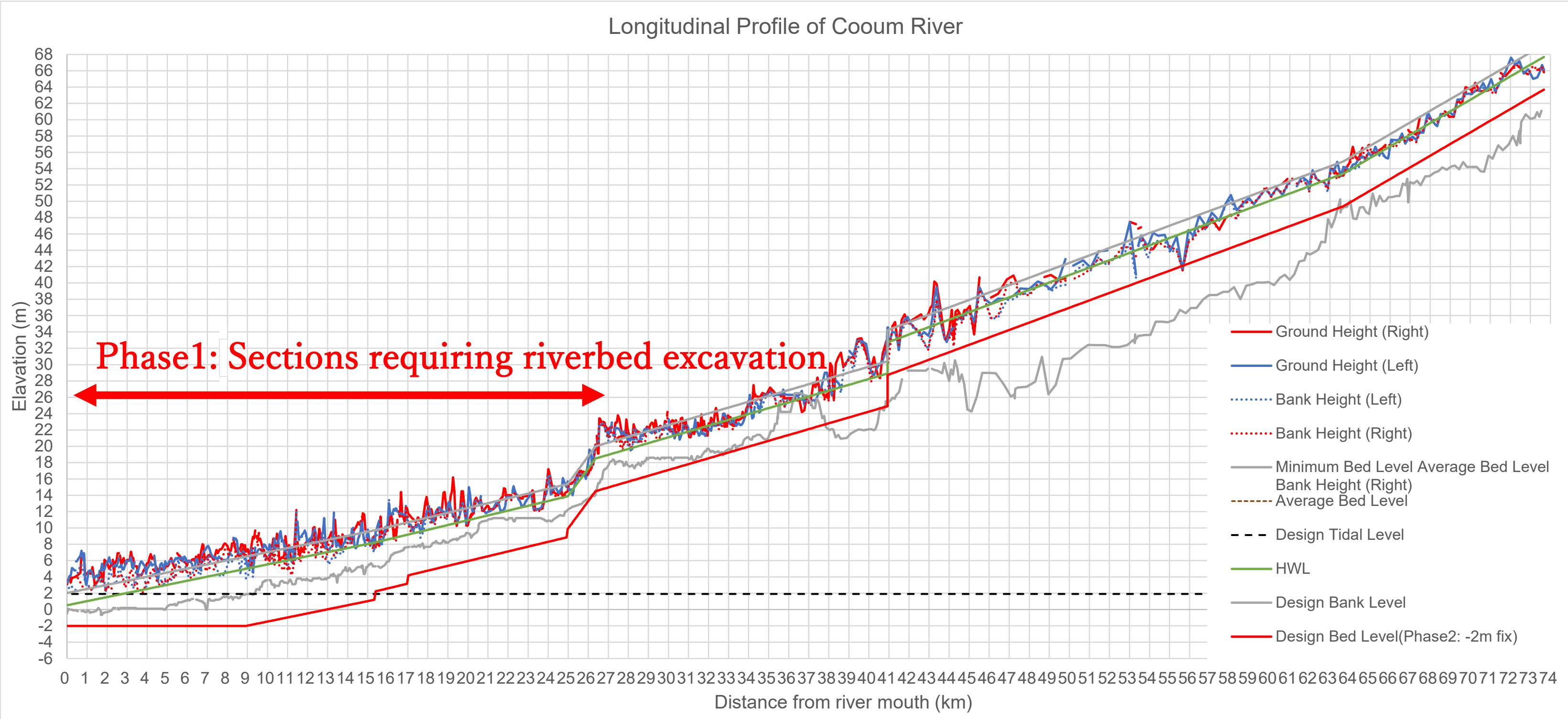
Excavation will be carried out only within the existing river channel.

Source: JICA Expert Team

Figure 9-22: Cooum River Plan View

(3) Longitudinal profile of the plan

Excavation will be carried out from the mouth (0.0 km) to 25.0 km, while excavation from the mouth to 9.0 km will be conducted at a dredging depth of -2 meters to maintain the river mouth.



Source: JICA ExpertTeam

Figure 9-23: Cooum River Longitudinal Profile Plan

9.4.3 Kosasthalaiyar River

9.4.3.1. River channel excavation

The standard cross-section for river channel excavation, sections that require partial widening, and the excavation profile are as follows.

(1) Standard Cross-section

The slope of the excavation area will be set at a 1:2 ratio as the standard, and excavation will be carried out accordingly.

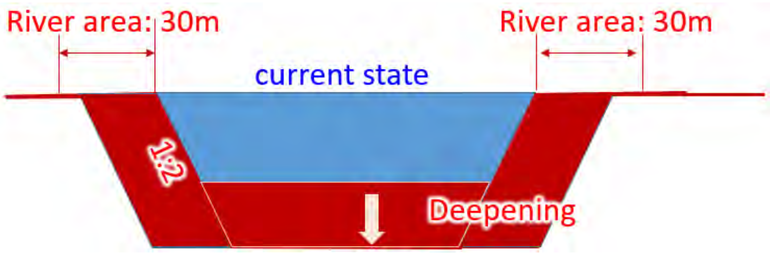
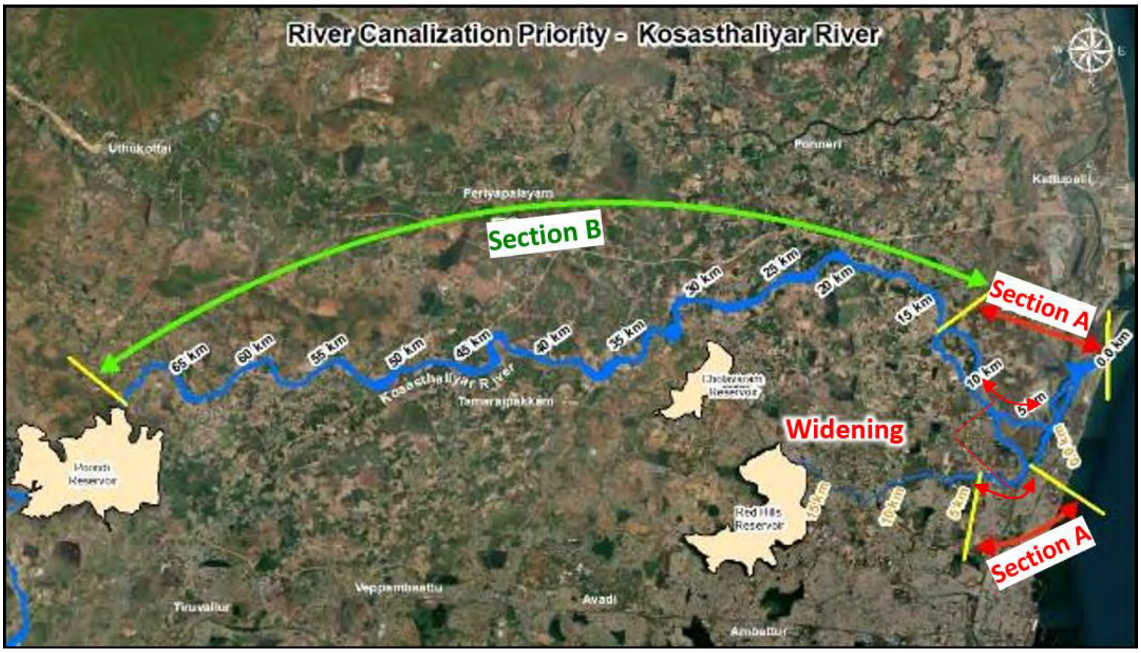


Figure 9-24 Image of Standard Excavation Cross-section

(2) Plan View

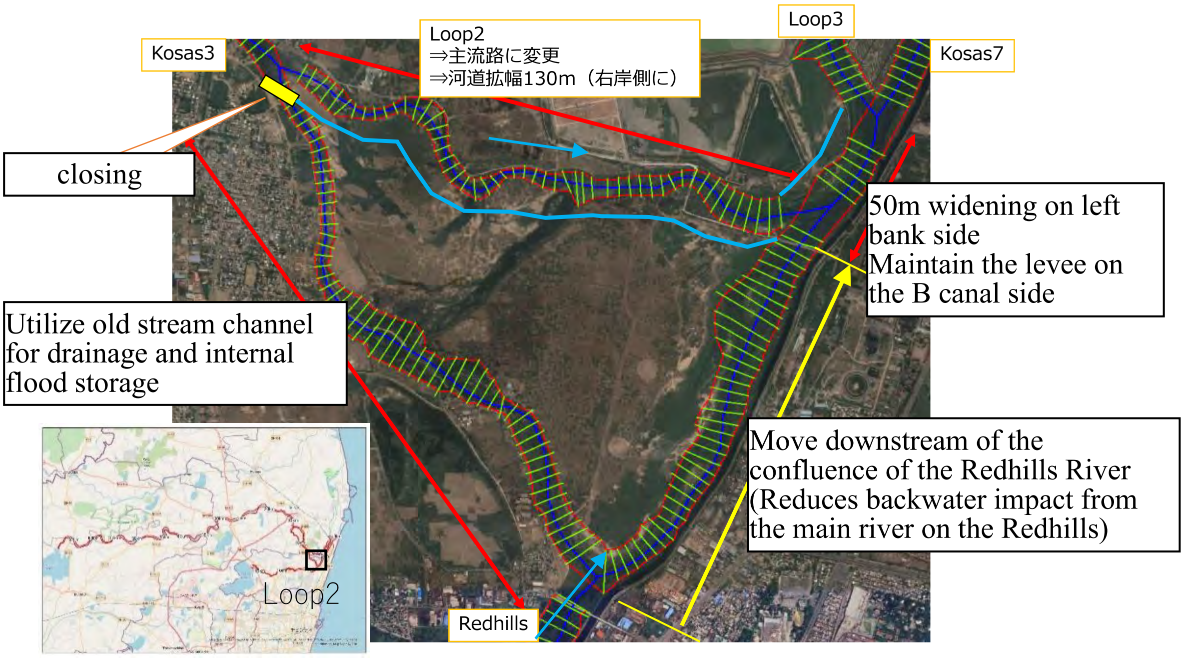
Figure 9-27 Shows the channel excavation section as developed in Phase 1 in the Kosasthalaiyar River.



Source: JICA ExpertTeam

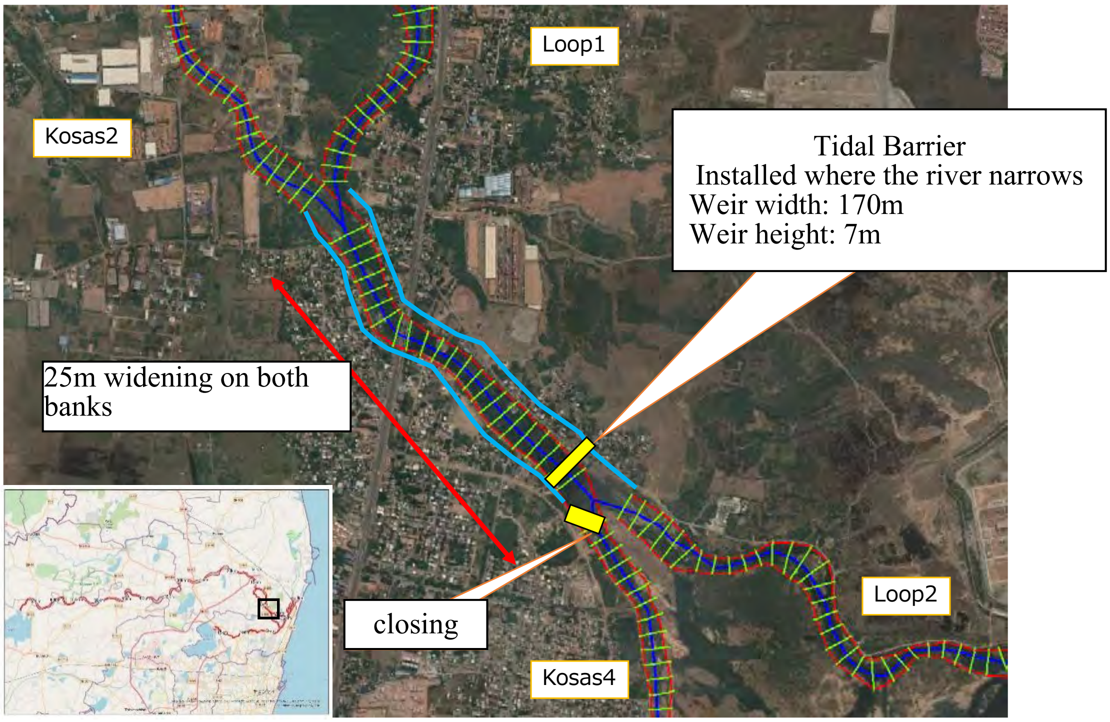
Figure 9-25: Kosasthalaiyar River Plan View

The sections to be widened are shown in **Figure 9-26** to **Figure 9-28**. In the section of Loop 2 in **Figure 9-26**, the right-hand channel will be closed to lower the confluence water level of the right tributary Redhills River and reduce the impact of backwater on the flow capacity. The channel on the left bank side will be widened to improve flow capacity. **Figure 9-27** shows the section between Loop 1 and Loop 2, where the channel width is narrower. This section will be widened to ensure the flow capacity by using a portion of **Figure 9-28**: The right tributary of Redhills River has a narrow channel width and insufficient flow capacity in the section between 3 km and 6 km, which will be widened to ensure flow capacity, taking into account that the surrounding area is agricultural land.



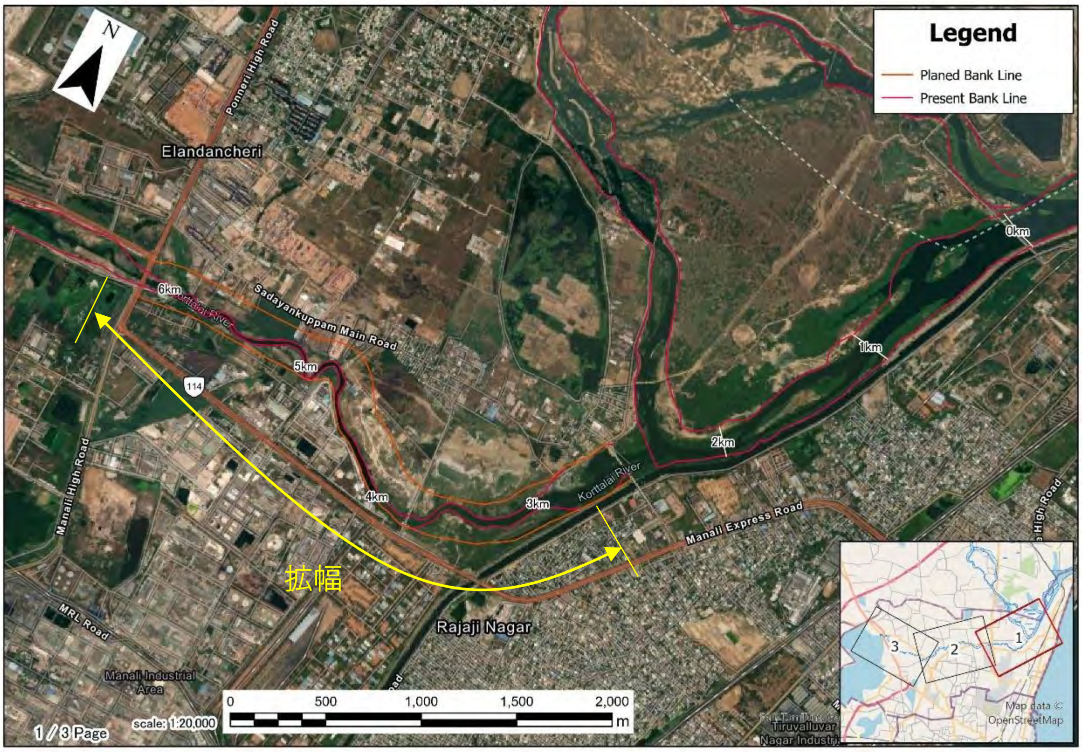
Source: JICA ExpertTeam

Figure 9-26: Bifurcation Point in the Kosasthalaiyar River No. 1



Source: JICA ExpertTeam

Figure 9-27: Bifurcation Point in the Kosasthalaiyar River No. 2

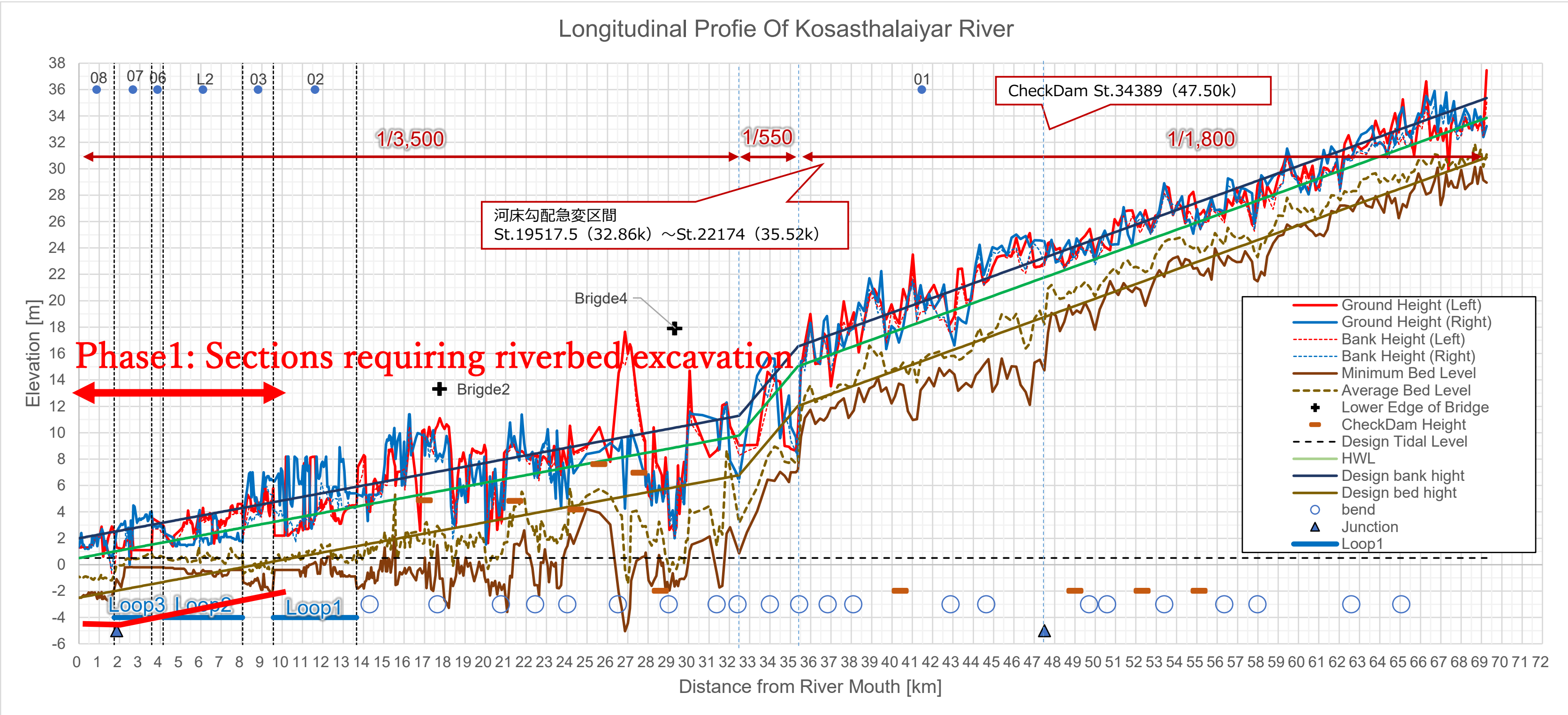


Source: JICA ExpertTeam

Figure 9-28: Widening Sections of Redhills Surplus (River)

(3) Longitudinal Profile of the Plan

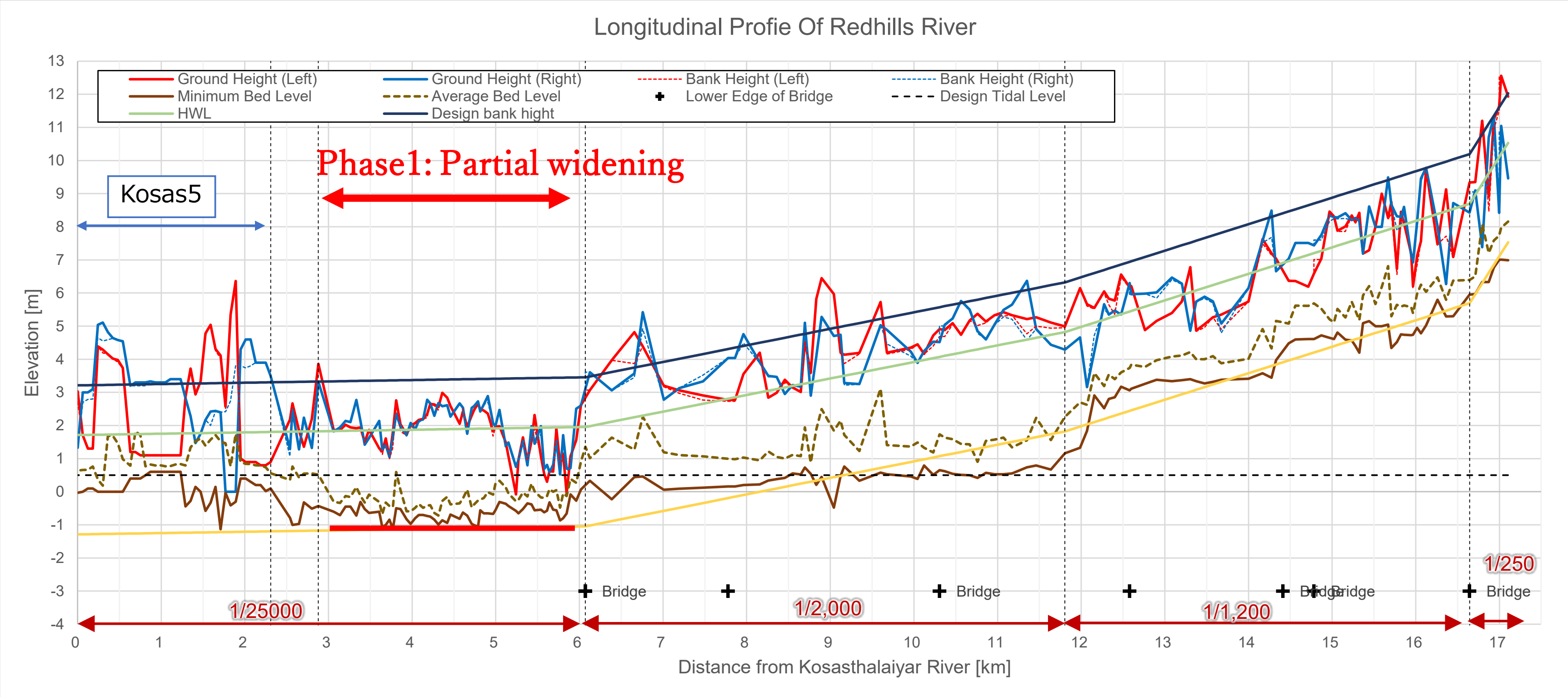
Based on the flow capacity assessment, the section from the upstream end of Loop 3 (3.6 km) to the downstream end of Loop 1 (9.6 km) has been identified as the target area. In this case, considering the riverbed at 3.6 km downstream as the current condition, sediment flowing downstream from upstream will tend to accumulate. Therefore, to maintain continuity in longitudinal excavation, excavation will be carried out down to the river mouth with a minimum dredging depth of -2 meters, which is the depth required to maintain the river mouth.



Source: JICA ExpertTeam

Figure 9-29: Kosasthaliyar Longitudinal Profile Plan

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.



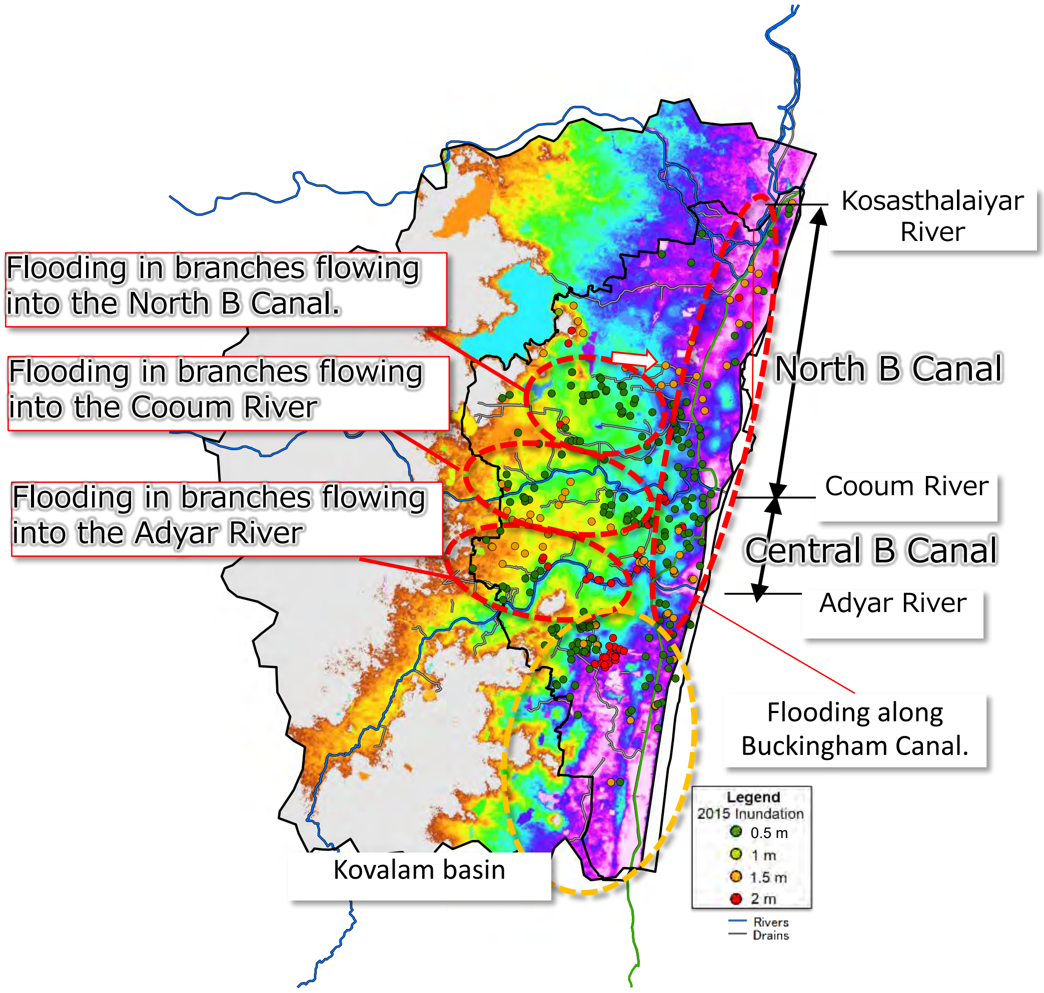
Source: JICA ExpertTeam

Figure 9-30: Redhills Surplus Longitudinal Profile Plan

9.4.4 Urban Flood Control

2015 floods caused inundation in various parts of Chennai's urban area, with inundation occurring along the Buckingham Canal, around tributary rivers, and in the Kovalam Basin. In these urban flood inundation measures, the effect of water level reduction at the end of tributaries is important for improving the flow capacity of the tributaries. The main areas where water level reduction is expected to have a positive effect are the following four categories.

- North B Canal and its tributaries
- Central B Canal (no major tributaries)
- Along the Adyar and Cooum Rivers
- Kovalam Basin



Source: JICA ExpertTeam

Figure 9-31: Topography in Chennai and Inundation During the 2015 Floods

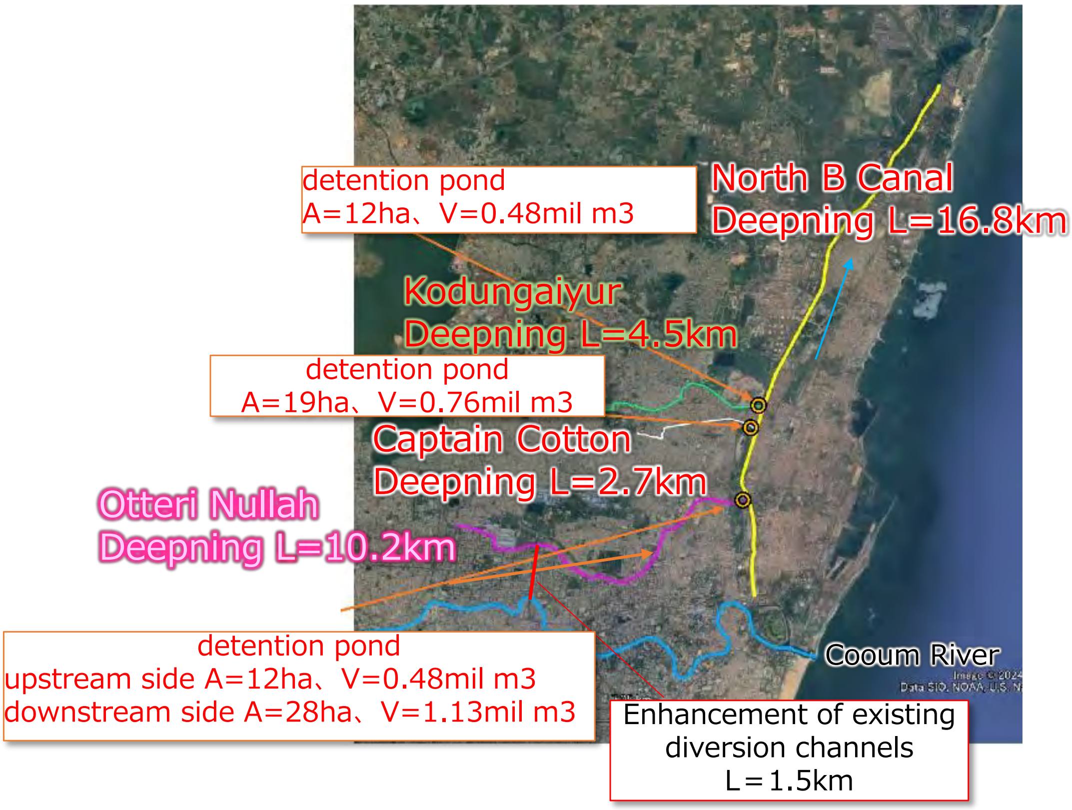
9.4.4.1. North B Canal and its tributaries

The North B Canal has insufficient flow capacity at present, and insufficient flow capacity in this section will also lead to reduced flow capacity in tributary rivers.

Therefore, in Phase 1, priority will be given to river improvement by channel excavation in the North B Canal, followed by river improvement by channel excavation in the tributaries. However, the flow capacity of the North B Canal is only equivalent to 60%, which is 1/10th of the current riverbank height assessment, even if channel excavation is carried out.

Therefore, to address the shortfall in flow capacity, new regulating reservoirs will be installed in three tributaries after the river channel excavation, and the existing Cooum River diversion channel will be strengthened in the Otteri Nullah tributary to achieve a 1/10th scale of improvement.

Furthermore, gates will be installed at the junction of the North B Canal with the Cooum River to prevent backflow.



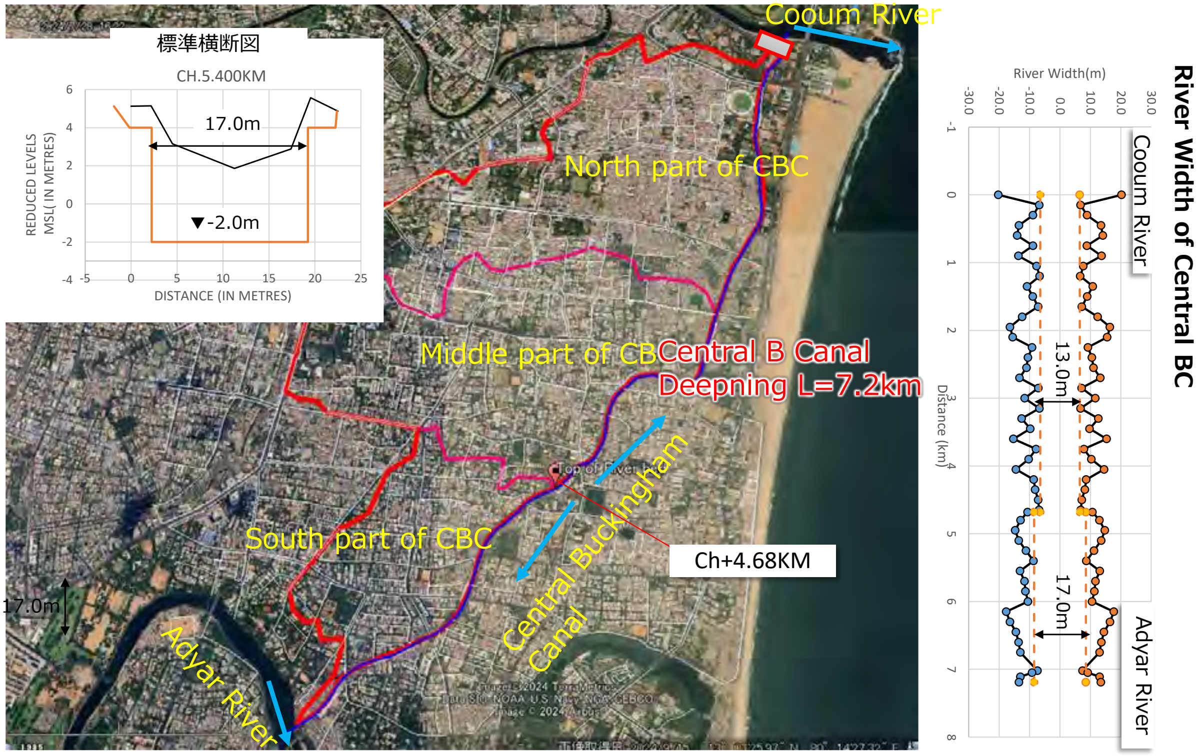
Source: JICA ExpertTeam

Figure 9-32: Proposed Countermeasure in the North B Canal for the Phase 1

9.4.4.2. Central B Canal

The Central B Canal has a small catchment area and no major tributaries, but to improve the flow capacity of the watercourse into the Canal, Phase 1 will start with river improvement by channel excavation in the Central B Canal. The excavation height was set at -2 m in combination with the excavation height in Phase 1 in the Adyar and Cooum Rivers, and the excavation width was set as shown below (13.0 mor17.0 m) as the excavation width without widening.

Furthermore, as the HWL of the Cooum River is higher than the river bank height, a gate will be installed on the Cooum side of the river after channelization to prevent backflow.



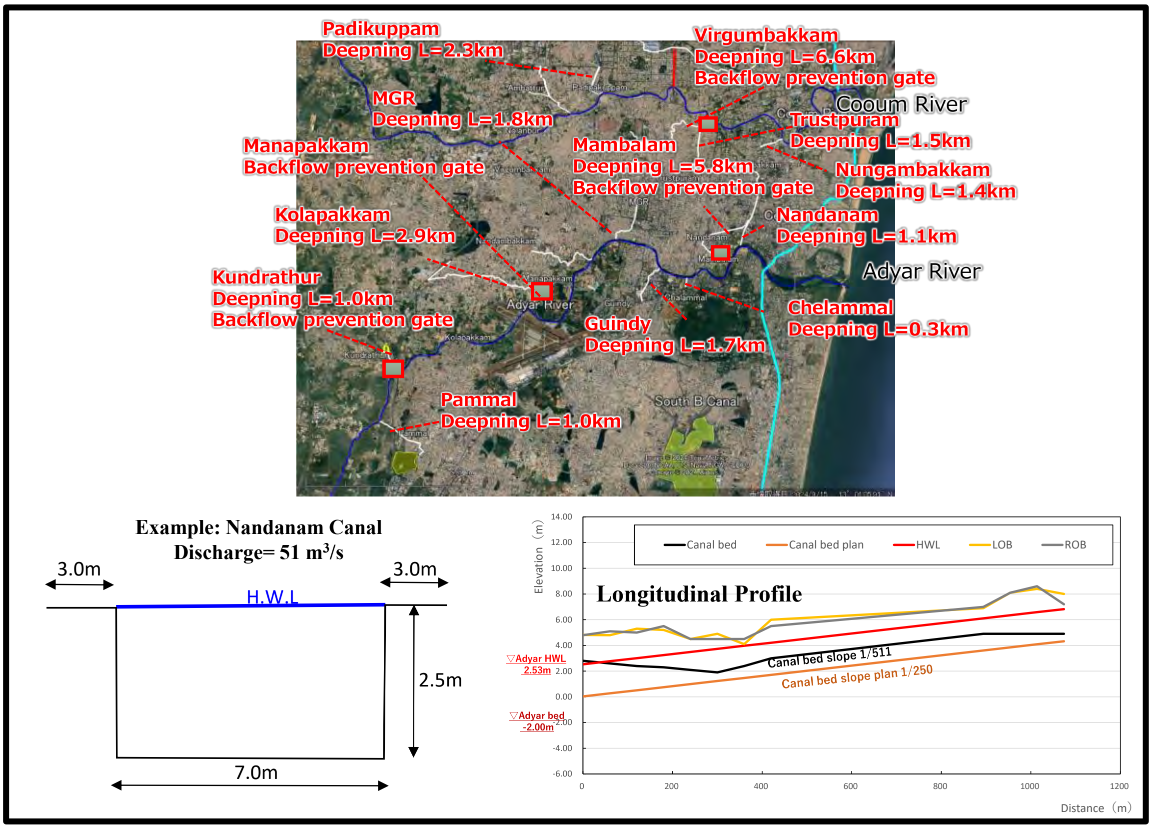
Source: JICA ExpertTeam

Figure 9-33: Proposed Countermeasure in the Central B Canal for the Phase 1

9.4.4.3. Improving Connecting Drainages to Adyar and Cooum Rivers

As the impact of backwater on the tributaries will be reduced by the rehabilitation of the main river in Phase 1, river improvement by channel excavation will be carried out for the tributaries with insufficient flow capacity on a combined 1/10 scale. Nine rivers of the Adyar River and three rivers of the Cooum River are targeted.

However, in the tributary rivers where the HWL is higher than the river bank height, backwater impacts on the tributary rivers are significant for the time being, and considering that it may take time to channelize the main river, backflow prevention gates will be installed first (4 gates).



Source: JICA ExpertTeam

Figure 9-34: Proposed Countermeasure in the Connecting Drains to Adyar and Cooum Rivers (Phase 1)

9.4.4.4. Kovalam Basin

Poor drainage is a major issue in Kovalam district due to the spread of low-lying areas, and a drastic measure is a diversion channel. Therefore, in Phase 1, it is important to proceed with the construction of the diversion channel first, but taking into account the time required for site negotiations, etc., and the backflow from the B Canal, the following steps will be taken.

a. Prevention of external flooding: installation of backflow prevention gates

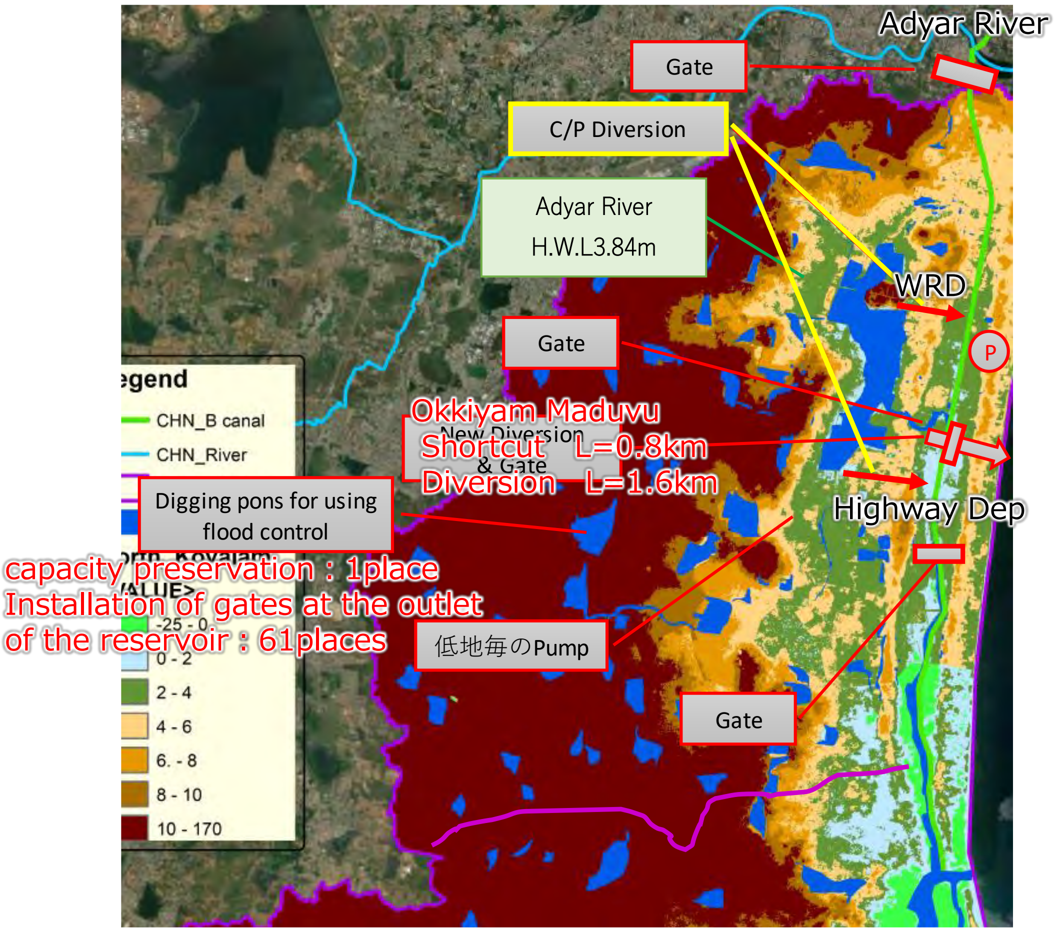
b. Internal flood prevention:

diversion channel

Expansion of flow capacity by short-cutting and excavation of Okkiyam Maduvu

Inland water exclusion pumps

c. Runoff control: Utilization of existing reservoirs
(sequentially within the maintenance period)



Source: JICA ExpertTeam

Figure 9-35: Location of Countermeasures in Kovalam Basin