SUPPORTING REPORT (1)

ANNEX 7 : OUTFALL TREATMENT

THE STUDY ON STORM WATER DRAINAGE PLAN
FOR THE COLOMBO METROPOLITAN REGION
IN
THE DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

FINAL REPORT

VOLUME III : SUPPORTING REPORT (1)

ANNEX 7 : OUTFALL TREATMENT

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CHAPTER 1 NATURAL CONDITIONS

1.1 Sea Conditions

The coastline of the study area extends from Negombo in the north to Kalutara in the south as shown in Figure 1.1.1. The natural conditions of the outfalls in southwest coast are described as follows.

1.1.1 General Condition of Southwest Coast

The climate of Sri Lanka is classified as tropical monsoon, which is characterized by northeast monsoons from Bengal Bay and southwest monsoons from the equator. In the study area, the northeast monsoon brings the dry season, while the southwest monsoon brings the rainy season.

As for the wave condition, the southwest monsoon from May to September causes wind waves with a short wave period, while the northeast monsoon causes swell with a long wave period. Because of this, seasonal change of coastal beach profile is observed.

Figure 1.1.2, made by the Coast Conservation Department (CCD) in 1988, shows the coastal erosion tendency on the southwest coast of Sri Lanka. The severe erosion is observed north of Kelani Ganga, between the stretch of Talpityia - Kalu Ganga and south of Galle. The littoral drift is northward throughout year.

1.1.2 Tide Level

Tide level has been recorded for the last 100 years at Colombo Port. The tide levels measured at Colombo Port can be applicable for the study area.

A port datum of low water ordinary spring tides (LWOST) is used for the hydrographic surveys by Sri Lanka Ports Authority (SLPA) and tide measurements by Hydrographic Division of SLPA and the National Hydrographic Office (NHO) of Sri Lanka (e.g. sea chart No.101). The port datum of LWOST is also referred to Mean Sea Level (MSL) and is defined as a level of 0.4328 m (1.42 ft) below MSL, the national datum. (0.42 m below MSL according to NHO chart No.101). (Ref /12/, 2000)

An example of offshore tide level was measured at Dehiwala as shown in Figure 1.1.3. (Ref /9/, 2000)

(1) Indian and British Tide Tables

Tidal variations are given in Indian and British Tide Tables (1993) related to LWOST as follows.

1) Mean High Water Springs (MHWS) : 0.72 m above MSL
2) Mean High Water Neaps (MHWN) : 0.48 m above MSL
3) Mean Sea Level (MSL) : 0.38 m above MSL
4) Mean Low Water Neaps (MLWN) : 0.30 m above MSL
5) Mean Low Water Springs (MLWS) : 0.06 m above MSL
6) Mean Lower Low Water Springs (MLLWS) : 0.02 m above MSL

(2) Long Term Tendency

Regarding the seasonal sea level change, the maximum storm causes a high level of about 0.3 m above MSL during a northeast monsoon and a low level of about 0.2 m below MSL during a southwest monsoon (Figure 1.1.3, Ref/6/, 1997). And regarding the long term tendency, the present average annual mean sea level is +0.53m LWOST. That indicates a sea level rise of about 10cm for the last 100 years. (Ref/12/, 2000)

(3) Lowest and Highest Tides

According to the study on the actual reported tides, the minimum water level is +0.020 m LWOST and the highest water level is +1.155 m LWOST, and it is recommended to use a lowest possible water level of -0.1 m and highest possible water level of +1.2 m LWOST. Consequently, the lowest possible water level corresponds to 0.53 m below MSL and the highest possible water level to 0.77 m above MSL.

(4) Revised Tidal Water Levels

The study also relates the important tidal water levels referred to LWOST as follows.

1) Highest Astronomical Tide (HAT) : 0.9 m above MSL
2) Mean High Water Springs (MHWS) : 0.7 m above MSL
3) Mean High Water Neaps (MHWN) : 0.5 m above MSL
4) Mean Low Water Neaps (MLWN) : 0.3 m above MSL
5) Mean Low Water Springs (MLWS) : 0.1 m above MSL
6) Lowest Astronomical Tide (LAT) : 0.1 m below MSL

1.1.3 Principal Tidal Constituents

In addition to the main tidal constituents at Colombo Port by Admiralty Tide Tables, the S4DQ current meter recording yielded the water level variation of Dehiwala behind the reef (Ref/9/, 1997). The water level range at spring tide is found to be 70 cm and at neap tide about 18 cm. The derived main tidal constituents and Admiralty Tide Tables for Colombo Port are indicated in the table below. There is not much variation in tidal constituent amplitudes.

Amplitudes of Principal Tidal Constituents

(Unit:m)

Site	M2	S2	K1	O1
Colombo (Admiralty Tide Tables)	0.18	0.12	0.07	0.03
Dehiwala (S4DW Current Measurements)	0.17	0.07	0.08	0.03

Source: Hydraulic Studies to Determine Layout and Design Parameters for Improvement of the Dehiwala Canal Sea Outfall, SLLRDC, by LHI, June 1997

1.1.4 Currents

Currents near the outfalls in the study area were studied in the past studies implemented by SLLRDC and Lanka Hydraulic Institute (LHI) and reported as follows. (Ref/9/, 1997)

(1) Tidal Current

The west coast of Sri Lanka is hardly influenced by the general circulation of the Indian Ocean, and the average velocities on the narrow continental shelf are in the range of 0.15 to 0.25 m/sec, are caused mainly by local wind. Currents can be increased by wind forces to about 0.3 to 0.4 m/sec with winds of 10 m/sec. This wind driven current is very dependent on the wind direction and thus surface cross-shore currents can be created.

(2) Near-shore Current

In areas where wave breaking occurs, the development of strong littoral currents could enhance the local currents beyond 1 m/sec.

The flow rate and direction near the shore are reduced not only by the offshore zone current, but also by wave height and direction, wind speed and direction, wave set up and bathymetrical irregularity along the shoreline.

1.1.5 Wave

The coasts in the study area are classified as the Southwest Coast Sector and the West Coast Sector of Sri Lanka separated at Colombo Harbor (Ref/2/, 1986). The wave climate of the Colombo Sector between Colombo and Mt. Lavinia was computed to 15 m depth MSL based on the data of directional wave measurement during more than three years at 70 m deep off Galle. (Ref/7/, 1994)

It is well known that there are two types of waves, one is swell and the other is sea wave (wind wave). The wave statistics are arranged and the following conclusions on swell and sea wave conditions at 15 m deep, of relevance to the Dehiwala area were derived. (Ref/9/, 1997)

1) Irrespective of the season, swell wave approaches in a narrow directional band mainly from 210 degrees to 230 degrees. The probability of

occurrence of wave direction is 95% in the Southwest (SW) monsoon (May to September) and 93% in the off-SW monsoon (October to April).

2) Swell wave height during the SW monsoon is somewhat higher than that occurring during off-SW monsoon. The average swell wave height is 0.92 m in the SW monsoon and 0.50 m in the off-SW monsoon.
3) About 85% of wind waves come from the direction sector 230 degrees to 280 degrees in the SW monsoon.
4) The wave in the SW monsoon is much higher than that of off-SW monsoon. The average wind wave height during the SW monsoon is 1.48 m. On the other hand, nearly 51% of the sea wave heights are below 0.1 m during the off-SW monsoon.

The analysis of directional wave measurement data from a program conducted at Chilaw, 80 km north of Colombo, at 11 m water depth during 1995-96, indicated a considerable percentage of wind waves approaching from the west and northwest direction. However, these recorded wind waves are quite moderate and it was concluded that they would have negligible influence on the extreme wave conditions at Dehiwala (Ref/9/, 1997).

There are near-shore reefs about 150 to 200 m away from the shoreline in front of most outfalls in the study area. Consequently, the near-shore wave condition is expected to be heavily influenced and the reef will cause high waves to break on it and reduce their wave energy. The wave breaking condition is also affected by water level. The wave height will show a direct dependence on the water level, with the wave height increasing with the water level. Broken waves stir up sand and littoral drift is very active in the surf zone.

1.1.6 Littoral Drift

The Master Plan for Coastal Erosion Management reported that the littoral drift was between 15,000 m^3/year and 50,000 m^3/year and most likely around 25,000 m^3/year (Ref./2/, 1986).

Also, the CCD study reported the sediment transport rate along the Southwest Coast of Sri Lanka (Ref./6/, 1992) on the basis of the study of directional wave measurement at Galle in 1989 to 1992. The wave condition was calculated for every unit area. The Southwest Coast of Sri Lanka was divided into 13 unit areas. By using five formulas the northward net littoral drift between Colombo and Mt.Lavinia was calculated as follows.

Northward Net Littoral Drift

(Unit: million m^3)

Formula	Net Transport
Engelund /Hansen	0.877
Van. Rijn	0.940
Bijker	0.339
Bailard	0.267
The CERC Method (a=0.014)	0.830

Source: Sediment Transport Study for the Southwest Coast of Sri Lanka, Coast Conservation Project, CCD, by GTZ, May 1992

The CERC (Coastal Engineering Research Center) Method made by Bagnold/Inman/Komer (1977) is based on field and model measurements and relates the volumetric sand transport rate along the coast in the breaker zone. This method is very commonly used.

It was concluded that the most dominant factor is swell. Although the coastline is eroded frequently by rough sea conditions during the SW monsoon, the change of coastal profile across the shoreline is temporary and localized. The along shore transport of material is basically caused by the incessant swell which is considerably high in the SW monsoon period.

The SLLRDC study reported sediment transport rate at the coastal stretch between the Wellawatta Outfall and the Dehiwala Outfall (Ref./11/, 1998). Although the sediment transport rate estimated by numerical model LITPACK module of MIKE 21 is 15,000 m^3/year, the report suggested 10,000m^3/year.

Regarding the rate of littoral drift, it is very difficult to estimate the actual rate, although many coastal researchers and engineers have studied it. The most reliable and standard way to evaluate the rate may be the CERC Method.

1.1.7 Sediment Supply

The Central Environmental Authority carried out the National Sand Study for Sri Lanka - Phase One (Ref./5/, 1992). Sediment balance of yield and mine was studied for the Maha Oya basin, the Kelani Ganga, the Kalu Ganga and the adjacent coasts. Sediment supply to the sea is estimated as follows.

Sediment Supply to the Sea

(Unit: million m^3/year)

River	Maha Oya	Kelani Ganga	Kalu Ganga
Sediment Yield from the basin	0.2	0.4	0.55
Sand Mining	1.9	0.8	0.3
Sediment Supply to the Coast	0.09	0.16	0.41

Source: National Sand Study for Sri Lanka - Phase One -, Ministry of Foreign Affairs, by NEI, January 1992

It is reported that the abstraction of sand far exceeds the production in the basin of the Maho Oya and Kelani Ganga. The situation is less serious in the Kalu Ganga.

Mining on the beach is reported as 0.1 million m^3/year and the whole mining operations are estimated at 2.75 million m^3 in total during the past 20 years.

1.1.8 Coastal Jurisdiction

For the purpose of coast conservation, CCD has defined the coastal zone. All activities in the coastal zone should have permission of CCD. The definition of coastal zone is shown in Figure 1.1.4 (Ref./10/, 1997).

1.2 Discharge in Wellawatta Canal

1.2.1 Water Level Duration Curve

(1) Available Data

After the construction of groynes and removal of clogging at Dehiwala Outfall early in 2001, Wellawatta Outfall was reversely clogged during dry season. This may be because most of the discharge through the Wellawatta Outfall flew into the Dehiwala canal.

Water level has been measured at the Wellawatta Canal and the flow velocity was measured for some floods. However, these measurement locations are obviously in the tidal reaches. The data obtained should be treated carefully, especially during low discharge or the dry season.

There are some other water level gauging stations and rainfall gauging stations around the Dehiwala Canal and Wellawatta Canal. The water level gauging stations and the rainfall gauging stations are listed below and their locations are shown in Figure 1.2.1.

1) Water Level Gauging Stations
- Serpentine Canal - Lesley Ramagala Mwatha Bridge
- Kotte North Canal - Sri Jayawardenapura Mawatha Bridge
- Kirillapone Canal - Near Open University Bridge
- Torrington Canal - Railway Bridge
- Wellawatta Canal - Galle Road Bridge
- Dehiwala Canal - Galle Road Bridge
- Heen Ela - Kirimandala Mawatha Road Bridge
- Kirillapone Canal - Nawala Road Bridge

2) Rainfall Gauging Stations
- Meteorological Observatory in CMC
- Ratmalana Station

(2) Water Level Duration Curve

The water level of Wellawatta Canal and daily rainfall at the Meteorological Observatory in CMC are shown in Figure 1.2.2. Though the water level records are not complete, a general relation between rainfall and water level can be known.

Most of the flow may have been discharged through the Wellawatta Outfall to the sea and sometimes through Dehiwala Outfall in heavy storm conditions.

1.2.2 Discharge Occurrence

(1) Correlation Coefficient

To examine applicability of other station's data to supplement the missing data of the Wellawatta Canal, correlation coefficients between each hydrological data and water level of Wellawatta Canal were calculated. The results are shown in the following table.

Hydrological Correlation

No	Location	Data	Correlation Equation	Correlation Coefficient	Rank
1	Serpentine Canal	WL	Y = 0.5293 X + 0.0868	0.611	4
2	Kotte North Canal	WL	Y = 0.5360 X + 0.0756	0.654	3
3	Kirillapone Can	WL	Y = 0.7214 X + 0.0194	0.717	2
4	Torrington Canal	WL	Y = 0.3701 X + 0.1860	0.531	7
5	Dehiwala Canal	WL	Y = 0.6343 X + 0.0791	0.600	5
6	Heen Ela	WL	Y = 0.4378 X + 0.1951	0.534	6
7	Kirillapone (Nawala)	WL	Y = 0.6087 X + 0.0652	0.845	1
8	CMC	Rainfall	Y = 0.0015 X + 0.3338	0.146	8
9	Ratmalana Station	Rainfall	Y = 0.0010 X + 0.3368	0.105	9

Note: WL: Water Level (MSL)
Rainfall: Daily Rain (mm)
X: Hydrological Data of Each Station
Y: Water Level of Wellawatta (MSL)

From this table, it is seen that the best correlation for Wellawatta is Kirillapone (Nawala) and Kirillapone, and there is no correlation with daily rainfall data. Kirillapone Canal is located just upstream of Wellawatta Canal. When heavy flood occurred, the flow of Kirillapone Canal was occasionally diverted to Dehiwala Canal.

(2) Substitution of Missing Data

Measurement of the water level at Wellawatta Canal was started in June 1995. As the data are interrupted, it is necessary to substitute from other data with the best correlation. The best correlative station with Wellawatta Canal is Kirillapone (Nawala), but the measurement there was started in March 2000. The other available data are those of Kirillapone where the measurement was started in June 1995.

(3) Discharge Frequency

Although a stage-discharge curve in this tidal reach canal is difficult to usecorrectly, the following discharge occurrence was presumed from the annual duration curve of water level.

Discharge Frequency

(Unit: m^3/sec)

Year	1996	1997	1998	1999
75-day discharge	17.16	8.49	8.96	5.33
185-day discharge	10.44	5.76	5.76	3.72
275-day discharge	5.76	2.61	3.34	1.93
355-day discharge	0.00	0.00	0.00	0.00

The flow pattern in 1999 may be the most probable pattern of actual flow considering the accuracy of the stage-discharge curve in the tidal reach. The base flow during dry season may be less than 1 m^3/sec and the discharge may range from almost zero to hundreds of liters/sec.

CHAPTER 2 OUTFALLS IN THE STUDY AREA

2.1 General

The study area is divided into four basins, namely Ja Ela basin, Kalu Oya basin, Greater Colombo basin and Bolgoda basin. There have been flood inundation problems mainly because of insufficient flow capacity and partial clogging of outfalls by sand bars.

The outfalls into the sea in the study area are shown in Figure 1.1.1. The following nine outfalls facing to the sea are subjects of the Study.

1) Negombo Lagoon Outfall (Ja Ela basin)
2) Kelani Ganga Outfall (Kelani River basin)
3) Beila Lake Outfall (Greater Colombo basin)
4) Unity Place Outfall (Greater Colombo basin)
5) Wellawatta Outfall (Greater Colombo basin)
6) Dehiwala Outfall (Greater Colombo basin)
7) Lunawa Lake Outfall (Independent basin)
8) Panadura River Outfall (Bolgoda basin)
9) Talpitiya Outfall (Bolgoda basin)

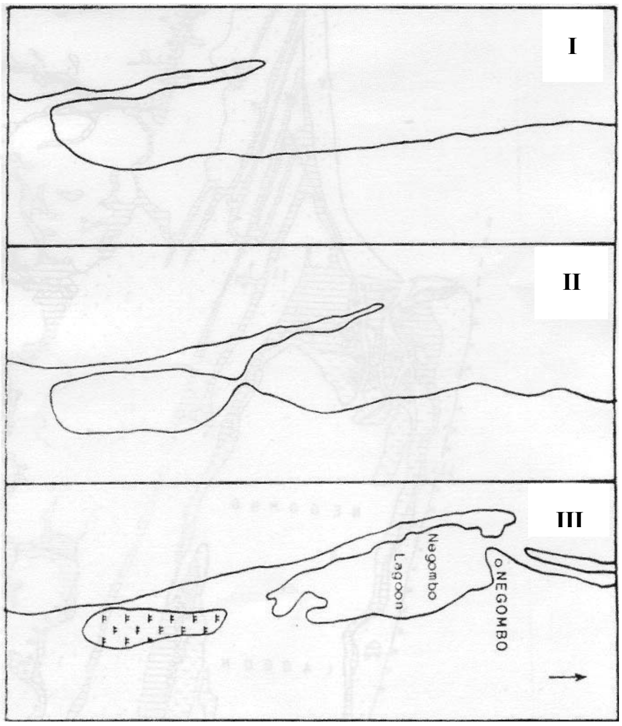
2.2 Present Condition of Outfalls

2.2.1 Negombo Lagoon Outfall

Negombo Lagoon Outfall has sufficient width and depth of outfall and is not clogged. This lagoon is formed by an extension of the sand bar, and will not be clogged rapidly in the future considering the present condition. There is a development plan around the lagoon, but Negombo Lagoon itself will be held as the Muthurajawela Conservation Area by Central Environmental Authority. Photo 1 and Photo 2 show Negombo Lagoon Outfall and its southern beach.

As the outfall faces to the north, the forces to clog the outfall such as wind, tide flow and wave are not strong and therefore the outfall is not clogged.

Possible growth stages of Negombo Lagoon are delineated as follows.



Growth of sand spit northwards from Mutwal and formation of Muthurajawela

Closing up of cuspate forelands and formation of Muthurajawela 'lake' and northward extension of the barrier spit

Filling up of the lake to form Muthurajawela swamp and northward extension of spit forming Negombo Lagoon

Possible growth stages of Negombo Lagoon

Source: Geological Evolution of the Coastal Zone of Sri Lanka, P.G. Cooray and J. Katupotha , Institute of Fundamental Studies, Kandy, Sri Lanka)

2.2.2 Kelani Ganga Outfall

As shown in Photo 3, Kelani Ganga outfall is not clogged. One of the reasons why Kelani Ganga outfall is not clogged is that flow discharges to flush out the sand bar at the outfall. Another reason is the location of the outfall, which is situated in the erosive coastal zone. The existence of Colombo harbor may stop almost all the littoral drift from the south coast to the north coast.

The north beach of Kelani Ganga is very erosive. At Pegasus beach located about 2.5 km north of Kelani Ganga outfall, detached breakwaters and groynes protect the beach. The main sediment source may be Kelani Ganga although the sediment from Kelani Ganga has decreased lately because of sand mining at Kelani River (Ref/4/, 1985, Ref/5/, 1992).

2.2.3 Beira Lake Outfall

There are two outfalls from Beira Lake. One is led to Colombo Harbor by a culvert and the other to the sea directly. The outfall to Colombo harbor has no clogging problem.

Another outfall to the sea is called the Beira Lake outfall. The water level of Beira Lake is kept high by a weir and sluice gate. The overflow water is discharged into the sea under the Galle Face road. The outfall is not clogged. The outfall would not easily become clogged as long as the water level of the outfall is higher than the sand built-up by wave force. The Beira Lake outfall is shown in Photo 4 and Photo 5.

2.2.4 Unity Place Outfall

There are many coastal protections of stone masonry or boulders at the west stretch of Colombo. Big boulders are placed on the coast along the railway.

Photo 6 shows Unity Place outfall, which is a concrete flume of 4 m wide with an L shape. The outfall is not clogged. This is because the coast from Wellawatta outfall to Colombo harbor is erosive so that the beach face is very narrow or of almost no width at all.

As the seabed profile is steep on the northward coast of Wellawatta outfall, as shown in Figure 2.2.1, the littoral drift from the south may have dropped into the sea so that the littoral drift is not strong enough to clog the outfall.

2.2.5 Wellawatta Outfall

Before construction of the groynes at Dehiwala outfall, the Wellawatta outfall had been opened throughout the year. However, the Wellawatta outfall has been clogged during the dry season since the construction of the groynes. Photos 7-9 show the Wellawatta outfall in November 2001.

Two groynes about 30 m long and up to depth of about 1.0 m below MSL have been constructed at Wellawatta outfall as shown in Photo 7. After the construction of Dehiwala outfall, the groyne at Wellawatta was modified to an L-shape (Photo 20).

(1) Coast around the Outfall

Sand beach is seen at the south coast of the outfall as shown in Photo 8. Though the coast of this area may be erosive according to past studies, the coast could retain the beaches because of the protection offered by the groynes at Wellawatta outfall.

The coast is protected by boulders north of Wellawatta outfall, and the sand beach can not be seen as shown in Photo 9.

The depth of the outfall is about 0.5 to 1.0 m and the predominant size of the riverbed material is about 1 mm.

As for the sea conditions south of Wellawatta outfall, the surf zone is seen more than 100 m offshore from the coastline, and there is a shipwreck.

On the other hand, the surf zone is not seen at the northern beach in December and waves break at a point very near shoreline. However, during the SW monsoon, the waves are high and a surf zone is seen offshore. The condition of surf zone is different between the northern and southern coasts of Wellawatta outfall.

(2) No Clogging Condition

Before the construction of groyne at Dehiwala outfall in December 2001, the outfall at Wellawatta had not been clogged for a long time. It is said, generally in Japan, that a training jetty at the outfall should be extended so as to cross over the width of the littoral drift and the depth should be more than 3 m to allow river flow throughout the year. From this, the front depth of groyne at Wellawatta outfall is much too shallow and might have been clogged sometimes.

Although the explanation of the mechanism that has prevented the outfall from becoming clogged is very difficult, it is conceivable it is as follows.

1) Morphological condition

One of the reasons for no clogging may be the morphological characteristic of the outfall. The beach, including the outfall, was originally located in the erosive zone.

Predominant direction of the littoral drift is northward, and the beach profile is steeper at the northern beach of Wellawatta outfall as shown in Figure 2.2.1. The offshore surf zone that is seen off the south beach is not seen off the north beach in December. The width of littoral drift is not as wide off the northern beach. During the off-SW monsoon, the littoral drift from the south might be shifted to the deep sea off the northern coast and there may be almost no sediment deposited along the northern coast. During the SW monsoon, the littoral drift will be able to transport solids to the northern coast and a small sand beach will be formed and the coast line will be maintained to a certain extent.

2) Flow condition

Another reason may be the existence of a certain quantity of river flow. The catchment area of Wellawatta canal is a part of the Greater Colombo basin and most of the runoff from the Greater Colombo basin is discharged from Wellawatta outfall. According to the discharge measurement carried out on 27 and 28 May 1993 by SLLRDC and LHI, the flow discharge was 2.8 m^3/sec near the Dehiwala outfall and 16.0 m^3/sec to 16.3 m^3/sec near the Wellawatta outfall. The ratio of discharge of Wellawatta canal is about 85% of total discharge.

(3) Present Condition

After the construction of the groyne at Dehiwala outfall the Wellawatta outfall was clogged during the dry season. The obvious fact is that the flow quantities of both Wellawatta Canal and the Dehiwala Canal are not sufficient.

2.2.6 Dehiwala Outfall

(1) Sea Condition

In the off-SW monsoon in November, the offshore surf zone is not seen at the southward coast of the outfall, but is seen at the northward coast in the offshore more than 100 m from shoreline and the offshore surf continues up to Wellawatta outfall.

In the SW monsoon, when the waves are high the offshore breaker zone is seen along the whole coastal stretch around the Dehiwala and the Wellawatta outfalls. The sediment transportation is very active and the sand bar at the outfall is easily formed.

(2) Conditions before Construction of the Groyne

Dehiwala outfall has been clogged by the sand bar throughout the year before the construction of the groyne. This is because the activity of the waves is very active and also the quantity of river flow is inadequate to flush out the sand bar. The condition may be similar for the other outfalls in the study area .

Photo 11 shows the beach north of Dehiwala Outfall in November 2001. As shown in the photograph there was a beach but it was narrow.

(3) Construction of the Groyne

The construction of the groyne at Dehiwala outfall was proposed in the study of 1988. (Ref./3/, 1988) After various studies and discussions the present groyne was constructed and the sand bar formed at the outfall was breached in early 2002. The shape of the groyne is shown in Figure 2.2.2. The groyne extends to a depth of about 1.0 m below MSL. Photos 10 and 21 show the groyne at Dehiwala outfall.

The groyne size was planned so as to minimize the coastal impact. The coastal revetment was also constructed to protect the beach north of the outfall.

2.2.7 Lunawa Lake Outfall

Lunawa Lake outfall is characterized by continuous clogging due to sand bar formation. The outfall must now be opened regularly by human power. There exists a sand beach across the outfall.

Because of the small catchment area of 10.26 km^2, the ordinary flow through the outfall is low and the wave action to form sand bar is very active. The outfall is always exposed to the menace of clogging due to strong wave activity to form a sand bar and the insufficiency of flow.

When the water level of Lunawa Lake rises to 1.2 m above MSL, the sand bar is excavated by manpower. After the sand bar is excavated, the lake water level drops to mean sea level within 24 hours, and a few days later, the outfall is clogged again.

The situation after the excavation is shown in Photos 13 to 15.

During the off-SW monsoon, the surf zone is restricted to the shoreline vicinities and the offshore surf zone is not seen along either the north or south coasts. This means that a major part of the activity of the littoral drift may be restricted to the shoreline vicinities.

In the SW monsoon, the surf zone near shore is wider than that in the off-SW monsoon due to high waves.

2.2.8 Panadura River Outfall

For small fishing boats, there is an anchorage at the Panadura outfall. The waterway of Panadura River has not been clogged due to the groyne and is kept open by dredging.

According to the staff of the fishery harbor, the situation was as follows.

Panadura outfall was completely covered with sand until the Irrigation Department constructed a rubble mound structure on the southern side of the outfall in 1982.

Under the harbor construction project this structure was extended and a groyne was constructed at the harbor entrance of 80 m. The depth at the entrance is around 4 m below MSL.

Though the northern beach of the Panadura outfall is erosive, there exists a sand beach. The source of sedimentation may be Panadura River. Photo 18 shows the northern beach of the Panadure outfall.

A large part of the littoral drift near the shoreline from the south might be trapped at the groyne.

Photos 16 and 17 show the Panadura outfall. The present condition of Panadura anchorage is shown in Figure 2.2.3. (Ref./8/, 1997)

2.2.9 Talpitiya Outfall

The Talpitiya outfall is usually clogged. Residents living around the outfall stated that they have not been affected by floods resulting from clogging since 1994. Also they stated that people breach the sand bar by manpower during severe flood. The clogging of Talpitiya outfall is not serious.

The littoral drift passes to north across the outfall. Photo 19 shows the Talpitiya outfall.

South Bolgoda Lake is connected to the sea through the Kalu Ganga and does not have a clogging problem.

CHAPTER 3 PREVIOUS STUDIES

Because of the importance of the sea outfalls, detailed investigations and studies were carried out by authorities concerned in the past. Among them, the following studies are related to the present Study.

(1) Master Plan - Coast Erosion Management - Volume 4 (South West Coast), Coast Conservation Department and DANIDA/Danish Hydraulic Institute, August 1986

1) Outline

In this master plan the erosion tendencies of the west and southwest coasts of Sri Lanka are shown in Figure 1.1.2. The stretch north from Kelani Ganga is defined as West Coast sector. On the other hand, the stretch south from Kelani Ganga up to Galle is defined as the Southwest Coast Sector. This figure is made based on interviews and not by actual measurement. The report pointed out that further detailed study was necessary.

2) Results

a) Colombo District

<u>Medium Term Recommendation</u>

Early implementation of the coastal conservation plan proposed by CCD was recommended.

<u>Long Term Recommendation</u>

The future needs depend to a large extent on hinterland requirements;

- Colombo North: Development plan for Crow Island.
- Colombo - Mt. Lavinia: The construction of a third railway track or coastal road on the seaside is proposed.

b) Kalutara District

<u>Medium Term Recommendation</u>

Construction and maintenance of groyne systems were recommended north and south of the Kalutara Barriers. Further work would have to be done in cooperation with the Irrigation Department with Fishery Harbors Cooperation.

<u>Long Term Recommendation</u>

The investigation on chronological change of the beach between Moganna Heads and Panadura River is proposed.

(2) Study of The Canal and Drainage System in Colombo, SLLRDC and WS Atkins International in association with GKW Consult and RDC Limited, December 1988

1) Outline

Improvement of canals and drainage systems in Colombo.

2) Results

The following proposal was made on the outfall clogging of Dehiwala Canal and Wellawatta Canal.

The following Option-a) or Option-b) is recommended and CCD will issue a permit to extend or construct groynes only if:

Option-a) the effect of groynes have to be thoroughly studied utilizing an outfall model and proven not to cause erosion problems or

Option-b) a guarantee is given that coastal conservation measures such as sea shore protection walls are carried out, if coastal erosion occurred after construction of groynes.

Option-a) will be best from the engineering point of view, but it requires considerable time and cost. The Option-b) is estimated at Rs. 15 million and would be easily accepted. The Option a) will not exceed Rs. 30 million. Consequently, the following recommendations were made.

- Clearing of the sand banks by manpower or machine at Wellawatta Canal, Dehiwala Canal and Mutwal Tunnel outfalls and observation of the time of re-clogging and a study on methods to keep the required opening for outfall discharge.
- Determination of the required extension/construction of groynes at Dehiwala and Wellawatta Canal outfalls on the basis of the above data.
- Early decision whether outfall modeling (Option-a) or eventual conservation measures (Option-b) should be adopted. If the outfall modeling is preferred, it should be made at least one year before construction of groynes.
- Repair and extension of the existing groynes at Wellawatta Canal outfall.
- Construction of new groynes at Dehiwala Canal outfall.
- Implementation of maintenance programs for continuous opening of all three outfalls.

(3) Beach Protection Investigations - Pegasus Reef Hotel, Carson Cumberbatch & Co., Ltd. and LHI, July 1985

1) Outline

Beach profile survey, sand sampling and analysis of grain size distribution and float tracking were conducted to protect the erosive beach, which is located 2.5 km north of Kelani Ganga outfall and is 200m long.

2) Results

The following remedial measures were proposed.

- To restore the old rubble mound groyne and construct a new curved groyne,
- To fill in an artificial beach between the two groynes,
- To measure the wave run-up line and the water line every second month.

(4) Directional wave climate study, Southwest Coast of Sri Lanka, CCD-GTZ Coast Conservation Project, May 1994

1) Outline

A buoy for wave measuring was installed 8 km south off Galle Harbor in about 70 m of water depth in February 1989. The measurements were carried out for three and a half years despite of some failure of the data transfer. The directional wave buoy had a total weight of 700 kg and diameter of 2.5 m.

2) Results

Based on directional wave measurement, wave statistics have been computed at 15 m below MSL for 13 different coastal stretches between Colombo and Matara including Wellawatta and Dehiwala outfall. These data were used as wave conditions in the studies on the outfalls.

(5) Investigations for Panadura Anchorage, ADB Fisheries Sector Development Project Implementation Unit Ceylon Fishery Harbors Corporation and LHI, July 1997

1) Outline

Panadura anchorage is located at the outfall of Panadura River. The objective of the study was to improve the performance as an anchorage for small fishing boats. A field measurement program, one-dimensional hydrodynamic tidal modeling and near-shore wave propagation modeling were conducted.

2) Results

The following staged improvement was proposed as shown in Figure 2.2.3.

- Existing Level: Depth at entrance is 1.5 m. The anchorage is accessible 61 days in the SW monsoon period without wave breaking.
- Stage-1: Comprised of option-1, rock blasting at the outfall, dredging to a depth at the entrance of 2.0 m and construction of breakwaters. Estimated cost is Rs. 67 million. This is expected to yield 83 accessible days.
- Stage-2: Comprised of option-2 and dredging. The depth at entrance is 2.5 m. Estimated cost is Rs. 50 million and would allow access 112 days.
- Stage-3: Comprised of option-3 and dredging. The depth at entrance is 3.0 m. Estimated cost is Rs. 55 million and would allow access 129 days.

For the most optimum solution would be rock blasting at the entrance, the construction of breakwaters in option-1 and dredging the harbor basin and river channel. Based on the observation of Stage - 1 work, option-2 could be initiated with suitable modifications as stage - 2. The implementation of Stage-3, i.e. option-3, would not be feasible because of the following reasons.

- Severe impact on the northern coastline of the harbor;
- Heavy expenditure that would be required;
- Marginal gain in the number of accessible days.

(6) Hydraulic Studies to Determine Layout and Design Parameters for Improvement of the Dehiwala Canal Sea Outfall, SLLRDC and LHI, July 1997

1) Outline

There were detailed descriptions about the model of tide flow, wave propagation and sand drift. The results of field survey were also taken into the models. As for the facility arrangement obtained from modeling, coastal impacts were investigated and mitigation measures were recommended. Alternatives, indicative costs and coastal impacts were also discussed.

2) Results

The recommended and alternative plans were proposed. Also, periodical sand replenishment every two years utilizing the sand to be trapped at the south of Dehiwala was recommended for the possible erosion after the construction of groyne. Monitoring of the coast should be considered necessary and the sand replenishment plan should be made according to the results of the monitoring.

a) Recommended Plan

The recommended plan is to bend the groyne to northward at right angle to the shoreline after extension of 86 m offshore.

The volume of sedimentation supposed to be trapped south of Dehiwala was estimated at about 100,000 m^3. It would take about ten years until the sand drift starts bypassing across the Dehiwala outfall from south to north. The riverbed should be excavated and maintained at 1.2 m below MSL to allow access of small boats.

b) Alternative Plan

An alternative plan was also suggested to mitigate the coastal impact. The length of the alternate groyne is 30 m shorter than the recommended one. The volume of the sediment deposit at the south of Dehiwala would be about 52,000 m^3. It would take three to five years before the sand drift starts bypassing. The access of small boats throughout the year would not be possible due to insufficient water depth.

c) Cost Evaluation

The costs for the recommended plan were estimated at Rs. 16.6 million for the construction of the groyne, Rs. 3 million for a coastal revetment 100 m long and Rs. 35 million for sand by-passing every two years for about ten years.

The costs for the alternative plan were also estimated at Rs. 12 million for the construction of the groyne, Rs. 3 million for the coastal revetment and Rs. 35 million for sand by-passing every two years for five to six years.

d) Conclusion

After a meeting with SLLRDC, it was decided to adopt the alternative plan and take mitigation measures against the coastal impact. The layout of the alternative plan is shown in Figure 2.2.2.

(7) Dehiwala Outfall Study, Coastal Impact Mitigatory Measures, SLLRDC and LHI, June 1998

1) Outline

For the alternative plan suggested in June 1997, further analysis was conducted and mitigation measures for coastal impact between Wellawatta and Dehiwala were studied.

2) Results

To protect the Kinross Beach located south of Dehiwala, alternative plans were studied.

a) Alternative-1 (Sand replenishment south of Dehiwala outfall)
Sand replenishment was proposed along the north coast of Dehiwala with 50,000 m^3 of sand that would be trapped before or during the construction of the groyne south of Dehiwala. A coast revetment of about 120 m was also proposed.

b) Alternative-2 (Beach protection of Kinross Beach)
This alternative is to protect Kinross Beach south of Wellawatta by stone or gabion revetment along the beach. In addition, the revetment between Dehiwala and Wellawatta outfall would have to be rehabilitated.

c) Alternative-3 (Detached breakwater and extension of the groyne with sand replenishment)
This alternative expects formation of a tombolo of sand by a 50 m extension of the groyne and construction of a detached breakwater of 55 m.
Before or during the construction of the groyne at Dehiwala, 30,000 m^3 of sand would be trapped there and 80,000 m^3 in total would be used for sand replenishment. This would also improve the drainage condition of Wellawatta outfall.

d) Alternative-4 (Extension of the groyne in an L-shape with sand replenishment)
This alternative is to extend the existing groyne about 70 m with an L-shape as shown in Figure 2.2.4 and the volume of sand deposit was estimated at about 15,000 m^3. A total sand volume of 60,000 m^3 is necessary. This alternative is also useful not only to protect the coast but also to maintain drainage of Wellawatta outfall.

e) Cost Evaluation
Alternative-1 costs Rs. 19 million, Alternative-2 Rs. 17.5 million, Alternative-3 Rs. 41 million and Alternative-4 Rs. 29.5 million.

f) Conclusion
After a discussion between SLLRDC and LHI, alternative-4 was adopted as a suitable option considering both functional and economical reasons.

(8) Improvement to Lunawa Sea Outfall-Final Report, SLLRDC and LHI, January 2001

1) Outline

For further improvement of Lunawa Lake outfall in addition to excavation by manpower, field surveys such as topography and sounding surveys were conducted and four plans were proposed.

2) Results

The outfall of Lunawa Lake is excavated by manpower every four to five days. The following four alternatives were proposed for improvement.

- Periodical excavation by machine.
- Construction of a groyne（Figure 2.2.5）
- Pump drainage（Figure 2.2.6）
- Sand by-pass by sand pump（Figure 2.2.7）

It was concluded that more detailed study would be necessary to select the best alternative.

CHAPTER 4 RELATION BETWEEN DISCHARGE AND CLOGGING

Generally, factors to determine minimum discharge needed to keep an outfall open may be the tidal range, tidal prism, width of the river, the length of the sand bar along the flow, the elevation of the sand bar, grain size, etc. As the mechanism of clogging has not been clear yet, a method to calculate the minimum discharge has not been established so far.

Two examples in Japan on the minimum discharge to keep the outfall open are reported as follows. (Ref./1/, 1978)

(1) Kobe River

The outfall of Kobe River is located in the Hyogo Prefecture. The bed material is sand. Mean diameter is 0.06 to 0.1 cm. The width of the outfall is about 300 m to 400m.

When the flow discharge is more than 10 m^3/sec the outfall is not clogged irrespective of sea condition. Therefore a minimum unit flow of 25 to 30 liters/sec/m is necessary to keep the outfall open irrespective of sea condition.

(2) Syokotsu River

The outfall of Syokotsu River is located in Hokkaido. The bed material is sand. Mean diameter is 0.1 cm mixed with gravel under 50 mm size. The length of the sand bar measured along the flow is about 100 m to 130 m. It is said that the flow discharge necessary to keep the outfall open irrespective of sea condition is more than 10 to 14 m^3/sec. Minimum unit flow of 20 liters/sec/m is necessary to keep the outfall open irrespective of sea condition.

Based on these reports, it can be said that the unit flow of 20 to 30 liters/sec/m is necessary to keep the outfall with a bed material size of 0.05 to 0.1 cm in diameter open irrespective of sea condition.

If this relation is adopted to the Wellawatta Canal, the minimum flow discharge to keep the outfall open is 0.5 m^3/sec to 0.75 m^3/sec. As for the Dehiwala Canal, it is 0.30 m^3/sec to 0.45 m^3/sec. These values seem to be larger than the actual flow of the Wellawatta Canal and Dehiwala Canal.

This indicates that it may be difficult to keep both outfalls of the Wellawatta Canal and Dehiwala Canal open under the present condition.

CHAPTER 5 POSSIBLE COUNTERMEASURES

The conceivable countermeasures to keep the outfall open are listed as follows.

(1) Jetty

The construction of a jetty is the most common method and there are many examples. It is constructed with one or two jetties at approximately right angles to the coastline.

1) Characteristics

The objectives of jetties are a) to fix the location of river mouth, b) to stabilize the watercourse, and c) to maintain the water depth at the river mouth.

In planning the jetty, it is necessary to carefully consider the purpose of the structure. The river mouth can be kept open by flushing out the sand bar with sufficient tractive force.

2) Remarks

It makes it easy for waves to intrude into the river and erosion at the downstream side of the littoral drift will occur. If the water depth at the top of the jetty is insufficient, the river mouth may become clogged.

(2) Box Culvert

A box culvert is sometimes constructed at the river mouth of a small basin.

1) Characteristics

The box culvert is placed at the river mouth under the sand bar, and it is necessary to keep the flow irrespective of the sand bar. Generally, the box culvert is planned when the planned discharge is small and the river water level is relatively high compared with the sea level.

2) Remarks

It is necessary to pay attention to local wave scouring at the top of the box culvert and also to clogging by the littoral drift.

(3) Excavation

Unnatural excavation is of two types. One is to excavate the river mouth on a large scale to maintain the flow and cross-sectional area of river semi permanently. The other is to partly excavate the sand bar to make it easy to flush and flow over it in flood time.

1) Characteristics

It is necessary to monitor whether the river section is maintained or not, because it will be easily re-clogged by waves and sand from upstream of the river.

In small rivers the river is often clogged and the water level rises up to the elevation of the sand bar, and sometimes higher than the flood level. It is necessary to breach the sand bar by manpower or machine according to the condition of the river mouth.

2) Remarks

It is not recommended to adopt this method for a large river, because before the flood season comes the excavated river mouth will be re-clogged with a sand bar formed by the big waves. This example is seen in Japan facing the Pacific Ocean, which is often attacked by Typhoons.

(4) Sluice Gate

A sluice gate should be planned referring to practices in similar rivers where the basin scale sand bar and sand size are similar to the outfall to be treated.

1) Characteristics

There are two purposes for sluice gate construction. One is to store the water in the river channel and to flush out the sand bar at the river mouth. The other is to flush out the sand bar by gate operation expecting local scour by wave action in front of the gate. Further, the gate sometimes has other purposes such as to prevent the intrusion of salt water, waves and high tide, and to maintain the water level in the river.

2) Remarks

Hydraulic model tests and actual operation tests after the construction are necessary. If a big sand bar is formed on the upper or lower sides of the gate, it should be removed.

(5) Other methods

Besides the above, the following measures are conceivable for outfall treatment; a) raising the river bank, b) construction of a tailrace, c) pump drainage, and d) construction of a dam. Those measures are to be adopted at the river mouth according to the characteristics and purpose of each basin and river mouth.

CHAPTER 6 RECOMMENDATIONS

From the viewpoint of outfall treatment for storm water drainage in the present Study, the followings are recommended for the Wellawatta, Dehiwala and Lunawa Lake outfalls, which are important for storm water drainage in their own basins.

6.1 Wellawatta Outfall

At Wellawatta outfall, the outfall had been kept open throughout the year and there was no serious problem of clogging. However, since July 2002, after construction of the groynes for of Dehiwala outfall, clogging of the Wellawatta outfall has been observed. It is thought that the natural discharge is not sufficient to keep the outfall open throughout the year. In November, the sand bar formed during the dry season was flushed out and the Wellawatta outfall is being kept open during rainy season.

From this fact, the clogging of the outfall during the dry season may be automatically removed by the flow during the rainy season. It is recommended to continue monitoring the behavior of the Wellawatta and Dehiwala outfalls.

If the sand bar formulation is excessively large, removal before the rainy season is recommended.

6.2 Dehiwala Outfall

The groynes were constructed at Dehiwala Outfall in June 2002. According to the report (Ref./11/, 1998), the sizes of the groynes are minimized to avoid coastal impact as much as possible. As of October 2002, the Dehiwala outfall has been kept open even during dry season because the flow discharge at the outfall after construction of the groynes was increased and made stable although the flow discharge at the Wellawatta outfall was decreased and resulted in clogging of that outfall.

However, the long-term tendency of both outfalls and the coastal impacts by construction of the groynes cannot be clearly recognized as the groynes were just completed in June 2002. Therefore, it is necessary to continue monitoring of the behavior of the outfalls and surrounding coasts.

6.3 Lunawa Lake Outfall

At Lunawa Lake outfall, the sand bar formed has been periodically removed by manpower. It will not be so troublesome to continue this method. If it is preferable to adopt natural measures such as a groyne, further study will be necessary, referring to the conceivable plans suggested in the Study of Improvement to the Lunawa Sea Outfall of January 2001 (Ref /13/, 2001).

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(7) Directional Wave Climate Study, Southwest Coast of Sri Lanka, CCD-GTZ Coast Conservation Project, May 1994

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(9) Hydraulic Studies to Determine Layout and Design Parameters for Improvement of the Dehiwala Canal Sea Outfall, SLLRDC, by LHI, June 1997

(10) Revised Coastal Zone Management Plan, Coast Conservation Department, October 1997

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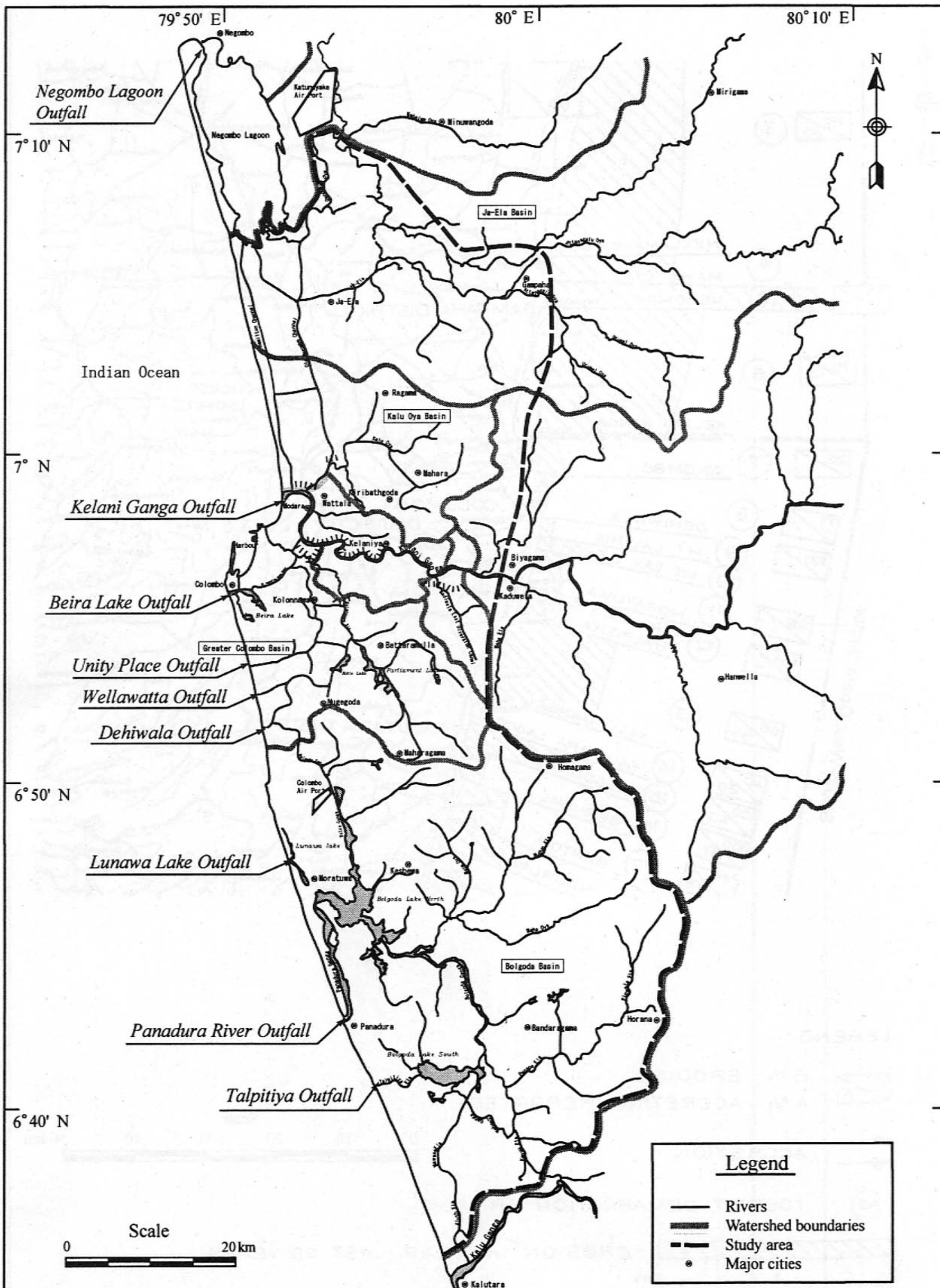
(13) Improvement to Lunawa Sea Outfall, SLLRDC, by LHI, January 2001

(14) Action Plan For the Control of Pollution in the Greater Colombo Canal System, Greater Colombo Flood Control and Environment Improvement Project – Phase 2 -, Volume Ⅱ, Data Book, SLLRDC, February 2001

Figures



The Study on Storm Water Drainage Plan for the Colombo Metropolitan Region in the Democratic Socialist Republic of Sri Lanka

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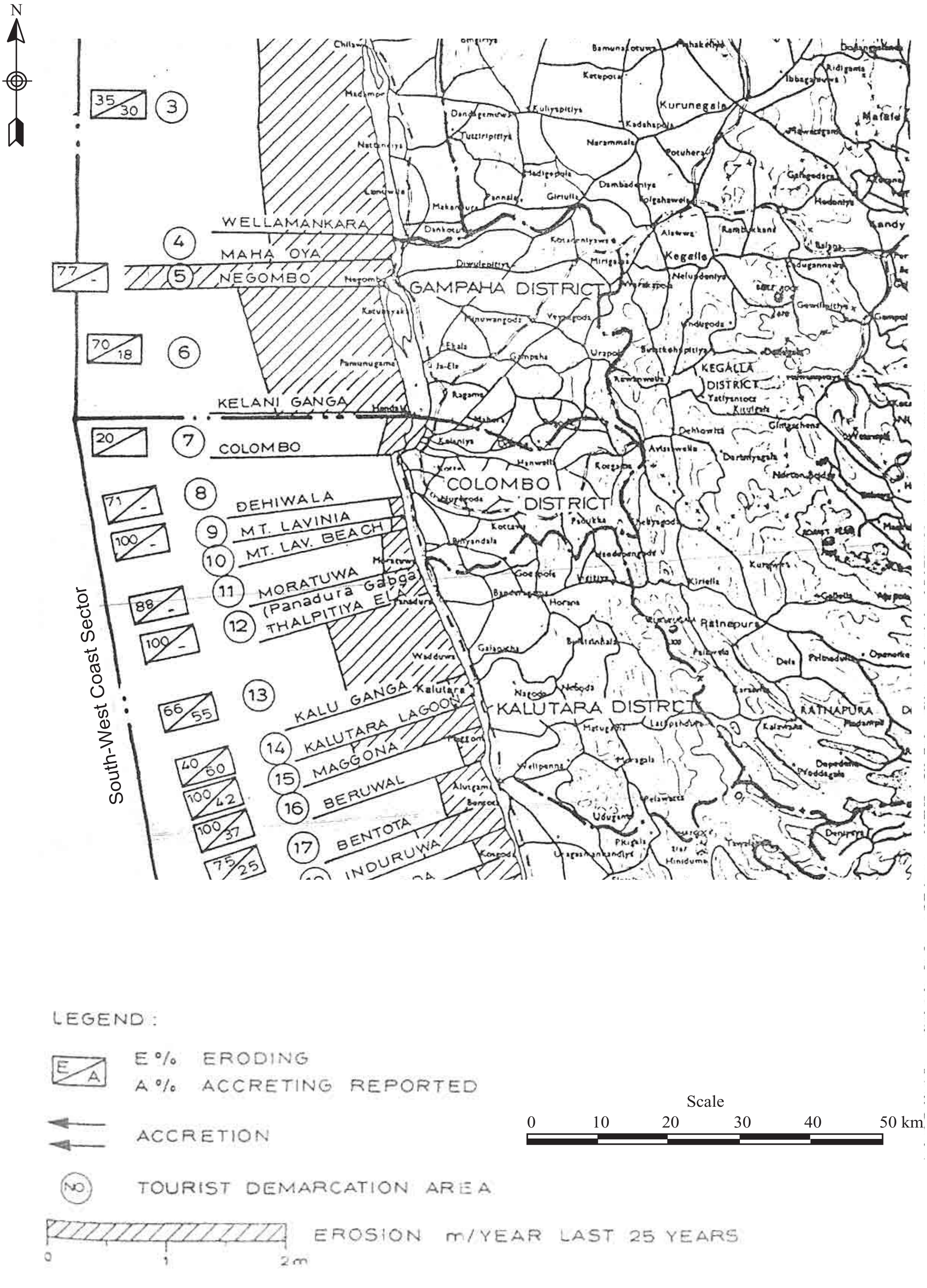
Figure 1.1.1
Locations of Outfalls



Source: Master-Plan - Coast Erosion Management - Volume 4 (South West Coast), Coast Conservation Department and Denida-Denish Hydraulic Institute, February 1986

The Study on Storm Water Drainage Plan for the Colombo Metropolitan Region in the Democratic Socialist Republic of Sri Lanka	Figure 1.1.2 Erosion Tendency of Southwest Coast of Sri Lanka
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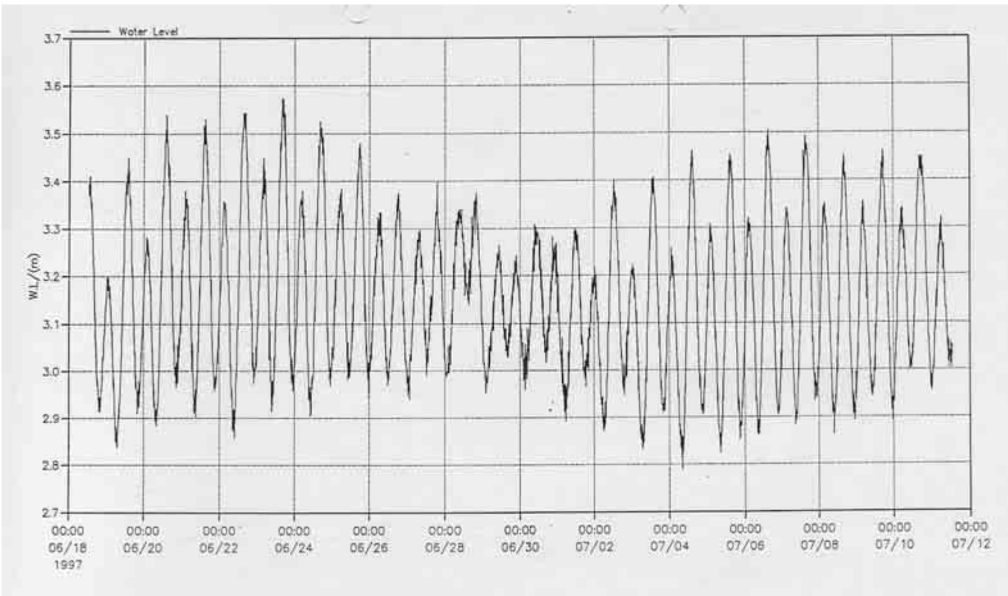
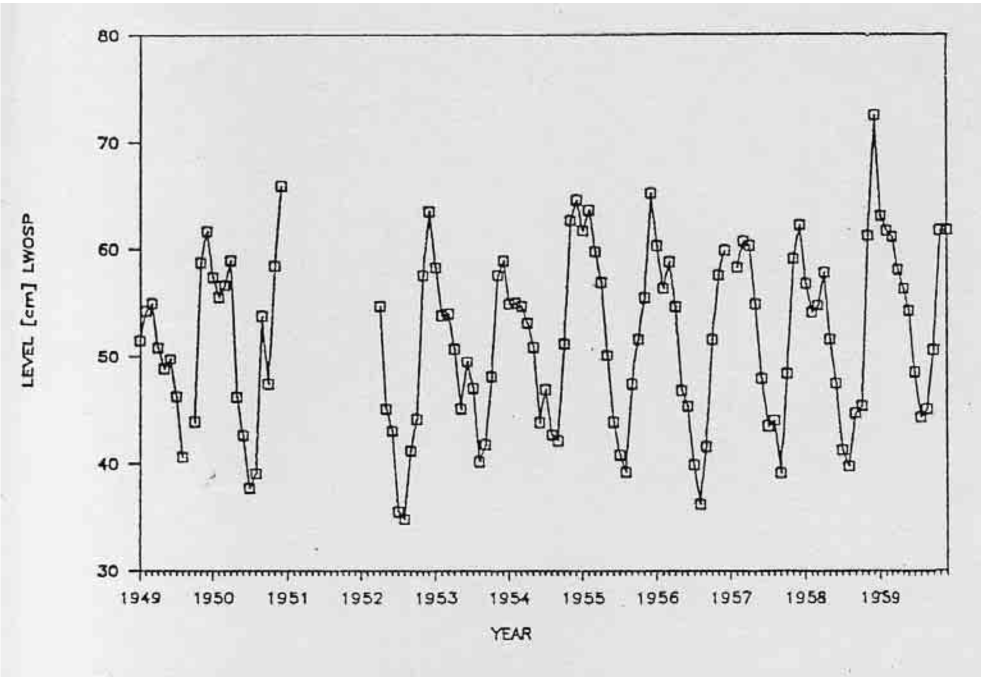


Tidal Record at Offshore of Dehiwala

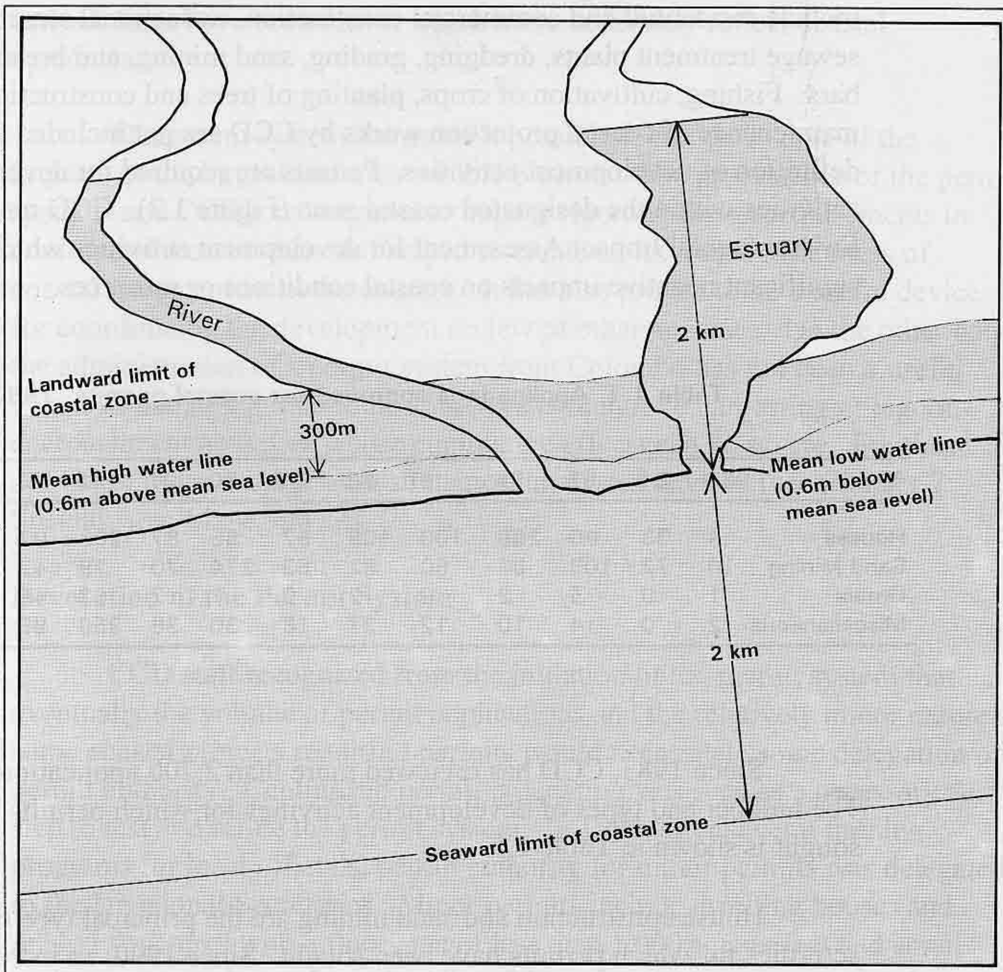
Source: Hydraulic Studies to Determine Layout and Design Parameters for Improvement of the Dehiwala Canal Sea Outfall, SLLRDC, June 1997)



Tidal Record at Colombo Port

Source: Sediment Transport Study for The Southwest Coast of Sri Lanka, CCD, May 1992)

The Study on Storm Water Drainage Plan for the Colombo Metropolitan Region in the Democratic Socialist Republic of Sri Lanka	Figure 1.1.3 Tidal Records at Dehiwala and Colombo Port
JAPAN INTERNATIONAL COOPERATION AGENCY	



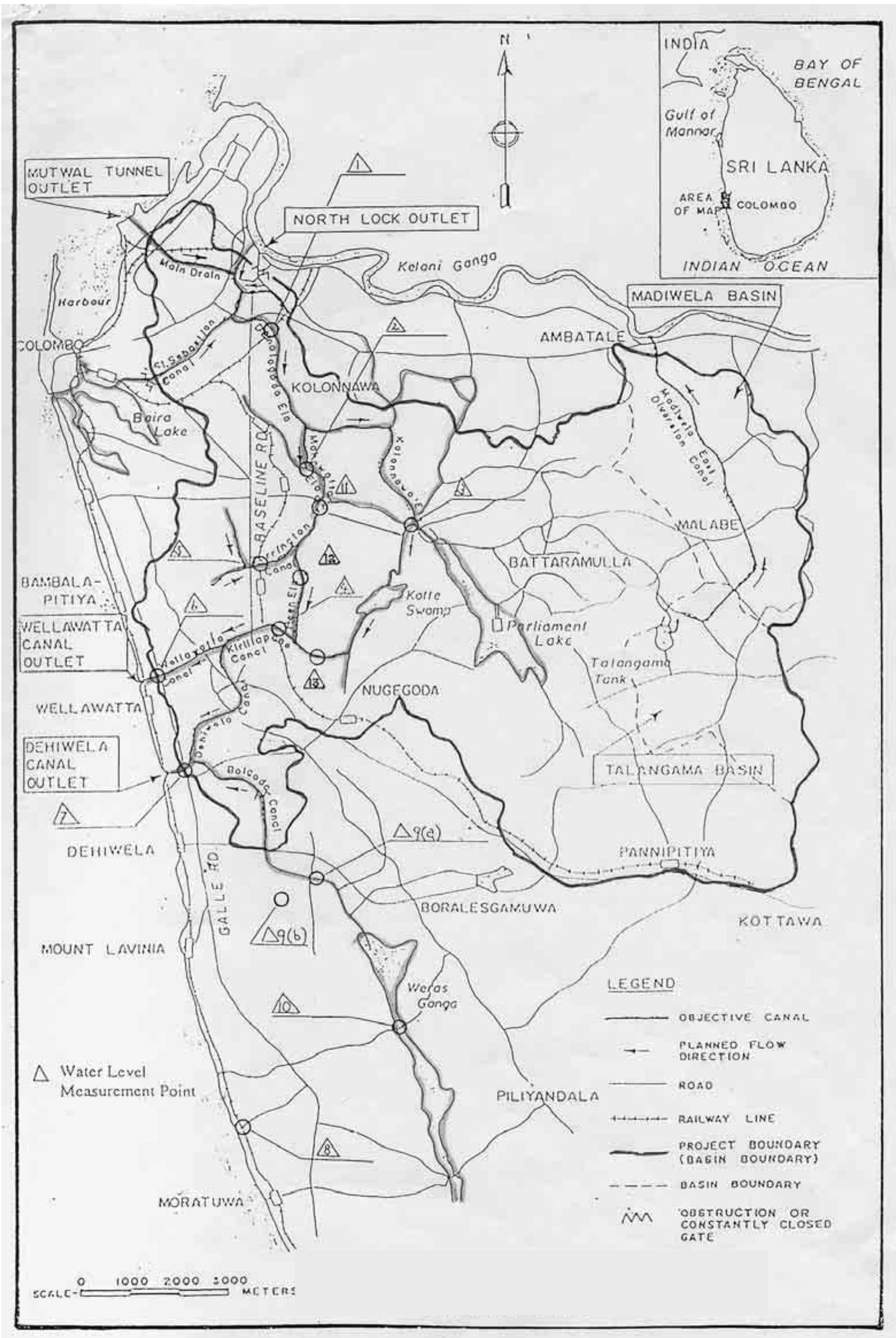
The "Coastal Zone" is defined in the Coast Conservation Act as:

"The area lying within a limit of three hundred meters landward of the Mean High Water Line and a limit of two kilometers seaward of the Mean Low Water Line and in the case of rivers, streams, lagoons, or any other body of water connected to the sea either permanently or periodically, the landward boundary shall extend to a limit of two kilometers measured perpendicular to the straight base line drawn between the natural entrance points [defined by the mean low water line] thereof and shall include waters of such rivers, streams and lagoons or any other body of water so connected to the sea."

(The coastal zone is shown shaded)

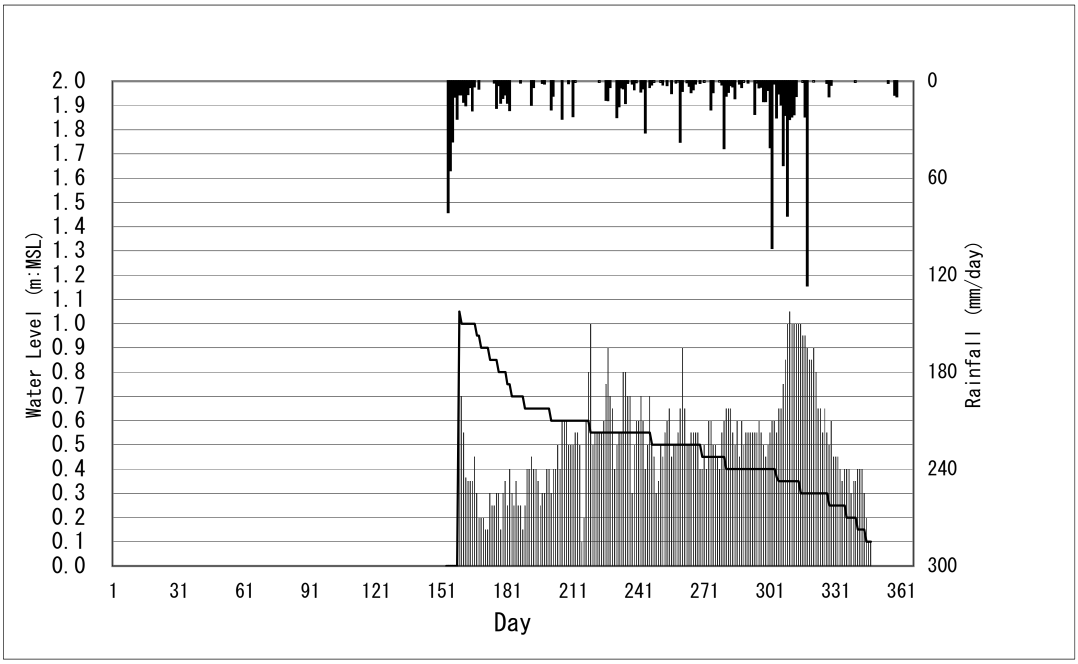
Source: Sediment Revised Coastal Zone Management Plan, CCD, October 1997

The Study on Storm Water Drainage Plan for the Colombo Metropolitan Region in the Democratic Socialist Republic of Sri Lanka	Figure 1.1.4 Definition of Coastal Zone
JAPAN INTERNATIONAL COOPERATION AGENCY	

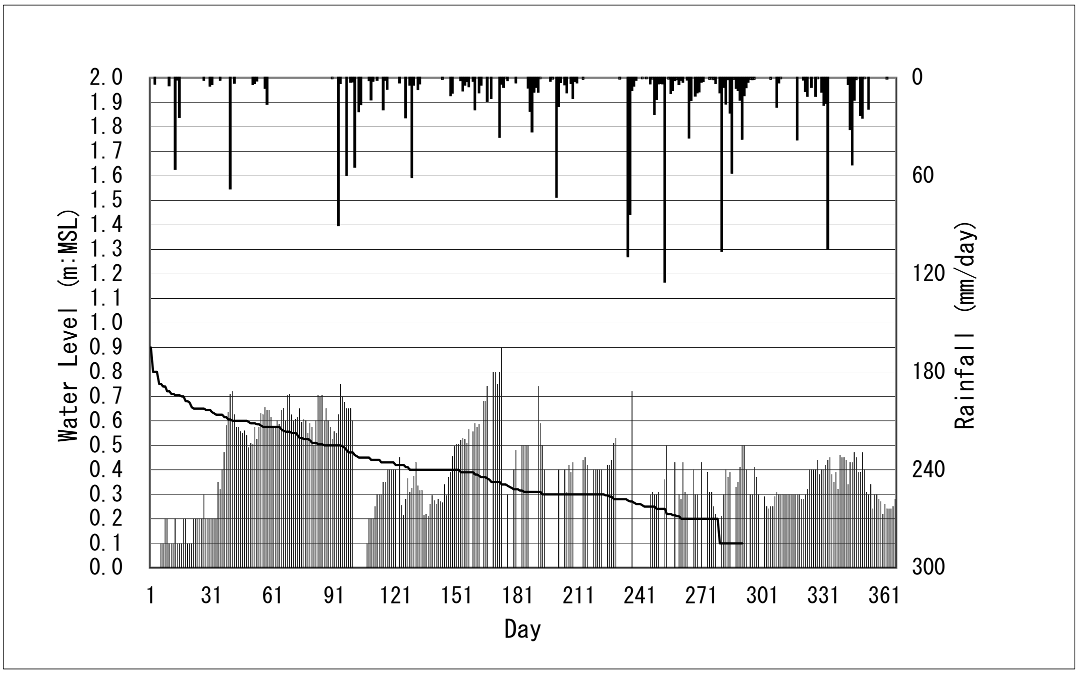


Source: Action Plan For the Control of Pollution in the Greater Colombo Canal System., Greater Colombo Flood Control and Environment Improvement Project – Phase 2 -, Volume Ⅱ, Data Book, SLLRDC, February 2001

The Study on Storm Water Drainage Plan for the Colombo Metropolitan Region in the Democratic Socialist Republic of Sri Lanka	Figure 1.2.1 Location of Hydraulic Measurement
JAPAN INTERNATIONAL COOPERATION AGENCY	

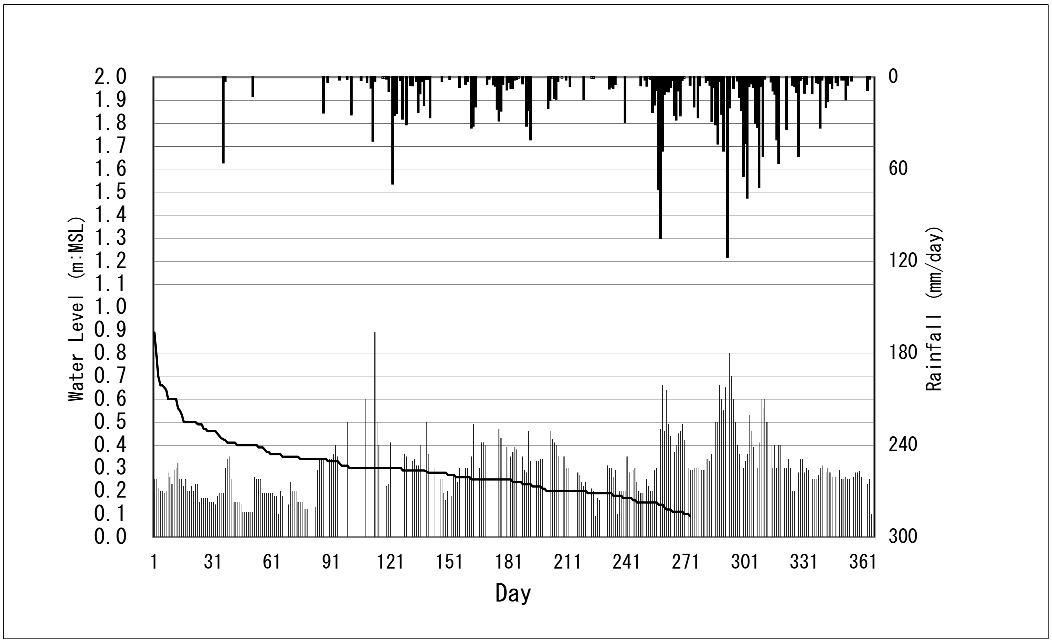


Daily rain and water level at Wellawatta (1995)

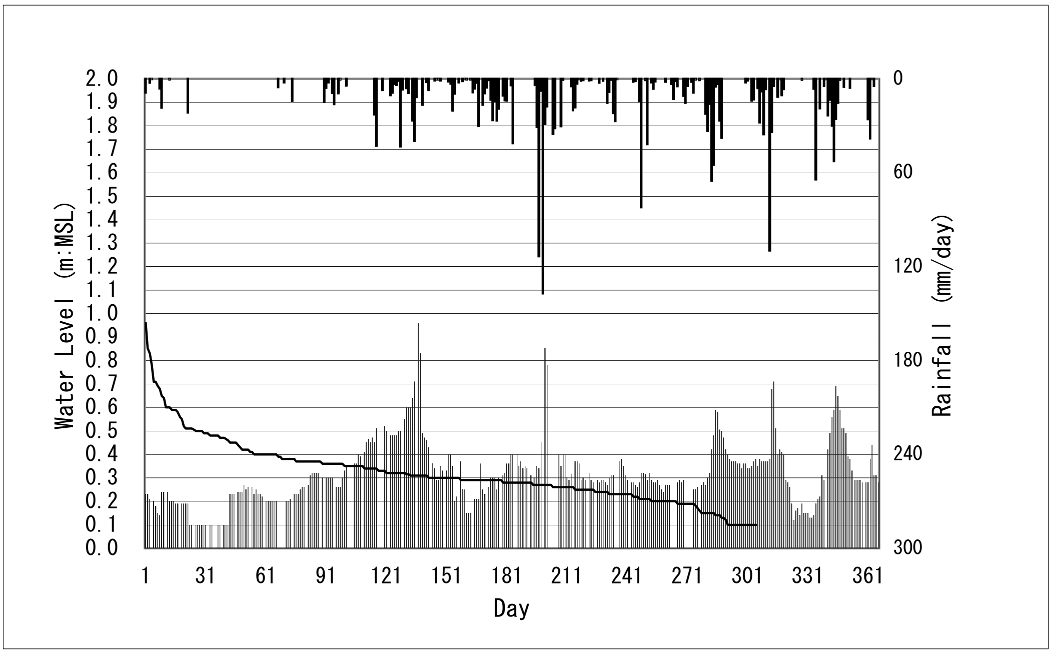


Daily rain and water level at Wellawatta (1996)

The Study on Storm Water Drainage Plan for the Colombo Metropolitan Region in the Democratic Socialist Republic of Sri Lanka	Figure 1.2.2 Water Level Duration Curve at Wellawatta Canal (1/3) (1995 and 1996)
JAPAN INTERNATIONAL COOPERATION AGENCY	

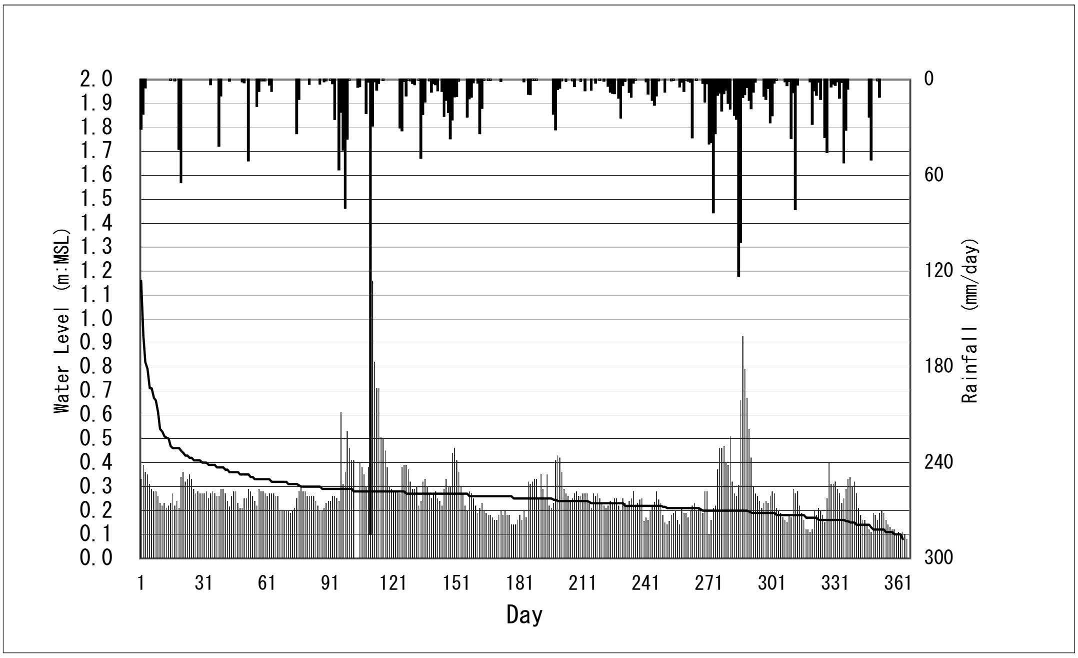


Daily rain and water level at Wellawatta (1997)

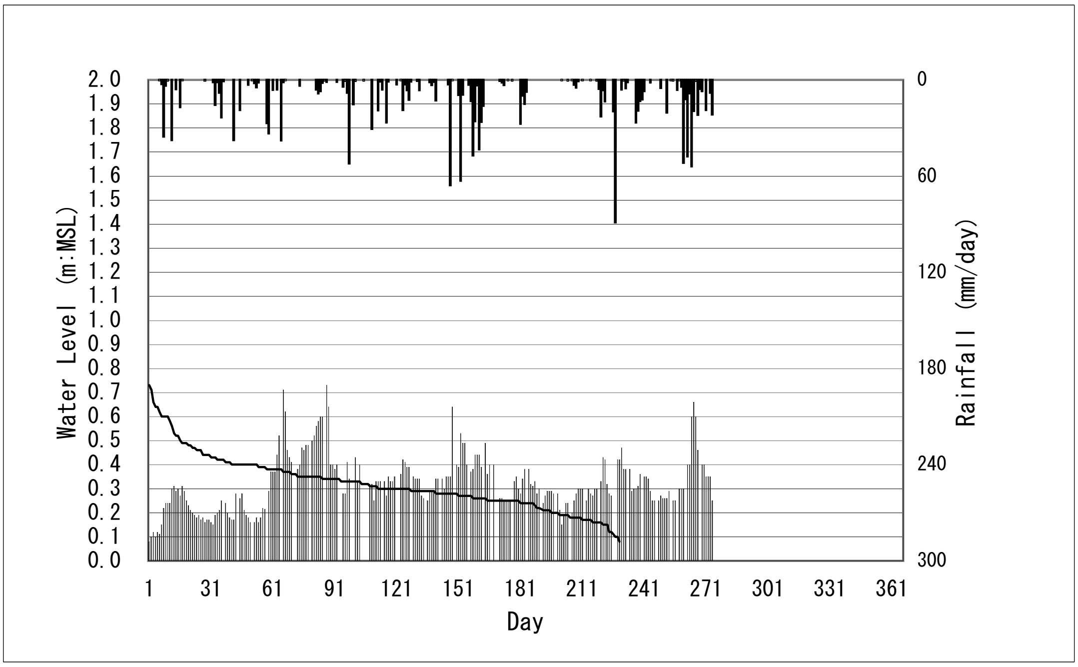


Daily rain and water level at Wellawatta (1998)

The Study on Storm Water Drainage Plan for the Colombo Metropolitan Region in the Democratic Socialist Republic of Sri Lanka	Figure 1.2.2 Water Level Duration Curve at Wellawatta Canal (2/3) (1997 and 1998)
JAPAN INTERNATIONAL COOPERATION AGENCY	

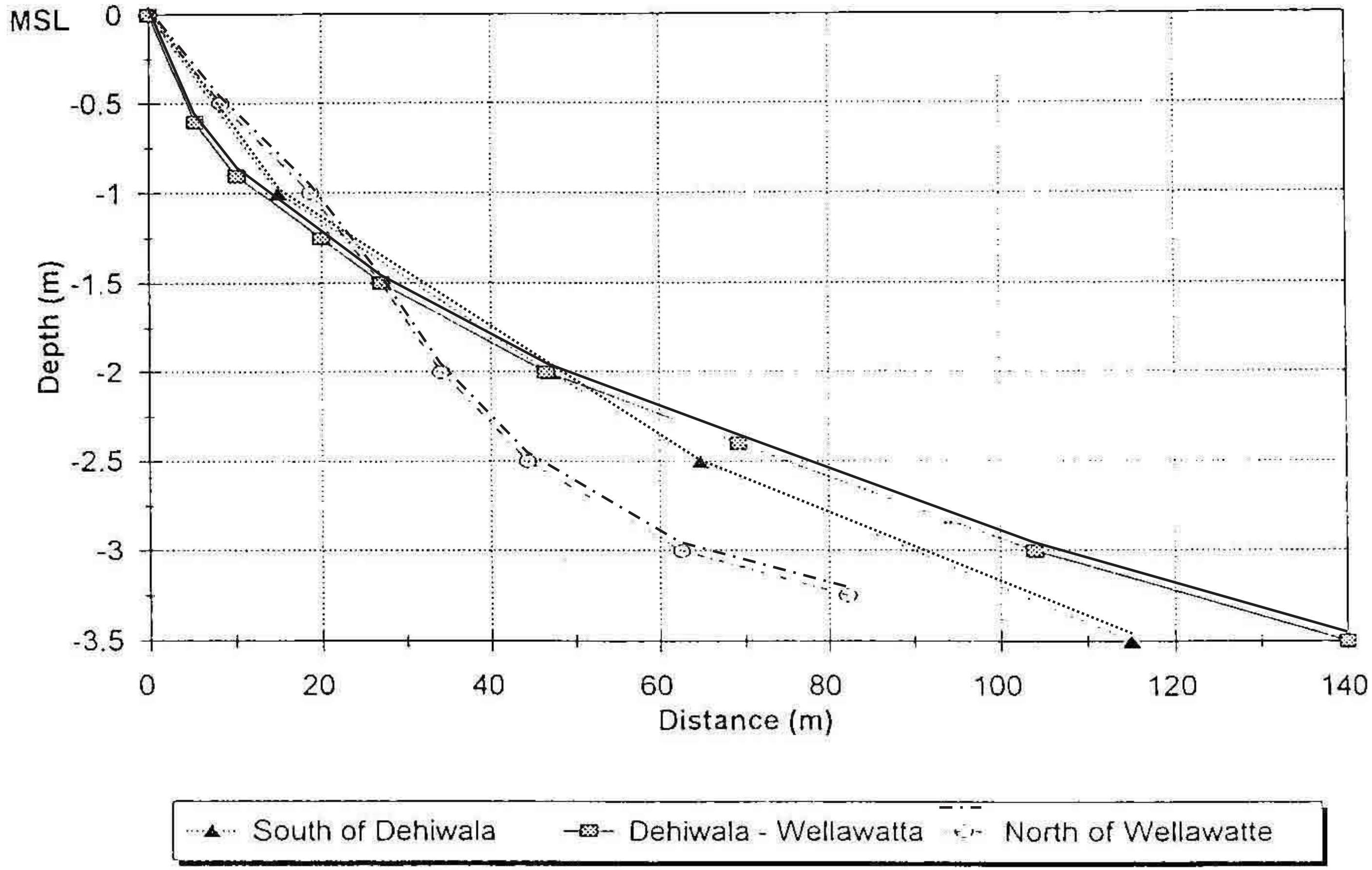


Daily rain and water level at Wellawatta (1999)



Daily rain and water level at Wellawatta (2000)

The Study on Storm Water Drainage Plan for the Colombo Metropolitan Region in the Democratic Socialist Republic of Sri Lanka	Figure 1.2.2 Water Level Duration Curve at Wellawatta Canal (3/3) (1999 and 2000)
JAPAN INTERNATIONAL COOPERATION AGENCY	



Source: Dehiwala Outfall Study, Coastal Impact Mitigatory Measures, SLLRDC, June 1998

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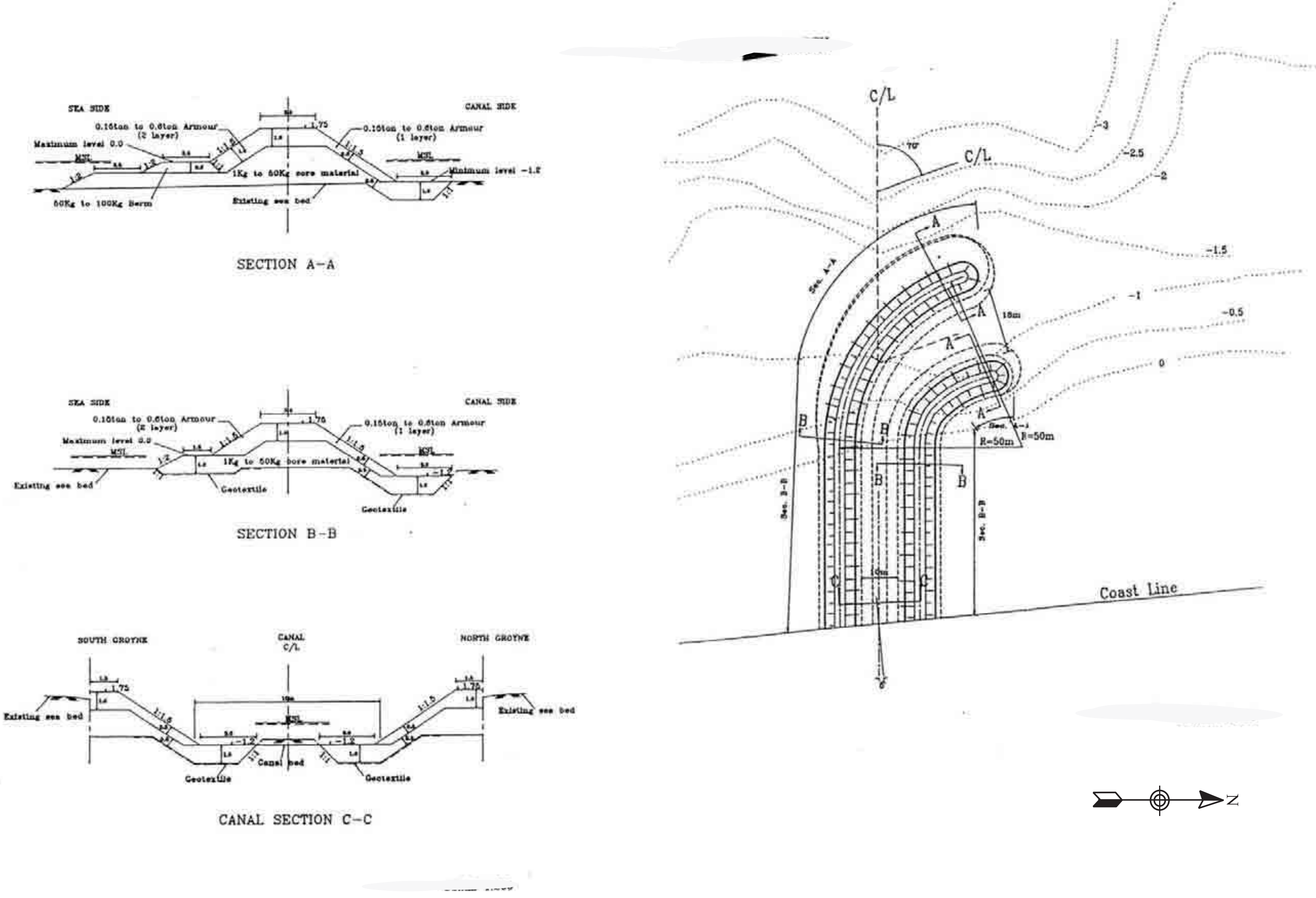
Figure 2.2.1

Sea Bed Profiles at Dehiwala and Wellawatta



Source: Hydraulic Studies to Improve Dehiwala Canal Outfall, Lanka Hydraulic Institute Ltd., August 1997

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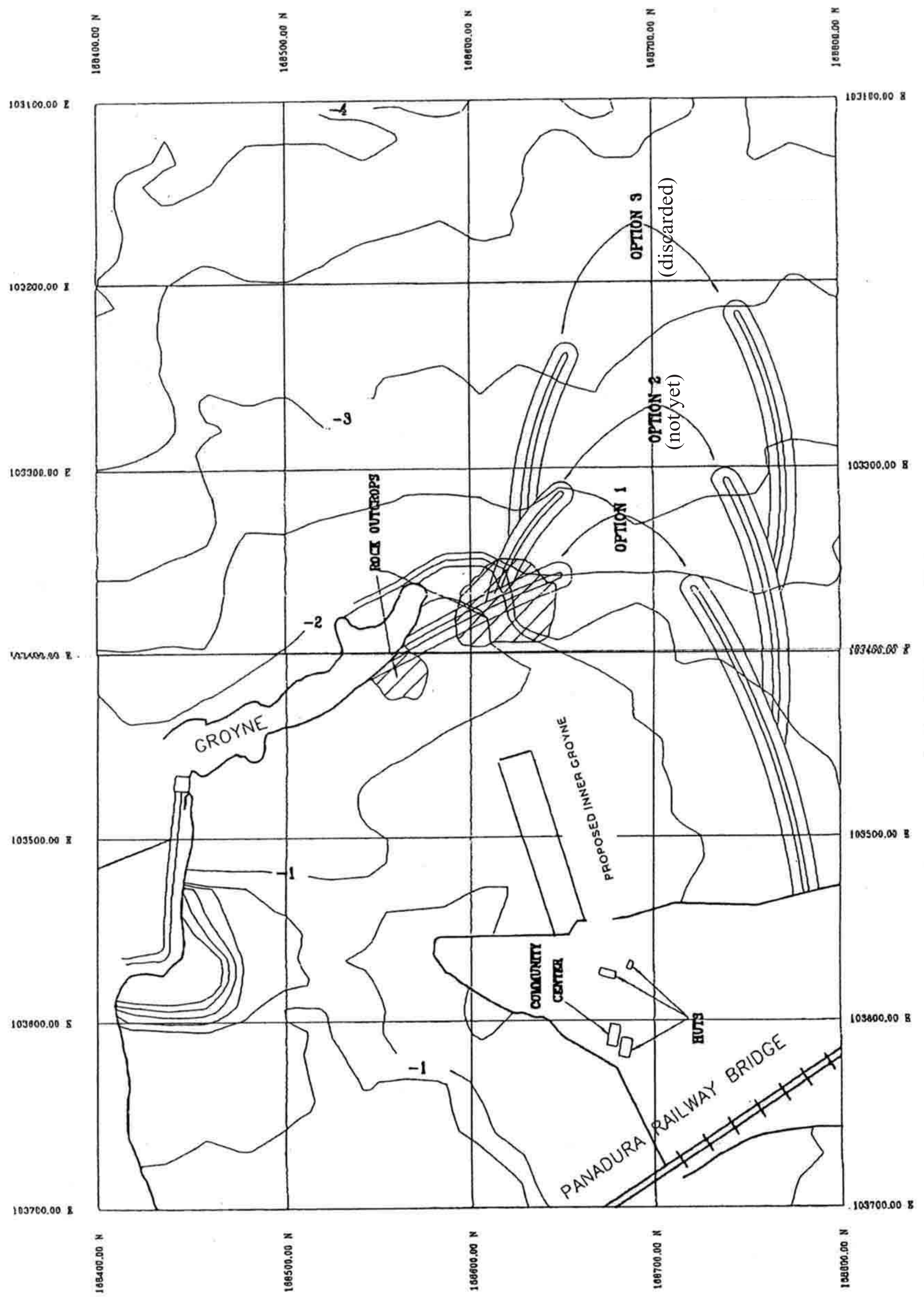
Figure 2.2.2
Groynes at Dehiwala Outfall



Source: Investigations for Panadura Anchorage, April 1997, ADB Fisheries Sector Development Project Implementation Unit Ceylon Fishery Harbours Corporation, by LHI

The Study on Storm Water Drainage Plan for the Colombo Metropolitan Region in the Democratic Socialist Republic of Sri Lanka	Figure 2.2.3 Improvement Plan of Panadura Harbour
JAPAN INTERNATIONAL COOPERATION AGENCY	