PART I : INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 Background of the Study

As the urbanized area of the Colombo Metropolitan Region (CMR) expands into the coastal lowland, the difficulty of drainage is causing an increase in the frequency of flood inundation. The inundation results in damage to property and deterioration of infrastructures as well as a worsening hygiene environment for residents. Implementation of remedial measures to reduce inundation is important to secure lands for future development in the CMR (population 5.3 million at 2001).

Since the early 1990's, the Government of Sri Lanka (GOSL) has been implementing the Greater Colombo Flood Control and Environment Improvement Project, being assisted by an Official Development Assistance Loan from the Government of Japan (GOJ). GOSL has also recognized the need for a comprehensive master plan for storm water drainage in the entire CMR and in September 1999 requested GOJ to undertake a study to formulate such a master plan

GOJ agreed to conduct the Study on Storm Water Drainage Plan for the Colombo Metropolitan Region in the Democratic Socialist Republic of Sri Lanka (the Study). The Scope of Work was agreed between the Sri Lanka Land Reclamation and Development Corporation (SLLRDC) of the Ministry of Urban Development, Construction & Public Utilities (presently Ministry of Housing & Plantation Infrastructure) and Japan International Cooperation Agency (JICA) on March 7, 2001.

1.2 Objectives of the Study

The objectives of the Study are:

1) To formulate a master plan for storm water drainage in the Colombo Metropolitan Region,
2) To conduct feasibility study on a priority project to be identified in the master plan, and
3) To carry out technology transfer to counterpart personnel in the course of the Study.

1.3 Study Area

The area for master plan study is shown in the Location Map, and covers part of the Colombo Metropolitan Region. The area is roughly divided into four drainage basins comprising Ja Ela basin, Kalu Oya basin, Greater Colombo basin and Bolgoda basin. The total catchment area is 830 km^2 as shown in Figure 2.1.

1.4 Priority Project for Feasibility Study

Based on the master plan study, the storm water drainage project for the sub-catchment of the Bolgoda basin, namely Weras Ganga basin, was selected as a priority project for the feasibility study. The Weras Ganga basin, with a catchment of 55.5 km^2 is shown in Figure 2.1.

1.5 Study Schedule and Activity

The Study is scheduled to be carried out for 18 months from September 2001 to February 2003 and the entire study period is staged into two phases as follows:

Phase 1: Master Plan Study

- Preparatory Work in Japan (0.2 months in September 2001)
- First Field Work in Sri Lanka (5.8 months from September 2001 to March 2002)
- First Home Work in Japan (0.5 months in June 2002)

Phase 2: Feasibility Study on Priority Project

- Second Field Work in Sri Lanka (3.5 months from July to October 2002)
- Second Home Work in Japan (1.5 months from October to November 2002)
- Third Field Work in Sri Lanka (0.5 months in December 2002)
- Third Home Work in Japan (0.5 months in February 2003)

(1) Phase 1

The first field work in Sri Lanka commenced on September 17, 2001. The Inception Report on the Study was agreed by GOSL at the meeting with the Steering Committee established for the Study held on October 10, 2001. The investigation works for the master plan study were carried out till March 9, 2002 in the fields of engineering, environment, social and economy. The results of the first field work were compiled as Progress Report (1).

At the end of the first field work, a workshop on the master plan was held on March 4, 2002 inviting personnel of the relevant organizations aiming at transferring technology and exchanging the opinions on the study results between the Study Team and Sri Lanka participants.

Based on the results of the first field work, the master plan study was carried out in Japan and the master plan study results were compiled in the Interim Report. In this

Report, the storm water drainage master plan for the Colombo Metropolitan Region and also the priority project for the feasibility study are proposed.

(2) Phase 2

The second field work commenced on July 1, 2002. The priority project for the feasibility study was affirmed at the Steering Committee meeting held on July 9, 2002 and the storm water drainage project for the Weras Ganga basin was determined as a priority project. Investigation works for the feasibility study were carried out till October 13, 2002 in areas of engineering, environment, social and economy.

The second Progress Report compiled the findings and interim results of the Second Field Work in Sri Lanka carried out for the feasibility study.

At the end of the second field work, a workshop on the feasibility study was held (on March 4, 2002) involving personnel of the relevant organizations and aimed at transferring technology and exchanging the opinions on the study results between the Study Team and Sri Lanka side.

Based on the results of the second field work, the feasibility study was carried out in the second home work in Japan and the result of feasibility study were compiled together with the master plan study result as the Draft Final Report.

The Draft Final Report was presented and discussed at the third field work in Sri Lanka. During this period, a seminar on the Study was held (on December 17, 2002) involving personnel of the relevant organizations and aimed at transferring technology and exchanging the opinions on the study results between the Study Team and Sri Lanka side.

The Final Report was prepared at the third home work in Japan in the light of the discussions at the presentation of the Draft Final Report and the comments issued by the Sri Lanka side afterwards. The Final Report was finalized in March 2002.

1.6 Technology Transfer

Technology transfer is one of the objectives of the Study. The technology transfer was carried out in the form of on-the-job training through joint work by the team member and the counterpart personnel, occasional discussion with other team members and counterpart personnel, workshop and seminar.

Workshops for technology transfer were held twice during the study period as below.

The first workshop was held on March 4, 2002 at Lanka Oberoi Hotel, Colombo in the first field work in Sri Lanka for the master plan study having 40 participants after inviting 78 from relevant central government agencies, relevant local authorities, foreign donors, etc. At the workshop, interim results of the master plan study were presented by the Study Team and discussed among the participants.

The second workshop was held on October 4, 2002 at Colombo Hilton, Colombo in the second field work in Sri Lanka for the feasibility study involving 55 participants from 87 invitations to relevant central government agencies, relevant local authorities, foreign donors, etc. At this workshop, interim results of the feasibility study were presented by the Study Team and discussed among the participants.

The technology transfer seminar was held on December 17, 2002 at Lanka Oberoi Hotel, Colombo in the second field work in Sri Lanka for the feasibility study involving 48 participants from 110 invitations to relevant central government agencies, relevant local authorities, foreign donors, etc. At this workshop, all the results of the Study and topics on storm water drainage in Japan and Sri Lanka were presented by the Study Team and Sri Lanka side and discussed among the participants.

In addition to the workshops, the JICA Team undertook a mini workshop on the master plan study for the counterpart personnel on July 4, 2002 at the meeting room of SLLRDC. The Study Team also held a mini seminar on the MIKE 11 software (for hydrological and hydraulic analyses used in the Study), for about 20 engineering staff of SLLRDC.

PART II : MASTER PLAN

CHAPTER 2 PRESENT CONDITIONS OF THE STUDY AREA

2.1 Natural Conditions

2.1.1 General Topography

The study area extends from Katunayake in the north to Kalutara in the south or approximately between lat. 6°36′N and lat. 7°10′N and between long. 79°50′E and long. 80°05′E. It is broadly bounded by Negombo Lagoon and Dandugam Oya to the north, the proposed route of the Outer Circular Highway to the east, and the Bolgoda Lake watershed to the south.

There are several drainage basins which are entirely or partly included in the study area. The delimitation of drainage basins in the study area for the purpose of the present study is shown in Figure 2.1 and tabulated below:

Relevant River Basins and Study Area

Basin	Basin Area (km^2)	Within Study Area (km^2)
Ja Ela	860	173
Kalu Oya	58	58
Kelani Ganga	2,292	89
Greater Colombo	85	85
Bolgoda	394	394
Other Areas along Coast	31	31
Total	-	830

Note: Extent of basin area is estimated from 1:50,000 scale topographic map.

(1) Ja Ela Basin

The study area covers the lower reaches of Ja-Ela and Dandugam Oya generally flowing from east to west and eventually pouring into the Negombo Lagoon. The lower Ja Ela basin of 173 km^2 is characterized by a vast extent of marsh called Muthrajawela and surrounding lowlands and hilly areas.

The Muthrajawela marsh extends over the most downstream part of the basin, having an elevation of 0 to 2 m above MSL. The lowlands consist of urbanized areas along the Negombo Road and paddy cultivation areas along the rivers. The elevation of such lowlands varies from 2 to 5 m above MSL. The hilly areas are located along the southern boundary of the basin at the elevation of 10 to 40 m above MSL.

(2) Kalu Oya Basin

The Kalu Oya basin covers an extent of 58 km^2 to the south of the lower Ja Ela basin. The Kalu Oya is the main stream of the basin and flows northeast to southwest. After crossing over the Negombo Road, the Kalu Oya finally pours into the Kelani

Ganga. The topographic characteristics of the basin are similar to those of the lower Ja Ela basin. The basin consists of marsh and surrounding lowlands as well as hilly areas along the basin boundary. The elevation of the basin ranges from 0 to 40 m above MSL.

(3) Kelani Ganga Basin

The study area covers the most downstream basin of the Kelani Ganga extends from the river mouth to Kaduwela. The basin area within the study area is 89 km^2. The left bank area is protected from the flood of the Kelani Ganga by flood bund (dike) system along the river with the length of 5 km. The surface elevation of the flood bund system including the Railway Embankment and Gotatuwa Bund varies from 6 to 8 m above MSL. Meanwhile, the unprotected area along the Kelani Ganga left bank in Kolonnawa is urbanized partly. The ground elevation of the unprotected area ranges from 1 to 2 m above MSL.

The right bank is also protected by flood bund but its height remains lower than the flood bund on the left bank. The surface elevation of the flood bund varies from 3 to 6 m above MSL. The right bank area covers Peliyagoda, Kelaniya and Biyagama. The ground elevation in the right bank area ranges from 2 to 5 m above MSL.

(4) Greater Colombo Basin

The Greater Colombo basin covers an area of 85 km^2 bounded by Nugegoda - High Level Road to the south, Talangama - Hokandara watershed to the east, Kelani flood bunds to the north, and elevated urbanized areas of Colombo along the coast to the west.

The western half of the greater Colombo basin is generally flat with ground elevations from less than 1 m to 6 m above MSL, with a few elevated and hilly areas with elevations from about 15 m to 20 m. Within the area, marshy lands of some 350 ha exist at an elevation of less than 1 m above MSL.

The eastern half of the basin is called the Madiwela catchment. The Parliament Lake is located in the most downstream and has a surface area of 95 ha under the normal flow condition. Surroundings of the lake are lowlands with an elevation of less than 1 m above MSL. The catchment rises to the elevations from about 10 m to 35 m above MSL up to the basin boundary.

(5) Bolgoda Basin

The Bolgoda basin has a drainage area of 394 km^2, located between the Greater Colombo basin to the north and the Kalu Ganga basin to the south. In the upper catchment area, the streams originate from the hills with the highest elevation of 20 m above MSL at the eastern boundary of the basin. The lower catchment area lies in the lowland widely spreading along the coast with water surfaces and surrounding marsh lands.

There is a unique water system in the basin comprising the two major lakes with incoming and outgoing waterways. There exist are two large lakes, North Bolgoda Lake (normal surface area 760 ha) and South Bolgoda Lake (normal surface area 340 ha). Both lakes are interconnected by Bolgoda Ganga. Almost all of the rivers pour these two lakes. The Bolgoda Lake North is connected to the sea through Panadura River, while the Bolgoda Lake South mainly drains to Kalu Ganga.

2.1.2 General Geology

Geologically Sri Lanka is related to India with which it was united as a part of the ancient southern continent of Gondawanaland. The entire island is underlain by a complex of metamorphic rocks, which is divided into Vijayan Series, Highland Series and Southwestern Series. The largest and oldest of these series is the Highland Series, which is exposed throughout most of the Northern and Central interior and is believed to be source from which the younger Vijayan Series is derived. The Vijayan Series is exposed in the south-eastern area of the island.

Many parts of the coastal plain owe their flatness to the presence of extensive flat-lying sedimentary deposits on a peneplained basement of crystalline rocks on the Miocene limestone. In the study area north of Colombo, coastal belt flat country has been formed by sand beaches, lagoonal silt and clay, blown sand, and river alluvium. The lowest peneplain and the coastal plain extends outwards from the island and under the sea as a submarine shelf, the Continental Shelf, for a distance of about 16 miles and at an average depth of 216 feet below the sea level.

The following major soil groups are encountered in different land forms / geological formations in different physiographic regions of the study area as given below:

Soil Groups in the Study Area

Geological Formation/ Land Form	Major Soil Groups Present	
	Coastal Plain	Mantled Plain
Recent beach deposits	Regosol	
Old (Pleistocene)beach deposits	Latosols	
Flood plain	Alluvial	
Flat valleys	Bog and Half Bog	
Valleys	Low Humic Gley	
Gently undulating to undulating (2 - 8 % slope)		Red Yellow Podzolic
Rolling plain (8 - 16 % slope)		Red Yellow Podzolic
Hilly terrain (16-30% slope)		Red Yellow Podzolic
Steep terrain (>30% slope)		Red Yellow Podzolic

Source: The Geology of Sri Lanka (Ceylon), P. G. Cooray, 1984

The distribution of different soil groups considering the basins and the aspect of the soil catena within the study area is as follows (e.g. upper aspect is referred to the upper section of a sloping land (soil) catena):

Soil Groups by Basin

Basin	Great Soil Groups Present	
	Upper Aspect of the Catena	Lower Aspect of the Catena
Ja-Ela basin	Red yellow podzolic soil (dominant soil group in the basin); Latasols; and Alluvial soils of the levees	Bog and half bog soils; Low humic gley soils; Alluvial soils of the basins and back swamps; and Regosols .
Kalu Oya basin	Red yellow podzolic soil (dominant soil group in the basin); and Latosol	Bog and half bog soil; and Low humic gley soils
Greater Colombo basin	Red yellow podzolic soil. (dominant soil group in the basin); and Alluvial soils of the levees	Bog and half bog soils; Low humic gley soils; and Alluvial soils of the basins and the back swamps.
Bolgoda basin	Red yellow podzolic soils (dominant soil group in the basin); Latosols; and Alluvial soils of the levees.	Bog and half bog soils; Low humic gley soils; Alluvial soils of the basins and back swamps; and Regasols.

Source: Wetland Site Report & Conservetion Management Plan, Ministry of Environment and Parliamentary Affairs, 1993

2.2 Socio-Economy

2.2.1 Administrative Division

The four basins that are covered in the study area consist of the west part of Colombo District, the southwest part of Gampaha District, and the northwest part of Kalutara District. Since the basin boundaries and the administrative boundaries do not always match, the area coverage of the District Secretariat (DS) Divisions within and outside the study area need to be estimated separately. The study area is estimated to cover 89.0% of the Colombo District, 48.8% of the Gampaha District, and 41.9% of the Kalutara District for a total of 64.2% of CMR. The DS Divisions within the study area are listed in Table 2.1 and shown in Figure 2.2.

The related local governments, which include municipal councils, urban councils and Pradeshiya Sabha (MC, UC and PS respectively), and DS Divisions are listed in Table 2.2.

2.2.2 Population

Total population of the study area in 2001 was estimated to be 3,438,000 which accounts for 64.4% of the total population of the Western Province (CMR) or 18.1% of total population of Sri Lanka (19 million), and makes it one of the highly populated areas in Sri Lanka. Of the three districts in the study area, Colombo District has the largest population with 57.7% of population share, followed by Gampaha District with 29.3% and Kalutara District with 12.9% as shown below.

Estimated Population of the Study Area

(Unit: 1,000 persons)

Item	Colombo	Gampaha	Kalutara	Study Area
Population (2001)	1,985	1,008	445	3,438
Population (1994)	1,933	803	392	3,128
Population (1981)	1,526	656	341	2,523
Population density (2001) persons/ha	51	27	14	32
Area (ha)	39,019	37,278	31,530	107,827

Source: Department of Census and Statistics, Colombo Metropolitan Regional Plan (UDA)
Note: Since the area and population are based on the administrative boundary, the total area mentioned here may not always match with the basin area.

2.2.3 Economic Conditions

Gross Domestic Product (GDP) of Sri Lanka in 2000 was Rs. 857,035 million and had been expanding throughout the 1990's with an annual average growth rate of 5.3%. The agriculture sector accounts for 20.5% of GDP in which tea, coconut, rubber, and paddy are the main agricultural products. Sri Lanka is the largest tea exporting country in the world with an export volume of 288 million kg in 2000 or Rs. 12,226 million. The share in the manufacturing sector is 17.4% or Rs. 149,115 million, the textile, chemical (fertilizer, rubber, pharmaceuticals) and agro-processing (tea and coconut), are main manufacturing activities. Export oriented industries, apparel and textile industries are contributing to the economic growth of industrial sector. Wholesale and retail trade sectors are the highest contributor to GDP by producing 22.1% of GDP (Rs. 189,366 million) and play important roles in the external trade (Table 2.3).

Because of the limited information, regional economy is measured for the Western Province or CMR. CMR plays a major role in economic activities in Sri Lanka by producing 43.3% of GDP or Rs. 179,720 million in 1995. Concentration of manufacturing activities is particularly high by contributing 72.4% of GDP for the manufacturing sector (Table 2.4). Assuming that the GRDP share of CMR remains the same, GRDP for CMR in 2000 is estimated to be Rs. 378,890 million.

2.2.4 Household Income

The household income in the study area is the highest in Sri Lanka. Average monthly household income in the three districts of Colombo, Gampaha, and Kalutara of the study area is Rs. 9,230, which is higher than the national average of Rs. 6,476. The average monthly household income is highest in Colombo District with

Rs.11,107. In the study area, the income from social welfare programs (food stamps, Janasaviya and Samurdhi) is low, particularly for Colombo District (Rs. 40 per household per month) compared with the national average (Rs. 156 per household per month). Income from salaries & wages accounts for 48.9% of income sources, income from non agricultural activities 18.1%, income from agriculture 3.1%, and Janasaviya & Samurdhi 1.1%.

Since the income is high in the study area, household expenditure is also high. The average monthly household expenditure is Rs. 10,833 in Colombo District, while the national average is Rs. 6,305. In the study area, expenditure on non-food items is large. The national average shows that the expenditure on non-food items is 43.7% of total expenditure, while Colombo District shows 57.2% is spent on non-food items, which is attributed to high housing cost. Also more money is allocated to cultural activities & entertainment, transport, communication and education. Colombo District provides a variety of urban amenities and social services compared with other areas of Sri Lanka.

2.2.5 Public Finance

Fiscal operation of the Central Government of Sri Lanka for the year 2000 shows revenue of Rs. 211,282 million and expenditure of Rs. 335,823 million that resulted in a fiscal deficit of Rs. 124,541 million. In the past decade, the fiscal revenue did not cover the current expenditure. Fiscal deficit in 2000 is approximately 10% of GDP, and cumulative government debt in 2000 reached 97% of GDP and continues to increase (Table 2.5).

The government fiscal condition has been worsening in past years. The growth rate of expenditure is higher than that of the revenue. Weakening of financial conditions in 2000 was mostly resulted from an increase in defense cost, salary of public officers and increase in world oil price for power generation.

According to the government forecasts, this fiscal condition is expected to continue for several years because of the amortization of short-term loans, which increases the expenditure and slows economic growth, which decreases revenue. The fiscal condition is expected to improve after 2004 when the economy regains and the payment of the short-term loans is expected to be completed.

2.3 Land Use

2.3.1 Available Data on Land Use

In order to determine the present pattern of land use, as well as to estimate future patterns of land use, it is a first-step task to collect several kinds of information: the land use maps, satellite images, aerial photos, and statistics on land-related activities, such as population density, land prices, and transactional data on lands. In forecasting the future patterns of land use, additional data, such as locations of future projects, proposed land use maps, must also be collected. In Sri Lanka, these kinds of data are archived at various kinds of organizations in a fragmented manner. During the period of Phase 1 study, the following data were made available for the use of the study on land use:

Available Data on Land Use in the Study Area

Data Available	Kind of Data	Issuing Organization
Land Use Map	Topographic Map, Scale 1:10,000 Topographic Map, Scale 1:50,000 (1989) Topographic Map, Scale 1:100,000 Land Use Map by DS Division (1996) Abandoned Paddy Land Map by DS Division (1996-2000) Land Use Zoning Map by Local Authority (1996-2000)	Survey Department Survey Department Survey Department LUPPD LUPPD UDA
Satellite Image	LANDSAT IKONOS (2001, 2002)	Survey Department UDA
Aerial Photos	1960s	Survey Department
Statistics	Population	Department of Statistics

Note: UDA - Urban Development Authority
LUPPD - Land Use Policy Planning Division, Ministry of Land

2.3.2 Present Land Use Pattern Extracted from the Topographic Map

Figure 2.3 shows the spatial extent of present land use for each category by five sub-watershed basis. Within the 80,716 ha of the study area, paddy land amounts to 14,229 ha (17.6%), built up area 10,851 ha (13.4%), marshy area 2,016 ha (2.5%) respectively. The share of paddy area is highest in the Ja Ela basin (24.3%). Meanwhile the Greater Colombo basin indicates the highest share of build up area (36.9% for the sum of urban and semi-urban area).

Present Land Use Pattern

Basin	Area (ha)	Urban	Semi-Urban	Paddy	Marsh	Water	Other
(a) Bolgoda	40,116	2.8%	5.7%	17.1%	0.3%	3.4%	70.7%
(b) Greater Colombo	9,072	21.4%	15.5%	8.5%	4.3%	0.1%	50.2%
(c) Ja Ela	17,485	5.1%	2.9%	24.3%	7.1%	0.1%	60.5%
(d) Kalu Oya	6,066	6.6%	12.0%	16.4%	2.5%	0.0%	62.5%
(e) Kelani Ganga	7,977	7.2%	12.6%	16.7%	1.4%	1.8%	60.4%
Total (a) - (e)	80,716	6.1%	7.3%	17.6%	2.5%	1.9%	64.6%

Note: Extent of each land use category is extracted from 1:50,000 scale topographic map.

2.3.3 Abandoned Paddy Land

The spatial distribution of the abandoned paddy land could be regarded as indicators for future urban land use patterns, because it has a high possibility to be converted into urban use. Thematic maps prepared by the Land Use Policy Planning Division (LUPPD) were utilized for the purpose of identifying the abandoned paddy lands around the study area. Results of the field reconnaissance and the IKONOS print out are also referred to verify the situation.

Figure 2.4 shows the spatial distribution of the abandoned paddy lands. Most of the abandoned paddy lands were located in the Kesbewa, Kelaniya, and Biyagama DS Divisions. Several reasons are considered for abandoning cultivation of paddy, such as flooding, poor drainage, water shortage, labor shortage, and tenurial dispute.

2.3.4 Trends in Conversion of Agricultural Land into Urban Use

Statistical indicators such as the number of building permits and the extent of land auctioned indicate the degree of intensity in terms of conversion of agricultural land into urban use (i.e. urban sprawl). In the Colombo Metropolitan Regional Structure Plan (CMRSP), trends on these indicators were analyzed in three selected areas, such as Gampaha PS, Kesbewa PS and Horana PS.

Building Permits

Area Classification	Kesbewa PS		Gampaha PS		Horana PS	
	Total	%	Total	%	Total	%
Area adjacent to Transport Routes	3,054	55	457	33	181	21
Area with Towns	1,605	29	328	24	163	19
Agricultural Area	848	15	590	43	94	11
Urban Council Area	-	-	-	-	405	48
Total	5,507	100	1,375	100	843	100

Source: Colombo Metropolitan Region Structure Plan, UDA

Land Auctioned

Area Classification	Kesbewa PS		Gampaha PS		Horana PS	
	Hectare	%	Hectare	%	Hectare	%
Area adjacent to Transport Routes	445.91	56	15.80	35%	130.38	68%
Area with Towns	202.22	25	7.91	18%	16.33	8%
Agricultural Area	149.56	19	21.28	47%	45.71	24%
Urban Council Area	-	-	-	-	-	-
Total	797.49	100	44.99	100	192.42	100

Source: Colombo Metropolitan Region Structure Plan, UDA

The results indicate that, among the three example areas, Kesbewa PS showed an exceedingly high value both in terms of the number of building permits issued and the extent of the land auctioned due to the nearness to the urban built-up area. It was also pointed out that along the roadside area of the Kesbewa PS, a large number of land parcels were auctioned. The CRMSP also indicates that about 1,600 ha of land were auctioned in the eleven PSs located in the outskirts of the CMR.

Land Auctioned in Selected PSs in CMR

District	PS	1992	1995	1992-1995
		ha	ha	ha
Colombo	Homagama	5.78	128.85	192.42
	Kesbewa	147.67	199.77	797.49
Gampaha	Gampaha	6.43	14.14	44.99
	Divulapitiya	12.96	26.17	100.08
	Biyagama	0.39	60.22	73.00
	Mahara	4.83	7.89	50.13
	Minuwangoda	2.63	17.63	49.27
Karutala	Horana	5.78	128.85	192.42
	Dodangoda	1.20	6.47	23.75
	Beruwala	6.10	14.00	33.21
	Bandragama	13.18	0.13	64.02
	Total	206.95	614.12	1620.78

Source: Colombo Metropolitan Region Structure Plan, UDA

2.3.5 Existing Land Use Plan

No available land use plan except the Colombo Metropolitan Region Structure Plan (CMRSP) that covers the whole study area could be found in the course of the field work.

The CMRSP proposes the six Growth Centers such as Negombo, Gampaha, Biyagama, Homagama, Horana and Matugama that are situated at the outskirts of the CMR and the development plan for the Core Area (Colombo-Greater Kotte Area). The detailed plan for the four growth centers has not yet been finalized in the plan, whilst the Core Area plan was described in the plan, which is comprised of zoning and building regulations including minimum and maximum densities. The detailed plan for Horana Growth Center and Negombo Growth Center has been finalized at the Planning Committee held on 28, November 2001, although the contents have not been open to the public.

The CMR was grouped into three areas, regions with urbanized characteristics, regions with semi-urbanized characteristics, and regions with rural characteristics. The urbanized area extends along the north-south axes. In the CRMSP, it was commented that the urban-growth has a biased uneven development in terms of direction, which means that in some areas of CMR, the urbanization process has been quite rapid, and conversion of agricultural lands into urban uses have been quite extensive. On the other hand, in other areas, the urbanization process has been very slow, and there is no significant change in land use.

Urban agglomeration, which means towns expanding rapidly beyond their original administrative boundaries, is also identified in the analysis. The CRMSP recommended that twenty-eight urban centers be considered as the contiguous area.

The CMRSP advocates the concept of Protected Area Network for paddy land and wetland. Suitability for existing paddy land and wetland was evaluated based on a set of criteria. Lands evaluated as suitable for agriculture and wetland were incorporated into the protected area network. The protected area network envisages identifying land available for urban expansion and minimizing land speculation relating to paddy land and wetland.

2.4 Natural and Social Environment

2.4.1 General Environmental Conditions in the Study Area

Environmental features of the study area can be represented by studded marshes with connecting water systems in the urban area. The study area is located in a southwestern coastal area and belongs to the wet zone where much of Sri Lanka's biodiversity is concentrated. Lowlands, where most of the lands are abandoned paddy and vacant land, form marshes, especially the upper catchments of the basins. Among the marshes, protected areas in the study area such as Muthurajawela Marsh and Bellanwila-Attidiya Marsh are the best birding sites for endemic and migratory birds in Sri Lanka

In the Ja Ela Basin, the Muthurajawela Marsh (3,068 ha) extending southward from the Negombo Lagoon (3,164 ha) receives surface water in the basin through the Ja Ela and Dandungam Oya. The marsh also connects the Old Negombo Canal and Hamilton Canal flowing to the Kelani Ganga.

In the Kalu Oya Basin, the urbanized area is concentrated in the downstream area of the basin where road transportation has been developing while the upper catchment has not yet urbanized, partly extending abandoned paddy. Surface water from the Kalu Oya flows into the Kelani Ganga through the Old Negombo Canal.

In the Greater Colombo Basin, there are three main marshes: Kolonnawa, Heen and Kotte Marshes, which are known as the Colombo Flood Detention Areas. The marshes along with the Parliament Lake constitute the green belt linked by the canals. Beira Lake has received large volumes of urban pollutant and suffers from high eutrophication at the urban center.

In the Bolgoda Basin, the Bellanwila-Attidiya Marsh (372 ha) in the upper catchment of the Weras Ganga receives part of surface water from the surrounding urbanized area. The Weras Ganga flows down to North Bolgoda Lake, and then to Panadura

River and South Bolgoda Lake. At the west coast of the basin, the Lunawa Lake is located though it is said no aquatic fauna exist due to pollution.

2.4.2 Environmental Protected Area

An Asian Wetlands Inventory Project was carried out in the 1980s. In the Directory of Asian Wetlands (Scott, 1989), 41 wetlands of Sri Lanka have been listed. Based on the inventory, the legally constituted protected areas under the Fauna and Flora Protection Ordinance (FFPO) were subsequently listed including the following protected area located within or in the surrounds of the study area. The locations of environmental protected areas in the study area are shown in Figure 2.5.

1) Sri Jayawardenepura sanctuary: 449 ha of the sanctuary declared in 1985, where partial protection is enforced, i.e., locally, sustainable extractive uses are permitted;
2) Bellanwila - Attidiya Marsh: 372 ha of Wildlife Sanctuary declared in 1990 by the Department of Wildlife Conservation;
3) Muthurajawela Marsh and Negombo Lagoon complex: 1,285 ha of sanctuary declared in 1995/1996.

According to the FFPO, all wild animals are fully protected within the Sanctuary, while trees, other plants and habitats in general are only protected in the State lands. As most of the land in the Bellanwila-Attidiya Marsh is privately owned, legal control over the vegetation, i.e., land exploitation for development, in the majority of the marsh has not been implementable[1].

A list of 35 additional wetlands considered to be of national importance were prepared locally and includes Beira Lake, Bolgoda Lake, Colombo Breakwaters, and the Colombo Flood Detention Area.

The Environmental Management Strategy (EMS) for the urbanized area by UDA (1994) has estimated the total area of marshes in the urbanized area at nearly 4,000 ha, which includes the Muthurajawela Marsh in the Wattala Local Authority area with an area of 3,068 ha. Over 200 ha of marshy lands have been filled for urban and industrial infrastructure development. Little data is available on the present conditions of the marshes, except for Muthurajawela and Bellanwila-Attidiya Marsh. However, according to the field observation in the Study, the environmental conditions in the marshes are poor due to solid waste dumping, unauthorized settlement, unplanned reclamation and inflow of polluted water.

In the Muthurajawela Marsh and Negombo Lagoon complex, the Conservation Zone includes both the Negombo Lagoon and the northern part of the Muthurajawela

Marsh. The rest of the marsh is left as the Buffer Zone (middle part) and the Mixed Urban Development Zone (southern part - sand filled for an industrial zone).

The major lakes in the study area are Beira Lake, Parliament Lake, Bolgoda Lake, Lunawa Lake and Negombo Lagoon. The Beira Lake and Lunawa Lake are seriously polluted. Negombo Lagoon is still a very valuable eco-resource because of its rich aquatic life and its vegetation containing mangroves and sea grass. It is an important breeding ground for the local fisheries and an important economic resource because of its high fish yield. Lunawa Lake is now devoid of life due to pollution.

2.4.3 Water Pollution

Surface water pollution is the most serious issue among the environmental problems in the study area. Pollution of urban water bodies by domestic wastewater and industrial wastewater causes environmental problems as well as health hazards. Most of the surface waters of the urbanized area in the study area are polluted to some extent. The serious water pollution problems exist in the canals and lakes in the western part of the study area, including Colombo MC, Kolonnawa UC, Dehiwela - Mount Lavinia MC, and Moratuwa UC.

The main causes of surface water pollution are:

1) Discharge of urban drainage water mixed with waste of industrial and domestic origin to natural streams (This includes runoff from open markets and garbage dumps);
2) Unauthorized connections of domestic wastewater pipes into drainage canals;
3) Direct discharge of industrial wastewater into rivers, lakes, canals and lowlands;
4) Uncontrolled and illegal dumping of waste of industrial and domestic origin in waterways, embankments and lowlands;
5) Discharge of sewage into canal/surface water bodies mainly by shanty settlements along canals and around the lowlands such as marshes;
6) Insufficient maintenance and cleaning of watercourses and embankments resulting in siltation, blockage and aquatic plant growth.

The Colombo Municipal Council (CMC) area is served with a sewerage drainage system that consists of a raw sewage drainage system draining into the sea via two sea outfalls and a storm water drainage system discharging into the canals. Since their construction at the beginning of the century, very few improvements and extensions have been made despite the considerable development in housing and

[1] Wetland Site Report & Conservation Management Plan: Bellanwila- Attidiya Marsh, CEA/Euroconsult, 1993

industry. As a result, both systems are overloaded and in a poor state of repair and hence, lead to water pollution. Septic tanks and latrines that discharge effluents to soakage pits serve most of the houses around the lowlands. Overflow of septic tanks and ingress of sewerage into storm water drains is a common feature, mainly during heavy rains.

Beira Lake offers example of typical polluted urban water lakes. Eutrophication and blooming are major water polluting issues in water bodies like Beira Lake due to wastewater and nutrient rich substances. It is reported that the Lunawa Lake, which had a healthy aquatic ecosystem in the past, is now devoid of almost all aquatic life due to pollution.

The groundwater quality in the urbanized area in the study area is likely being adversely affected by the following factors:

1) Faecal contamination by seepage of domestic wastewater from sanitation facilities;
2) Chemical contamination by seepage of wastewater from industries and solid waste dumping sites;
3) Seawater intrusion into groundwater especially due to over-extraction from wells along the coast.

Regarding coastal water pollution, little data on the quality of the seawater are available. These waters receive liquid waste from Kelani Ganga, Beira Lake spillover, Wellawatta and Dehiwala Canals, Lunawa Lake and Bolgoda Lake, two sea outfalls of the CMC sewerage system at Mutwal and Wellawatta and some minor wastewater discharges from coastal communities. Colombo Harbor is also a source of coastal water pollution. In the near coast waters, fishing is of minor importance as most of the fishing is carried out offshore at the edge of the continental shell.

2.4.4 Poverty and Under-served Settlements

The measurement of the poverty situation in Sri Lanka varies according to the criteria and indicators used. According to the National Human Development Report (UNDP 1998), 27 % of the population of Sri Lanka is poor based on the Human Poverty Index. According to the Department of Census and Statistics (1995/96), 22.9 % of the population is poor, as indicated by the lower consumption poverty line (Rs. 791 per person per month), while 25.9 % is poor as indicated by the higher consumption poverty line (Rs. 950 per person per month). (ADB, 2001[2])

The urban settlements denied of basic urban service and having poor quality or socially unacceptable housing and living conditions can be referred to as Under-

Served Settlements (USS). The term "USS" is an expression of the physical condition of the housing and residential health, sanitation and other social conditions of the settlers, other than just an expression of income level since a large percentage of occupants in the USS earn reasonable incomes through the informal sector[3].

The crucial factor that separates these settlements from other urban settlements is not the level of income of the occupants but the poor level of infrastructure services in the settlements. The types of settlements classified as USS in the urban context are slums, shanty settlements, old low-income flats, relocated housing, old deteriorated quarters, unplanned permanent dwellings, walkup apartments and suburban housing estates.

The USS populations in the CMC and CMR in 1998 are shown below.

Population and USS in CMC and CMR Areas

Item	CMC (1)	Outside CMC (2)	Total of CMR (3)=(1)+(2)
Land Area	3,370 ha	392,990 ha	396,360 ha
Total Population (in 1996)	728,000	3,912,500	4,640,500
Population in USS (estimated in 1998)	363,000	419,895	783,000
USS Pop. as % of Total Population	50 %	11 %	17 %
Number of USS in 1998	1,506	656	2,160
Number of Housing Units in USS in 1998	66,021	83,979	150,000
Average Number of Housing Units per USS	44	128	70

Source: USIP Project Implementation Plan, The Plan (Vol. 2), 2000. (CSP of, 1998; CMRSP 1998; USIP Database 1999)

The Clean Settlements Project (CSP) identified about 390 ha of land classified as USS within the CMC area. Among all the types of the USS mentioned above, slums (71%) and shanties (12%) are the most significant categories in the number of the USS. In general, low-income inhabitants are concentrated in such settlements.

2.4.5 Community Inventory Survey

(1) Surveyed Communities

A Community Inventory Survey was conducted by subletting to a local consultant from November to December 2001. Objective of the survey was to identify socio-economic conditions of inhabitants that might be affected by the implementation of the projects proposed in the Study. The areas to be surveyed were flood-prone areas, low-income residential areas, and shanty areas of which information could be obtained from the relevant local authorities in the study area.

2 Perceptions of the Poor - Poverty Consultations in Four Districts in Sri Lanka, ADB, 2001

3 Clean Settlement Program, Project Preparation Report 3, Survey of Under-served Settlements, Ministry of Housing and Urban Development, 1998.

In the survey, Grama Niladhari (GN) division was used as the smallest unit for collection of data on a community. Based on the survey objective, 217 GN divisions that have been affected by flood or were low-income were identified for the survey, which is 17% of the total 1,274 GN divisions in the study area as shown below and in Figure 2.6. The number of surveyed GN divisions by type of waters nearby is shown below.

Number of GN Divisions Covered under the Community Inventory Survey

Basin	GN Divisions in the Basin	GN Divisions Surveyed	Percentage
Ja Ela	208	26	13%
Kalu Oya	178	28	16%
Greater Colombo	237	61	26%
Bolgoda	651	102	16%
Total	1,274	217	17%

Source: Community Inventory Survey, JICA Study Team, 2002 (Data from DS offices)

Number of GN Divisions by Type of Waters Nearby

Basin	GN Divisions Surveyed	River/Stream		Reservoir/Pond		Wetland	
Ja Ela	26	26	100%	0	0%	2	8%
Kalu Oya	28	28	100%	11	39%	5	18%
Greater Colombo	61	57	93%	0	0%	36	59%
Bolgoda	102	100	98%	4	4%	67	66%
Total	217	211	97%	15	7%	110	51%

Source: Community Inventory Survey, JICA Study Team, 2002 (Data from GN offices)

Among the GN divisions surveyed in the Community Inventory Survey, GN divisions which are located in and around the proposed project sites were identified and some selected surveyed data items are summarized by each proposed plan as shown below and in Table 2.6.

(2) Communities Concerned with Storm Water Drainage Plan

Total population of the surveyed GN divisions is about one million. That is 27 % of the total population in the four basins as shown below. This figure indicates that about one million people are living in the settlements affected by flood and/or under low-income, and half of them live in the Greater Colombo basin.

In total, 30 % of the households are classified poor[4] (62,800 households). Among the four basins, the number of poor households is larger in the Colombo basin (26,900 households) and Bolgoda basin (22,300 households).

[4] In the Community Inventory Survey, information on the poor households was collected based on the GNs' long-term experience with the following points: a) Only the chief householder is employed and even his/her employment does not generate adequate income for living, b) The house is small in size and the roof is not permanent, and c) Family size is large and many are dependent on the chief householder.

The number of houses affected by flood in the surveyed GN divisions is 27,600 in total while 14,600 houses are located in the Greater Colombo basin.

Potential Population Directly Affected by the Proposed Flood Control Measures

(Unit: household (person))

Category	Total		Ja Ela		Kalu Oya		Greater Colombo		Bolgoda	
Total HH/Population Affected	59,978 (311,983)	100% (100%)	6,101 (29,803)	10% (10%)	12,494 (81,426)	21% (26%)	20,566 (96,028)	34% (31%)	20,817 (104,726)	35% (34%)
Illegal Occupants	5,569 (28,290)	9% (9%)	122 (487)	2% (2%)	1,816 (9,351)	15% (11%)	2,485 (12,090)	12% (13%)	1,146 (6,362)	6% (6%)
Under Poverty Line	18,553 (89,985)	31% (29%)	2,568 (12,275)	42% (41%)	4,011 (21,631)	32% (27%)	4,541 (21,384)	22% (22%)	7,433 (34,695)	36% (33%)
Houses Located in Riverside Land	3,533	6%	573	9%	728	6%	1,060	5%	1,172	6%
Houses Frequently Inundated in Storm Season	8,807	15%	1,244	20%	3,007	24%	2,530	12%	2,026	10%

Note: The figures in % in the table mean the percentage to total households (persons) in each basin.
Source: Community Inventory Survey, JICA Study Team, 2002 (Data from GN offices)

Total number of households (HHs) living in and around the proposed project sites for all projects of four basins are about 60,000 HHs (312,000 people). This would be the potential population directly affected by the proposed projects.

Some 5,600 HHs (28,300 people) among the above population are illegal occupants who do not have any land tenure. The number of households who are under the poverty line is 18,600 HHs (31% of total). The Bolgoda Basin Storm Water Drainage Plan has the largest number of households who are under the poverty line at 7,400 HHs.

Houses located on riverside land are counted as 3,500 houses in total of the four basins, which might be relocated by the proposed projects in connection with the land acquisition and regulation of land use.

The number of houses frequently inundated in the storm season is 8,800 houses, which might be a part of the potential direct beneficiaries of the proposed projects in relation to improvement of storm water drainage, and upgrading of storm water-related infrastructure on-site and off-site.

2.5 Storm Water Drainage

2.5.1 Present Drainage Systems

(1) Attanagalu Oya and Ja Ela (Figure 2.7)

The Ja Ela basin with a drainage area of 860 km^2 is located between the Maha Oya basin to the north and the Kelani Ganga basin to the south. The basin has a complicated waterway system with interconnections and branches in the downstream reaches.

The Attanagalu Oya originates from the hills with the highest elevation of 300 m above MSL at the eastern boundary of the basin, located some 40 km away from the sea. From Gampaha to Ekala, the Attanagalu Oya runs through flat land along the A33 Road in parallel with the Uruwal Oya, which drains the southern part of the basin. These two streams interconnect at some locations in this area.

Around Ekala, the two main streams branch in different directions. One stream goes to the north as the Dandugam Oya. The other is a man-made canal called the Ja Ela flowing to the west.

The Dandugam Oya turns to the south near the International Airport after joining the two tributaries, the Mapalam Oya and Kimbulapitiya Oya draining the northern part of the basin. The river crosses the Negombo Road and runs through the northern part of the Muthurajawela Marsh, then eventually pours into the Negombo Lagoon.

The Ja Ela flows down a deep-cut section before crossing the Negombo Road and goes through the Muthurajawela Marsh, then pours into the Negombo Lagoon.

These two streams are also interconnected through the Old Negombo Canal, which branches from the Dandugam Oya in the north and runs along the seaward side of the Negombo Road down to the Kelani Ganga to the south.

(2) Kalu Oya (Figure 2.8)

The Kalu Oya basin is a relatively small catchment located between the Ja Ela basin to the north and the Kelani Ganga basin to the south. Topography of the basin is flat, as a whole, with a maximum elevation of 40 m above MSL at the northeastern boundary. The stream originates in the northeastern part of the basin some 15 km away from the sea. Draining the semi-urbanized areas in the basin, the main stream flows crossing the Kandy Road and Negombo Road afterwards, then joins the Old Negombo Canal.

Because of the low lying topography in the basin, marsh lands are formed along the main stream and tributaries. The marshlands spread widely in Pinammeda, Horape and Mabole areas located along the reaches between the Kandy Road and Negombo Road. The ground elevation in these marshlands is less than 1 m above MSL.

The Kalu Oya is the only major drainage for the basin, crossing the Negombo Road of which the surface elevation is more than 5 m higher than the marshlands. The drainage of the Kalu Oya is affected by the water level of the Kelani Ganga connecting through the Old Negombo Canal. This difficulty of drainage is a main cause of the inundation in the basin.

(3) Hamilton Canal and Old Negombo Canal (Figure 2.9)

The Muthurajawela Mash, a wetland of vast extent, lies along the western coast between the Negombo Lagoon and Kelani Ganga. The Marsh, with an area of 3,068 ha, is separated from the sea by a sand barrier along the coast. There are two major canals connecting the Negombo Lagoon with the Kelani Ganga, which were constructed in colonial time for navigation purposes.

The Hamilton Canal runs along the coast north to south with a length of 15 km. This canal is well maintained with a road running alongside and is still utilized as a navigation waterway for fishery boats.

The Old Negombo Canal originally connected the Dandugam Oya with Kelani Ganga but is separated into two sections by a bund constructed along the southern bank of Ja Ela. This canal was also constructed for the purpose of navigation or irrigation for paddy cultivation envisaged in the past but is no longer utilized for such purposes at present.

(4) Kelani Ganga (Figure 2.10)

The Kelani Ganga drains a basin area of 2,292 km^2 originating in the central highlands of the country with a highest elevation of 1,500 m. The river flows down the western slopes of the central highlands, collecting water from its tributaries. The main stream of the river reaches the boundary of the study area around Biyagama and runs through the flatland, then eventually pours into the Indian Ocean near Crow Island in the north of Colombo. The length of the river is 145 km from its origin to estuary. Within the study area, the length of the main stream section from Biyagama to Crow Island is around 20 km with a gradient of 1/6,000.

(5) Greater Colombo (Figure 2.11)

According to the GCFC&EIP, the Greater Colombo area is defined as the area covering the local authority areas of Colombo MC, Sri Jayawardenapura Kotte MC, Kolonnawa MC, Dehiwela - Mount Lavinia MC, and Moratuwa MC. The total area of the Greater Colombo area is 165 km^2.

In view of drainage systems, the Greater Colombo area is composed of a major drainage basin and other small catchments. The major drainage basin covers an area of 85 km^2 bounded by Nugegoda - High Level Road to the south, Talangama - Hokandara watershed to the east, Kelani flood bunds to the north, and elevated urbanized areas of Colombo along the coast to the west. The streams collect runoff in the upstream catchment and flow into Parliament Lake. After Parliament Lake, the urbanized areas are drained by the canal system improved by the GCFC&EIP Phase I. Runoff in the basin is discharged through the North Lock Gate to the Kelani Ganga and the Mutwal Tunnel to the sea in the north as well as the Wellawatta and Dehiwala sea outfalls in the south.

There are lowlands with a ground elevation lower than 1 m above MSL. The majority of lowlands spread around Parliament Lake, Heen Ela, Kolonnawa Ela, and Kotte Ela and function as storm water retention areas in the major drainage basin. The total area of these lowlands was estimated at 686 ha in the study stage of the GCFC&EIP Phase I but would be decreasing due to land filling for development.

The rest of the Greater Colombo area mainly consists of small drainage basins along the coast or belongs to the Bolgoda basin.

(6) Bolgoda Lake (Figure 2.12)

The Bolgoda basin, located between the Kelani Ganga basin to the north and the Kalu Ganga basin to the south, has a drainage area of 394 km^2. In the upper catchment area, the streams originate from the hills with a highest elevation of 20 m above MSL at the eastern boundary of the basin. The lower catchment area lies in the lowlands widely spreading along the coast with water surfaces and surrounding marshlands. There is a unique water system in the basin comprising the two major lakes with incoming and outgoing waterways.

The Weras Ganga is one of the major water waterways continuing from Bolgoda Lake North. The Weras Ganga collects runoff in the northern part of the basin. The drainage area of the Weras Ganga is the most developed area of the basin covering the urban areas of Nugegoda, Dehiwala - Mount Lavinia, Moratuwa, Maharagama and Kesbewa. Marsh lands spread along the Weras Ganga and incoming streams, which are partly subject to land fillings for development.

North Bolgoda Lake, with a water surface area of 760 ha at normal water level of 0.07 m above MSL, is located connecting with the southern end of the Weras Ganga. The lake collects runoff from the Weras Ganga catchment in the north and the Maha Oya catchment in the east through the Bolgoda Ganga. Incoming runoff to the lake is finally drained through the Panadura Ganga, which is the largest outfall to the sea.

The Bolgoda Ganga is a waterway interconnecting the North and South Bolgoda Lakes. The length of the waterway is around 12 km between the two lakes. The waterway remains almost natural and the areas along the waterway have not been developed because of the difficulty of access through the wetlands.

South Bolgoda Lake has a water surface area of 340 ha at normal water level of 0.10 m above MSL and still remains natural as a whole. Collecting incoming runoff mainly from the Bolgoda Ganga, the lake would drain runoff southwards through the two canals called Kepu Ela and Aluth Ela connecting to the Kalu Ganga but flow directions of both canals would depend on the water level of the Kalu Ganga. There is another canal named Talpitiya Ela connecting the lake with the sea but its sea outfall is closed by sandbar almost throughout the year.

The Maha Oya and Panape Ela are the major streams draining the upper catchment, almost corresponding to the eastern half of the basin.

The Bolgoda basin can be broadly classified into three regions in the light of the current development and land use. The northern region, in and around the Weras Ganga catchment, is covered by the highly urbanized areas of Nugegoda, Dehiwela-Mount Lavinia, Moratuwa and Kesbewa. The southern region, covering the southern half of the basin, remains rural as a whole, such as Panadura, Kalutara, Bandaragama and Horana areas. The northeastern region around Homagama occupying the upper catchment of the Maha Oya is semi-urbanized with a mixture of urban centers and rural areas.

2.5.2 Storm Water Drainage Project in the Past

(1) Kelani Ganga Flood Protection Scheme

To protect the downstream basin areas from the critical floods, a series of flood bunds (dikes) were constructed since 1924 and strengthened thereafter. The flood bunds along the southern bank of the Kelani Ganga were constructed to prevent the city of Colombo from flooding. On the other hand, the bund levels along the northern bank are kept lower than the southern bank. The protection level of the northern bank is for a 50-year return period flood. In the case of a flood event exceeding the protection level, flooding would overtop the northern bank but the southern bank is still offers protection. The city of Colombo located on the southern bank of the Kelani Ganga is therefore protected against 500-year flood events.

(2) New Capital City Drainage Project Feasibility Study

This study was carried out in 1981 and is called the ‘Samitar Study’. The objective of this study was to provide improved storm water drainage for Colombo and its environs, particularly in the area of the new capital city of Sri Jayawardenapura Kotte, where the present Parliament Complex is located. The proposals of the study comprise inflow and outflow regulation for the area of the new capital city. The planning scale for the proposed improvement was a 200-year return period flood.

The Samitar Study covered the corresponding basin area of the Greater Colombo basin and established the basic concept for the improvement of storm water drainage in the basin. Of the proposals of the Samitar Study, the improvement of existing canal systems were materialized by the succeeding studies and implemented afterwards as described hereunder.

(3) Greater Colombo Flood Control and Environment Improvement Project Phase I (GCFC&EIP Phase I, Figure 2.13)

The feasibility study was carried out in 1988 as “The Study of the Canal and Drainage System in Colombo” under NWSDB. The review and update of the study and detailed design were afterwards conducted in 1992 as “The Greater Colombo Canal and Drainage System Rehabilitation Project” under the Sri Lanka Land Reclamation and Development Corporation (SLLRDC). The project was implemented from 1992 to 1998 and called the Greater Colombo Flood Control and Environment Improvement Project Phase I (GCFC&EIP Phase I). The major drainage canals improved during the Phase I project are 44 km in the total length including 24 stretches as shown in Table 2.7.

(4) Urban Drainage in Greater Colombo Area

In 1993, SLLRDC conducted a feasibility study for the Greater Colombo area (Colombo and its environs, consisting of five MCs/UCs), aimed at establishing an overall storm water drainage improvement plan, including the flood damage survey in the area.

Based on that feasibility study in 1993, the GCFC&EIP Phase II was taken up for implementation. This project is to prevent localized flooding in five urgent areas identified within the Colombo MC. In addition, the Phase II work included the Review of F/S carried out by SLLRDC in 1993. The Review of F/S covered 19 storm water drainage schemes in the CMC area, five schemes in DMMC and MMC areas and some other small scale pump drainage schemes in the areas of Kolonnawa UC and Kotte MC.

Five schemes in DMMC and MMC areas, namely Kawdana, Attidiya, Mahakuburuowita, Lunawa North and Lunawa South, were reviewed as priority projects, of which two schemes, Kawdana and Attidiya, were taken up for detailed design under the Phase II of GCFC&EIP and the construction work is now in progress under the Phase III of GCFC&EIP.

(5) Greater Colombo Flood Control and Environment Improvement Project Phase II (GCFC&EIP Phase II, Figure 2.13)

To alleviate the major local floods (inundation) habitually observed in the Colombo Municipal Council (CMC), GCFC&EIP Phase II was implemented from 1998 to 2001 by SLLRDC. The project includes the following five drainage schemes located in the highly built-up area inside the CMC and the total coverage area is around 560 ha.

1) Torrington West Scheme
2) Dematagoda Scheme
3) St. Sebastian-2 Scheme
4) Serpentine Canal Scheme
5) Unity Place Scheme

These schemes were recognized as the most urgent schemes to resolve the fundamental problems on the storm water drainage system in each drainage area, which were confirmed through the investigations of the drainage system and inundation surveys during the Review of F/S. The project includes construction of trunk drains including underground pipes/culverts under the roads and rehabilitation of existing open channels. The total length of drainage channels improved in this project is around 7 km. All these trunk drains were connected to the main canals improved under the GCFC&EIP Phase I or directly to the sea. The principal features of each scheme are summarized in Table 2.8.

2.5.3 On-going Drainage Project and Existing Plan

(1) Greater Colombo Flood Control and Environment Improvement Project Phase III (GCFC&EIP Phase III, Figure 2.13)

A large part of the Dehiwala - Mount Lavinia Municipal Council (DMMC) area is already urbanized but a satisfactory storm water drainage system has not been provided. Unlike the CMC area, there is no systematic drainage network in these areas. In general, storm water drainage in these areas consists of natural streams as trunk drains partly canalized with masonry or concrete works and smaller open drains collecting and leading storm water to the trunk drains. It appears that such drains have been constructed part-by-part without a proper engineering design processes.

In order to improve the drainage condition in the urban area to the south of CMC area, the following 5 storm water drainage improvement schemes were proposed by SLLRDC. These schemes were designed on the basis of a rainstorm event with a 2-year return period to alleviate the frequent inundation.

1) Mahakunbruowita Scheme
2) Kawdana Scheme
3) Attidiya Scheme
4) Lunawa Lake North Scheme
5) Lunawa Lake South Scheme

Out of the 5 schemes, the Kawdana and Attidiya schemes are being implemented as the GCFC&EIP Phase III project by SLLRDC. The total coverage area of the two schemes is 522 ha. A storm water drainage system including trunk drain channels, secondary drains and roadside ditches is to be constructed for the entire area. The total length of all the drain channels to be constructed is around 40 km. The principal features of Phase III Schemes are summarized in Table 2.9.

(2) Lunawa Lake Environment Improvement and Community Development Project (Figure 2.13)

The project area covers the Lunawa Lake basin with a drainage area of 615 ha including the two major drainage areas, namely, Lunawa Lake North (353 ha) and Lunawa Lake South (262 ha) extending over DMMC and MMC areas.

This project is composed of two major components. One is storm water drainage improvement with resettlement site construction and procurement of O&M equipment. In this component, two drainage schemes, that is, the Lunawa Lake North scheme and the Lunawa Lake South scheme are to be implemented. These schemes were identified and studied together with the two drainage schemes that are now being implemented under the GCFC&EIP Phase III. The construction work consists mainly of improvement of existing trunk drains and secondary drains. Other than the trunk and secondary drains, part of the tertiary drains (roadside drains) are also to be improved. The total length of drains to be improved under this project is around 87 km.

The community development component envisages a community's contribution to sustain an effective drainage-based flood alleviation program, which aims to empower the community as a self-help and voluntary organization in both terms of replicating environmental conservation practices and upgrading their living standard on a sustainable basis.

Two groups of communities are subject to upgrading under the project, i.e., about 450 families to be relocated in connection with the implementation of drainage improvement works and accommodated in four resettlement sites, and 441 families in 11 under-served communities affected by inundation. The principal features of the project are summarized in Table 2.10.

2.5.4 Flood Damage Survey

(1) General

The flood damage survey was carried out to clarify flooding situations in the study area. The preliminary information of flooding situations was collected from the local authorities at first to identify locations of inundation areas. The questionnaire surveys were conducted thereafter at the locations identified. These works were done by the local consultant on subcontract basis under supervision of the study team for the period from November 2001 to February 2002.

The preliminary information of areas prone to habitual inundation were collected from the 25 local authorities such as Municipal Council (MC), Urban Council (UC), and Pradeshiya Sabha (PS) relevant to the study area. In addition to the local authorities, the information was also collected from the other authorities or agencies such as the Urban Development Authority (UDA), the Irrigation Department, and Divisional Secretary Offices.

Based on the collected information, 394 locations of inundation areas were identified within the study area as shown in Figure 2.14. Inundation areas by district are 60 locations in Ja Ela basin (accounting for 15% of the total number), 45 in Kalu Oya basin (11%), and 148 in Greater Colombo basin (38%) and 141 in Bolgoda basin (36%).

The questionnaire survey covered all the inundation areas identified within the study area. Interviews to local residents were carried out using the questionnaire for the respective locations of the inundation areas. Samples for each location were 2 or 3 in general and the total number of samples resulted in 1008. Samples by district are 129 samples in Ja Ela basin (accounting for 13% of the total number), 104 in Kalu Oya basin (26%), and 441 in Greater Colombo basin (44%) and 334 in Bolgoda basin (33%).

Number of Identified Inundation Areas

Basin	No. of Inundation Areas	No. of Questionnaires
Ja Ela	60	129
Kalu Oya *1	45	104
Greater Colombo *2	148	441
Bolgoda *3	141	334
Study Area	394	1008

Source: Flood Damage Survey in 2001, JICA Study Team

Note:
1) The number of inundation areas in the Kalu Oya basin covers those in the Kalu Oya basin and Kelani Ganga right bank.
2) The number of inundation areas in the Greater Colombo basin covers those in the Greater Colombo basin, Kelani Ganga left bank and neighboring coastal area.
3) The number of inundation areas in the Greater Colombo basin covers those in the Bolgoda basin and neighboring coastal area

(2) Frequency of Inundation

Frequency of inundation outside house/building ranges mainly from 2 to 6 times a year, accounting for 81% of the samples. An averaged frequency of inundation outside house is estimated at 4.3 times a year. The frequency of inundation inside house/building indicates that 72% represent frequency of 3 times a year or less. An averaged frequency of inundation inside house is estimated at 3.1 times a year.

Frequency of Inundation in the Study Area

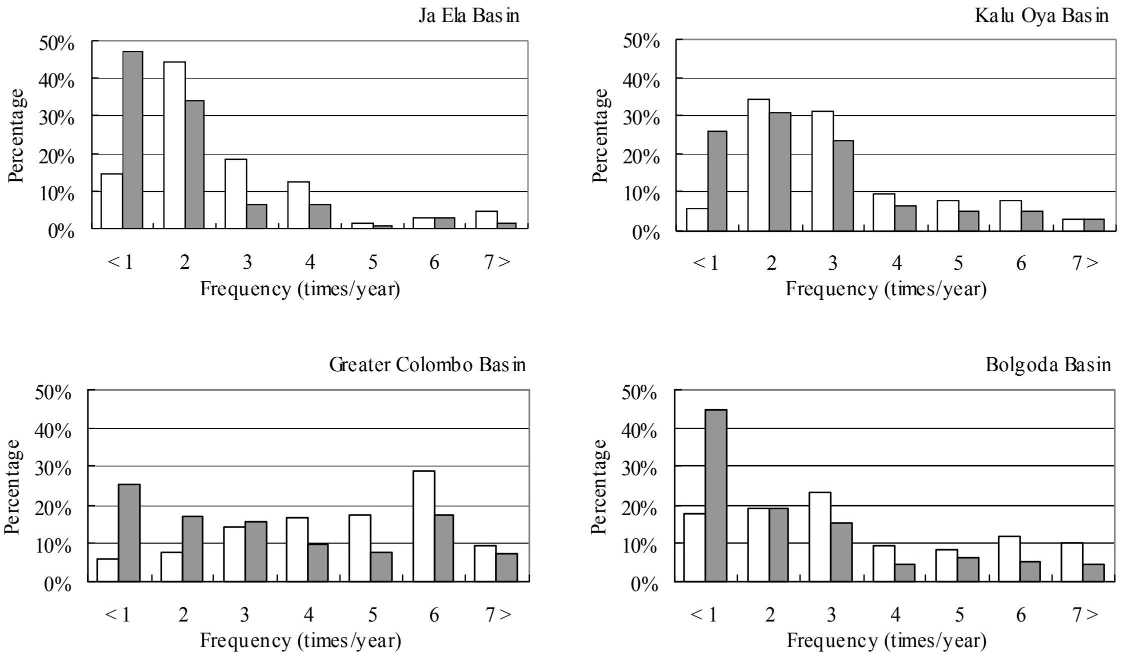
Inundation	Frequency (times/year) and Percentage						
	1 or Less	2	3	4	5	6	7 or More
Outside house/building	11%	19%	20%	13%	11%	18%	8%
Inside house/building	35%	22%	15%	7%	6%	10%	5%

Source: Flood Damage Survey in 2001, JICA Study Team

Frequency of Inundation by Basin (times/year)

Inundation	Ja Ela	Kalu Oya	Greater Colombo	Bolgoda	Study Area
Outside house/building	2.9	3.3	5.0	4.1	4.3
Inside house/building	1.7	2.6	3.8	2.9	3.1

Source: Flood Damage Survey in 2001, JICA Study Team



Note: Inundation Outside House/Building Inundation Inside House/Building

(3) Duration of Inundation

Duration of average inundation varies mainly within 2 days representing 69% of the samples. Duration within 2 days is also dominant with a rate of 52% in the case of maximum inundation but the rates for longer duration tend to increase, compared with average inundation. Duration of inundation indicates different characteristics by basin. Duration of 7 days or more is dominant in the Ja Ela basin and Kalu Oya basin and implies the difficulty of natural drainage in marsh and surrounding lowland in these basins. The majority of duration is 1 day or less in the Greater Colombo basin and Bolgoda basin, reflecting the characteristics of inundation in urbanized areas.

Duration of Inundation in the Study Area

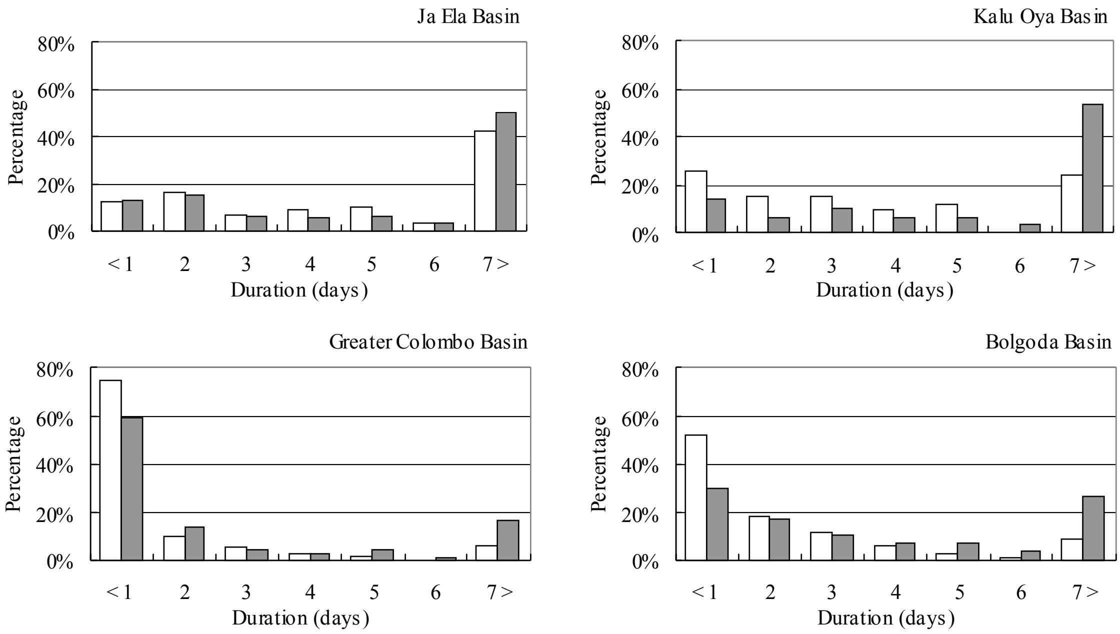
Inundation	Duration (days) and Percentage						
	1 or Less	2	3	4	5	6	7 or More
Average	55%	14%	9%	5%	4%	1%	13%
Maximum	38%	14%	7%	5%	5%	2%	28%

Source: Flood Damage Survey in 2001, JICA Study Team

Duration of Inundation by Basin (days)

Inundation	Ja Ela	Kalu Oya	Greater Colombo	Bolgoda	Study Area
Average	5.7	5.1	1.4	2.6	2.7
Maximum	9.3	9.5	3.1	5.2	5.3

Source: Flood Damage Survey in 2001, JICA Study Team



Note: Duration of Average Inundation Duration of Maximum Inundation

2.5.5 Existing Problems on Storm Water Drainage

(1) Cause of Flooding

Based on the natural characteristics of present drainage systems and the results of flood damage survey, the major causes of flooding in the respective basins are classified into the followings:

1) Ja Ela basin
   - Overflow from main streams such as Attanagalu Oya, Urwal Oya, Dandugam Oya and Ja Ela
   - Natural drainage difficulty in lowland surrounding Muthurajawela Marsh
   - Lack of storm water drainage system for draining storm water runoff to the main streams or Muthurajawela Marsh
2) Kalu Oya basin and Kelani Ganga right bank
   - Natural drainage difficulty from Kalu Oya and Old Negombo Canal to Kelani Ganga
   - Lack of storm water drainage system for draining storm water runoff to the main streams such as Kalu Oya and Old Negombo Canal
   - Decrease of marsh and surrounding lowland functioning as storm water retention area due to land filling
3) Greater Colombo Basin and Kelani Ganga left bank
   - Deterioration and under-capacity of existing urban drainage sytem
   - Uncontrolled urbanization of unprotected area under the Kelani Ganga Flood Protection Scheme
4) Bolgoda Basin
   - Lack of storm water drainage system for draining storm water runoff to the main streams
   - Natural drainage difficulty in lowland surrounding the downstream water system

(2) Estimated Inundation Area and Flood Damage

Based on the results of the inundation analysis and assessment of direct and indirect damages, the amount of annual damage under the present condition is estimated at Rs. 1,757 million/year for the entire study area.

Estimated Flood Damage in the Study Area

Sub-basin	Estimated Extent of Inundation Area by Return Period (ha)					Annual Damage (million Rs.)
	2-year	5-year	10-year	25-year	50-year	
Ja Ela	1,113	1,609	1,938	2,755	3,390	509
Kalu Oya	283	384	449	496	558	329
Greater Colombo	153	288	408	581	774	549
Bolgoda	2,419	2,929	3,278	3,645	3,913	370
Study Area	3,968	5,210	6,073	7,477	8,635	1,757

2.6 Outfall Treatment

2.6.1 Present Condition of Outfalls

The study area is broadly divided into four basins, namely Ja Ela basin, Kalu Oya basin, Greater Colombo basin and Bolgoda basin. There have been flood inundation problems because of mainly insufficient flow capacity and partly clogging of outfalls by sand bar. There are 9 major outfalls to the sea in the study area as shown in Figure 2.15. The present conditions of the sea outfalls are described below:

(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.

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.

Negombo Lagoon Outfall

(2) Kelani Ganga Outfall

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.

Kelani Ganga Outfall

(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.

(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. Unity Place outfall 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.

Unity Place Outfall

As the seabed profile is steep on the northward coast of Wellawatta outfall, 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.

(5) Wellawatta Outfall

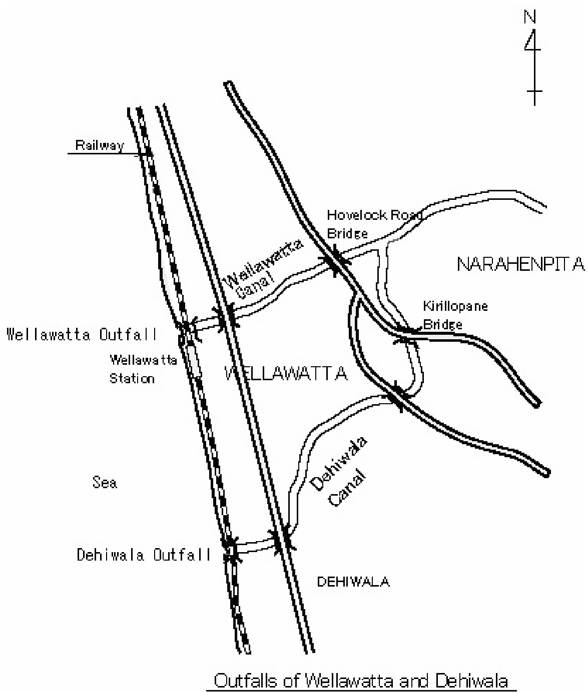
Two groynes about 30 m long and up to depth of about 1.0 m below MSL have been constructed at Wellawatta outfall. After the construction of Dehiwala outfall, the groyne at Wellawatta was modified to an L-shape.

Wellawatta Outfall

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. 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.

Before the construction of groyne at Dehiwala outfall in December 2001, the outfall at Wellawatta had not been clogged for a long time.



Locations of Wellawatta and Dehiwala Outfalls

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.

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.

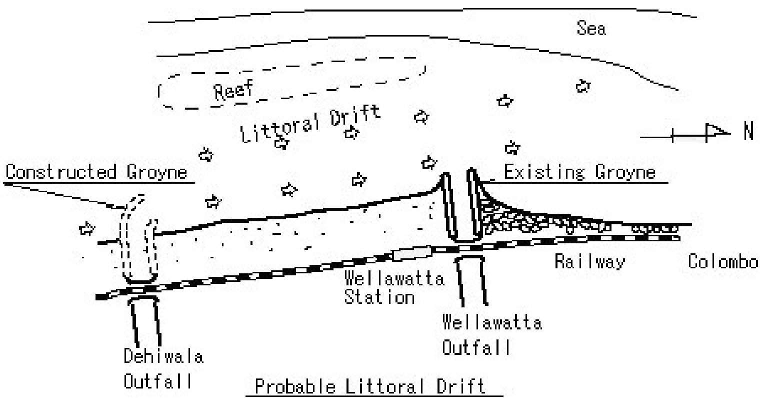
(6) Dehiwala Outfall

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.

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.

The construction of the groyne at Dehiwala outfall was proposed in the study of 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 groyne extends to a depth of about 1.0 m below MSL. 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.

Dehiwala Outfall



Probable Littoral Drift around Dehiwala Outfall

(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.

Lunawa Lake Outfall

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.

(8) Panadura 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.

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.

Panadura Outfall

Though the northern beach of the Panadura outfall is erosive, there exists a sand beach. The source of sedimentation may be Panadura River. A large part of the littoral drift near the shoreline from the south might be trapped at the groyne.

(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.

Talpitiya Outfall

The littoral drift passes to north across the outfall. South Bolgoda Lake is connected to the sea through the Kalu Ganga and does not have a clogging problem.

2.6.2 Studies in the Past

Several studies on the sea outfalls around the present study area have been carried out so far. Those studies are outlined as follows:

(1) Master Plan - Coastal Erosion Management (Volume 4: Southwest Coast), by Coast Conservation Department and DANIDA/DHI, February 1986

Investigation was carried out for the southwest coast of Sri Lanka from Kelani Ganga to east of Galle (155 km long) and a medium and long term coast erosion management master plan was proposed. This master plan presented a coast erosion tendency map shown in Figure 2.16. As the map was prepared based on the interview, the study proposed necessity of more detailed investigation. The study proposed the following actions against erosion.

1) Coast around Colombo
   - Continuation of development of hinterland in the north of Colombo
   - Construction of railway or road along the coast from Colombo to Mt. Lavinia
2) Coast around Kalutara
   - Construction of coast revetment against local erosion
   - Long term monitoring of sand beach between Moganna Head and Panadura.

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

This study aimed at proposing improvement of the canal and drainage system in Colombo, but it proposed the following actions on maintenance of the Wellawatta and Dehiwala outfalls.

1) Temporary excavation of outfalls and study on dimensions of the groins
2) Improvement of existing groins of the Wellawatta outfall
3) Construction of new groins for Dehiwala outfall

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

The beach protection in front of Pegasus Reef Hotel, 2.5 km north from the Kelani River, was planned. The protection is beach nourishment of about 145 m between two groins.

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

In the study, wave height, wave period, wave direction, etc. were observed by using buoy at the point 8 km offshore from Galle for three and half years from February 1989 to August 1992. Based on the data obtained, wave characteristics of the southwest coast of Sri Lanka were analyzed.

(5) Investigation for Panadura Anchorage, ADB Fisheries Sector Project, Project Implementation Unit, Ceylon Fishery Harbours Corporation, by LHI, April 1997

In order to prepare the improve plan of the Panadura harbour, coastal field investigation and numerical model analysis were carried out. The proposal consists of removal of rock outcrop, dredging and construction of groin.

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

Construction of a groin was proposed on the basis of numerical model analysis for the outfall of Dehiwala canal. The layout of groin was determined not so as to completely cut off the littoral drift. This proposal was made on condition that the protection measures against coast erosion between Dehiwala and Wellawatta are provided with the groins.

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

Based on the proposal made in the study in June 1997, the influence by groin to the coast between Dehiwala and Wellawatta was studied. Construction of a L-shaped groin at Dehiwala outfall was proposed aiming at trapping the drift and nourishing the coast.

(8) Improvement of Lunawa Sea Outfall, SLLRDC, by LHI, January 2001

Due to deterioration of water quality of the Lunawa Lake, a permanent measure to keep the outfall open was needed although the river mouth clogging is being removed by manual excavation. In order to prepare the improvement plan, topographic survey and sounding survey were carried out around the outfall. Based on the data, the following ideas were proposed. SLLRDC has a plan to carry out the further detail study.

1) Periodical excavation of the outfall by machine
2) Maintenance of the outfall by groin
3) Drainage of lake water by pump
4) Sand bypass by sand pump

2.7 Institution and Legislation

2.7.1 Present Institutional Setting Related to Storm Water Drainage Works

The main agencies related to the storm water drainage works including planning, approval, implementation and O&M are shown below. The demarcation of their current responsibility is indicated in Table 2.11.

(1) Executing Agencies

1) Sri Lanka Land Reclamation and Development Corporation (Ministry of Housing & Plantation Infrastructure)

Colombo District (Low-lying Area) Reclamation and Development Board, the former Sri Lanka Reclamation and Development Corporation, was established in 1968 by Act No. 15 of 1968. The objectives of the Board were 1) to reclaim and develop every reclamation and development area declared by the Minister, which included lowland, marshy, waste or swampy areas and 2) to have the custody, management and control of lands comprising such areas.[5]

General powers of the Board include 1) to acquire, hold or take on lease any property, or to mortgage, pledge, sell or otherwise dispose of any property, 2) to undertake the preparation and execution of development schemes in the areas, 3) to cause the construction of roads in the areas, and 4) to cause the construction of works for the provision of public services in the areas including surface water drainage, sewerage and disposal of sewage, lighting and water supply.

The Act was subsequently amended in 1976, which allows the Board to sell reclaimed lands. Further amendments were done in 1982 allowing acquisition and vesting of lowlands in any part of the country. The name of the Board changed to the present one at that time.

The canals and waterways in and around Colombo were handed over from the Irrigation Department to SLLRDC for maintenance in 1979. Since then, SLLRDC has been expanding its responsibilities for canal and waterway maintenance. The present major maintenance activities include Hamilton, Dutch, St. Sebastian, Dematagoda, Diyamanua Oya, Kirillapone and Dehiwara Canals and Diyawanna Lake.

SLLRDC has 1,696 staff including 619 casual employees. The permanent staff consists of 132 executive and managerial staff, 105 supervising staff, 179 clerical staff, 88 secretaries and 573 operators and mechanics. Canal Development & Maintenance Division has responsibility for maintenance of canals, having a workshop with 355 staff and relevant heavy equipment and machinery.

[5] Colombo District (Low-lying Areas) Reclamation and Development Board Act No. 15 of 1968

2) Irrigation Department (Ministry of Irrigation and Water Management) and Provincial Irrigation Department (Western Provincial Council)

IRD is the old organization and no acts exist for its establishment. The relevant statutes describing responsibilities and powers of IRD are the Irrigation Ordinance No. 48 of 1968[6] and the Flood Protection Ordinance No. 4 of 1924[7]. IRD is responsible to undertake irrigation and drainage works, conservation of catchments of rivers and major reservoirs and flood protection for the area declared by IRD.

IRD is, in principal, responsible for inter-provincial irrigation schemes, whilst the Provincial Irrigation Departments are responsible for provincial irrigation schemes.

Waterways can be grouped into three categories by objectives, 1) irrigation schemes, 2) flood protection and drainage schemes and 3) drainage and salt-water exclusion schemes. IRD is responsible for major irrigation schemes (over than 1,000 acres) and medium schemes (200 to 1,000 acres), whilst the Provincial Irrigation Departments or the Agrarian Development Department is responsible for minor schemes (less than 200 acres). Flood protection and drainage schemes and drainage and salt-water exclusion schemes can be handled by either IRD or the Provincial Irrigation Departments, based on the principal above.

IRD has 5,000 employees and is operating the Irrigation Training Institute at Galgamowa for all staff of irrigation related organizations including local authorities, NGOs, private companies and farmers.

(2) Agencies Responsible for Land Use Plan and Regulation

1) Urban Development Authority (Ministry of Urban Public Utilities)

The Urban Development Authority Law No. 41 of 1978 provides for the establishment of UDA to permit integrated planning and implementation of economic, social and physical development of urban development areas in the country, which are specific areas declared by the Ministry.

UDA is vested with strong powers to execute, regulate and control development plans in urban development areas, which includes 1) to formulate and implement an urban land use policy, 2) to develop environmental standards and

6 This Ordinance provides for the charging of irrigation rates, constitution of district agricultural committees and construction and maintenance of irrigation works.

7 This Ordinance enables the declaration of any area in Sri Lanka to be a flood area for the protection of such areas subject to damage from floods.

prepare schemes for environmental improvements, 3) to acquire and hold any movable or immovable property or dispose of same, 4) to formulate and execute housing schemes, 5) to cause the clearance of slum and shanty areas and to undertake their redevelopment, 6) to approve, coordinate, regulate, control or prohibit any development scheme or project, or any development activity, of any government agency and 7) to regulate any planning projects or schemes prepared by any government agency[8].

In order to perform the responsibilities vested by the Law, UDA had 1,449 staff as of November 2001, which consisted of 1,327 permanent, 89 contract-based, 8 daily-based and 25 trainee employees. Distribution by professions is 210 planning staff, 62 project staff, 35 administrative staff, 13 legal staff, 58 financial staff, 4 engineers, 14 GIS staff, 112 technical staff and others.

2) Agrarian Development Department (Ministry of Agriculture and Livestock)

ADD was renamed from Agrarian Services Department by the Agrarian Development Act No. 46 of 2000. Objectives of the Act are to ensure maximum utilization of agricultural land for agricultural production by introducing clear restrictions to be imposed on persons using agricultural land for non-agricultural purposes.

In the definition by ADD, any land can be divided into two types, low land and high land. The low land is divided into two categories, paddy fields (including abandoned paddy fields) and marsh. The high land has several categories including agriculture, urban, forestry, park and so on. The categories covered by the Department are paddy fields in the low land and agricultural land in the high land. Marsh is an area of SLLRDC coverage.

There exists a strong demand to develop paddy land, particularly in urban and urbanizing areas such as Colombo, Gampaha, Karutara, Galle and Kandy. Development of paddy land by land filling requires the permission of the Commissioner-General of ADD, for which several steps are needed as described in Figure 2.17. ADD receives over 1,000 proposals for land filling of paddy land every year, of which, 100 to 150 proposals are approved.

In case of illegal land filling in paddy and abandoned paddy lands, the Act empowers ADD to take legal actions such as the removal of earth and imposing of fines. ADD took such legal actions for 37 cases in 2000. In case of illegal

8 Extracted from Section 8 in Urban Development Authority Law No. 41 of 1978, its amendment No. 4 of 1982, and No. 44 of 1984

land filling in other lands within UDA declared areas, UDA is empowered to take legal actions. Although local authorities are also empowered to take legal actions for illegal land filling within their respective administrative boundaries, they usually ask UDA or ADD to take legal actions in order to avoid intervention by local politicians.

ADD has 13,000 staff and 25 district offices. There are 9,600 Agrarian Research and Production Assistants at the village level and 542 Agrarian Development Committees covering all the country.

(3) Agencies Related to Land Acquisition and Resettlement

1) Ministry of Land

By the Land Acquisition Act, the Ministry of Land has a sole responsibility to acquire land, which is owned by state, local authority or private companies/individuals, for public projects approved by the central government.

The Land Registration Department (LRD) is responsible for registration of land titles. These records are maintained and updated by district offices under the supervision of LRD. The responsibility of the Land Valuation Department is the estimation of land prices, based on market price, for compensation, which is paid to land owners in the case of local authorities or private companies/individuals. The Land Commissioner's Department is in charge of alienation for the State land.

2) Urban Settlement Improvement Program (Ministry of Urban Public Utilities)

USIP was initially a Project Unit established in 1999 under the Ministry of Urban Development to execute the World Bank funded Community Infrastructure Improvement Project in CMR. Two JBIC funded projects have been added, the Community Development Component of the Kaluganga Project and the Human Settlement Component of the Lunawa Environment Improvement & Community Development Project.

USIP aims at facilitating the development of sustainable community based environmental infrastructure services in the under-served settlements on a participatory and partnership basis. Therefore, housing development and shanty relocation are not, in principle, the scope of USIP, although USIP is assigned to the shanty relocation component in the Lunawa Project. NHDA and UDA are the organizations responsible for housing development in rural and urban areas, respectively. The Urban Housing Division of NHDA is officially responsible for relocation of legal and illegal dwellers for public projects, while USIP may undertake activities of relocation on a project basis.

USIP is promoting community contracts for basic infrastructure improvement in the under-served communities. This approach is used for drainage development, maintenance and solid waste management, for which, the above on-going projects are budget sources.

USIP has 20 employees at present, which will be increased to 30 when the Lunawa Project commences.

3) National Housing Development Authority (NHDA), Ministry of Housing and Plantation Infrastructure

NHDA was established by the National Housing Development Authority Act No. 17 of 1979. This act empowers the Authority to promote housing development and to directly engage in the construction of flats, houses and other living accommodations in urban and rural areas. However, these activities in the urban areas were handed over to UDA and since then NHDA has been focusing on housing development for lower income groups in the rural areas only.

The Urban Housing Division of NHDA used to be under UDA, where the Division was assigned for shanty relocation in the JBIC funded Greater Colombo Flood Control and Environment Improvement Project Phase 1. The Division shifted to NHDA after the recent administrative reform by the new cabinet.

The current major responsibilities are 1) relocation of legal and illegal dwellers for public projects, 2) renewal and redevelopment of urban housing, 3) sale of land after relocation, 4) land acquisition. The Division now has 20 staff.

(4) Regulatory Agency

1) Central Environmental Authority (Ministry of Environment and Natural Resources)

CEA was established by the National Environmental Act No. 47 of 1980. The powers, functions and duties of the Authority include to require the submission of proposals for new projects and changes in existing projects and to require any local authorities to comply with any recommendations relating to environmental protection.

As for land use management, CEA is responsible to formulate and recommend a land use scheme, which includes 1) a scientifically adequate land inventory and classification system, 2) determination of present land use, 3) comprehensive and accurate determination of the adaptability of land for various economic activities, 4) a method for exercising government control over the use of land and 5) a policy for influencing the location of new areas for resettlement of persons and the methods for assuring appropriate controls over land use. Land use plans for areas declared by UDA are finalized by UDA in consultation with CEA for environmental aspects.

CEA organized an inter-ministerial committee called the Committee on Environmental Policy and Policy Management (CEPON), an agency to provide guidelines, approval and monitoring related to environmental preservation. There are five CEPONs currently working, 1) urban and industries, 2) land, 3) fishery, 4) energy and 5) biodiversity. CEPONs are operated by a co-chair of both Secretaries of the Ministry of Environment and the Ministry related to each CEPON. SLLRDC and UDA are members of CEPON for urban affairs and industry.

CEA has 630 staff including 300 staff working at local authorities as District Environmental Officers. Over 250 staff are scientists or engineers and 20 % of the total staff are highly educated having master, Ph.D., and equivalent qualifications.

(5) Responsible Organization for Flood Forecasting and Fighting

IRD has a system of 9 water level gauging stations in the Kelani River Basin for flood forecasting. IRD forecasts by using these data, rainfall records and weather forecasting by the Meteorological Department. Based on flood forecasts by IRD, the Meteorological Department gives warnings and evacuation orders by means of broadcasting through TV and radio.

The responsible agency of flood fighting is Social Service Department in local authorities guided by the Mayor or the flood authority. Local authorities decide and inform people of safe shelters such as temples and public buildings and evacuation routes in advance and Community Leaders guide people in cooperation with Social Service Department. In case of serious flooding, military forces come to rescue flood victims.

(6) Local Authorities

The local authorities which lie on the study area are listed in Table 2.12 and the location is shown in Figure 2.18. The local authorities are categorized into three depending on the scale, that is, Municipal Council (MC), Urban Council (UC) and Pradeshiya Sabha (PS). In relation to storm water drainage works, the major functions of the local authorities are construction and maintenance of drainage facilities, approval of proposal for building construction and land filing and flood fighting. One of the most serious problems in local authorities is illegal land filling and canal encroachment. Local authorities are empowered to file an action against these illegal activities, however there have been only rare cases due to shortage of personnel in charge and budget constraint. Local authorities approve proposed projects of land filling, only if the SLLRDC approves. The general description of the local authorities is given below.

1) Municipal Councils (MCs)

There are four MCs in the study area, that is, Colombo (CMC), Sri Jayewardenepura Kotte (KMC), Dehiwara-Mt. Laviniya (DMMC) and Moratuwa (MMC). MC is headed by Mayor and Municipal Commissioner is under Mayor. Under the Municipal Commissioner, there are several Departments in charge of services. Administrative capacities vary among MCs. CMC has 12,500 staff (9,500 permanent staff), whilst KMC, DMMC and MMC have 1,000, 2,200 and 700 staff, respectively. In terms of the population, revenue, expenditure, etc., MC has the largest scale out of the three categories and all the four MCs in the study area are located in the Greater Colombo area that has highly developed around the CMC.

2) Urban Councils (UCs)

There are seven UCs in the study area. UC is headed by Chairman and Secretary is under Chairman. Under the Secretary, there are several Departments in charge of services such as health, technical and administrative. Most of the UCs have over 100 staff, but very limited number of university graduates. Chairman is elected by election. UC is a local government with large scale next to MC. MC or UC areas may be generally defined as urban area.

3) Pradeshiya Sabhas (PSs)

There are 28 PSs in the study area. PS is managed by Chairman and Secretary under the Chairman. Under the Secretary, there are some Sections in charge of services. The major activities and responsibilities are as same as those of Urban Council. Since most of PSs are extended in the outskirts of MC or UC and have a broad area, the government activity is executed based on some sub-offices. The government scale is small compared to those of MC and UC.

As shown in Figure 2.19, the local authorities are independent organization of the central government at national level. In terms of the administrative hierarchy, those are under Provincial Minister of Local Government in Western Provincial Council which is a central government organization at sub-national level and has responsibility of coordination of local authorities.

(7) Related Acts, Laws and Ordinances

Acts, laws and ordinances discussed in connection with the present institutional setting are summarized in Table 2.13. Each of them has been amended several times and therefore it is observed that there is some overlapping, duplication and inconsistency among these acts, laws and ordinances, which results in unclear demarcation of responsibilities among central and local government agencies related to the storm water drainage.

2.7.2 Present Organization and System for O&M

(1) Related Organizations for O&M of Storm Water Drainage Facilities

In the study area, there are many waterways which function as a storm water drainage channel, including natural rivers, artificial canals, underground conduits and road side ditches. At present the organizations which are responsible for O&M of storm water drainage facilities/rivers in the study area can be categorized into two groups. One is the SLLRDC as a central government agency which deploy the nationwide activities and the other is local authorities. The detailed descriptions on O&M activities of the SLLRDC and local authorities are given below.

1) Sri Lanka Land Reclamation and Development Corporation (SLLRDC)

The SLLRDC is responsible for the regular maintenance of the rivers and canals which are situated in the declared areas such as the Greater Colombo basin. The responsibility lies with the Canal Development and Maintenance Division (CD&M) of SLLRDC. This division operates under a Deputy General Manager (DGM) and also deals with aspects of developing the canal network and underground pipe system for storm water drainage purpose, with projects like a series of the Grater Colombo Flood Control and Environment Improvement Project (GCFC&EIP) financed by the Government of Japan.

The division is divided into two general areas, of which the O&M side is one. The O&M part of the division is headed by an Assistant General Manager (AGM), the most senior member of staff whose time is entirely committed to canal maintenance. The organization chart of SLLRDC and its CD&M Division is illustrated in Figures 2.20 and 2.21.

The O&M organization is structured into four Regional Offices, each responsible for O&M activities in a defined geographical area. Table 2.14 lists the Regional Offices, together with the coverage areas and the individual canals.

2) Local Authority

As stipulated in REPORT OF THE COMMISSION OF INQUIRY ON LOCAL GOVERNMENT REFORMS 1999, drainage is among the important functions of any local authority and the responsibility of local authorities in this regard is very high. The organization structures of local authorities are basically same by MC, UC and PS, however the each structure is different by authority itself especially due to the government scale. MC and UC have several Council Departments under Municipal Commissioner or Secretary. The responsibility of drainage maintenance lies with either the Engineer's Department or the Health Department. (Only CMC has 15 Departments and the Drainage Division, a division under the Engineer's Department undertakes drainage maintenance.)

On the other hand, the organization of PS is not divided into so many work areas. It has a few sections under the Secretary and the Health Section normally undertakes drain cleaning together with road cleaning, garbage collection and other related works without separate section for drainage maintenance.

The current O&M system and activities of each responsible organization are provided in Annex 11 of Supporting Report (1).

2.7.3 Issues and Constraints

(1) Unclear Responsibilities among Government Agencies for Storm Water Drainage Works

The SLLRDC, the Irrigation Department (IRD), the Provincial Irrigation Department (PIRD) and local authorities are responsible organizations for developing and maintaining waterways including rivers, canals and all other channels. Out of these, waterways, rivers and irrigation canals have been developed and maintained by IRD or PIRD. It is, however, the current situation that those rivers and canals function also as an important urban drainage channel with which small drainage channels from urban/town areas are connected. Especially in the study area, paddy cultivation tends to be abandoned and the paddy fields are filled to meet the land demand due to urbanization. It is, therefore, presumed that there are many irrigation canals that are not maintained by the irrigation related agencies, but actually function as storm water drainage channels in the study area.

SLLRDC has developed and maintained storm water drainage only in the declared areas. The responsibility of the local authorities is limited to maintain urban drains and watercourses. Other than that, there are many small channels and natural streams for which the responsible organization is not clear.

As mentioned above, it is the current situation that many rivers and canals are kept from proper maintenance or improvement due to unclear work demarcation among river work related organizations and this eventually causes flooding problems.

(2) Lack of Authorized Land Use Plan

Based on the State physical plan, Provincial Councils develop provincial physical plans. Then, referring to provincial physical plans, local authorities develop their own physical plans. Based on these physical plans, UDA develops physical plans for areas declared by Gazette for specific urban development areas. Based on these physical plans, line agencies, such as SLLRDC, NWSDB (National Water Supply and Drainage Board), NHDA, IRD, RDA (Road Development Authority), CEB (Ceylon Electricity Board), SLR (Sri Lanka Railway) and CCD (Coast Conservation Department), develop various plans to achieve their missions.

However, it is the current situation that there is no authorized land use plan. Therefore, the line agencies tend to develop their development plans to serve their own interests, and it causes conflicts among development plans. These development plans, such as land filling for urbanization and road construction, may cause serious loss of detention capacity in low land areas, which causes storm water flooding.

(3) Malfunction of the Regulation System for Low Land Development

There exists an official evaluation/approval process for low land development as shown in Figure 2.17. However, this system can be presumed to not work properly due to the following reasons.

1) No comprehensive statute relating to land use regulation exists. (Legal actions by UDA or local authorities, which are empowered to take legal action to stop, demolish, punish and fine may be restricted because of this.)

2) The Planning Committee in SLLRDC, with participation from UDA and CEA, is to evaluate all land filling proposals submitted by government agencies, local authorities, private companies/individuals at the last stage of the existing evaluation/approval process, however the evaluation system doesn’t function effectively because of the predominance of UDA in legal power and because relevant agencies which undertake development works do not participate in the committee.

3) There is no concrete guideline for evaluating proposals for land filling, especially from the viewpoint of the affect to the detention function of the

low land.

4) This system might deteriorate due to political pressure and other factors, to the point that the approved physical and environmental plans and the scientific drainage analysis could be totally ignored.

(4) Insufficient Resources for Storm Water Drainage Works

SLLRDC and the local authorities are the main organizations that undertake storm water drainage works. The constraints of the respective organization are described below.

1) SLLRDC

The SLLRDC has been increasing managerial staff, technical staff and other employees including laborers, and O&M equipment through undertaking large scale storm water drainage projects for this 10 years. Therefore, the SLLRDC has staff together with the knowledge/experience required and O&M equipment for managing storm water drainage works as an agency for planning, implementation and O&M at present.

However, the number of staff and equipment may not be sufficient for undertaking O&M works in the broad area of the Greater Colombo canal system where rapid siltation, growth of weeds and garbage dumping by canal side residents are observed, and for undertaking O&M of urban drainage facilities. And if, in the future, the responsible area is extended, it will be required to take over drainage channels from other agencies, the actual undertaking of maintenance works on request/contract basis from local authorities and providing training for the staff of local authorities which do not have proper maintenance capacity. This will necessitate further development of the human resources and an increase in O&M equipment to meet these future needs.

2) CMC

The responsibility of CMC for storm water drainage works is mainly to clean and repair underground drainage systems and small drain channels in the built up area. As far as looking into the responsibility and the staff structure, CMC is considered to have enough managerial staff. However, the total channel length to be maintained is quite long (approx. 350 km) and most of the channels are not well maintained. This implies a shortage of technical and operation staff together with a shortage of O&M equipment and tools, especially light equipment such as tractors, water pumps and generators. It seems the budget allocated for storm water drainage is not enough compared to the total length of drain channel to be maintained.

3) Other local authorities

The drainage related activities of the other local authorities are to clean and repair small drain channels including roadside ditches. Most of the local authorities have no engineers and only a few technical officers manage, with assistance of supervisor level staff, not only drainage related works, but maintenance of other infrastructures and public health related works as well. Typically, equipment owned by most of the local authorities is limited to one backhoe and several tractors and this equipment is not used exclusively for storm water drainage maintenance.

An urgent increase of staff and equipment may not be required for the present work duty and volume for channel maintenance. Considering the annual revenue scale (generally several tens of million rupees), it is actually difficult for those local authorities to increase staff and equipment for maintaining a storm water drainage system. However, as urbanization to the outskirts of the existing urban area extends, drainage facilities will also increase and proper maintenance works will be required of the local authorities. Therefore, an increase in staff and equipment should be considered.

In the major municipal councils in the Greater Colombo area, the improvement of the storm water drainage systems are now being carried out by SLLRDC or is about to commence. Those systems are to be transferred to the local authorities. The strengthening of all levels of staff together with O&M equipment will be an essential issue to undertake the maintenance works and for further improvement of drainage systems including planning and construction by local authorities themselves.

2.8 Foreign Aid

2.8.1 Donors for Sri Lanka

Foreign aid plays an important role in implementing projects in Sri Lanka. More than 30 DAC nations and multilateral agencies have been contributing their assets to Sri Lanka with the annual average commitments of Rs. 55.3 billion and Rs. 46.6 billion annual average disbursement for the period 1995 - 2000.

Foreign Aid Commitments and Disbursements 1995 – 2000

(Rs. billion)

Year	1995	1996	1997	1998	1999	2000	Average
Commitments	41.9	81.2	56.0	58.8	57.9	35.8	55.3
Disbursements	55.0	48.0	43.4	55.4	36.6	41.0	46.6

Note: US$1 = Rs. 80.0098
Source: Foreign Aid Review Sri Lanka 2000, External Resources Department, Ministry of Finance and Planning

For the year 2000, annual disbursement of foreign aid by major donors was Rs. 33.2 billion. In terms of disbursement by its source, ADB and IDA are the major owners among the multilateral agencies with each has a share of 18.7% (Rs. 6.2 billion) and 11.1% (Rs. 3.7 billion), respectively (Table 2.15). Japan and Germany dominate the bilateral sources with 49.6% (Rs. 16.5 billion) and 6.6% (Rs. 2.2 billion) of outstanding aid, respectively. Japan is the largest donor among the all agencies by providing 50% of loan and 71% of grant in 2000.

Economic Infrastructure sector has the largest share in terms of sector allocation with 34.5% (annual average disbursement of Rs. 15.5 billion or US$193.4 million) followed by Social Infrastructure of 19.8% and Agriculture of 15.8% (Table 2.16). The high share of infrastructure related foreign aid matches with the priority of the Government of Sri Lanka, which emphasizes the importance on infrastructure development particularly power and energy, transport, communication, education and water supply and sewerage.

2.8.2 Activities of Donors

Each donor has its own emphasis on which sectors or fields to support, which ranges from economic development to social development, and to infrastructure development. Basic principles of donors are summarized as shown in Table 2.17. Based on the principles of each donor, projects are formulated and their programs are implemented.

2.8.3 Storm Water Drainage Project

A number of donors that support the storm water drainage projects is limited. Japan is a main donor which provides funds for the storm water drainage projects, which focus on the Greater Colombo Area, with the total amount of Rs. 15,900 million (JPY 22,044 million (Rs.100 = JPY 72.3), which is composed of Greater Colombo Flood Control and Environment Improvement Project Phases I, II, III since 1990.

Some small scale storm water drainage projects are implemented under the urban or rural development scheme such as Urban Development and Low Income Housing Project funded by ADB.

One reason for the limited donors for the storm water drainage projects is that importance of storm water drainage had not widely been recognized in Sri Lanka, so that other infrastructure projects receive more attention. Only in recent years, the importance of storm water drainage has been recognized, particularly in the Colombo Metropolitan Region where a large portion of assets is concentrated, and the rapid urbanization extends the flood prone area and increases the flood damages. According to the Department of National Planning, Ministry of Finance and Planning, storm water drainage system, which is considered as a basic infrastructure, is important for the development of CMR and needs to be developed in order to reduce the risk of flood damage.

Other reason is that the priority is given to energy and transport sectors, so that the Government of Sri Lanka allocates more funds to energy and transport development. As the energy problem is expected to be improved within a few years, there will be a possibility for other infrastructure development to receive funds.

2.8.4 Potential Storm Water Project related to the Study

Considering the needs of the Government of Sri Lanka and the policy on foreign aid by the donor countries, possibility of implementing the storm water drainage projects is expected to increase. The potential donors will be limited to ADB, World Bank, Japan, USA, and Germany which have a policy of supporting infrastructure development. In addition, since most donors have not been supporting storm water drainage projects actively, the number of independent storm water drainage projects is expected to remain small. The storm water drainage projects are most likely to be implemented as a sub-project of other infrastructure development scheme such as urban and rural development, agricultural development and poverty reduction.

CHAPTER 3 HYDROLOGICAL ANALYSIS

3.1 Objective Drainage Basins

Although the boundary line of the northern part of the study area crosses the middle reaches of the Dandugam Oya and the Ja Ela main streams as shown in Figure 2.1, it is appropriate that the basin upstream of those channels is also included in the objective area in this hydrological analysis. In this hydrological analysis, therefore, the following are set as objective drainage basins.

Objective Drainage Basins for Hydrological Analysis

No.	Drainage Basin	Catchment Area
1.	Ja Ela	860.6 km^2
2.	Kalu Oya	57.6 km^2
3.	Greater Colombo	98.5 km^2
4.	Bolgoda	394.0 km^2

Of the above, the study area covers the middle and lower catchment with an area of 173 km^2 in the Ja Ela basin. The other catchment areas are located within the study area. The catchment area of Greater Colombo basin above comprises 85.7 km^2 of Greater Colombo basin and 12.8 km^2 of Malabe basin, which are connected each other by Madiwela East diversion channel.

3.2 Observation Network of Meteorological and Hydrological Records

3.2.1 Rainfall Records

A number of rainfall gauging stations are located in and around the drainage basins relevant to the study area. Of these, it was found that some stations are not operated properly or already closed. The daily rainfall records were therefore collected from the selected stations that are well maintained at present and have a sufficient period of records for the purpose of the study. The daily rainfall records were collected from the following 14 rainfall gauging stations:

Rainfall Gauging Stations

No.	Station	No.	Station
1.	Angoda	8.	Horana
2.	Bandaragama	9.	Kalutara
3.	Boralesgamuwa	10.	Katunayake
4.	Dehiwala	11.	Pasyala
5.	Halgahapitiya	12.	Ratmalana
6.	Hanwalla	13.	Vincit
7.	Henarathgoda	14.	Colombo

Locations of these stations are shown in Figure 3.1. The majority of these have more than 30 years of recent records with some intermittent. Of the rainfall gauging stations above, pluviographs and short interval data at rainstorm events were also made available for the recording rainfall gauging stations of Katunayake (No.10), Ratmalana (No.12) and Colombo (No.14).

3.2.2 Water Level and Discharge Measurement Records

The number of water level gauging stations is 56 stations in the objective drainage basins as of December 2001 as shown in Figure 3.2. All the gauging stations are of non-recording (staff gauge) and water level is observed once or twice (morning and evening) a day. Discharge measurements are also made a few times per month. Utilizing these observed water level and discharge measurement records, the relationship between water level and discharge (H-Q curves) is estimated for at least 9 stations, i.e., Station Nos. 19, 20, 22, 23, 26, 27, 28, 29 and 31. The existence of H-Q curves of other stations has not been confirmed.

Although the H-Q curves at 9 gauging stations are available, since the discharge measurement is seldom conducted during flood events, the discharges obtained by the H-Q curves are unreliable in high stage water levels.

3.3 Rainfall Analysis

3.3.1 Characteristics of Storm Rainfall

Heavy rainstorms in the study area located in the southwest quarter of the country occur mainly in the Southwest Monsoon period from May to September and occasionally in the two Inter-monsoon periods (Mach-April and October-November) as well. The rainstorms are caused by climatic features in the tropics, i.e., convection, convergence activity of Inter Tropical Convergence Zone (ITCZ), depressions, and cyclonic wind circulations.

Generally, heavy rainstorms brought by convergence, depressions, and cyclonic wind circulations are widespread phenomena while convection brings local thunderstorms with localized heavy rainfall.

The rainfall records at Colombo indicate that the annual maximum daily rainfall amounts to 130 mm in a normal year. It is observed that events of daily rainfall exceeding 250 mm occurred only twice in the last 30 years with 493 mm/day in July 1992 and 284 mm/day in April 1999.

According to the available short interval data at Colombo, most rainstorm events would have a duration of 3 hours or less and would show a distinct peak within a storm. On the other hand, exceptional rainstorm events are comprised of a series of storms. The rainstorm event in April 1999 indicates two separate main storms. In the historically extreme event in June 1992, four main storms occurred successively within 12 hours. Short interval data at Colombo for several rainstorm events are shown in Figure 3.3.

3.3.2 Design Storm Rainfall for Objective Drainage Basin

The annual maximum series of basin average rainfall for each objective drainage basin were extracted on the basis of 24-hour rainfall records at the 14 rainfall gauges by employing the Thiessen Polygon method. The extreme value analyses were carried out for the annual maximum series of basin average rainfall. The results of probable 24-hour rainfall for the return period of 2-, 5-, 10-, 25- and 50-years are summarized below:

Estimated Probable Basin Average 24-hour Rainfall

(Unit: mm)

Return Period (years)	Drainage Basin			
	Ja Ela	Kalu Oya	Greater Colombo	Bolgoda
2	103	130	117	103
5	135	184	176	137
10	156	220	214	160
25	183	266	270	188
50	203	230	320	210

In order to generate basin average rainfall as an input of flood runoff model, it is necessary to convert the daily basis value into hourly distribution in the light of observed rainstorm patterns. Such rainstorm patterns observed by automatic rainfall gauges are quite limited in the study area. Therefore, the rainstorm patter of a major event recorded at Colombo is adopted. The rainstorm event occurred on 20th April 1999 (24-hour rainfall: 284 mm) corresponds to 50-year return period event and its hourly pattern is employed for generating the design rainstorm pattern of the basin average rainfall as shown in Figure 3.4.

In estimating runoff from an objective basin, this design basin average rainfall is assumed to occur with aerial uniformity in this study. Therefore a careful consideration should be made when a time series distribution of a station, i.e., Colombo, is applied to an entire basin. Although it is impossible to verify this assumption based on the existing data and records, the study regards this as an acceptable supposition because the main causes of large scale rainstorm events in the study area are convergence, depressions, and cyclonic wind circulations, and these events have a relatively large coverage area.

3.4 Flood Runoff and Inundation Analysis

3.4.1 General

The flood runoff and inundation analysis was carried out in order to;

1) Determine the present flood inundation condition,
2) Predict the change in the inundation state due to future land use development such as urbanization or reclamation of lowlands, and
3) Estimate the effect of proposed structural measures on the flood mitigation.

MIKE11, a one-dimensional (1D) and one-layer flow calculation software package developed by Danish Hydraulic Institute (DHI), comprises a lot of calculation modules such as hydrodynamic (HD), structural operation (SO), rainfall-runoff (RR) and so on. Following are the modules mainly used for this Study:

1) Hydrodynamic Module (HD) for the computation of unsteady flow in channels
2) Structural Operation Module (SO) for the computation of the effect of artificial structures such as weirs, culverts etc.
3) Rainfall Runoff Module (RR) for the computation of runoff from drainage basins

3.4.2 Digital Elevation Model (DEM)

The Digital Elevation Model (DEM) for the study area was assembled from spot levels and contours available on the topographic maps obtained from the Survey Department. Maps of a variety of scales were used and the data were either digitized from paper or sometimes extracted directly from digital data provided by the Survey Department. The results of river cross section surveys and spot level surveys of marshy land boundaries conducted in this Study were also utilized for DEM generation.

These spot levels were converted to DEM using the DEM generation tool of MIKE11 GIS. The DEM grid size is 50 m × 50 m for all basins, and the elevation value of a grid is the distance weighted average of spot level data around it. The DEMs under "Present Land Use Condition" were generated using original spot level data reflecting existing conditions, while those under "Future Land Use Condition" were generated considering reclamation of marshy and paddy areas according to the projection of future (2010) land use condition conducted in the Study.

3.4.3 Channel Network for Hydrodynamic Model

(1) Input Data and Parameters

Main input data for MIKE11 channel network model comprises:

1) Geographical information for the calculation points, i.e., the coordinates (longitude and latitude) of points where discharge (Q) or water level (h) is calculated,
2) Information regarding channel connections,
3) Information regarding structures (weirs, culverts, etc.) such as specifications or locations,
4) Channel cross section data, and
5) Lateral inflow (to be imported from the basin runoff model).

The channel network model for each objective basin comprises the main streams and major tributaries.

There are two kinds of parameter groups to be considered. One is the parameter group for description of flood phenomenon and the other is for stability of implicit finite difference equations converted from above mentioned two basic equations. A typical parameter for the former group is Manning's roughness coefficient (n), and for the latter, spatial or temporal steps (Δx or Δt).

(2) Flood Cells

In order to include the behavior of the flood plain in the hydrodynamic model, "flood cells" are extracted from the generated DEMs and attached to the cross section database of the model. The flood cell is described by the relationship between elevation and inundation area (H-A curve). The flood cells of both present and future land use conditions were extracted from the DEMs of each objective basin.

(3) Boundary Conditions

1) Tidal Levels

According to the Indian and British Tide Tables, tidal variations at Colombo harbor, related to MSL, are given below:

- Lowest Astronomical Tide (L.A.T.) : 0.50 m below MSL
- Mean Low Water Springs (M.L.W.S.) : 0.32 m below MSL
- Mean Low Water Neaps (M.L.W.N.) : 0.08 m below MSL
- Mean Sea Level (M.S.L.) : 0.00 m above MSL
- Mean High Water Neaps (M.H.W.N.) : 0.10 m above MSL
- Mean High Water Springs (M.H.W.S.) : 0.34 m above MSL
- Highest Astronomical Tide (H.A.T.) : 0.50 m above MSL

However, according to the observed tidal level at Colombo harbor, the actual tidal levels are higher than the values above. The tidal records at Colombo harbor between April to June 2002 show the occurrence of tidal levels over 0.50 m above MSL as shown below:

Record of High Tidal Level at Colombo Harbor (April to June 2002)

Date (Time)	Tidal Level (above MSL)
Apr. 12, 2002 (15:00)	0.51 m
Apr. 13, 2002 (15:00)	0.53 m
Apr. 14, 2002 (15:00)	0.53 m
Apr. 26, 2002 (14:00)	0.54 m
Apr. 27, 2002 (15:00)	0.64 m
Apr. 28, 2002 (16:00)	0.66 m
Apr. 29, 2002 (16:00)	0.63 m
Apr. 30, 2002 (16:00)	0.52 m
Jun. 12, 2002 (15:00)	0.51 m
Jun. 13, 2002 (16:00)	0.54 m

Source: Sri Lanka Port Authority

Considering the situation above, the assumption that a high tidal level of over 0.50 m above MSL occurs during a flood event is reasonable. The lowest tidal level during the probable floods was set around M.H.W.N. from a conservative viewpoint. Finally, the tidal level data, which ranges between 0.13 and 0.61 m above MSL, was derived from the records at Colombo Harbor and set as the downstream boundary condition at sea outfalls.

2) Water Level at the Kelani Ganga

The 10-year probable flood water level data, which had been simulated by DHI, was set as the downstream boundary condition for the outfalls connecting to the Kelani Ganga. The 10-year probable maximum water level of the Kelani Ganga at Nagalam Street (10 km upstream from the Kelani Ganga outfall) had been calculated as 2.98 m above MSL by DHI. The high water level, with a water level of more than 2 m at Nagalam Street, continues for about 4 days according to the simulation result.

It is reported that the long duration of flood in the Kelani Ganga promotes severe local inundation especially in the Kalu Oya basin. In order to relieve the severe situation and stand on the conservative side, a 10-year flood in the Kelani Ganga was applied as the design boundary condition in this study.

3.4.4 Basin Runoff Model

(1) Input Data and Parameters

NAM, originally developed by the Technical University of Denmark, is a lumped and conceptual basin runoff model, simulating the overland-, inter-, and base-flow components as a function of the moisture content in four storages, i.e., surface, lower or root zone, ground water, and snow.

There are a lot of parameters to be set in the NAM model, and of them, the following 7 parameters are important for estimating flood runoff from the objective drainage basins. They are constituent elements of the surface and root zone parameter set:

1) Maximum water content in surface storage (U_{max})
2) Maximum water content in root zone storage (L_{max})
3) Overland flow runoff coefficient (CQOF)
4) Time constant for interflow (CKIF)
5) Time constant for routing interflow and overland flow (CK_{12})
6) Root zone threshold value for overland flow (TOF)
7) Root zone threshold value for interflow (TIF)

A function of auto-calibration of the above parameters is available in the MIKE11 RR module. However, since neither water level observations nor discharge measurement records on an hourly basis are available in the study area as mentioned in the section 3.2, those parameters are principally set by an empirical method based on the land surface or land use conditions.

The parameter setting was therefore made introducing the following concepts referring to the past study carried out in 1995 as a part of the "Greater Colombo Flood Control and Environment Improvement Project (Phase I)", which also utilized MIKE11 and NAM. Land use is classified in four types such as Urbanized, Semi-urbanized, Rural/Paddy and Water/Marsh, considering the hydrological characteristics. A set of NAM parameters is given to a typical basin representing each land use type.

The NAM parameters of sub-catchments are decided as the area-weighted average of above four types of land use condition utilizing GIS information of present and future land use conditions prepared in this Study.

(2) Model Calibration

The validity of hydrological-hydraulic models was examined in the Greater Colombo basin. The reasons why this basin was selected for model calibration are 1) hourly rainfall records are available from an automatic rainfall gauging station in this basin, 2) the basin scale is relatively small and the rainfall pattern of one rainfall station is judged to be applicable to the basin average rainfall pattern, 3) water level observation records are available for some storm rainfall events.

The storm event on April 20 and 21, 1999 is selected as a target event for model calibration because the land use condition in 1999 is similar to that at present. Furthermore, since Madiwela East diversion canal was completed in 1997, no modification of the channel network model is needed for this calibration work.

Instantaneous water level records from April 20 to 24 were collected at 5 points in the Greater Colombo drainage system as shown in Figure 3.5. The NAM parameters of 4 land use types and Manning's roughness coefficient (n) were adjusted by trial and error in order to make simulated water level coincide with those observed.

Although there are relatively large discrepancies between observed and simulated flood duration, the model shows adequate validity for the maximum water levels. Therefore it was judged that the model shows enough accuracy for the master planning purpose.

The probable peak runoff discharges under present condition are estimated at the most downstream base points of the respective basins as follows:

Probable Peak Runoff by Basin

Return Period (years)	Probable Peak Runoff (m^3/sec)			
	Attanagalu Oya ($800 km^2$)	Kalu Oya ($58 km^2$)	Greater Colombo ($85 km^2$)	Bolgoda ($394 km^2$)
2	105	2	31	106
5	157	3	56	116
10	192	13	75	124
25	235	18	103	135
50	266	21	132	144

3.4.5 Results of Analysis

(1) Ja Ela Basin

Twenty-seven (27) base points were set in the Attanagalu Oya channel system and examined simulated water levels and/or discharges at each point. The locations of those points are shown in Figure 3.6. Figure 3.7 shows water level and discharge hydrographs of 4 base points, i.e., BP-2, 3, 19 and 20. No significant change in flood phenomena is observed from the figure since urbanization in this basin does not progress significantly according to the land use projection maps.

The 50-year probable maximum discharges under future land use conditions at the cross-points of Negombo road and the Dandugam Oya (BP-19) and that of Negombo road and the Ja Ela (BP-20) were calculated at 197 m^3/sec and 70 m^3/sec, respectively.

Figure 3.8 shows the simulated flood inundation area for 2-, 10- and 50-year probable floods both under present and future land use conditions. Flood inundation area is summarized by each land use category in Table 3.1. There is no significant change in inundation area for any land use category.

(2) Kalu Oya Basin

Seventeen (17) base points were set in the Kalu Oya basin as presented in Figure 3.9. Water level and discharge hydrographs of the 50-year probable flood at 4 base points, i.e., BP-1, 2, 8 and 13, are illustrated in Figure 3.10. Both water level and discharge increase significantly as a result of basin-wide urbanization and large scaled reclamation. At the downstream base point BP-13, maximum flood water level increases more than 10 cm for every probable flood, and more than 30 cm increase is observed for the 2-year probable flood. Maximum flood discharge also increases more than 40% in each probable flood.

Figure 3.11 shows the simulated flood inundation area for 2-, 10- and 50-year probable floods both under present and future land use conditions. A summary of inundation area by land use category is listed in Table 3.1. Total inundation area is to be reduced due to the land reclamation along the proposed Outer Circular Highway, however that of the urbanized area and semi-urbanized area increases due to the reclamation and urbanization.

(4) Greater Colombo Basin

Twenty-five (25) base points were set in the Greater Colombo basin as seen in Figure 3.12. Water level and discharge hydrographs of the 50-year probable flood for 4 base points, i.e., BP-22, 17, 18 and 19, are illustrated in Figure 3.13. The 50-year probable maximum flood discharge at Welawatta (BP-19) and Dehiwala (BP-20) outfalls are 55 m^3/sec and 31 m^3/sec, respectively under future land use conditions, while they are 49 m^3/sec and 29 m^3/sec respectively under present land use conditions. Water level increases 7 to 14 cm. The increase in water level and discharge is caused by urbanization.

Figure 3.14 shows the simulated flood inundation area for 2-, 10- and 50-year probable floods both under present and future land use conditions. Summarized inundation area by land use category is shown in Table 3.1. The inundation area of the built-up area and semi-urbanized area increase significantly.

(4) Bolgoda Basin

Thirty (30) base points were set in the Bolgoda basin as shown in Figure 3.15. Figure 3.16 shows the 50-year probable water level and discharge hydrographs at 4 base points, i.e., BP-9, 19, 20 and 30. Water level and discharge at Weras Ganga outfall (BP-9) increases significantly due to urbanization and land reclamation. There are no significant changes in flood characteristics except for the Weras Ganga basin (northwestern part of Bolgoda basin).

probable floods both under present and future land use conditions. Summarized inundation area by land use category is shown in Table 3.1. Although total inundation area is reduced due to the land reclamation in the Weras Ganga basin, the inundation area of built-up and semi-urbanized areas increases.

CHAPTER 4 FORMULATION OF MASTER PLAN

4.1 Socio-economic Framework

4.1.1 General

For the present study, the CMR Structure Plan (CMRSP) is closely related to the setting of socio-economic conditions such as population, economy, land use, properties, etc. in the future. Basic policy of the CMRSP is to ease the urbanization pressure in the Core Area defined as the existing urban area of Colombo Municipality and surrounding area to Growth Centers outside the Core Area. For setting the macro frame, development policy in the CMRSP and other indicators are used.

4.1.2 Population Framework

Since CMR is a center of economic and social activities, urbanization in the study area is expected to continue and the population is expected to grow. The population framework of the urban area in the CMR is proposed in the CMRSP. The population growth rate is estimated to be 2.4%, which is higher than the CMR average of 1.4%. This rate is even higher than the rate for the study area for the period of 1981-1994 when it was 1.7%. The population of the CMR is expected to reach 6.5 million in 2010 or 1.2 times of the 2001 population of 5.3 million. The percentage of the population living in urban areas is the highest in Colombo District with 94% followed by 64% for Gampaha District and 47% for Kalutara District. Table 4.1 shows the estimated population of core areas and urban centers in the CMR for 2005 and 2010.

The estimate for the population in the study area in 2010 is from the CMRSP and the area coverage of the study area in the CMR mentioned in the section 1.2 Administrative Division. The population of the study area in 2010 is estimated to be 4.18 million composed of 2.43 million for Colombo District, 1.23 million for Gampaha District, 0.52 million for Kalutara District.

Estimated Population of CMR and Study Area in 2010

District	Projected Population (CMR) (million)	Urban Population (CMR) (million)	Urban Population (%)	Rural Population (CMR) (million)	Rural Population (%)	Study Area Population (million)
Colombo	2.73	2.57	94	0.16	6	2.43
Gampaha	2.53	1.62	64	0.91	36	1.23
Kalutara	1.24	0.58	47	0.66	53	0.52
Total	6.50	4.77	74	1.73	26	4.18

Source: CMRSP, 1997, Urban Development Authority

4.1.3 Economic Framework

According to “Vision 2010 Sri Lanka”, Sri Lanka’s GDP growth rate is targeted between 7% and 8% during the decade up to 2010. The leading growth sectors will be manufacturing and services-related activities such as information technology, electronics, communications, transshipment and financial and business services. The emphasis of a macro perspective will be on increasing value addition, together with the efficient utilization and processing of domestic resources. The following table shows macro economic indicators set in the Vision 2010.

Macro Economic Indicators, 2000-2010

Item	2000	2003	2006	2008	2010
GDP Growth Rate (%)	6.0	6.3	7.4	7.6	8.2
Unemployment Rate (%)	7.4	6.3	5.1	3.8	3.0
Inflation (%)	6.2	5.9	3.9	3.5	3.5
Per Capita Income (US$)	897	1,100	1,380	1,945	2,490

Sources: Vision 2010 Sri Lanka, National Planning Department, Ministry of Finance and Planning

The economic framework of the study area has been analyzed based on the characteristics of the economic activities of the study area and national trends. The basic conditions and the economic framework are summarized below.

1) CMR GRDP is applied to estimate the status of the economic framework of the study area based on the assumption that most economic activities are seen in the study area.
2) GRDP growth rate for the study area tends to be higher than the rate for GDP.
3) The growth rate of the agriculture sector is low and will continue to be low due to a projected decrease in agricultural land.
4) The growth rate for the industry and service sectors is high.
5) GRDP growth rate of the study area is estimated to be 7.2% up to 2005 and 7.9% up to 2010.
6) Because of the slow growth rate of the agriculture sector, the share of agriculture in GRDP is expected to decrease from 3.7% in 1995 to1.8% in 2010.
7) The share of the industry sector in GRDP, on the other hand, is expected to increase from 36.8% in 1995 to 49.7% in 2010, while the share of the service sector is expected to decrease from 59.5% in 1995 to 48.5% in 2010.
8) An investigation of the economic framework by districts in the study area shows that the Colombo District has a high percentage of the service sector, Gampaha District has high percentage of the industry sector, and Kalutara District has high percentage of the agricultural sector.

Economic Framework of the Study Area

Sector	Growth Rate (2001-05) (%)	Growth Rate (2006-10) (%)	GRDP (Rs. million)	Sector Share (%)
Agriculture	1.6	1.6	10,765	1.8
Industry	9.9	10.9	305,497	49.7
Service	6.3	7.0	298,621	48.5
CMR GRDP	-	-	614,883	100.0

Note: Estimated by JICA Study Team

Economic Framework of the Study Area by Districts

(Unit: Upper Rs. million, (Lower %))

District	Agriculture	Industry	Service	District GRDP
Colombo	1,601 (14.9)	109,262 (35.8)	152,691 (51.4)	263,553
Gampaha	3,945 (36.6)	150,376 (49.2)	95,851 (32.1)	250,173
Kalutara	5,219 (48.5)	45,859 (15.0)	50,080 (16.8)	101,158
Sector GRDP	10,765 (100.0)	305,497 (100.0)	298,621 (100.0)	614,883

Note: Estimated by JICA Study Team

4.1.4 Future Properties

(1) Land Value

In the past 10 years, the rate of increase has varied between high in the early 1990s and low in the late 1990s. The average increase rate for the period of 1990 to 1995 was 5% and that for the period of 1996 to 2001 was 4%. Since high inflation is not expected until 2010, the value in 2010 is estimated based on the past trend. The table below shows the expected land values in 2010.

Average Land Value by Land Use in 2010

(Unit: Rs./m^2)

District	Residential Area		Commercial Area	
	High	Low	High	Low
Colombo	19,192	1,556	50,309	16,491
Gampaha	7,568	503	11,475	4,195
Kalutara	3,125	230	11,580	5,307

Note: Estimated by JICA Study Team

(2) Residential and Commercial Values

The residential and commercial values are derived from construction cost and the size of the building. The values in 2010 are estimated based on economic growth for which 7.2% is applied. The method of estimating property value is discussed in the section 8.1 Economic Evaluation.

1) Residential value

The residential value for houses and household property is estimated for three house types. The future value is derived by applying a 7.1% growth rate to the present value.

Household Property in 2010

Group	Average Value of Houses (Rs.)	Household Property Value (Rs.)
Group 1	57,951	17,387
Group 2	925,731	277,719
Group 3	1,869,574	560,873

Note: Estimated by JICA Study Team
Group 1 Temporary: temporary house made of wood or mud in the main
Group 2 Permanent (medium): permanent house made of cement (average quality and medium floor area)
Group 3 Permanent (large): permanent house made of cement (better material and large floor area)

2) Commercial value

The value of commercial property is estimated for shops, offices and factories, which is estimated from the information provided by ICTAD and an insurance company. Future value is derived by using the same method as for household value.

Value for Shops and Offices

(Unit: Rs.)

Item	2001	2010
Building	1,421,775	2,658,177
Facility*1	853,065	853,065

Note: *1: 50% of value of building

4.1.5 Alternative Scenarios for Socio-economic Frame

A storm water drainage master plan will be proposed by the Study based on socio-economic conditions projected at some future date, which will also be the basis of evaluating projects to be proposed by the Study. The CMRSP provides the projected socio-economic conditions that will be realized with the proposed development projects to be implemented. Therefore, the study will follow the socio-economic conditions projected by CMRSP in principle.

The CMRSP was prepared in 1996 targeting its realization by the year 2010. At the present time in 2002, it appears that this target year would be too near to complete the numbers of the proposed development projects such as the detail planning and implementation of urban development for one Core Area and six Growth Centers.

As for the storm water drainage master plan to be processed, it will include various projects to attain a certain flood safety level for the four subject basins. One proposed project would require several years for implementation and also a large investment. Therefore, the year 2010 would also be too near to realize the entire storm water drainage master plan to be proposed in the Study.

The Study will therefore consider the following alternative scenarios to identify a realistic implementation:

1) Basic Scenario: Realization of the future socio-economic conditions projected based on CMRSP by 2010
2) Alternative Scenarios: Delay in realization of the future socio-economic conditions till 2015 or 2020

4.2 Future Land Use Pattern

4.2.1 Future Projects

Future projects are one of the driving forces that determine the future pattern of land use. The projects were investigated by collecting materials and interviewing key informants of the relevant organizations, such as UDA and CEA. The following seven projects are identified in the course of the first fieldwork of the Study:

1) Werisala Warehouse Project;
2) Peliyagoda Project;
3) Mudun Ela Development Project;
4) Wedamulla Project - Stage II;
5) Muthurajawela and Negombo Lagoon Project;
6) Kaduwela- Kolonnawa Development Scheme; and
7) Outer Circular Highway Project

The locations of the projects are concentrated in the northern part of the Colombo area, especially in the Kalu Oya catchment area, where newly constructed roads are supposed to pass through.

4.2.2 UDA Declared Areas

The prospects for the UDA declared area is very useful information for considering future urban sprawl. Table 4.2 shows the list of UDA declared areas at the present. All the Colombo District, some parts of the Gampaha District, and some urban Council areas in Kalutara District have already been declared as UDA areas. The areas for future declaration are listed below:

1) Gampaha District
   - Seeduwa-Katunayake Urban Council
   - Wattala Urban Council
   - Peliyagoda Urban Council

- Veyangoda urban area
- Nittamubuwa-Watupitiwela urban area
- Kiribathgoda urban area
- Biyagama urban area
- Ja-Ela Pradeshiya Sabha

2) Kalutara District
- Amalgamation of Maradagahamula, Dunagaha and Badalgama urban areas to the declared area of Divulapitiya
- Amalgamation of Mirigama industrial area to the declared area of Mirigama Pradeshiya Sabha

4.2.3 Driving Forces of Land Use Change

Several driving forces were considered for the change of land use in each category such as built-up areas, paddy land, and marshy areas. Urban sprawl, which means the expansion of built-up areas, could be conditioned by three factors, such as planning factor, population density factor, transportation factor and limiting factor as described hereafter.

(1) Planning Factor

Planning factors determine which areas the planning authority on land use thinks should be developed. In Sri Lanka, UDA is primarily responsible for this matter. Therefore, designation as a UDA development area is one of the indicators for urban sprawl. Core Areas that are planned in the Colombo Metropolitan Regional Structure Plan are also good information sources for considering the future built-up areas. Future project sites are described in the sub-section 4.2.1. The following spatial extents were considered for determining future sprawl areas.

1) The spatial extent of the Core Area which has been described in the Colombo Metropolitan Regional Structure Plan;
2) The spatial extent of the UDA development areas;
3) The areas of future projects which have been mentioned in the sub-section 4.2.2

(2) Population Density Factor

According to the Colombo Metropolitan Regional Structure Plan, the population density of the core area was planned for 100 persons per ha. This figure is equal to the density of population in 1994 in the three DS Divisions of Colombo, Kolonnawa and Nugegoda, which were already built-up areas in 1994. Therefore, population density with 100 persons/ha could be regarded as the criteria for determining the urban built-up area.

(3) Transportation Factor

Transportation is a factor that determines the direction of urban sprawl. In the Colombo Metropolitan Area, there is a railway that extends in the directions of north, south, and northeast. Also, major roads such as Colombo-Negombo Road, Galle Road, Colombo-Kandy Road, Colombo-Horana Road, Low-level road, extend in the directions of north, south, northeast, southeast, and east. Buffers along the transportation route would also be important factors for considering the expansion of the built up area. It is observed in Japan that, within an area 1 km wide along the newly constructed roads and interchanges, there is observed an increase of land value, representing the growth of potential of the land. It takes a decade to fulfil the potential value of land triggered by the construction of infrastructure. It is expected that the same situation will occur in Sri Lanka, although there is no empirical data that supports this phenomenon.

(4) Limiting Factor

A limiting factor for considering urbanization is the area reserved for environmental reasons. From the fieldwork in Sri Lanka, three sanctuary areas, such as the Muthurajawela Sanctuary, the Sri Jayawardenapura Kotte Sanctuary, and the Bellanwila-Attidiya Marsh Sanctuary were identified. These areas are not to be converted into urbanized use.

Abandoned paddy land could be regarded as a source of supply for urbanized land use. By overlaying the map of future project areas and urban sprawl areas onto the abandoned paddy lands, paddy lands that might be converted into the urbanized use were identified. As for the marshy area, only landfilling triggered by the construction of highways, and the Muthurajawela project area were considered.

4.2.4 Future Land Use Pattern

Figure 4.1 shows the spatial distribution of future land use patterns in the study area in the year 2010. According to the results, urbanization will progress rapidly in the areas of the Kalu Oya basin and the Kelani basin.

In this study, land use categories in the study area are broadly classified into a) urban, b) semi-urban, c) rural, d) paddy, and e) marsh. The percentage of built up areas, which is represented by the sum of both categories of urban and semi-urban, is supposed to be increased in Kalu Oya basin and Kelani basin, from the present level of 18.6% and 19.8%, to 62.2 % and 57.5 % respectively. These values exceed the level of the Greater Colombo basin, which is 56.9 %. In terms of change of paddy lands, the percentage occupied is on the decline in areas of the Ja Ela and Kalu Oya basins, and decreases from 24.3% to 23.7%, and from 16.7% to 14.3% respectively.

The percentage of marshy land in the Kalu Oya basin shows a sharp decline from 2.5% to 1.0%, which is triggered by the several projects.

Land Use Distribution by Basin

(Unit: %)

Basin	Status	Urban	Semi-Urban	Paddy	Marsh	Water	Rural
Ja-Ela Basin	Present	5.1	2.9	24.3	7.1	0.1	60.5
(17,485 ha)	Future	8.0	11.8	23.7	7.1	0.1	49.4
Kalu Oya Basin	Present	6.6	12.0	16.4	2.5	0.0	62.5
(6,066 ha)	Future	16.3	45.9	16.0	1.0	0.0	20.7
Kelani Basin	Present	7.2	12.6	16.7	1.4	1.8	60.4
(7,977 ha)	Future	16.7	40.8	14.3	1.3	1.8	25.2
Greater Colombo Basin	Present	21.4	15.5	8.5	4.3	0.1	50.2
(9,072 ha)	Future	33.1	23.8	8.3	4.3	0.1	30.4
Bolgoda Basin	Present	2.8	5.7	17.1	0.3	3.4	70.7
(40,116 ha)	Future	10.1	16.7	16.2	0.3	3.4	53.4
Total	Present	6.1	7.3	17.6	2.5	1.9	64.6
(80,716 ha)	Future	13.3	21.0	16.7	2.4	1.9	44.7

Note: Estimated by JICA Study Team

4.3 Planning Scale and Comprehensive Master Plan

4.3.1 Targeted Planning Scale

Planning scale is generally indicated using a rainstorm event return period and also gives a safety level against such a flood caused by said rainstorm in an objective river basin. The planning scale is decided on the basis of ‘degree of importance’ of the river in view of flood control, which is evaluated mainly from the following:

1) Scale of the river
2) Socio-economic importance of the area to be protected against flood
3) Direct and indirect damages anticipated by flooding
4) Historical records of flood disasters

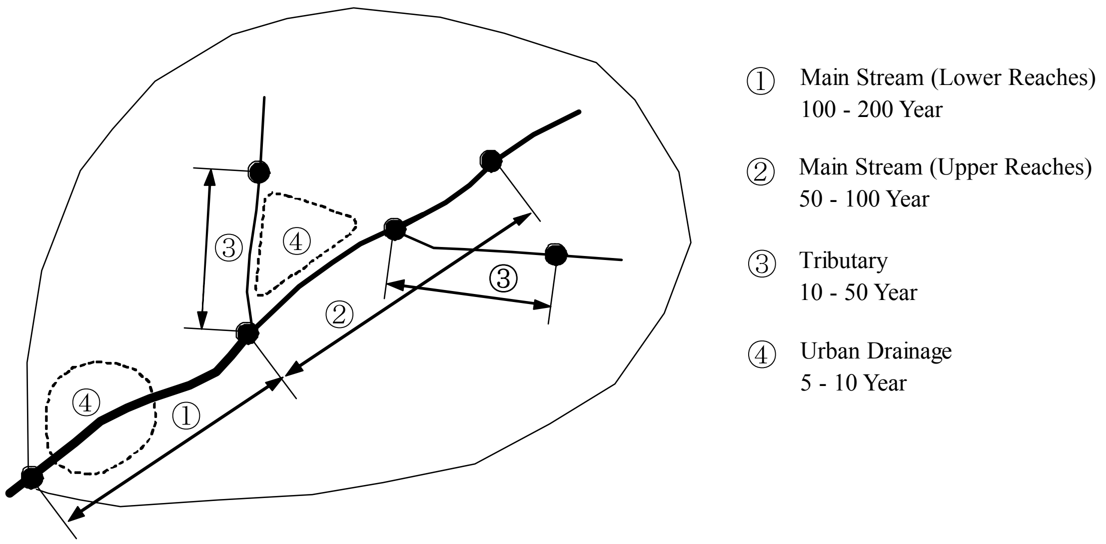
From the above, the planning scale would be different for different rivers. It is therefore necessary to consider a balance of planning scale among different river basins in a country. A Japanese guideline suggests the degree of importance of a river and a corresponding planning scale as follows:

Importance of River and Planning Scale for Flood Control Master Plan

Degree of Importance	Description	Planning Scale (Return Period)
A	Important stretches in large scale rivers	200 years or More
B		100 – 200 years
C	Stretches of large scale rivers other than A or B above Middle scale rivers Rivers in urban areas	50 – 100 years
D	Small scale rivers	10 – 50 years
E	Tributaries	10 years or Less

Source: Guidelines for River and Sabo Works, Ministry of Land, Infrastructure and Transport, Japan

In a river basin, a balance of planning scale should be maintained between upper and lower reaches as well as between main streams and tributaries in view of consistency in planning scales for the entire basin. When a planning scale is applied for a main stream in lower reaches, an equivalent or lower planning scale is given for that main stream in its upper reaches. Planning scales for tributaries are lower than that for main streams.



Basic Concept of Planning Scale (Example)

For the study area, the Kelani Ganga Flood Protection Scheme indicates an example of planning scale applied for a large river system in Sri Lanka. The basin area of the Kelani Ganga is 2,292 km^2 and the flood protection levels by existing bunds in the downstream reaches were evaluated for a 500-year return period on the left bank and for a 50-year return period on the right bank. These flood protection levels would suggest the planning scales for the neighboring basins related to the study area. The degree of importance of the Kelani Ganga may be evaluated as A or B. The others are evaluated as follows based on a relative comparison with the Kelani Ganga:

Degree of Importance of Basins Relevant to the Study Area

Basin	Scale of Basin Area (km^2)	Characteristics of Area to be Protected	Suggested Degree of Importance
Kelani Ganga	2,292	Urbanizing areas (right bank) Highly urbanized and socio-economic center of the country (left bank)	A or B
Ja Ela	860	Limited urbanizing areas in the downstream reaches and mostly rural areas in the middle and upstream reaches	C
Kalu Oya	60	Urbanizing areas in the entire basin	C or D
Greater Colombo	86	Highly urbanized areas and socio-economic center of the country	C or D
Bolgoda	467	Limited urbanizing areas in the north and mostly rural areas in the other parts of the basin	C

From the suggested degree of importance above, the planning scale of a 50-year return period, which is the same as recommended by the Colombo Metropolitan Regional Structure Plan (CRMSP), would be reasonable for the basin-wide storm water drainage plan for the basins relevant to the study area.

The flood safety level accomplished by the completion of GCFC&EIP Phase I gives a suggestion to decide a planning scale for the study. The present safety level of the main canals in the Greater Colombo basin was evaluated in the range of a 5-year to 25-year return period. Substantial improvement was accomplished by GCFC&EIP Phase I but further improvement should also be considered in order to cope with economic growth in the basin and the increase of social requirements for flood protection in the future. Provision of a higher planning scale is therefore necessary for the storm water drainage plan.

A large-scale flood event experienced in the past was also taken into consideration for application of planning scale. It is a usual practice to determine a planning scale based on the actual experienced rainstorm event that caused basin-wide damages. The recent major events occurred in 1992 and 1999 in the study area. Of those, the 1992 event was exceptionally large and is regarded to be beyond any measures for protection while the return period of the second largest event in 1999 was evaluated around 40-year. To prevent the same scale flooding, the planning scale of a 40-year return period or more should be applied.

As a conclusion of the points discussed above, a planning scale of a 50-year return period is reasonable as the long-term target for the basin-wide master plan in the study area.

4.3.2 Options of Planning Scale

The study proposes the planning scale of a 50-year return period for the basin-wide master plan for storm water drainage in the study area on the basis of the engineering considerations as described above. However, the planning scale is one of the fundamental subjects to determine a policy of flood management for the future and the final decision will be made by the government in compliance with various administrative issues in the country.

For the decision-making by the government, the study presents several options of planning scale for comparative examination. The following options of planning scale are to be taken into consideration:

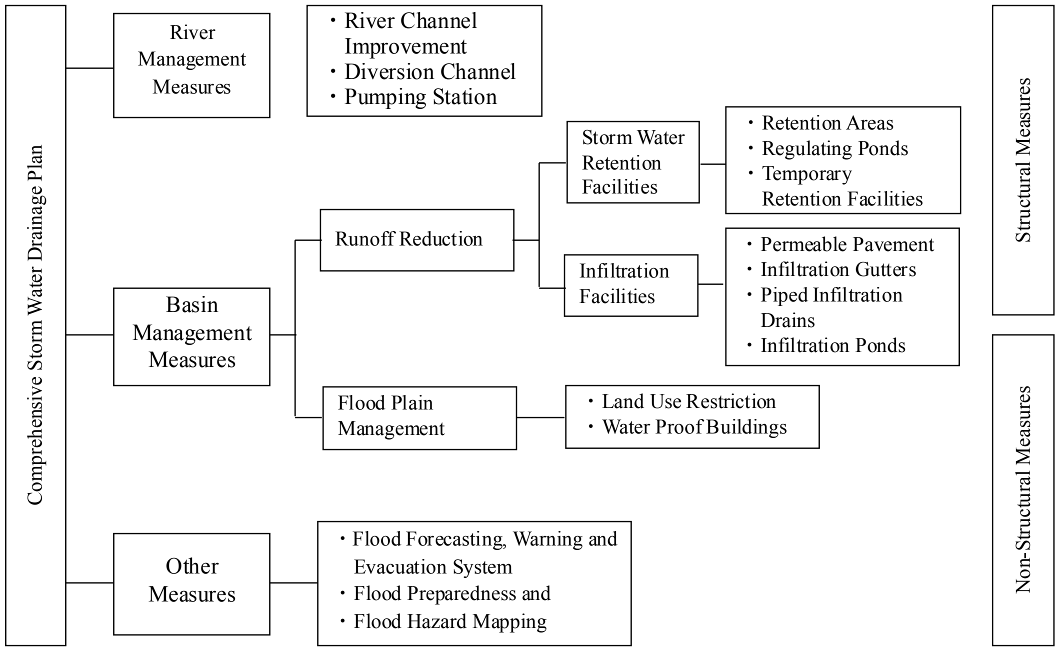
1) 50-year Return Period
2) 25-year Return Period
3) 10-year Return Period

The planning scale of a 50-year return period is a basic option proposed by the study. The lower return period is the option for reducing the total investment of structural measures. The possibility of a rainstorm event exceeding the planning scale becomes higher as the lower return period is applied. Floods exceeding the planning scale are beyond control under the storm water drainage measures provided and bring widespread damage by inundation. To alleviate the damages, non-structural measures are required on the premise that widespread inundation occurs in the case of a rainstorm event exceeding the planning scale.

The study indicates storm water drainage measures including structural and non-structural measures for the respective options and an evaluation of their viability.

4.3.3 Basic Concept of Comprehensive Storm Water Drainage Plan

The study envisages formulating a comprehensive storm water drainage plan integrating structural and non-structural measures. A conceptual diagram of the comprehensive storm water drainage plan is illustrated below:



Concept of Comprehensive Storm Water Drainage Plan

In compliance with the present conditions discussed in the previous chapters, the conceivable structural and non-structural measures for the study are identified as follows:

(1) Structural Measures

1) Improvement of main drainage system

Improvement of the main drainage system is a fundamental measure for the basin-wide storm water drainage plan, including improvement of the main streams and drainage channels and construction of diversion facilities. Plans for improvement of the main drainage system are based on analyses on the storm water runoff regime and potential flood damage in an objective basin.

2) Storm water retention areas

Storm water drainage in urbanized areas employing solely river and drainage channel improvement is not only extremely costly but also causes immense effects on natural and social environments. Therefore, it is realistic to incorporate storm water retention areas with the storm water drainage plan.

In the study area, it is expected that existing marsh and lowlands are to be utilized as storm water retention areas. The GCFC&EIP planned that approximately 380 ha of marsh and lowland should be reserved as storm water areas. However, piecemeal reclamation is occurring both legally and illegally because of the lack of clear enforcing administrative capabilities. There are opinions to reduce storm water retention areas by partially switching from storm water retention to construction of sea outfalls or pumping stations.

The study attempts to secure water retention areas for the future, by clearly defining a required extent (nature reserves and development areas that are designated to be flood plains in case of flooding, etc.) that is in concert with other basin development plans after carefully considering the various demands apparent in this background.

3) Construction of facilities for storm water runoff reduction

The study proposes basic principles for subsequent studies on urban drainage improvement in the light of present and future urbanization by basin. It is pointed out that the urban drainage schemes have been studied and implemented mainly based on the channel improvements likely to be constrained by urbanized condition.

To resolve such constraints, temporary storm water retention facilities need to be introduced to urban systems in highly urbanized areas. The utilization of existing open lands such as playgrounds, parks, school compounds, etc. for temporary storm water retention areas is a conceivable measure for preventing local inundation caused by rapid concentration of storm water runoff to the drainage channels. New land development in the basin should also be subject to this measure to reduce storm water runoff from development areas by provision of storm water retention facilities.

(2) Non-Structural Measures

1) Management of marsh and lowland

There are large expanses of marsh and lowlands in the study area, which have large storm water retention effects. However, due to the reclamation of marsh and lowlands for development housing and industrial estates following the recent rapid expansion of the urbanizing areas, the storm water retention effects of the marshes and lowlands have declined.

It is both technically and financially difficult to replace the storm water retention effects of marshes and lowlands with other structural riparian works. Therefore, it is imperative for storm water drainage that the existing marshes and lowlands should be properly conserved as storm water retention areas. Legal means of restraining the reclamation will be analyzed.

2) Development control and land use regulation

Land use regulation is an important issue to harmonize the storm water drainage and the need for land development in the CMR. A study will be conducted to prepare a future land use plan including urbanization controlling areas, conservation areas, green areas for storm water retention, etc. for the purpose of regulating disordered land development adversely affecting storm water drainage.

3) Disaster preparedness

The study will also focus on disaster preparedness in case that a rainstorm would exceed the design scale of the structural measures. It is also necessary to consider the preparedness before provision of structural measures since it will take a long period to implement structural measures throughout the study area. The following will be the main items of non-structural measures to be studied and proposed through assessment of the present disaster preparedness system in Sri Lanka:

- Clarification of possible inundation areas from an inundation hazard map
- Introduction of 'pilot type' housing in possible inundation areas
- Institutional arrangements for establishment of a flood preparedness system

(3) Institutional Development Plan

A comprehensive institutional set-up of interrelated organizations will be required for effective performance of integrated flood control including both structural and non-structural measures. A basic concept of such an institutional set-up is recommended through review of present roles and responsibilities of different organizations concerned with project implementation and O&M works relating to flood protection and storm water drainage.

(4) Operation and Maintenance Plan

An operation and maintenance plan for storm water drainage systems in the study area will be prepared based on the study on the present operation and maintenance systems of SLLRDC and local authorities. The plan mainly consists of the following:

1) Strategy for operation and maintenance
2) Organizational set-up with staff arrangement
3) Financial management
4) Equipment plan
5) Staff training plan

(5) Human Resources Development Plan

The storm water drainage projects are being implemented mainly around the city of Colombo but will be evolved to the suburbs. Capacity building for project implementation and operation and maintenance of storm water drainage facilities is a key issue for SLLRDC as well as local authorities. The present main problem on this issue is the insufficiency of human resources managing storm water drainage in local authorities.

As a short-term objective, on-the-job training under the leadership of SLLRDC is regarded as a practical method for improving the capability of local authorities. The study proposes strengthening the leadership of SLLRDC to implement effective training programs for local authorities.

The study also focuses on a comprehensive program to train engineers and technicians in the sector of storm water drainage. Such a program is recommended as a long-term objective.

4.4 Ja Ela Basin

4.4.1 Basic Principle for Planning

In the Ja Ela downstream basin, there are two main streams i.e. Dandugam Oya and Ja Ela. Problems of flooding of the main streams to the downstream urban areas along these rivers are relatively small, suggested by the following characteristics of the basin:

1) Paddy lands extending from Ekala to Gampaha in the middle basin are naturally functioning as flood retention areas, which effect to reduce flood peak runoff to the downstream reaches.
2) The Muthurajawela Marsh is the major flood plain in the downstream end and retards flood runoff in vast wetlands where significant raising of water level is not expected.
3) The urbanized areas are located between the above-mentioned paddy lands and Muthurajawela Marsh. The combined effects of the upstream paddy lands and downstream wetlands contribute to alleviating a high concentration of flood runoff of the rivers.

The future land use projection indicates that the urbanization in the basin will proceed mainly along the Negombo Road and at a few inland locations such as Gampaha and Minuwangoda. In the light of the projection, a significant increase of storm water runoff of the main streams is not expected within the time-scale to the target year 2010.

On the other hand, the Colombo-Katunayake Expressway (CKE) is being constructed in parallel with the Negombo Road. The route of CKE runs along the Muthurajawela Marsh and crosses the two main streams of the basin. The necessary openings for storm water drainage across the CKE have already been studied and should therefore be taken into consideration for the storm water drainage plan.

The storm water drainage plan for the Ja Ela basin is therefore proposed to protect the future urbanized areas along the Negombo Road by means of the following principles:

1) The capacities of the two main streams in the downstream areas should be preserved to secure a required flow capacity for attaining the designated planning scale into the future.
2) The paddy lands in the middle basin presently functioning as a storm water retention area should be conserved to the extent required for the future.
3) The Muthurajawela Marsh should be conserved as a flood plain to maintain the natural flood retarding capacity for the storm water runoff of the main streams.

4.4.2 Basic Flood Runoff

The basic flood runoffs in the Ja Ela basin for probable 10, 25, and 50-year rainstorm events under the future land use conditions are estimated for several base points along the river channel as shown in Figure 4.2. In comparison with the estimated flood runoff with the basin retention effect as shown in Figure 4.3, the peak runoffs of basic floods increase by 41% for a 10-year return period, 69% for a 25-year storm, and 87% for a 50-year storm in the Dandugam Oya at Negombo Road. Figures 4.4 and 4.5 show the comparison of flood hydrographs in the Dandugam Oya at Negombo Road and the Ja Ela at Negombo Road.

Comparison of Flood Discharge with and without Basin Retention Effect in Ja Ela Basin

Location	Return Period (years)	Basic Flood Runoff (m^3/sec)	Flood Runoff with Basin Retention Effect (m^3/sec)
Dandugam Oya at Negombo Road	10	205	145
	25	295	175
	50	365	195
Ja Ela at Negombo Road	10	65	50
	25	90	60
	50	110	70

4.4.3 Flow Capacity of Main Stream

The flow capacities of the main streams in the Ja Ela basin were evaluated from the channel cross sections surveyed and estimated probable runoff.

The flow capacity of the Ja Ela is smaller than the probable 2-year flood runoff in most downstream reaches and the flood plain near Ekala. Other than these sections, the flow capacity is larger than the probable 5-year flood runoff except for a few locations.

The flow capacity of the Dandugam Oya is smaller than the probable 2-year flood runoff in the downstream reaches from the flood plain near Kotudoda while the upstream reaches from the flood plain mostly indicate a flow capacity larger than the probable 5-year flood runoff.

Flow Capacity of Mainstream in Ja Ela Basin

Ja Ela (Unit: m^3/s)

Section	Minimum	Maximum	Average
0-10 km	12	85	38
10-22 km	14	133	55
22-26 km	12	43	24
26-28 km	14	53	26

Dandugam Oya (Unit: m^3/s)

Section	Minimum	Maximum	Average
0-12 km	53	227	120
12-23 km	22	245	76
23-34 km	30	337	70
34-40 km	14	223	69

4.4.4 Conceivable Structural Measures

The conceivable structure measures for storm water drainage in the Ja Ela basin are illustrated in Figure 4.6 and listed below:

1) Channel Improvement of Dandugam Oya
    - Stretch from edge of the Muthurajawela Marsh to junction with the Mapalam Oya (length 9.9 km)
2) Channel Improvement of Ja Ela
    - Stretch from the edge of the Muthurajawela Marsh to the downstream end of the possible storm water retention area around Ekala (length 7.0 km)
3) Diversion Channel from Kotugoda to Seeduwa
    - A short-cut channel of Dandugam Oya from Kotugoda to Seeduwa (length of 3.1 km)
4) Storm Water Retention Area
    - Defined by ground surface elevation around the proposed locations as follows:

Conceivable Retention Areas

Mainstream	Location	Elevation in Retention Area (above MSL)	Extent of Retention Area (ha)
Mapalam Oya	Walanagoda - Unnaruwa	Below 4m	1,357
Dandugam Oya	Madawala - Heenatiyana - Urukalana		
Ja Ela	Kotugoda - Ekala -Visakawatta		
Uruwal Oya	Tibbotugoda - Ratmalwita	Below 7m	101
Attanagalu Oya	Medagama - Asgiriya South	Below 10m	275
		Total	1,733

4.4.5 Comparative Study of Alternative Drainage Plans

(1) Alternative Combinations

The storm water drainage plan for the Ja Ela basin is prepared comprising a combination of the conceivable measures described above, a comparative study is carried out for the following alternative combinations:

Alternative Combinations

Case	Channel Improvement of Ja Ela	Channel Improvement of Dandugam Oya	Kotugoda - Seeduwa Diversion Channel
J1	Length = 7.0 km Width = 45m	Length = 9.9 km Width = 65 m (3.5-7.5 km) Width = 55 m (7.5-13.4 km)	-
J2	Length = 7.0 km Width = 50m	Length = 9.9 km Width = 70 m (3.5-7.5 km) Width = 60 m (7.5-13.4 km)	-
J3	Length = 7.0 km Width = 55m	Length = 9.9 km Width = 75 m (3.5-7.5 km) Width = 65 m (7.5-13.4 km)	-
J4	Length = 7.0 km Width = 45m	Length = 9.9 km Width = 65 m (3.5-7.5 km) Width = 55 m (7.5-13.4 km)	Length = 3.1 km Width= 20 m
J5	Length = 7.0 km Width = 60m	Length = 9.9 km Width = 80 m (3.5-7.5 km) Width = 70 m (7.5-13.4 km)	-
J6	Length= 7.0 km Width = 80m	Length = 9.9 km Width = 100 m (3.5-7.5 km) Width = 90 m (7.5-13.4 km)	-

(2) Effect of Retention Area in Lower Basin

The alternative combinations above are based on the conservation of storm water retention areas as described in the sub-section 4.4.4. The effects of the retention areas in the lower basin are analyzed for the four options of the delimitation level such as 4 m above MSL for the base option, and 3 m, 2 m, and 1 m above MSL for the other options of retention area reduction. For these options, it is assumed that the proposed retention areas in the upper basin remain as described in the sub-section 4.4.4 above.

Extent of Retention Area by Delimitation Level

(Unit: ha)

River/Location	Delimitation Level (above MSL)			
	4 m	3 m	2 m	1 m
Mapalam Oya /Walanagoda - Unnaruwa Dandugam Oya / Madawala -Heenatiyana - Urukalana Ja Ela / Kotugoda - Elakala -Visakawatta	1,357	948	572	237
Uruwal Oya /Tibbotugoda - Ratmalwita	101 (Delimitation Level 7m)			
Attanagalu Oya /Medagama - Asgiriya South	275 (Delimitation Level 10m)			
Total	1,733	1,329	953	618

It is assumed that land reclamation would be conducted above the delimitation level with a sufficient height to cope with the inundation level increasing with the reduction of the retention area. The results of the analysis for the effects of retention area are retrieved as shown in Table 4.3, Figure 4.7.

When the water level rises with the reduction of the retention area, the capacity of the drainage facilities downstream should be enlarged to lower the water to the allowable level. The total extent of the lower retention areas required for securing the allowable water levels is derived from the graphs shown in Figure 4.7. Case J2 satisfies the allowable water levels in the lower retention areas, Ja Ela at Negombo Road, and Dandugam Oya at Negombo Road when the total extent of the lower retention areas is reduced from 1,357 ha to 650 ha. The corresponding delimitation level is 2.2 m above MSL in the lower retention area. Case J5, with the larger channel, keeps the allowable water levels on the condition that the lower retention area is reduced to 500 ha corresponding to the delimitation level of 1.8 m above MSL.

Required Extent of Lower Retention Area (50-year Return Period)

Case	Required Retention Area by Allowable Water Level (ha)			Minimum Required Retention Area (ha)
	Ja Ela 1.65 m	Dandugam Oya 1.58 m	Lower Retention Area 3.50 m	
J1	100	700	920	920
J2	---	640	650	650
J3	---	560	400	560
J4	100	1,150	200	1,150
J5	---	500	---	500
J6	---	330	---	330

Note: --- means the water level for the required retention area of 0 ha is still lower than the allowable water level.

(3) Evaluation of Alternative Combinations

The alternatives are evaluated by the economic evaluation. Benefit-cost ratio (B/C) and economic internal rate of return (EIRR) for each alternative are computed from economic cost and annual benefit from flood damage mitigation. In addition to the benefit of flood damage mitigation, land enhancement benefit is taken into account for lands free from inundation by alternative measures.

The land area equivalent to the reduction of the retention area is also regarded as free from inundation and would be available for possible development. This opportunity for development is counted as an incremental benefit combined with the flood damage reduction benefit by structural measures while the cost for land development is also incorporated in with the economic evaluation.

Economic Evaluation for Alternative Combinations (50-year Return Period)

Case	Retention Area (ha)	Project Cost (million Rs.)	Annual Benefit (million Rs.)	B/C	EIRR (%)
J1	920+376	2,663	264	1.10	10.9
J2	650+376	2,965	349	1.30	12.6
J3	560+376	3,507	394	1.24	12.1
J4	1,150+376	3,029	191	0.84	8.7
J5	500+376	3,679	440	1.34	12.9
J6	330+376	4,400	645	1.63	15.2

4.4.6 Study on Optional Planning Scales (25-year and 10-year Return Periods)

The alternative combinations are similar to those described in the sub-section 4.4.5 above, but the cross section of the channel is reduced and is sufficient for the probable 25-year and 10-year flood runoff. In these cases, it is assumed that the channel improvement is only composed of the construction of dikes (flood bunds) on both sides of the channel to secure the required channel width. The estimated water level from a rainstorm event for each return period under the present land use condition is adopted as the allowable water level.

Allowable Water Level (25- and 10-year Return Period)

Planning Scale (Return Period)	Ja Ela at Negombo Road	Dandugam Oya at Negombo Road	Lower Retention Area
25-year	1.47 m above MSL	1.43 m above MSL	3.24 m above MSL
10-year	1.24 m above MSL	1.22 m above MSL	2.83 m above MSL

The effect of the retention area is also carried out on the alternatives for the planning scales of 25-year and 10-year return periods. The effect of raising the water level in the retention areas and the required additional measures for reducing the water level are as shown in Table 4.3. The alternative combinations with required retention areas are evaluated by benefit-cost ratio (B/C) and economic internal rate of return (EIRR).

Economic Evaluation for Alternative Combinations (25- and 10-year Return Period)

a) Planning scale: 25-year return period

Case	Retention Area (ha)	Project Cost (million Rs.)	Annual Benefit (million Rs.)	B/C	EIRR (%)
J1	1,170+376	2,222	132	0.66	6.5
J2	1,080+376	2,288	188	0.90	9.1
J3	950+376	2,381	266	1.22	11.9
J4	1,357+376	2,462	156	0.88	9.0
J5	930+376	2,471	282	1.25	12.2
J6	780+376	2,830	383	1.47	13.5

b) Planning scale: 10-year return period

Case	Retention Area (ha)	Project Cost (million Rs.)	Annual Benefit (million Rs.)	B/C	EIRR (%)
J1	1,020+376	2,076	207	1.04	10.4
J2	950+376	2,147	250	1.22	12.0
J3	850+376	2,249	310	1.49	14.2
J4	1,357+376	2,345	137	0.88	9.1
J5	810+376	2,331	335	1.55	14.8
J6	680+376	2,699	420	1.69	15.2

4.4.7 Proposed Storm Water Drainage Plan

The study proposes the planning scale of a 50-year return period for the storm water drainage plan in the Ja Ela basin. The Ja Ela and Dandugam Oya are the main streams in the basin. A certain high planning scale is required for such main streams as mentioned in the section 4.1. In case that the project cost for the planning scale of a 50-year return period becomes a financial burden to the government, a stage-wise implementation is proposed. The planning scale of a 10-year or 25-year return period is to be attained in the first stage and is to be increased in the latter stages.

The results of economic evaluation show that the cases J2, J3, J5, and J6 indicate good economic viability when the land enhancement benefit would be expected. Of those, case J6 with the larger openings than the already proposed openings of the CKE is regarded as a reference. In view of the long-term objective for flood protection, it would be desirable to secure the allowable maximum channel width for each main stream running through the potential urbanization areas. The following case J5 is therefore proposed as the storm water drainage plan for the Ja Ela basin

1) Channel Improvement of Ja Ela (total length 7.0 km)
    - Width 60 m from 2.0 to 9.0 km

2) Channel Improvement of Dandugam Oya (total length 9.9 km)
    - Width 80 m from 3.5 to 7.5 km
    - Width 70 m from 7.5 to 13.4 km
3) Storm Water Retention Area (total 876 ha)
    - Lower Retention Areas: 500 ha
    - Upper Retention Areas: 376 ha

The general layout and conceptual designs for the proposed storm water drainage plan are illustrated in Figures 4.8 to 4.15.

4.5 Kalu Oya Basin

4.5.1 Basic Principle for Planning

The Kalu Oya basin faces the difficulty of natural drainage from the lowlands on the right bank of the Kelani Ganga. The higher embankment of the Negombo Road and Railway separates these low-lying lands, which might be a cause of the formation of the marshlands on the upstream side.

The Kalu Oya main stream is the only major drainage for the basin crossed by the Railway and Negombo Road. The drainage of the Kalu Oya is affected by the backwater of the Kelani Ganga. It is reported that the inundation in the lowlands sometimes continues for one week or more once a heavy rainstorm occurs.

The Kalu Oya basin is subject to urbanization expanding from Colombo and is expected to be urbanized rapidly. Further urbanization is projected, not only in the downstream areas along the Negombo Road, but also in the upstream areas along the Kandy Road and the planned route of the Outer Circular Highway. According to future land use projections, urbanization will be expanding throughout the basin.

The route of the Colombo-Katunayake Expressway (CKE) being constructed runs from south to north in the Kalu Oya basin. The necessary openings for storm water drainage across the CKE have already been studied and should therefore be taken into consideration for the storm water drainage plan.

In view of storm water drainage, the Kalu Oya basin requires solutions for the fundamental drainage problems and protection against future increase of storm water runoff due to the urbanization in the basin. For these objectives, a combination of the following measures is conceivable

1) Channel improvement of the Kalu Oya downstream of the existing inland marsh area
2) Diversion of storm water runoff to the Muthurajawela Mash as a storm water retention area

3) Conservation of lowlands as storm water retention areas
4) Reduction of storm water runoff by introduction of storm water retention facilities in urban areas

4.5.2 Basic Flood Runoff

The basic flood runoffs in the Kalu Oya basin for probable 10, 25 and 50-year rainstorm events under future land use conditions are estimated for several locations along the river channel as shown in Figure 4.16. In comparison with the estimated flood runoff with the basin retention effect as shown in Figure 4.17, the peak runoffs of basic floods increase around five times if the storm water runoff is confined completely within the channels without the retention areas. The significant difference in peak runoff with and without retention effect in the basin suggests the difficulty of drainage to the Kelani Ganga causing stagnation of storm water runoff over the low-lying lands in the Kalu Oya basin. Figure 4.18 shows the comparison of flood hydrographs in the Kalu Oya at Negombo Road.

Comparison of Flood Discharge with and without Basin Retention Effect

Location	Return Period (years)	Basic Flood Runoff (m^3/sec)	Flood Runoff with Basin Retention Effect (m^3/sec)
Kalu Oya at Negombo Road	10	110	20
	25	150	30
	50	185	35

4.5.3 Flow Capacity of Main Stream

The flow capacity of the Kalu Oya was evaluated from the channel cross sections surveyed and estimated probable runoff. The flow capacity of the Kalu Oya is smaller than the probable 2-year flood as a whole except the most downstream reaches and upstream of the Kandy Road.

Flow Capacity of Kalu Oya

(Unit: m^3/sec)

Section	Minimum	Maximum	Average
0-6 km	6	28	13
6-13 km	3	22	10
13-15 km	2	27	10

4.5.4 Conceivable Structural Measures

Based on the basic principle of storm water drainage planning, the conceivable structural measures for storm water drainage in the Kalu Oya basin are identified as described hereafter and illustrated in Figure 4.19.

1) Channel Improvement of Kalu Oya
    - Stretch from inland marsh to confluence of Kelani Ganga (length 5.0 km)
2) Old Negombo Canal Improvement
    - Stretch from confluence of Kalu Oya to Muthurajawela Marsh (length 4.5 km)
3) Diversion Channel to Muthurajawela Marsh
    - A diversion channel across Negombo Road from inland marsh to Muthurajawela Marsh (length 3.6 km)
4) Wattala Pumping Station
    - A pumping station at downstream end of Kalu Oya
5) Storm Water Retention Area
    - Retention area delimitated by ground elevation of 2 m above MSL in lower reaches (434 ha)
    - Retention area delimitated by ground elevation of 4 m above MSL in upper reaches (89 ha)

4.5.5 Comparative Study of Alternative Drainage Plans

(1) Alternative Combinations

The conceivable alternative components described above are evaluated by a preliminary cost-benefit analysis. Scale alternatives are also taken into consideration for the component projects. The following alternative components are examined:

Alternative Components for Kalu Oya Basin

Case	Measures
K1	Channel Improvement of Kalu Oya (B= 40 m, L= 5,000 m)
K2	Channel Improvement of Kalu Oya (B= 45 m, L= 5,000 m)
K3	Channel Improvement of Kalu Oya (B= 50 m, L= 5,000 m)
K4	Wattala Pumping Station (Q= 10 m^3/sec)
K5	Wattala Pumping Station (Q= 20 m^3/sec)
K6	Wattala Pumping Station (Q= 30 m^3/sec)
K7	Diversion Channel to Muthurajawela Marsh (B= 30 m, L=1,200+2,400 m)
K8	Improvement of Old Negombo Canal to Muthurajawela Marsh (B= 30 m, L= 4,500 m)
K9	Improvement of Old Negombo Canal to Muthurajawela Marsh (B= 35 m, L= 4,500 m)
K10	Improvement of Old Negombo Canal to Muthurajawela Marsh (B= 40 m, L= 4,500 m)

Note: B: width of channel, L: length of channel, Q: discharge capacity

From the results of the preliminary cost-benefit analysis, alternative components to divert storm water to the Muthurajawela Marsh (cases K7, K8, K9 and K10) indicate good economic viability. Cases K1, K2 and K3 of channel improvement of Kalu Oya give a lower EIRR. Cases K4, K5 and K6 for the Wattala pumping station appear not to be economically viable.

Both options to divert storm water to the Muthurajawela Marsh are therefore incorporated into the alternative components for the storm water drainage plan. On the other hand, the channel improvement of Kalu Oya is an essential measure for storm water drainage in the Kalu Oya basin from the technical point of view. Since this stretch is the only substantial waterway in the Kalu Oya basin to drain storm water runoff to the Kelani Ganga, the channel improvement is a fundamental requirement for storm water drainage in the basin.

Alternative combinations of the component projects are examined based on the condition that an allowable water level should be secured in the Kalu Oya inland marsh area. The estimated water level of 1.67 m above MSL from a 50-year rainstorm event under the present land use condition is adopted as the allowable water level.

Alternative Combinations

Case	Measures
K11	K1+K8+Retention Area
K12	K2+K9+Retention Area
K13	K3+K10+ Retention Area
K14	K1+K7+K8+ Retention Area
K15	K1+K6+K8+Retention Area
K16	K1+K7+ Retention Area
K17	K1+K9+ Retention Area
K18	K1+K10+ Retention Area
K19	K3+K7+K10+ Retention Area
K20	K3+K6+K7+10+ Retention Area

(2) Effect of Retention Area

The alternative combinations above are based on the conservation of storm water retention areas as described in sub-section 4.5.4. The effects of the retention areas in the lower reaches are analyzed for the four options of the delimitation level. The results of the analysis are as shown in Table 4.4.

Extent of Retention Area by Delimitation Level

(Unit: ha)

Lower Retention Areas	Delimitation Level (above MSL)			
	2 m	1.5 m	1.0 m	0.5 m
	434	357	250	131
Upper Retention Areas	89			
Total	523	446	339	220

The total extent of the lower retention areas required for securing the allowable water levels is derived from the graphs shown in Figure 4.20. Case K13 satisfies the allowable water level in the basin with a retention area of 360 ha corresponding to the delimitation level of 1.5 m above MSL in the lower retention areas. Case K20 with the larger channel keeps the allowable water levels with the condition that the retention area is reduced to 160 ha corresponding to the delimitation level of 0.6 m above MSL.

(3) Evaluation of Alternative Combinations

The alternative combinations are evaluated by the economic evaluation. Benefit-cost ratio (B/C) and economic internal rate of return (EIRR) for each alternative are computed from economic cost and annual benefit from flood damage mitigation as well as land development cost and land enhancement benefit.

Comparison of Alternative Combinations (50-year Return Period)

Case	Retention Area (ha)	Project Cost (million Rs.)	Annual Benefit (million Rs.)	B/C	EIRR (%)
K11	434+89	1,927	162	1.02	10.2
K12	434+89	2,182	192	1.08	10.6
K13	360+89	2,463	422	1.98	17.8
K14	290+89	2,806	655	2.93	24.1
K15	340+89	5,896	519	0.90	9.0
K16	340+89	2,390	493	2.34	20.3
K17	434+89	2,001	173	1.11	10.9
K18	434+89	2,136	182	1.08	10.7
K19	200+89	3,331	888	3.20	25.7
K20	160+89	7,422	1,113	1.75	15.2

Note: Average water level in the retention area is 1.67 m above MSL for all cases.

4.5.6 Study on Optional Planning Scales (25-year and 10-year Return Periods)

The alternative combination is the same as described in sub-section 4.5.5 above, except that the cross section of the channel is reduced but still sufficient for the probable 25-year and 10-year flood runoff. In these cases, it is assumed that the channel improvement is only composed of the construction of dikes (flood bunds) on both sides of the channel to secure the required channel width. The estimated water level from a rainstorm event for each return period under the present land use condition is adopted as the allowable water level. The allowable water level in the retention area is 1.60 m for a 25-year return period and 1.51 m above MSL for a 10-year return period.

The effect of the retention area is also carried out on the alternatives for the planning scale of 25-year and 10-year return periods. The required additional measures for reducing water level in the retention area are summarized in Table 4.4. The alternative combinations were evaluated by B/C and EIRR as follows:

Comparison of Alternative Combinations for Reduction of Retention Area

a) Planning Scale: 25-year Return Period

Case	Retention Area (ha)	Project Cost (million Rs.)	Annual Benefit (million Rs.)	B/C	EIRR (%)
K11	434+89	1,772	148	1.08	10.7
K12	390+89	1,879	298	1.90	16.8
K13	330+89	1,975	489	2.84	23.0
K14	265+89	2,594	690	2.98	24.1
K15	250+89	5,762	797	1.53	14.6
K16	310+89	2,249	551	2.78	22.8
K17	434+89	1,802	161	1.15	11.2
K18	390+89	1,801	302	2.00	17.5
K19	175+89	2,807	987	3.90	29.3

Note: Average water level in retention area is 1.60 m above MSL for all cases.

b) Planning Scale: 10-year Return Period

Case	Retention Area (ha)	Project Cost (million Rs)	Annual Benefit (million Rs.)	B/C	EIRR (%)
K11	434+89	1,751	149	1.25	11.8
K12	320+89	1,810	405	3.41	25.7
K13	250+89	1,899	618	4.66	32.1
K14	215+89	2,533	713	3.84	28.5
K15	150+89	5,671	969	2.66	21.9
K16	290+89	2,219	481	3.04	24.0
K17	325+89	1,704	389	3.50	26.2
K18	275+89	1,699	525	4.59	31.6

Note: Average water level in retention area is 1.51 m above MSL for all cases.

4.5.7 Proposed Storm Water Drainage Plan

Although B/C and EIRR become higher because of the land enhancement benefit as the planning scale is lowered, the study proposes the planning scale of a 50-year return period for the storm water drainage plan in the Kalu Oya basin. As mentioned in the section 4.1, a certain high planning scale is required for the Kalu Oya basin being urbanized and expected as a future development area next to the Greater Colombo basin. In case that the project cost for the planning scale of a 50-year return period becomes a financial burden to the government, a stage-wise implementation is proposed. A planning scale of a 10 or 25-year event is to be attained in the first stage and is to be increased in the latter stages.

The alternative combinations of K14, K16, K18 and K19 include the diversion channel component (K7) and indicate a higher B/C and EIRR than the others without K7. However, the diversion channel requires additional crossings for both Negombo Road and CKE, which would cause rather difficult technical and social problems.

Based on the above considerations, case K13 with the highest B/C and EIRR among the alternative combinations without the diversion channel component is proposed as the storm water drainage plan for the Kalu Oya basin:

1) Channel Improvement of Kalu Oya
    - Total Length 5.0 km
    - Width 50 m from 0.0 km to 3.8 km (Trapezoidal Cross Section)
    - Width 25 m from 3.8 km to 5.0 km (Rectangular Cross Section)
2) Channel Improvement of Old Negombo Canal
    - Total Length 4.5 km
    - Width 40 m (Trapezoidal Cross Section)
3) Strom Water Retention Area (449 ha)
    - Lower Retention Areas: 360 ha
    - Upper Retention Areas: 89 ha

The general layout and conceptual designs for the proposed storm water drainage plan are illustrated in Figures 4.21 to 4.27.

4.6 Greater Colombo Basin

4.6.1 Basic Principle for Planning

In the Greater Colombo basin, the present safety level of the main canal system was evaluated in the range of a 5-year to 25-year return period. Substantial improvement was accomplished by the GCFC&EIP Phase I but further improvement should also be considered in order to cope with economic growth in the basin and an increase in social requirements for flood protection in the future.

It is projected that the Greater Colombo basin will be urbanized extensively with land development expanding to the suburbs. As a result, it is anticipated that the inundation in the case of heavy rainstorms will be worsening due to the significant increase in storm water runoff to be caused by the extensive urbanization even though the existing storm water retention areas will be conserved properly.

To alleviate the increase of storm water runoff, it is essential to conserve the presently functioning storm water retention areas and preserve other lowlands available for the purpose of storm water retention as much as possible. In addition, the existing storm water drainage system should also be augmented to increase the flood safety level.

For the purpose of the above, a combination of the following measures is proposed as a basin-wide storm water drainage plan:

1) Conservation of existing storm water retention areas and utilization of other lowlands for storm water retention purposes

2) Augmentation of the capacity to drain storm water runoff out of the basin
3) Increase in the flow capacity of existing major drainage canals

4.6.2 Basic Flood Runoff

The basic flood runoffs in the Greater Colombo basin for the probable 10, 25, and 50-year rainstorm events under the future land use conditions are estimated for several base points along the river channel as shown in Figure 4.28. In comparison with the estimated flood runoffs with the basin retention effect as shown in Figure 4.29, the peak runoffs of the basic flood increases by 88 % for a10-year return period, 109 % for a 25-year event, and 114 % for a 50-year event in Krillapone Canal at Open University Bridge. Figure 4.30 shows the comparison of flood hydrographs in Kirillapone Canal at Open University Bridge.

Comparison of Flood Discharge with and without Basin Retention Effect in Greater Colombo Basin

Location	Return Period (years)	Basic Flood Runoff (m^3/sec)	Flood Runoff with Basin Retention Effect (m^3/sec)
Kirillapone Canal at Open University Bridge	10	75	40
	25	115	55
	50	150	70

4.6.3 Flow Capacity of Main Stream

The GCFC&EIP Phase I indicates that the allowable water level of the canal system is 1.85 m above MSL at Parliament Lake and 1.75 m above MSL for the urban part west of Parliament Lake. Under the GCFC&EIP Phase I, the canal bed level was dredged down to 1.0 m below MSL for the entire improved section. The canal bank was improved by raising it to an elevation of 1.8 m to 2.0 m above MSL for the urbanized sections. The canal bank level remains at lower elevations for the other sections located along the low-lying areas, which function as the storm water retention areas. The present flow capacity of the canal system is evaluated as follows:

Flow Capacity of Canal System in Greater Colombo Basin

(Unit: m^3/sec)

Canal	Minimum (m^3/sec)	Maximum (m^3/sec)	Average (m^3/sec)
Main Drain	9	27	16
St. Sebastian Canal	3	17	8
Dematagoda Ela	5	18	11
Heen Ela	12	44	22
Torrington Canal	7	47	29
Kolonnawa Ela	5	60	30
Kotte Ela	19	48	32
Kirillapone Canal	17	56	31
Wellawatta Canal	12	47	34
Dehiwela Canal	8	35	14

4.6.4 Conceivable Structural Measures

Based on the basic principle of storm water drainage planning, the conceivable structural measures for storm water drainage in the Greater Colombo basin are identified as described hereafter and illustrated in Figure 4.31.

1) Maradana Pumping Station and Improvement of Galle Face Sea Outfall
    - Connection of St. Sebastian Canal with Beira Lake across Maradana Road
    - A pumping station for draining storm water from St. Sebastian Canal to Beira Lake
    - Improvement of Beira Lake sea outfall at Galle Face
2) North Lock Pumping Station
    - A pumping station at North Lock gate
3) Gotatuwa Pumping Station
    - A pumping station at Gotatuwa flood bund
4) Madiwela South Diversion Canal
    - A diversion channel across High Level Road from Madiwela catchment upstream of the Parliament Lake to Weras Ganga (length 8.6 km)
5) Restoration of Existing Mutwal Tunnel
    - Restoration of deteriorated existing tunnel connecting Main Drain with sea outfall (dia. 1.8 m, length 550 m)
6) New Mutwal Tunnel
    - A new tunnel connecting Main Drain with sea outfall (dia. 4.0 m, length 740 m)
7) Widening of Wellawatta and Kirillapone Canals
    - Widening of Wellawatta Canal (length 1,900 m)
    - Widening of Kirillapone Canal (length 1,200 m)

8) Storm Water Retention Area

- Delimitated by ground elevation of 2 m above MSL as follows:

Storm Water Retention Area

(Unit: ha)

Retention Area	Land Area Lower than 2 m above MSL
Kolonnawa Ela	157
Heen Ela	72
Kotte Ela	115
Parliament Lake Surroundings	30
Other Areas	61
Total	435

4.6.5 Comparative Study of Alternative Drainage Plans

(1) Alternative Combinations

The conceivable alternative components described above were evaluated by a preliminary cost-benefit analysis. Scale alternatives are also taken into consideration for the components. The following alternative components were examined:

Alternatives Components

Case	Measures
G1	Maradana Pumping Station (Q= 5 m^3/sec) and Improvement of Galle Face Outfall
G2	Maradana Pumping Station (Q= 10 m^3/sec) and Improvement of Galle Face Outfall
G3	North Lock Pumping Station (Q= 10 m^3/sec)
G4	North Lock Pumping Station (Q= 15 m^3/sec)
G5	Gotatuwa Pumping Station (Q= 30 m^3/sec)
G6	Gotatuwa Pumping Station (Q= 40 m^3/sec)
G7	Madiwela South Diversion Channel
G8	Restoration of Existing Mutwal Tunnel (D=1.8 m)
G9	New Mutwal Tunnel (D= 3 m)
G10	New Mutwal Tunnel (D= 4 m)
G11	Widening of Wellawatta and Kirillapone Canals

To cope with a 50-year rainstorm event under the future land use condition, a storm water drainage plan in the Greater Colombo basin requires a combination of some alternative components.

The analysis discussed here adopts the average water level of 1.75 m above MSL in the retention areas along the Kolonnawa Ela, Heen Ela and Kotte Ela as the allowable water level. This water level represents almost the same condition as the allowable water levels of 1.85 m above MSL at Parliament Lake and 1.75 m above MSL for the urban part west of Parliament Lake in the Greater Colombo basin. Resulting from the hydrological analysis, the following alternative combinations were prepared:

Alternative Combinations

Case	Measures
G12	• G7 Madiwela South Diversion Channel • G8 Restoration of Existing Mutwal Tunnel (D=1.8 m) • Retention Area
G13	• G7 Madiwela South Diversion Channel • G9 New Mutwal Tunnel (D= 3 m) • Retention Area
G14	• G7 Madiwela South Diversion Channel • G10 New Mutwal Tunnel (D= 4 m) • Retention Area
G15	• G8 Restoration of Existing Mutwal Tunnel (D=1.8 m) • G9 New Mutwal Tunnel (D= 3 m) • Retention Area
G16	• G8 Restoration of Existing Mutwal Tunnel (D=1.8 m) • G10 New Mutwal Tunnel (D= 4 m) • Retention Area
G17	• G7 Madiwela South Diversion Channel • G11 Widening of Wellawatta and Kirillapone Canals • Retention Area
G18	• G7 Madiwela South Diversion Channel • G8 Restoration of Existing Mutwal Tunnel (D=1.8 m) • G9 New Mutwal Tunnel (D= 3 m) • Retention Area
G19	• G7 Madiwela South Diversion Channel • G8 Restoration of Existing Mutwal Tunnel (D=1.8 m) • G10 New Mutwal Tunnel (D= 4 m) • Retention Area
G20	• G7 Madiwela South Diversion Channel • G8 Restoration of Existing Mutwal Tunnel (D=1.8 m) • G11 Widening of Wellawatta and Kirillapone Canals • Retention Area
G21	• G7 Madiwela South Diversion Channel • G9 New Mutwal Tunnel (D= 3 m) • G11 Widening of Wellawatta and Kirillapone Canals • Retention Area
G22	• G7 Madiwela South Diversion Channel • G10 New Mutwal Tunnel (D= 4 m) • G11 Widening of Wellawatta and Kirillapone Canals • Retention Area

(2) Effect of Retention Area

The alternative combinations above are based on the conservation of storm water retention areas as described in sub-section 4.6.4. The effect of the retention areas is analyzed for the following four options of delimitation level.

Extent of Retention Area by Delimitation Level

(Unit: ha)

Retention Area	Delimitation Level (above MSL)			
	2 m	1.5 m	1.0 m	0.5 m
Kolonnawa Ela	157	142	119	42
Heen Ela	72	56	31	5
Kotte Ela	115	101	77	13
Parliament Lake Surroundings	30	27	13	6
Other Areas	61	54	44	3
Total	435	380	284	71

With the reduction of the storm water retention area, the capacity of drainage facilities should be enlarged to cope with the increased runoff. The results of the analysis are as shown in Table 4.5 and Figure 4.32.

Case G19 satisfies the allowable water level with a retention area of 380 ha corresponding to the delimitation level of 1.5 m above MSL. Case G20 with the larger facilities keeps the allowable water level with the condition that the retention area is reduced to 290 ha corresponding to the delimitation level of 1.0 m above MSL.

(3) Evaluation of Alternative Combinations

The alternative combinations are evaluated by a cost-benefit analysis to identify the most economical combination. The results of the cost-benefit analysis for the alternative combinations are summarized below:

Comparison of Alternative Combinations (50-year Return Period)

Case	Retention Area (ha)	Project Cost (million Rs.)	Annual Benefit (million Rs.)	B/C	EIRR (%)
G17	435	5,393	678	1.40	13.5
G18	435	4,473	681	1.70	15.7
G19	380	4,389	886	2.23	19.5
G20	360	5,307	933	1.93	17.5
G21	320	5,940	1,114	2.06	18.4
G22	290	6,009	1,251	2.28	20.0
G23	280	6,133	1,303	2.33	20.3
G24	170	8,804	1,850	2.32	20.3

Note: G23 = G7+G8+G10+G11
G24 = G4+G7+G8+G10+G11
Average water level in retention area is 1.75 m above MSL for all cases.

4.6.6 Study on Optional Planning Scales (25-year and 10-year Return Periods)

The cost-benefit analysis was carried out for the alternative components in the same manner as described in the sub-section 4.6.4.

For the planning scale of a 25-year return period, most of the alternative components individually achieve the allowable water level of 1.85 m MSL at Parliament Lake and 1.75 m MSL for the urban part west of Parliament Lake.

The results of the hydrological study indicate that the existing major canal system in the Greater Colombo basin is sufficient for runoff from a probable 10-year rainstorm event under the future land use condition. Hence, the present major canal system in the basin will provide the safety level for a 10-year return period in the future, assuming that the storm water retention area is delimitated at less than 2 m above MSL. But some additional measures would be necessary if the retention areas are reduced

Similarly to the descriptions in the sub-section 4.6.5 above, the effect of retention area is analyzed. The results of the analysis are summarized in Table 4.5. The alternative combinations were evaluated by B/C and EIRR as follows:

Comparison of Alternative Combinations

a) Planning Scale: 25-year Return Period

Case	Retention Area (ha)	Project Cost (million Rs.)	Annual Benefit (million Rs.)	B/C	EIRR (%)
G7	190	3,327	1,144	3.74	27.8
G10	340	855	452	5.72	38.3
G12	170	3,451	1,247	3.94	29.8
G13	150	4,112	1,373	3.65	28.2
G14	135	4,181	1,461	3.83	29.1
G15	320	908	478	4.83	37.4
G16	310	978	549	6.09	39.8
G19	125	4,305	1,515	3.86	29.3

Note: Average water level in retention area is 1.75 m above MSL for all cases.

b) Planning Scale: 10-year Return Period

Case	Retention Area (ha)	Project Cost (million Rs.)	Annual Benefit (million Rs.)	B/C	EIRR (%)
G8	330	302	103	3.81	28.9
G9	270	785	295	4.22	30.8
G10	240	855	393	5.12	35.1

Note: Average water level in retention area is 1.48 m above MSL for all cases.

4.6.7 Proposed Storm Water Drainage Plan

The study proposes a planning scale of a 50-year return period for the storm water drainage plan in the Greater Colombo basin. In the light of the socio-economic importance of the basin in the country, a high planning scale needs to be provided for the future. If the project cost for the planning scale of a 50-year return period becomes a financial burden to the government, a stage-wise implementation is proposed, i.e., a planning scale of a 25-year event to be attained in the first stage and the 50-year event in a latter stage. The planning scale for a 10-year return period with a significant decrease of storm water retention area would not be affordable in view of the social requirements for storm water drainage and conservation of appropriate natural environment in the basin even though the benefit of land development is quite large.

For the planning scale of a 50-year return period, the cases G19, G22, G23 and G24 indicate high B/C and EIRR. Case G19, which also comprises the components of G10 and G8, can be completed for the least cost among the three combinations and shows the highest economic viability for the 25-year and 10-year return periods. It is therefore proposed as the storm water drainage plan for the Greater Colombo basin.

1) Restoration of Mutwal Tunnel
   - Total Length 554 m
   - Diameter 1.8 m
2) Construction of New Mutwal Tunnel
   - Total Length 740 m
   - Diameter 4.0 m
3) Madiwela South Diversion Channel
   - Total Length 8,800 m
   - Width 32 m (Trapezoidal Cross Section)
4) Storm Water Retention Areas (380 ha)

The general layout and conceptual designs for the proposed storm water drainage plan are illustrated in Figures 4.33 to 4.42.

4.7 Bolgoda Basin

4.7.1 Storm Water Drainage Plan in Bolgoda Basin

The Bolgoda basin is characterized by the drainage system in the downstream lowlands consisting of the two major lakes and waterways interconnecting each other. These constitute an integrated system functioning as a natural flood plain. According to the future land use projection, extensive urbanization in the basin is not expected within the time-scale to the target year 2010 except the Weras Ganga basin covering the areas of Dehiwela - Mount Lavinia, Moratuwa, Maharagama and Kesbewa in the northern part of the Bolgoda basin.

For the basin-wide flood management in a long-term view, conservation of existing natural drainage systems in the downstream end is an essential need in the basin. Any large-scale structural measures such as channel improvements and runoff diversion facilities will not be affordable within the time scale to the target year 2010 from both technical and environmental viewpoints. On the other hand, the Weras

Ganga basin requires channel improvements to the main stream and major tributaries to cope with runoff to be increased by the projected urbanization. Therefore, the present study mainly focuses on the storm water drainage plan for the Weras Ganga basin.

From the considerations above, the storm water drainage plan in Bolgoda basin is proposed on the basis of the following principles:

1) Conservation of existing water surface areas and surrounding lowlands for storm water retention as well as environmental protection in the entire Bologda basin
2) Channel improvement of the Weras Ganga for draining storm water runoff concentrating from its urbanized catchment
3) Channel improvements to the tributaries of the Weras Ganga for alleviating storm water drainage problems in the respective drainage areas

4.7.2 Study on Storm Water Drainage Plan in Weras Ganga Basin

The Phase I - Master Plan study was carried out, based on the available topographic maps with the scale of 1:50,000 and 1:10,000, for the storm water drainage plans of the respective main streams together with conservation of the retention areas as the primary objectives.

It was identified that the majority of existing problems in the Weras Ganga basin were directly caused by the unsatisfactory conditions of the Weras Ganga main stream as well as the principal drainage channels (major tributaries) or urban drainage channels to drain storm water runoff into the Weras Ganga. It is therefore necessary to conduct a series of in-depth studies on the characteristics of the particular problems on storm water drainage in the entire Weras Ganga basin. Such studies require accurate baseline data including topography, urbanization and drainage system, which are obtainable from the latest maps with a scale of 1:2000 or more detail.

A series of in-depth studies were enabled with the latest 1:2,000 scale topographic maps produced by the Survey Department in 2001, which cover the entire Weras Ganga basin. As a result of the in-depth studies carried out in the early stage of the Phase II - Feasibility Study, the storm water drainage plan for the Weras Ganga basin was formulated. Details of the study on the storm water drainage plan are discussed in Volume IV - Supporting Report (2). The storm water drainage plan for the Weras Ganga basin is outlined in the subsequent sections and is incorporated with the storm water drainage plan for the Bolgoda basin.

4.7.3 Basic Flood Runoff

The basic flood runoffs in the Bolgoda basin for probable 10, 25, and 50-year rainstorm events under the future land use conditions were estimated for several locations along the river channel as shown in Figure 4.43. In comparison with the estimated flood runoff with the basin retention effect as shown in Figure 4.44, the peak runoffs of a basic flood increases by 35% for a 10-year return period, 45% for a 25-year storm, and 55% for a 50-year storm in the Panadura Ganga at the sea outfall if the retention and areas are eliminated. Figure 4.45 shows the comparison of flood hydrographs in Panadura Ganga at the sea outfall.

Comparison of Flood Discharge with and without Basin Retention Effect in Bolgoda Basin

Location	Return Period (years)	Basic Flood Runoff (m^3/sec)	Flood Runoff with Basin Retention Effect (m^3/sec)
Panadura Ganga at Sea Outfall	10	175	130
	25	210	145
	50	240	155

4.7.4 Flow Capacity of Main Stream

The flow capacities of the main streams in the Bolgoda basin were evaluated from the channel cross sections surveyed and estimated probable runoff. The flow capacities of the main streams were evaluated as follows:

Flow Capacity of Mainstream in Bolgoda Basin

(Unit: m^3/sec)

River/Canal	Minimum	Maximum	Average
Bolgoda Canal	30	55	44
Weras Ganga	14	228	98
Panadura Ganga	127	577	267
Bolgoda Ganga	8	38	17
Maha Oya	7	95	36
Panape Ela	6	114	30
Aluth Ela	8	44	22
Kepu Ela	4	135	29

4.7.5 Conceivable Structural Measures

The conceivable structural measures for storm water drainage in the Bolgoda basin are illustrated in Figures 4.46 to 4.48.

1) Channel Improvement of Weras Ganga and Tributaries
   - Dredging of Weras Ganga
   - Construction of dike on the right bank of Weras Ganga
   - Channel improvement of tributaries in sub-basins

2) Storm Water Retention Area
   - Storm water retention areas in Weras Ganga basin (372 ha)
   - Conservation of lowland (4,739 ha)
3) Urban Drainage
   - Urban drainage improvement of highly urbanized area on the right bank of Weras Ganga (Kandawala and Telawala areas, drainage area 3.3 km^2)

4.7.6 Comparative Study on Alternative Drainage Plans

(1) Component Schemes

The conceivable structural measures for the Weras Ganga and tributaries are grouped into the component schemes broadly demarcated by sub-basin as follows:

Component Schemes of Storm Water Drainage Plan

Component Scheme	Measures
(1) Weras Ganga	• Weras Ganga Dredging: length 5,500 m • Flood Protection Wall on Right Bank: length: 2,300 m • Weras Ganga Swamp Retention Area: 65 ha • Maha Ela Marsh and Lowland Retention Area: 132 ha
(2) Nugegoda-Rattanapitiya Scheme	• Channel Improvement of Nugegoda-Ela: length 1,580 m • Channel Improvement of Delkanda Ela: length 1,760 m • Channel Improvement of Rattanapitiya Ela: length 2,130 m • Retention Areas: total extent 36 ha
(3) Bolgoda Canal Scheme	• Channel Improvement of Bolgoda Canal: length 2,400 m • Bellanwila-Attidiya Marsh Retention Area: 108 ha
(4) Boralesgamuwa North Scheme	• Channel Improvement of Depawa Ela: length 3,090 m
(5) Boralesgamuwa South Scheme	• Channel Improvement of Werahera Tributary: length 980 m
(6) Maha Ela Scheme	• Channel Improvement of Maha Ela: length 2,700 m • Channel Improvement of Maha Ela Tributary: length 1,760 m
(7) Ratmalana-Moratuwa Scheme	• Urban Drainage Improvement: 11,120 m • Kandawala Retention Pond: 3 ha • Telewala Retention Pond: 10 ha • Channel Improvement of Katubedda Tributary: length 1,250 m • Retention Area: 23 ha

(2) Dredging Width of Weras Ganga

The Weras Ganga Scheme envisages alleviating direct flood damage in the densely urbanized lowland on the right bank as well as improving the principal drainage channels such as Bolgoda Canal and Rattanapitiya Ela connecting to the Weras Ganga by increasing its flow capacity.

For the dredging of the Weras Ganga, alternative dredging widths of 20, 40, and 60 m were examined. Hydraulic analyses were carried out for the respective dredging widths under the storm water drainage plan comprising all the component schemes and retention area described above. The results of water level projections are summarized below:

Water Level of Weras Ganga by Dredging Width

Dredging Width	Water Level (above MSL)		
	Elawella Road	Borupana Bridge	Confluence of Maha Ela
20 m	1.42	1.01	0.95
40 m	1.41	0.99	0.93
60 m	1.41	0.96	0.88

The alternatives of the storm water drainage plan with different dredging widths are evaluated in the economic evaluation. Benefit-cost ratio (B/C) and economic internal rate of return (EIRR) for each alternative are computed from economic cost and annual benefit from flood damage mitigation as well as land development cost and land enhancement benefit.

Comparison of Alternative Dredging Width

Dredging Width	Project Cost (million Rs)	Annual Benefit (million Rs/year)	B/C	EIRR
20 m	5,128	624	1.50	13.9
40 m	5,317	706	1.60	14.7
60 m	5,657	715	1.52	14.1

(3) Required Extent of Retention Area in Weras Ganga Basin

Of the proposed retention area of 372 ha, a required extent of retention area is analyzed by hydraulic simulation under the following assumptions:

1) The upstream retention areas of 36 ha in the Nugegoda-Rattanapitiya sub-basin should be kept, essentially, for the storm water drainage plan in the sub-basin.
2) The following locations of retention areas would be subject to loss, suggested by present situations of land filling and its influence to the marshes in the vicinity of future urbanized areas:
    - Marsh areas with small extent surrounded by highly urbanized area, such as Katubedda Tributary and Thumbowila Tributary, total extent of 31 ha
    - Bellanwila-Attidiya Marsh, north, east and southeast, 40 ha
    - Maha Ela Marh and Lowland upstream of Colombo-Piliyandala Road, 26 ha

Influence by loss of retention area is evaluated with a relationship between an extent of retention area and average of water level in the Weras Ganga. When the average water level ‘without’ the project is regarded as an allowable water level, the required extent resulting from the hydraulic simulation analysis is shown by each retention area as follows:

Retention Areas for Storm Water Drainage Plan in Weras Ganga Basin

Retention Area	Proposed Retention Area (ha)	Required Extent of Retention Area (ha)
Upper Nugegoda Ela	7	7
Lower Nugegoda Ela	20	20
Delkanda Ela	9	9
Bellanwila-Attidiya Marsh	108	88
Weras Ganga Swamp and Surrounding Marsh	65	65
Maha Ela Marsh and Lowland	132	106
Katubedda Triburary	23	0
Thumbowila Tributary	8	0
Total	372	295

A total extent of 372 ha of storm water retention area is initially proposed according to the future land use projections. The result of the analysis for the required extent of storm water retention area shows that a total of 295 ha should be ensured for minimizing the influence of the loss of the initially proposed retention area. If the balance of 77 ha is assumed to be free from inundation, the economic evaluation of the storm water drainage plan for the Weras Ganga basin results in the following.

Economic Evaluation for Proposed Storm Water Drainage Plan by Retention Area

Retention Area	B-C (million Rs.)	B/C	EIRR (%)
372 ha	1,853	1.60	14.7
295 ha	3,768	2.22	19.2

4.7.7 Effect by Reduction of Lowland in Bolgoda Basin

The assessment of effect by reduction of lowland in the entire Bolgoda basin is conducted to identify basin-wide impacts.

The lowland is defined by ground surface elevation around the downstream water system. The lowland is defined as the area lower than 1.5 m above MSL. By this definition, the extent of lowland becomes 4,739 ha.

Reduction of the lowland will cause an increase of runoff and water level in drainage channels and remaining areas. In the assessment, the four cases of delimitation level were provided such as 1.5 m, 1.0 m, 0.5 m and 0.0 m above MSL.

Extent of Lowland by Delimitation Level

(Unit: ha)

Delimitation Level (above MSL)			
1.5 m	1.0 m	0.5 m	0.0 m
4,739	3,710	2,227	950

It was assumed that land reclamation would be conducted above the delimitation level with a sufficient height to cope with the inundation level increasing due to the reduction of the lowlands. The results of water level rising at the Weras Ganga, North Bolgoda Lake, and South Bolgoda Lake are shown in Figure 4.49 and summarized below:

Effect by Reduction of Lowland (50-year Return Period)

Delimitation Level (m)	Extent of Lowland (ha)	Water Level (above MSL)		
		Weras Ganga	North Bolgoda Lake	South Bolgoda Lake
1.5	4,739	1.43	0.69	0.78
1.0	3,710	1.51	0.70	0.79
0.5	2,227	1.73	0.74	0.83
0.0	950	1.89	0.78	0.92

As mentioned above, the ground surface elevation of reclaimed land is assumed to be sufficient to protect against flood water level in the remaining lowlands. On the other hand, the water level rising in the remaining lowlands affects the water level of the incoming channels. Difficulty of drainage would arise in the incoming channels affected by backwater and then flooding occurs in the upper reaches.

4.7.8 Study on Optional Planning Scales (25-year and 10-year Return Periods)

The type of alternative combinations is the same as described in the sub-section 4.7.5 above. The comparative study for different dredging width of the Weras Ganga for each planning scale is summarized below:

Comparison of Alternative Dredging Width

a) 25-year Return Period

Dredging Width	Project Cost (million Rs)	Annual Benefit (million Rs.)	B/C	EIRR (%)
20 m	4,911	931	2.21	19.0
40 m	5,100	1,012	2.29	19.6
60 m	5,439	1,021	2.16	18.8

b) 10-year Return Period

Dredging Width	Project Cost (million Rs)	Annual Benefit (million Rs.)	B/C	EIRR (%)
20 m	4,909	878	2.09	18.2
40 m	5,099	955	2.17	18.8
60 m	5,438	963	2.04	18.0

The effect of the retention area is also carried out on the conceivable plans for the planning scale of 25-year and 10-year return periods. The effect of raising the water level in the retention areas is examined in the same manner as described in the sub-section 4.7.6. The required extent of retention area for each planning scale is obtained from the results of simulation analyses tabulated below:

Comparison of Economic Evaluation by Planning Scale

Return Period	Required Retention Area (ha)	Project Cost (million Rs)	Annual Benefit (million Rs.)	B/C	EIRR (%)
50-year	295	5,102	1,022	2.22	19.2
25-year	295	5,100	1,012	2.29	19.6
10-year	295	5,099	955	2.17	18.8

4.7.9 Proposed Storm Water Drainage Plan

The study proposes a planning scale of a 50-year return period for the storm water drainage plan in the Weras Ganga sub-basin. The Weras Ganga is one of the main streams constituting the water system in the Bolgoda Basin. Such a main stream should be improved with a high planning scale as mentioned in the section 4.1. On the other hand, the proposed plan includes the improvement of the tributaries with a planning scale of a 10-year return period.

The reduction of the lowlands would have only a small effect on raising the water level in the lakes because there will be no great change in the land use in the Bolgoda basin to the year 2010 and the storm water runoff from the entire basin will not increase significantly. However, a large reduction of the lowlands is not acceptable without proper offsetting measures for storm water drainage. Conservation of the lowlands needs be undertaken in compliance with future land use for a longer time-scale.

On the other hand, the loss of lowland, including the proposed retention areas in the Weras Ganga basin, would cause water level rising of some 0.5 m in the Weras Ganga. The lowlands in the Weras Ganga basin should be conserved as a part of the storm water drainage plan.

As a conclusion of the considerations above, the following storm water drainage plan is proposed for the Bolgoda basin:

(1) Storm Water Drainage Plan for the Weras Ganga basin:

1) Weras Ganga Scheme

- Weras Ganga Dredging: length 5,500 m
- Flood Protection Wall on Right Bank: length: 2,300 m
- Weras Ganga Swamp Retention Area: 65 ha
- Maha Ela Marsh and Lowland Retention Area: 106 ha

2) Nugegoda-Rattanapitiya Scheme

- Channel Improvement of Nugegoda-Ela: length 1,580 m

- Channel Improvement of Delkanda Ela: length 1,760 m
- Channel Improvement of Rattanapitiya Ela: length 2,130 m
- Retention Areas: total extent 36 ha

3) Bolgoda Canal Scheme

- Channel Improvement of Bolgoda Canal: length 2,400 m
- Bellanwila-Attidiya Marsh Retention Area: 88 ha

4) Boralesgamuwa North Scheme

- Channel Improvement of Depawa Ela: length 3,090 m

5) Boralesgamuwa South Scheme

- Channel Improvement of Werahara Tributary: length 980 m

6) Maha Ela Scheme

- Channel Improvement of Maha Ela: length 2,700 m
- Channel Improvement of Maha Ela Tributary: length 1,760 m

7) Ratmalana-Moratuwa Scheme

- Urban Drainage Improvement: 11,120 m
- Kandawala Retention Pond: 3 ha
- Telewala Retention Pond: 10 ha
- Channel Improvement of Katubedda Tributary: length 1,250 m

(2) Conservation of Lowlands in Entire Bolgoda Basin (4,739 ha)

The general layout and conceptual designs for the proposed storm water drainage plan are illustrated in Figures 4.50 to 4.71.

4.8 Non-structural Measures for Storm Water Drainage

4.8.1 Conceivable Measures

The effective storm water drainage plan should be formulated in combination of structural and non-structural measures. In the study area, the following non-structural measures will be conceivable to support the structural measures taking into account the basin conditions.

1) Storm water retention area management
2) Development control in urban development areas
3) Land use regulation in lowland areas
4) Dissemination of flood information to the public
5) Flood-proofing of buildings in flood-prone areas
6) Flood fighting

They are explained in the subsequent sub-sections.

4.8.2 Storm Water Retention Area Management

This is a sort of floodplain management. As mentioned in the proposed storm water drainage plan, a role of the storm water retention area is very important from the technical and economic viewpoints. If the storm water retention area is not provided, it is quite difficult to confine the storm water in the river channel and also such idea requires a huge cost. Therefore, it is proposed to keep the storm water retention areas. The following retention areas to be conserved are proposed in the Study. They are shown in Figures 4.8, 4.21, 4.33 and 4.50.

Proposed Storm Water Retention Areas in Weras Ganga Basin

Basin	Proposed Retention Area	Area (ha)
Ja Ela Basin	Upper	376
	Lower	500
Kalu Oya	Upper	89
	Lower	380
Greater Colombo	-	380
Bolgoda	-	295
	(Weras Ganga Basin)	4,739

In order to properly keep those storm water retention areas, the following measures are required.

(1) Legal Designation of Storm Water Retention Area

The study area is located mostly in the low-lying area as mentioned before. Because of this, it is proposed to keep the storm water retention area properly from the viewpoint of minimization of the storm water drainage project cost. The existing marshes, lowlands and paddy lands are functioning as a storm water retention area. However, illegal filling and uncontrolled development in such lowlands are often observed at many places in the study area. The decrease of retention area results in decrease of storm water retention capacity and increase of flood damage.

The reasons for such activities may be a lack of social understanding for importance of storm water retention effect and also unclearness of the required extents of retention area. It is necessary to clearly demarcate the required storm water retention area and show the retention area on the authorized land use plan and legally designate the retention area as an authorized one.

In addition, the designated retention area should be notified to the government agencies concerned and the public for their understandings to stop and control the illegal filling and uncontrolled development in the designated retention area.

As no authorized detailed land use plan has been prepared yet for the entire study area. It should be prepared as early as possible before implementation of the proposed storm water drainage projects.

It should be noted that the storm water retention areas proposed in the Study are identified by the hydrological and hydraulic analyses based on the topographic maps with scales of 10,000 and 50,000, however those maps have only contour lines of 5-10 m intervals for the lowland and they are insufficient to demarcate the retention area with a satisfactory accuracy. The accurate extents of the proposed retention areas should be reviewed with more detailed topographic data.

(2) Regulation of Land Use in Storm Water Retention Area

The proposed storm water retention areas are extensive open space. There may be demand to utilize the retention area for other purposes such as play ground, park, cultivation, etc. Utilization of the retention areas for the purpose other than storm water retention can be allowed under the condition that the storm water retention effect is not decreased, but it should be properly regulated by the agency concerned such as SLLRDC.

(3) Strict Legal Action for Illegal Activities

As mentioned before, illegal activities such as filling of marshes and lowlands, garbage dumping to canals and lowlands, encroachment of canal area, etc. are observed at many places in the study area. Local authorities and UDA have a power to regulate or stop the illegal activities, but this regulation system has not functioned satisfactorily because of various reasons. The filling of lowlands and garbage dumping to the canal decrease the capacity of storm water drainage system as a whole. It is important to maintain the designed capacities of the storm water drainage facilities to avoid flood damages as much as possible.

The strict legal action against the illegal activities mentioned above should be taken by the local authorities and UDA.

4.8.3 Development Control in Urban Development Areas

Urbanization in the study area causes increase of flood runoff. However, there is a limit to increase the discharge capacity of rivers and drainage canals to cope with increase of the flood runoff. In this context, construction of flood retarding ponds, rainwater storage facilities and seepage facilities are effective measures to reduce the flood runoff. In order to reduce the flood runoff in the urbanized area, all developers including the government agencies in charge of urban development should obligate construction of those facilities in implementation of the development projects.

To ensure the construction of the storm water retention facilities, legislation for mandatory construction is proposed. The main points of the legislation will be as follows referring to the Japanese Guideline on the provision of flood retarding pond.

1) The storm water retarding ponds should be constructed in the large scale development with a development area of more than 10 ha.
2) The peak runoff from the objective development area should not exceed the peak runoff under the conditions before development.
3) SLLRDC should be a responsible agency for evaluation, approval and monitoring of the development plan from storm water drainage aspect, and for providing technical guidance on plan/design of the storm water retention facilities.
4) SLLRDC should be empowered to take a legal action to contravention.

4.8.4 Land Use Regulation in Lowlands

As often seen in the study area, the houses affected by storm water inundation are mostly located in and around the lowlands which are originally flood-prone areas.

To stop recurrence of the same situation, it is proposed to regulate the land use in the lowland areas so as to stop dwelling in the flood-prone lowland.

4.8.5 Dissemination of Flood Information

In the previous sub-section 4.8.2, importance of conservation of the storm water retention areas is stressed. To properly conserve the retention areas, the various information such as related regulations, prohibited activities, boundaries of the retention areas, etc. should be disseminated to the public to get their understandings and awareness for the flood control.

Further, it also will be effective to mitigate the flood damage to disseminate the information on flooding condition of the residential areas and lowlands to the public. The information useful will be flooding area, flood magnitude, flood duration, flood frequency, evacuation route, etc. For this purpose, a flood hazard map is commonly prepared although it needs detailed topographic maps to accurately forecast the inundation area and depth.

Based on the information disseminated, the people are expected to avoid dwelling in the areas with flooding risk such as lowlands and also learning how to cope with flood.

4.8.6 Flood-proofing of Buildings in Flood-prone Areas

In principle, it is better to relocate the houses in the flood-prone areas such as marsh and natural flood retention areas to mitigate the flood damages. However, if it is inevitable to dwell in the flood-prone areas because of certain circumstances, flood-proofing of the buildings (houses) should be introduced. There are several types of flood-proofing such as raising of foundation ground, piloti type building, wall-fencing around house and waterproof building.

4.8.7 Flood Fighting

If the flood exceeding the design flood scale occurred, flood damage is inevitable. In order to mitigate the flood damages as much as possible, the precautionary measures such as flood fighting, dissemination of information on flooding condition to the public, etc. should be taken.

As mentioned before, the flood fighting system has been established in Sri Lanka. The existing flood fighting system should be fully utilized.

4.8.8 Flood Warning System

Flood forecasting and warning is also one of measures to mitigate the flood damage, but it is not recommended in the study area because of the reasons mentioned below.

According to the field survey in the study area, except the flood prone area of Kelani River, there are no flood prone areas where emergency evacuation and flood fighting activities are strictly required for avoiding any critical damage to human life during heavy rainfall. The inundation depth during heavy rainfall is reported at around 50 to 100 cm in the maximum and almost all inundation do not affect immediately to human life and do not produce any destructive damages to houses and buildings. Mobilization of the flood forecasting and warning system may not be in reality in the study area.

4.9 Outfall Treatment

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.

(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.

(2) Dehiwala Outfall

The groynes were constructed at Dehiwala Outfall in June 2002. According to Dehiwala Outfall Study - Coastal Impact Mitigatory Measures, SLLRDC, by LHI, June 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.

(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, SLLRDC, by LHI, January 2001.

4.10 Institutional Development Plan

In the sub-section 2.7.3, critical constraints in implementation of storm water drainage projects were identified, including 1) unclear responsibilities among government agencies for storm water drainage works, 2) lack of an authorized land use plan and 3) insufficient resources for storm water drainage works. In this section, an institutional development plan is proposed to eliminate the first two constraints. The third constraint is discussed in the sections 4.11 and 4.12.

4.10.1 Demarcation of Responsibilities for Storm Water Drainage Works among Agencies

As for planning, implementation and O&M for flood control/storm water drainage facilities, the following demarcation of responsibilities is proposed in order to develop a clear institutional arrangement considering the present situation of the related activities in the study area.

1) Related organizations for the above activities are SLLRDC, local authorities and the Irrigation Department (IRD).
2) SLLRDC is responsible for all the works related to storm water drainage in the declared areas and local authorities are responsible for those in their respective local areas.
3) The IRD is responsible for all the works related to flood control in inter-provincial river basins that extend over two or more provincial areas.
4) Road side drains are usually constructed by the Road Development Authority (RDA) together with roads. Taking the normal practice of the maintenance into consideration, local authorities are to maintain the roadside drains in the respective local areas, except those facilities, which are attached to a high grade road such as Katnayake Expressway.

The proposed demarcation is tabulated below.

Proposed Demarcation of Responsibility for the Storm Water Drainage

Objective Area	Planning	Construction	Maintenance
Within Provincial Basin			
Declared Area by SLLRDC	SLLRDC	SLLRDC	SLLRDC
Area of Local Authority	LA	LA	LA
Road Side Drain	RDA	RDA	LA
Inter-provincial Basin			
Irrigation Canals and Rivers Situated in the Inter-provincial Basin	IRD	IRD	IRD

Since the demarcation of work for urban drainage is not clear under the current legislative setting, the Colombo District (Low-lying Area) Reclamation and Development Board Act and the Ordinances of local authorities should be amended to establish a clear demarcation as proposed above.

Meanwhile, it is the current situation that the work capacity of local authorities except Colombo MC (CMC), are too small to undertake the storm water drainage works based on the above demarcation. Therefore, the above demarcation for local authorities is considered to be a long term target and SLLRDC’s assistance in planning, implementation and O&M will be needed to achieve the target. As a short term measure, planning and implementation of storm water drainage by SLLRDC and transfer to local authorities are proposed.

4.10.2 Lowland Management by SLLRDC

As discussed in the section 4.8, the retention function of lowlands including paddy field and marsh is an important factor to develop an effective storm water drainage system. Proper extent of the lowlands in the study area should be kept from land filling for flood alleviation and natural conservation.

However, in spite of a general recognition of the importance of low land function, it is the current situation that the areas to be preserved are not clearly identified and both legal and illegal fillings are proceeding for various development purposes without proper land use plans.

At present, there exists a process for evaluation, permission and regulation of land development in which UDA, local authorities and SLLRDC are involved (refer to Figure 2.17). However, this process is complicated and does not seem to function properly. Therefore, in order to simplify the process and to materialize an effective lowland use regulation, especially for storm water retention, it is proposed to establish lowland management by SLLRDC. For this purpose, the following actions are proposed.

(1) Empowerment of SLLRDC

It is proposed that SLLRDC become the sole agency for lowland management related to storm water drainage works with the following tasks.

1) Evaluation/approval of land filling proposals in coordination with UDA, CEA, local authorities and line agencies for development works
2) Development of a data base of land filling proposals
3) Monitoring of illegal land filling

In order to implement the above duties and functions, legislative empowerment of SLLRDC is necessary and the following amendment should be made to the Colombo District Low-lying Area Reclamation and Development Board Act:

1) Any land filling projects in low land areas declared under the SLLRDC Act have to be approved by SLLRDC in written form.
2) SLLRDC can take an immediate legal action or issue an injunction order to any person who acts in contravention of the Act in the declared area.
3) No constructions are allowed on any areas declared as canal reservation by SLLRDC. A legal action can be taken by SLLRDC for contravention of the Act.

(2) Formulation of Land Use Plan

Establishment of an authorized land use plan at each level, national, sub-national and local authority should be urged. Authorized land use plans will give clear guidelines for the land use regulation activities including evaluation and approval of land filling proposals, monitoring of illegal land filling and legal action for contravention. The most important objective of the land use plan is to demarcate clearly each land area by the expected function. In the plans, lowland areas which will contribute to storm water retention should be clearly shown, and further could be divided into some zones by each category as follows:

1) Strictly reserved zone for retention purpose
2) Reserved zone for retention of minor flood but to be used for nature parks and so on
3) Reserved zone for retention of major flood but to be used for urban parks and community parks and so on, and some high ground parts of the area to be used for housing schemes

(3) Combined Activities with Local Authorities

Under the existing legislative system, local authorities are empowered to take a legal action to stop, demolish, punish and fine. However, considering the malfunction of this regulation function due to insufficient work resources, political pressure and other local specific constraints, it is proposed to utilize the function of local authorities in combination with SLLRDC's lowland management. Under this cooperation system SLLRDC and local authorities can organize a network for effective monitoring and regulation of land filling for the broad area including SLLRDC's declared areas and the areas of local authorities. This combination will be useful for the lowland management from the basin-wide aspect.

(4) Achievement of Social Understanding on Lowland Management

In addition to the actions proposed above, it is important to take actions to achieve social understanding on the lowland management. It will be possible to execute substantially the function and duty on land use regulation through the actions such as the opening of the land use plan to the public, presentation of the importance to preserve lowland areas showing flood inundation hazard maps to the public and public awareness on land use regulation with the mass media. These activities by SLLRDC and local authorities will be necessary for sustainable lowland management.

4.11 Operation and Maintenance Plan

Operation and Maintenance (O&M) is a key issue to establish a sustainable storm water drainage system. At present there are many drainage structures/facilities which are maintained by each responsible organization. In addition, new storm water drainage systems will be proposed through this Study. The O&M activities will depend on the type and scale of the system to be maintained and the organization managing it. Based on the present situation of the O&M activities in the study area and the drainage systems to be newly proposed, practical O&M systems should be established.

4.11.1 Policy for Operation and Maintenance

O&M plan is prepared for various storm water drainage improvement schemes proposed through the study on the basis of the policy given below.

1) As proposed in the Institutional Development Plan, the responsible organizations for storm water drainage are SLLDC and local authorities including MCs, UCs and PSs.
2) SLLRDC undertakes the O&M of drainage facilities including main and secondary canals/rivers and urban drainage channels in the declared areas.
3) Local authorities have responsibility for the O&M of drainage facilities including main and secondary canals/rivers, urban drainage channels and road side drains in the respective land area.
4) Taking the insufficient O&M capacities of the local authorities except CMC into consideration, SLLRDC shall assist the local authorities in undertaking the O&M works for the drainage facilities for a few years after transfer of those facilities to local authorities. During this period, SLLRDC shall provide local authorities with technical guidance and staff training through joint operation, on-the-job training and lectures.
5) As a long term objective (for example, 10 years), local authorities promote expansion of resources for storm water drainage works including planning, construction and O&M with a view to managing all the works by themselves.

4.11.2 Organization Set-up with Staff Arrangement

(1) SLLRDC

SLLRDC's management capacity including the organizational set-up and staff for storm water drainage works has been developing especially through undertaking of the large scale storm water drainage projects in the Greater Colombo area. However, considering the future expansion of the coverage area and the work volume, further expansion of the organizational set-up and staff is proposed as below.

1) A new section is proposed within the existing CD&M divisions such as the Urban Drainage Maintenance Section, which undertakes O&M works for storm water drainage systems in built up areas and provision of technical guidance and staff training on O&M of storm water drainage systems to local authorities other than CMC. The proposed organization chart is shown in Figure 4.72.

2) As shown in Figure 4.72, it is proposed to set up the implementation part of the new section in the Kirimandara Mawatha and Colombo North Regional Offices, considering the location of the new urban drainage systems constructed by SLLRDC and that the actual O&M activities for the existing canals are also handled by the regional offices. Furthermore, it will be effective for the same implementation section in Kirimandara Mawatha office to initiate the local authorities into O&M works for storm water drainage system.
3) For the above new section, employment of one managerial staff member (AGM), a few engineers and several engineering assistants, including an O&M trainer, will be necessary for preparation of the work procedure and schedule and arrangement for the implementation. Furthermore, several supervisors who engage in supervision of the work on site, based on the work procedure and schedule, and training of operators for the operation of cleaning machines in the confined space, will be proposed. The proposed staff arrangement is shown below.

Staff Arrangement of the Proposed New Section in CD&M Division

Staff	No. of Person
AGM(Assistant general Manager)	1
Chief Engineer(CE)	1
Other Engineer	1
Engineering Assistants	3
O&M Supervisor	1
Other staff (utilize existing man power)	-

4) As a long term aspect, it is proposed to promote the expansion of the SLLRDC's organizational set-up so that SLLRDC can undertake overall works in the flood control/storm water drainage sector including planning, implementation, O&M and regulation/instruction activities on land filling, and further, to provide technical guidance, training and flood information for local authorities. For this purpose, the development of staff capacity at all levels including managers, engineers, technician/operators and other general staff will be necessary.

(2) Local Authority

In order to execute the O&M works of storm water drainage systems on a regular basis, the following organizational set-up and staff expansions are proposed.

1) The organization for the O&M system is basically established and a number of staff and work forces are available, however considering that, at present, the technical and operational staff which engage in the actual O&M works

on site is in short supply, an increase in technical staff, supervisors and machine operators will be required. From the practical aspect, it is proposed at first to arrange the staff for O&M of the major urban drainage channels.

2) In local authorities other than CMC, an exclusive section for storm water drainage works is not currently established because the drainage facilities for which maintenance is required are not highly developed. However, considering the development of storm water drainage systems in the future, it is proposed to establish a section that exclusively undertakes storm water drainage works with the key staff as proposed below.

Staff Arrangement of the Proposed Section in Local Authorities

(Unit: No. of Persons)

Staff	CMC	Other local authorities
Managerial Staff (Engineer)	-	1
Technical Officer	1	1
Work Supervisors	2	2
O&M equipment Operators	2	2
Clerical staff	-	2

Especially, in the Dehiwela - Mount Lavinia MC and the Moratuwa MC, since the construction of new drainage systems is going on and it is scheduled to be transferred to those local authorities from SLLRDC, establishment of the exclusive section with staff arrangement for handling O&M of storm water drainage will be an urgent issue.

4.11.3 Equipment Plan

(1) SLLRDC

O&M equipment presently owned by SLLRDC is not adequate to handle the O&M works for the entire Greater Colombo Canal system and the responsible area as it will be extended in the future. Therefore, from the long-term aspect, it is proposed to procure some additional heavy equipment such as a dredger for maintenance of major canals in the above areas. Meanwhile, some O&M equipment for storm water drainage has been procured under the GCFC&EIP Phase II. Furthermore, as a short term plan, O&M equipment listed in Table 4.6 is scheduled to be procured under the on-going GCFCEIP-Phase III and the Lunawa Lake Environment Improvement & Community Development Project.

(2) Local Authority

In general, the major O&M work of local authorities is cleaning and minor repair of the existing small drain channels, however local authorities do not have a sufficient amount of equipment for regular maintenance work of these drainage facilities. Therefore, light equipment such as tractors, small back hoes and water pumps will be necessary to implement the proper O&M of the existing urban drainage systems.

Since CMC owns O&M equipment at present as shown in Table 4.7, it will be possible to allocate the required equipment for the O&M of the major urban drainage channels by utilizing the existing equipment.

Meanwhile, equipment presently owned by local authorities other than CMC is quite insufficient for undertaking the works on regular basis. As a short-term objective, it is proposed to procure equipment as given below to fulfill the minimum requirements for regular O&M activities.

O&M Equipment for Local Authorities (except CMC)

Equipment	Nos.
Tractor with trailer	2
Middle scale dump track	1
Middle scale back hoe	1
Water pump with generator	2
Pick-up track	2

From the long-term aspect, possession of cleaning machines for underground pipes such as jetting machines, winch machines and conventional heavy equipment may be considered.

4.11.4 Financial Arrangement

(1) SLLRDC

The financial source for all O&M activities of SLLRDC is provided by the Government budget. SLLRDC shall make due arrangements to acquire enough budget for required O&M works based on the work plan, staff employment/training plan and equipment plan. Based on the staff arrangement and equipment plan for the new section proposed for the SLLRDC, financial arrangements with the following extent are assumed to be required. Purchase cost of equipment shown in the previous sub-section 4.11.3 is not counted as an annual O&M cost.

Annual Financial Arrangement for O&M Routine Works in SLLRDC

Item	Amount (Rs. 1,000)
1) Employees salary, fuel, tools and miscellaneous (tel. bill, postage, etc.)	1,000
2) Minor construction and repair	3,000
3) Purchase of minor equipment and parts	3,000
Total	7,000

(2) Local Authority

Since the CMC budget scale is quite large and clearly categorized compared to those of other local authorities, it will be easy to arrange the budget for the O&M staff and the equipment mentioned in the previous sub-sections.

The annual budget for local authorities other than CMC allocated for drainage maintenance is too small to carry out the substantial regular works. At present, only the actual expenditure for permanent employees' salaries is reimbursed by the Western Provincial Council and all other expenditures have to be managed with their annual revenue.

Considering the small scale of revenue of the local authorities, it is proposed to review this financial arrangement by the Western Provincial Council so that the local authorities can achieve the funding for procurement of equipment and staff. This financial arrangement should be made together with preparation of a detailed procurement plan by local authorities, evaluation of the plan and audit by the Western Provincial Council. Considering the actual budget scale of the local authorities, the rough budget amount for the proposed storm water drainage section is assumed as below for the initial stage of the establishment.

Annual Financial Arrangements for O&M Routine Works in Local Authorities (other than CMC)

(Unit: 1,000 Rs.)

Item	Amount
1) Employees' salaries, fuel, tools and miscellaneous (tel. bill, postage, etc.)	1,000
2) Minor construction and repair	2,000
3) Purchase of minor equipment and parts	1,000
Total	4,000

4.12 Human Resource Development Plan

Human resource development for the storm water drainage sector is one of the key issues for the executing agencies, that is, SLLRDC and local authorities. In this section, a training package for SLLRDC and local authorities is proposed for a short term aspect for O&M and a long term aspect for the overall capacity building.

4.12.1 Staff Training Program for SLLRDC and Local Authorities

(1) SLLRDC

In order to ensure the successful implementation of the O&M works, SLLRDC should attempt to strengthen the capability of handling the O&M activities. In this context, it is proposed that a strengthening program for the O&M staff of SLLRDC utilizing the existing O&M manual shall be mobilized by SLLRDC itself. This program will aim at strengthening various routine activities, such as leadership, motivation creation, teamwork, collaborations, responsibility, communication and performance evaluation. Among others, the subjects to be taken up in the program may be as follows:

1) Create awareness of the objectives of the program among all O&M related staff
2) Review the functions and responsibilities of each work section, and revise if some of them are duplicate or obscure
3) Assess staff capability, including qualifications, experience, tasks and duties assigned
4) Assess appropriateness of number of staff assigned to each work section
5) Designated performance targets or goals to be attained by each work section
6) Conduct workshops from time to time to discuss issues arising from the actual O&M works and to evaluate the functions/duties being achieved by the sections

At the same time, the results of this program should be reflected in the O&M manual for continuous improvement.

(2) Local Authority

The work forces of local authorities have practical knowledge as to maintenance works for existing small drains. In addition, for the purpose of developing additional knowledge of O&M technologies for regular maintenance of storm water drainage systems in urban areas, a series of training programs are required for the engineers and technical officers of local authorities. Especially for the major MCs in the Greater Colombo area, establishment of this training program should be considered soon. As a short term objective, on-the-job training and lectures under the leadership of SLLRDC will be regarded as a practical method for improving the capability of local authorities. On-the-job training by SLLRDC is proposed to execute the following step according to the O&M policy mentioned in the sub-section 4.11.1.

1) During the 1st year after transfer of drainage facilities to the local authority O&M works are undertaken by SLLRDC together with the staff of the local authority. During this period, staff of the local authority achieve O&M knowledge by joint-operation with SLLRDC staff.
2) During the 2nd year after transfer of drainage facilities to the local authority O&M works are undertaken by the local authority under the supervision of SLLRDC. Required equipment and machinery are also transferred by SLLRDC.
3) During the 3rd year after transfer of drainage facilities to the local authority O&M works are undertaken by the local authority. SLLRDC staff visits the

work site, at least once a week, for inspection, monitoring and advice.

The lecture programs will include the following:

1) Lectures on the management of O&M works
2) Lectures on health and safety procedures
3) Preparation of O&M manuals (involving Consultants hired by SLLRDC)
4) Lectures on O&M manuals
5) Lectures on procedures of coordination with other institutions and community organizations

The above program for local authorities should be applied also for local authorities in rural areas according to the progress of development of storm water drainage facilities in the areas.

4.12.2 Overall Training Program for Human Resource Development

From the long term aspect, it will be necessary to establish overall training programs to continuously develop the capability of staff at all levels in the responsible organizations for storm water drainage works. In this section, a framework of the training programs for human resources development is proposed for each target group in SLLRDC and local authorities.

(1) Target Training Participants

1) SLLRDC

SLLRDC will be the sole government agency to be responsible for storm water drainage in the country. As shown in Table 4.8, there are over 1,000 permanent staff working in 13 divisions.

Among these divisions, the Division of Research and Design is the most important section and is in charge of planning, design and approval of storm water drainage projects and land filling proposals on request from UDA or local authorities.

The Division of Canal Development & Maintenance and the Division of Plant & Equipment are also playing important roles for O&M for storm water drainage. A mission of the Department of Reclamation & Planning is partly related to storm water drainage works. The Departments of Human Resource Development & Administration, Finance and Lands & Marketing are supporting sections to make storm water drainage works smooth.

Analyzing the current work performance of SLLRDC, it is proposed that training should cover not only engineering & technical areas but also managerial/administrative and social development areas. In this connection, the numbers of target training participants in SLLRDC are proposed as shown in Table 4.8.

2) Local Authorities (LAs)

The study area consists of 5 MCs, 12 UCs and 28 PSs. As for storm water drainage works, staff allocation and therefore activities vary among local authorities. CMC has 250 staff including 25 engineers in the Division of Water Supply and Drainage. Although other MCs have a few engineers, they are in charge of all engineering and technical works in the local authorities, which implies no professional staff are available in these MCs. UCs and PSs have no engineers but have a few technical officers. They are in charge of all technical works in the local authorities, which again implies no specialized staff available for storm water drainage works.

Taking this present understaffing in all local authorities except CMC into account, it is proposed to allocate staff specialized in storm water drainage works in each local authority, as shown in Table 4.9. These staff are the target training participants for storm water drainage.

(2) Training Package

The training package is proposed to strengthen capabilities of staff in charge of storm water drainage, as shown in Table 4.10. The training package consists of four categories, i.e., managerial and administrative, technological and technical, social development and O&M.

Managerial and administrative training courses are divided into three groups, i.e., general management and administration, computer literacy and information management. Technological and technical training courses are divided into three groups, i.e., planning, design and drawing and construction management. Social development training courses are divided into four groups, i.e., land management, community development, awareness campaign and relocation of settlement. O&M training courses are divided into two groups, i.e., Operation of O&M equipment and O&M management. Each group has some modules.

Table 4.11 indicates the types of modules, training duration, pre-requisites and candidates for training providers. There are three training types, that is, lecture or conventional classroom training, practical training by using facilities and workshops.

The proposed training providers are briefed below. The details of each training provider are given in Annex 2 of Volume III: Supporting Report (1).

1) SLIDA: Sri Lanka Institute of Development and Administration (Ministry of Public Administration Management and Reforms)
A premier public sector training organization for the development of knowledge and managerial skills of senior and middle managers in public administration
2) NIBM: National Institute of Business Management (Ministry of Enterprise Development, Industrial Policy and Investment Promotion)
A public organization providing training, consulting and research in the fields of productivity, management and information technology
3) CHPB: Center for Housing Planning & Building (Ministry of Housing and Plantation Infrastructure)
A public organization providing training for staff in central government agencies, local authorities, private companies and individuals in broad areas of housing, human settlement, urban infrastructure and urban development. CHPB developed training modules and materials such as community based disaster management, natural disaster mitigation, risk control planning and guidelines for mitigating damages to dwellings in flood-prone areas.
4) SLILG: Sri Lanka Institute of Local Government (Ministry of Home Affairs Provincial Council and Local Government)
A public organization providing trainings for trainers in provincial training units in the fields of technical, management and social development
5) PTU/WP: Provincial Training Unit in Western Provincial Council
A public organization providing managerial, administrative and technical trainings for officers of LAs in Western Province

In addition, NGOs also can be training providers, particularly in the field of social development. Objectives and contents of each training module are shown in the Attachment in Annex 2 of Volume III: Supporting Report (1).

4.13 Comprehensive Storm Water Drainage Master Plan

The comprehensive storm water drainage master plan consists of structural measures for each basin, non-structural measures, institutional development plan, operation and maintenance plan, and human resources development plan. They are studied in the previous sections and the following plans are proposed as the comprehensive storm water drainage master plan.

(1) Ja Ela Basin Storm Water Drainage Master Plan (Structural Measures)

1) Ja Ela Channel Improvement (Width = 60 m, Length = 7 km)
2) Dandungam Oya Channel Improvement (Width = 70-80 m, Length = 9.9 km)
3) Storm Water Retention Area (Lower Area=500 ha, Upper Area=376 ha)

(2) Kalu Oya Basin Storm Water Drainage Master Plan (Structural Measures)

1) Kalu Oya Channel Improvement (Width = 25-50 m, Length = 5 km)
2) Old Negombo Canal Improvement (Width = 40 m, L = 4.5 km)
3) Storm Water Retention Area (Lower Area = 360 ha, Upper Area = 89 ha)

(3) Greater Colombo Basin Storm Water Drainage Master Plan (Structural Measures)

1) Madiwela South Diversion Canal (Width = 32 m, Length = 8.8 km)
2) Existing Mutwal Tunnel Restoration (Diameter = 1.8 m, Length = 554 m)
3) New Mutwal Tunnel (Diameter = 4 m, Length = 740 m)
4) Storm Water Retention Area (Kolonnawa Marsh, Kotte Marsh, Heen Ela Marsh and Parliament Lake Area = 380 ha in total)

(4) Bolgoda Basin Storm Water Drainage Master Plan (Structural Measures)

1) Weras Ganga Storm Water Drainage Plan
   a) Channel Improvement of Weras Ganga and Tributaries
      - Weras Ganga Scheme (Length 5,500 m)
      - Nugegoda-Rattanapitiya Scheme (Length 5,470 m)
      - Bolgoda Canal Scheme (Length 2,400 km)
      - Boralesgamuwa North Scheme (Length 3,090 m)
      - Boralesgamuwa South Scheme (Length 980 km)
      - Maha Ela Scheme (Length 4,460 km)
      - Ratmalana-Moratuwa Scheme (Length 11,120 m)
   b) Storm Water Retention Area
      - Storm water retention areas in Weras Ganga basin (295 ha)
2) Storm Water Retention Area (Low-lying Areas in Lower Bolgoda Basin = 4,739 ha)

(5) Non-structural Measures

1) Storm water retention area management
2) Development control in urban development areas
3) Land use regulation in lowland areas

4) Dissemination of flood information to the public
5) Flood-proofing of buildings in flood-prone areas
6) Flood fighting

(6) Institutional Development Plan

1) Demarcation of responsibilities on storm water drainage sector among related agencies
2) Lowland management by SLLRDC

(7) Operation and Maintenance Plan

1) Demarcation of O&M works among SLLRDC and Local Authorities
2) Organization strengthening of SLLRDC
3) Organization setting-up of Local Authorities

(8) Human Resources Development Plan

1) Training of staff of SLLRDC and Local Authorities for O&M
2) Overall training for human resources

CHAPTER 5 CONSTRUCTION PLAN AND COST ESTIMATE

5.1 Construction Plan

5.1.1 Mode of Construction

The construction works will be executed by contractors capable of executing the works properly. The selection of the contractors will be executed through international competitive bidding (ICB) complying with the regulations of the Government of Sri Lanka and the guidelines of international financing agencies. It is intended to utilise local contractors in order to reduce the construction cost and to develop the capacity of local contractors in Sri Lanka.

5.1.2 Construction Period

Construction periods of each project proposed in the Master Plan are assumed to be three to four years taking into account work volumes of the proposed projects and construction periods of similar past projects.

The assumed construction periods are as follows:

Planned Construction Periods of the Proposed Projects

Proposed Plan	Construction Period
1. Ja Ela Basin	
1) Ja Ela Channel Improvement (B = 60m, L = 7 km)	3 years
2) Dandungam Oya Channel Improvement (B = 80 m, L = 9.9 km)	4 years
2. Kalu Oya Basin	
1) Old Negombo Canal Improvement (B = 40 m, L = 4.5 km)	3 years
2) Kalu Oya Channel Improvement (B = 50 m, L = 5 km)	3 years
3. Greater Colombo Basin	
1) Restration of the Existing Mutwal Tunnel (D = 1.8 m, L = 550 m)	3 years
2) Madiwela South Diversion Canal (B= 40 m, L = 8.8 km)	4 years
3) New Mutwal Tunnel (D = 4 m, L = 740 m)	3 years
4. Bolgoda Basin	
1) Dredging of Weras Ganga (B = 40 m, L = 5.5k m)	2 years
2) Channel Improvement of Bolgoda Canal (L = 2.4 km) and Tributaries (L = 5.5 km)	3 years
3) Urban Drainage (L = 11km)	3 years

Note: B: Width, L: Length, D: Diameter

5.2 Cost Estimate

5.2.1 Basic Conditions

(1) Composition of Project Cost

The financial project cost comprises the following cost items.

1) Construction cost
2) Land acquisition and compensation cost
3) Engineering service cost
4) Administration cost
5) Price escalation
6) Physical contingency
7) Tax

(2) Price Level and Foreign Exchange Rate

All costs are estimated at the price level on August 30, 2002.

The exchange rate is set as follows:

US$1.0 = Rs. 96.26 = ¥118.94

(3) Foreign and Local Currency Portion

All costs are estimated by separating the foreign currency portion (FC) and local currency portion (LC) based on the ratio of the imported and local materials and equipment and also by referring to similar projects such as GCFC&EIP Phase III.

(4) Construction Cost

The construction cost comprises direct construction cost and preparatory work cost. The direct construction cost is estimated on the unit cost basis. The unit costs are estimated based on the current prices of construction resources and the construction plan. The unit construction cost for the urban drainage is based on the data of current similar projects such as GCFC&EIP Phase III.

The preparatory work cost is estimated at 10 % of the direct construction cost.

(5) Land Acquisition and Compensation Cost

1) Land Acquisition

Land acquisition cost is estimated by the required land area and its unit cost. The unit cost of land is estimated based on the data from the Chief Valuer's Department of the Ministry of Finance.

The applied unit costs are as follows:

Unit Cost of Land

(Unit: Rs./m^2)

Basin		Urban	Rural
Ja Ela Basin		1,900	20
Kalu Oya Basin		1,900	50
Greater Colombo Basin	CMC area	12,000	200
		* 20,000	
	Other areas	2,200	200
Bolgoda Basin	Weras Ganga Basin	2,200	200
	Other areas	600	20

Note: *: Primary commercial area

2) Compensation

Compensation cost includes the cost for compensation for house relocation and properties affected by project implementation. The compensation cost is assumed to be 20% of the land acquisition cost for the master plan study.

(6) Engineering Service Cost

The engineering service cost includes costs for field investigations, basic and detailed design including preparation of pre-qualification documents and tender documents, assistance for pre-qualification and tendering, and construction supervision. The engineering service cost is assumed to be 15% of the construction cost referring to the similar projects.

(7) Administration Cost

The Government's administration cost for the project implementation is assumed to be 2 % of the total of the construction cost, engineering service cost, and land acquisition and compensation cost. The rate is referred to the "JBIC SAPROF for Lunawa Lake Environment Improvement and Community Development Project, February 2001 (the Lunawa Project)".

(8) Price Escalation

The following price escalation rates were applied to the SAPROF study for the Lunawa Project.

1) 0.8% per annum for foreign currency (FC)
2) 2.8% per annum for local currency (LC)

The above price escalation rate for local currency was determined based on the following price index data up to the year 1999.

Colombo Consumer's Price Index (1997-1999)

Year	1997	1998	1999
Colombo Consumer's Price Index (CCPI) (% change)	9.6	9.4	4.7

Source: Central Bank of Sri Lanka Annual Report - 2001

The future price index is projected by Central Bank of Sri Lanka as follows:

Projected Colombo Consumer's Price Index (2002-2006)

Year	2002	2003	2004	2005	2006
CCPI (% change)	9.0	6.0	5.5	4.5	3.8

Source: Central Bank of Sri Lanka Annual Report - 2001

According to the above projections, the long-term escalation rate may be presumed to decline to below 3.0 %.

Consequently, the price escalation rates to be applied to the present Study are set at the same rates as those of the SAPROF study for the Lunawa Project.

(9) Physical Contingency

Physical contingency is set as follows referring to the SAPROF study for the Lunawa Project:

1) 10% of the construction cost, land acquisition and compensation cost
2) 5% of the equipment procurement cost, engineering service cost, and administration cost

(10) Tax

Tax is estimated as follows based on the current tax system of Sri Lanka:

1) 30% for the construction cost
2) 40% for the equipment procurement cost
3) 20% for the engineering service cost

5.2.2 Project Cost

Project costs for the proposed Master Plan are estimated by basin. The total project cost for the Master Plan amounts to Rs. 15.6 billion as tabulated below:

Project Cost of the Proposed Plan

Basin	Planning Scale	Retention Area (ha)	Project Cost (million Rs.)
Ja Ela Basin	50-year	876	3,679
Kalu Oya Basin	50-year	449	2,463
Greater Colombo Basin	50-year	380	4,389
Bolgoda Basin	50-year	295	5,102
		Total	15,633

The features of the storm water drainage plans and project costs for the respective basins are described below:

(1) Ja Ela Basin Storm Water Drainage Master Plan (Structural Measures)

1) Ja Ela Channel Improvement (Width = 60 m, Length = 7 km)
2) Dandungam Oya Channel Improvement (Width = 70-80 m, Length = 9.9 km)
3) Storm Water Retention Area (Lower Area = 500 ha, Upper Area = 376 ha)

Project Cost for Ja Ela Basin Storm Water Drainage Plan

(Unit: million Rs.)

Cost Item	FC	LC	Total
1.Construction Cost	1,507	583	2,090
Preparatory Works (10%)	137	53	190
Construction Cost	1,370	530	1,900
2.Land Acquisition & Compensation Cost	0	223	223
Land Acquisition	0	185	185
Compensation (20% of Land Acquisition Cost)	0	37	37
3.Engineering Service (15% of Construction Cost)	219	94	313
4.Administation Cost (2% of the above)	0	53	53
Total of (1+2+3+4)	1,726	953	2,679
5. Price Escalation	21	41	62
6. Physical Contingency	162	88	250
7. Tax	0	690	690
Project Cost	1,908	1,771	3,679

(2) Kalu Oya Basin Storm Water Drainage Master Plan (Structural Measures)

1) Kalu Oya Channel Improvement (Width = 25-50 m, Length = 5 km)
2) Old Negombo Canal Improvement (Width = 40 m, Length = 4.5 km)
3) Storm Water Retention Area (Lower Area = 360 ha, Upper Area = 89 ha)

Project Cost for Kalu Oya Basin Storm Water Drainage Plan

(Unit: million Rs.)

Cost Item	FC	LC	Total
1.Construction Cost	990	311	1,301
Preparatory Works (10%)	90	28	118
Construction Cost	900	283	1,183
2.Land Acquisition & Compensation Cost	0	288	288
Land Acquisition	0	240	240
Compensation (20% of Land Acquisition Cost)	0	48	48
3.Engineering Service (15% of Construction Cost)	137	59	195
4.Administation Cost (2% of the above)	0	36	36
Total of (1+2+3+4)	1,126	694	1,820
5. Price Escalation	14	30	43
6. Physical Contingency	106	65	170
7. Tax	0	429	429
Project Cost	1,246	1,217	2,463

(3) Greater Colombo Basin Storm Water Drainage Master Plan (Structural Measures)

1) Madiwela South Diversion Canal (Width = 32 m, Length = 8.8 km)
2) Existing Mutwal Tunnel Restoration (Diameter = 1.8 m, Length = 554 m)
3) New Mutwal Tunnel (Diameter = 4 m, Length = 740 m)
4) Storm Water Retention Area (Kolonnawa Marsh, Kotte Marsh, Heen Ela Marsh and Parliament Lake Area = 380 ha in total)

Project Cost for Greater Colombo Basin Storm Water Drainage Plan

(Unit: million Rs.)

Cost Item	FC	LC	Total
1.Construction Cost	1,747	734	2,481
Preparatory Works (10%)	159	67	226
Construction Cost	1,588	668	2,256
2.Land Acquisition & Compensation Cost	0	280	280
Land Acquisition	0	234	234
Compensation (20% of Land Acquisition Cost)	0	47	47
3.Engineering Service (15% of Construction Cost)	261	112	372
4.Administation Cost (2% of the above)	0	63	63
Total of (1+2+3+4)	2,008	1,189	3,197
5. Price Escalation	24	51	75
6. Physical Contingency	188	110	298
7. Tax	0	819	819
Project Cost	2,219	2,170	4,389

(4) Bolgoda Basin Storm Water Drainage Master Plan (Structural Measures)

1) Weras Ganga Storm Water Drainage Plan

a) Channel Improvement of Weras Ganga and Tributaries

- Weras Ganga Scheme (Length 5,500 m)
- Nugegoda-Rattanapitiya Scheme (Length 5,470 m)
- Bolgoda Canal Scheme (Length 2,400 km)
- Boralesgamuwa North Scheme (Length 3,090 m)
- Boralesgamuwa South Scheme (Length 980 km)
- Maha Ela Scheme (Length 4,460 km)
- Ratmalana-Moratuwa Scheme (Length 11,120 m)

b) Storm Water Retention Area

- Storm water retention areas in Weras Ganga basin (295 ha)

Project Cost for Bolgoda Basin Storm Water Drainage Plan

(Unit: million Rs.)

Cost Item	FC	LC	Total
1.Construction Cost	1,765	762	2,527
Preparatory Works (10%)	160	69	230
Construction Cost	1,605	693	2,298
2.Land Acquisition & Compensation Cost	0	828	828
Land Acquisition	0	690	690
Compensation (20% of Land Acquisition Cost)	0	138	138
3.Engineering Service (15% of Construction Cost)	265	114	379
4.Administation Cost (2% of the above)	0	75	75
Total of (1+2+3+4)	2,031	1,778	3,809
5. Price Escalation	24	76	101
6. Physical Contingency	190	168	358
7. Tax	0	834	834
Project Cost	2,245	2,857	5,102

5.3 Operation and Maintenance Cost

5.3.1 Maintenance Cost of the Canals

Annual maintenance cost of the canal per kilometer is estimated based on the data in SLLRDC as follows:

Annual Maintenance Cost of Canals

(Unit: million Rs./km)

Work	Canal of 5-10m wide	Canal of 10-30m wide
Dredging	0.20	0.60
Surface clearing	0.60	0.60
Canal bank maintenance	0.20	0.20
Total	1.00	1.40

Source: SLLRDC

According to SLLRDC, the annual maintenance cost in 2001 of the Greater Colombo Canal System of GCFC&EIP Phase I, of which the total length is 44 km, was Rs. 66 million. This figure corresponds to about 1% of the construction cost of GCFC&EIP Phase I.

Considering the above, the annual operation and maintenance cost of canals is assumed to be 1 % of the construction cost.

5.3.2 Maintenance Cost of the Other Civil Structures

The annual operation and maintenance costs for the other civil structures are also assumed to be 1% of the construction cost.

5.3.3 Operation and Maintenance (O&M) Cost of the Pumping Stations

Annual O&M cost of pumping stations including personnel expenses, power costs and costs for materials and equipment for O&M works is assumed to be 2.5% of the electrical and mechanical facility cost of the pumping station referring to the data of similar projects.