NATIONAL DRAINAGE AND IRRIGATION AUTHORITY
MINISTRY OF AGRICULTURE
THE CO-OPERATIVE REPUBLIC OF GUYANA

DATA COLLECTION SURVEY
ON
DRAINAGE CAPACITY IN GEORGETOWN
IN
THE CO-OPERATIVE REPUBLIC OF GUYANA

FINAL REPORT

OCTOBER 2017

JAPAN INTERNATIONAL COOPERATION AGENCY

CTI ENGINEERING INTERNATIONAL CO., LTD.

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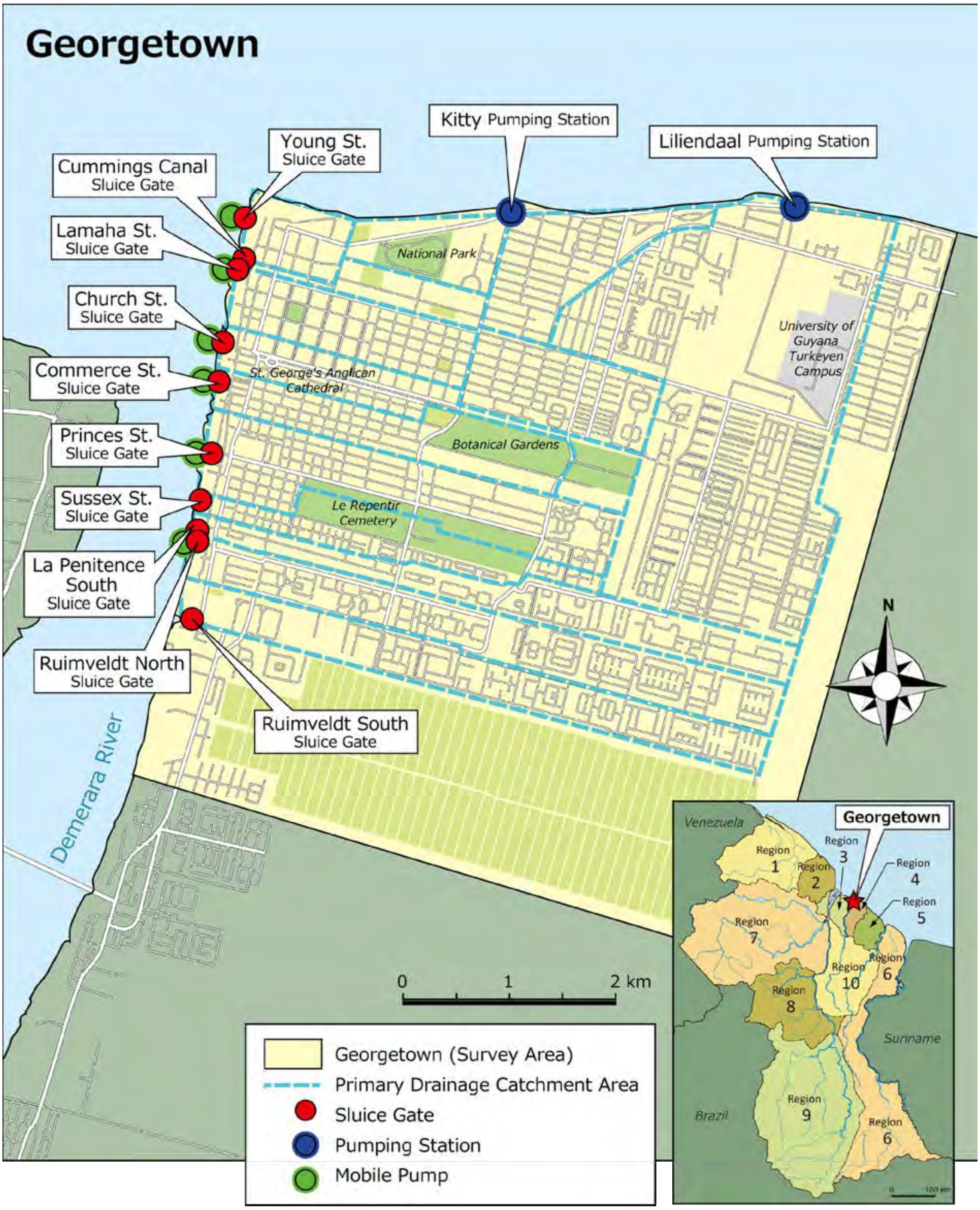

Source: Prepared by JICA Survey Team based on "Modeling of Floods in Georgetown, 2015 (NDIA)"

LOCATION MAP

PHOTOGRAPHS (1/2)

Liliendaal Pumping Station

Kitty Pumping Station

Young St Sluice Gate and Mobile Pump

Cummings Sluice Gate

Cummings Drainage Channel

Lamaha St. Sluice Gate and Mobile Pump

Church St. Sluice Gate and Mobile Pump

Commerce St Sluice Gate and Mobile Pump

Flow Direction

PHOTOGRAPHS (2/2)


Commerce St. Drainage Channel


Princess St. Sluice Gate


Princess St. Drainage Channel


Sussex St. Sluice Gate


La Penitence South Sluice Gate


La Penitence South Drainage Channel


Ruimveldt North Sluice Gate


Ruimveldt North Drainage Channel

Flow Direction

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ABBREVIATIONS AND ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
ADCP	Acoustic Doppler Current Profiler
ASTM	American Society for Testing and Materials
CAP	The Conservancy Adaptation Project
CCRIF	Caribbean Catastrophe Risk Insurance Facility
CDB	Caribbean Development Bank
CDC	Civil Defence Commission
CHPA	Central Housing & Planning Authority
DANA	Damage Assessment and Needs Analysis
DRR	Dutch Risk Reduction
EDWC	East Demerara Water Conservancy
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
EU	European Union
GCRG	Government of the Co-operative Republic of Guyana
GD	Georgetown Datum
GDA	Georgetown Drainage Authority
GIMU	Geospatial Information Management Unit
GIS	Geographical Information System
GL&SC	Guyana Lands and Surveys Commission
GWA	Guyana Water Authority
GWI	Guyana Water Incorporated
HS	Hydrometeorological Services
IDB	Inter American Development Bank
IDRM	Integrated Disaster Risk Management
IEE	Initial Environmental Examination
IEIA	Initial Environmental Impact Assessment
IPCC	Intergovernmental Panel on Climate Change
JCCCP	Japan-Caribbean Climate Change Partnership
JICA	Japan International Cooperation Agency
LAT	Lowest Astronomical Tide
LCDS	Low Carbon Development Strategy
MARAD	Maritime Administration Department
MOA	Ministry of Agriculture
MOC	Ministry of Communities
MOF	Ministry of Finance
MOLA	Ministry of Legal Affairs
MONR	Ministry of Natural Resources
MOP	Ministry of the Presidency
MOU	Memorandum of Understanding
MPI	Ministry of Public Infrastructure
MSL	Mean Sea Level
M&CC	Mayor and City Council
NDIA	National Drainage and Irrigation Authority
NTFC	National Task Force Commission
OCC	Office of Climate Change
SRDD	Sea and River Defence Division
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
WB	World Bank
WSG	Work Services Group

(Length)		(Weight)	
mm	: millimeter(s)	mg	: milligram(s)
cm	: centimeter(s)	g, gr	: gram(s)
m	: meter(s)	kg	: kilogram(s)
km	: kilometer(s)	ton	: tonne(s)

(Area)		(Time)	
mm^2	: square millimeter(s)	s, sec	: second(s)
cm^2	: square centimeter(s)	min	: minute(s)
m^2	: square meter(s)	h(hrs)	: hour(s)
km^2	: square kilometer(s)	d(dys)	: day(s)
ha	: hectare(s)	y, yr(yrs)	: year(s)

(Volume)		(Speed/Velocity)	
cm^3	: cubic centimeter(s)	cm/sec, cm/s	: centimeter per second
m^3	: cubic meter(s)	m/sec, m/s	: meter per second
ℓ	: liter(s)	km/hr, km/h	: kilometer per hour

(Flow/Discharge)		(Concentration)	
ℓ/sec, ℓ/s	: liter per second	mg/ℓ	: milligram per liter
m^3/sec, m^3/s	: cubic meter per second		
m^3/yr, m^3/y	: cubic meter per year		

(Electrical Units)		(Stress)	
W	: watt(s)	kg/cm^2	: kilogram per square centimeter
kW	: kilowatt(s)	ton/m^2	: ton per square meter
MW	: megawatt(s)		
kWh	: kilowatt-hour		
MWh	: megawatt-hour	(Monetary Terms)	
GWh	: gigawatt-hour	¥	: Japanese Yen
V	: volt(s)	US$	: United States Dollar
kV	: kilovolt(s)	G$	: Guyana Dollar

CHAPTER 1 PRESENT CONDITION OF DRAINAGE SYSTEM IN GEORGETOWN

1.1 Background

The City of Georgetown, the capital and largest city in the Co-operative Republic of Guyana (hereinafter referred to as Guyana), serves as the administrative and financial centre in the country. As of 2012, it had the population of more than 118 thousand, or about 15% of Guyana's total population of approximately 740 thousand (refer to the 2012 Census, Guyana.)

The network of open channels was originally developed to irrigate and drain the sugar plantations which occupied the land on which Georgetown now stands. Since Georgetown lies marginally below mean sea level, gravity drainage can take place only for about 8 to 10 hours on either side of low water when the sluices on the Demerara River are opened. The sluice gates are locked and the pumps are operated during high tide. There is no inundation damage due to back-flow from the seaside in high tide, but frequent inundation damage due to inland floods have recently occurred.

Severe flooding has been experienced at an average of 4 times per year during the two rainy seasons. Particularly, the flood damage in Guyana concentrates in Georgetown, which is situated at the mouth of the Demerara River. Recently, torrential rainfalls have caused extensive damage to Georgetown. Particularly, the flood event in 2005 resulted in the loss of 34 lives, and economic damage cost was estimated at approximately 60% of the GDP.

The executive office of the Caribbean Community (hereinafter called CARICOM) is located in Georgetown. Thus, the improvement of drainage system in Georgetown is an urgent task in line with the "National Integrated Disaster Risk Management Plan" of Guyana. Likewise, the importance of drainage improvement in Georgetown is pointed out in the JICA (Japan International Cooperation Agency) survey called "Data Collection Survey on Disaster Risk Management in CARICOM Countries." In this context, the Government of the Co-operative Republic of Guyana (hereinafter called "GCRG") made a request for technical cooperation for the Project from the Government of Japan, through the Japan's Grant Aid scheme, to improve the drainage system in Georgetown, such as, additional pumping stations and improvement of drainage channels.

On the other hand, the data/information on the existing drainage system in Georgetown has not been collected, accumulated or updated. The master plan formulated by the Guyana Water Authority has not been updated since 1994. There is no accurate data on the capacity and connection state of the existing drainage channels. The establishment of the drainage system has not been associated with the urban development plan of Georgetown. The "DRR-Team (Dutch Risk Reduction Team) Mission Report (2016)" pointed out that the reduction of drainage capacity in Georgetown is due to the urbanization, siltation and vegetation in the drainage channel. Furthermore, the data on groundwater level and the status of utilization, which might influence the drainage system in Georgetown, is insufficient.

JICA has recognized that flood mitigation/drainage improvement is required from the viewpoint of economic loss and health hazard due to flood events. Therefore, further data/information of the existing drainage system in Georgetown is required for the implementation of effective and sustainable countermeasures. To figure out the major causes of flood and the challenges to the existing drainage system, and to collect data for the future planning of drainage system improvement, the "Data Collection Survey on Drainage Capacity in Georgetown" (hereinafter collectively called "the Survey") is executed.

1.2 Flood/Inundation Damage

1.2.1 Flood/Inundation Record and Economic Loss

The flood damage in Guyana concentrates in the lower Demerara River and coastal area. Georgetown, which is located on the lower Demerara River, and the coastal area is in Region 4. Major flood damages in Guyana between 1971 and 2016 are as given in **Table R 1.2.1**.

Table R 1.2.1 Major Flood Damage in Guyana (1971-2016)

Month/Year	Damaged Region	Affected Person (Person)	Economic Loss (Million USD)	GDP (Million USD)	Percentage of Economic Loss to GDP (%)
Jul. 1971	—	21,000	0.2	282	0.1
Jul. 1996	All Region	38,000	—	705	—
Jan. 2005	2, 3, 4, 5, 6	274,774	465.1	825	56.4
Jan. 2006	2, 5	35,000	169.0	1,458	11.6
Dec. 2008	2, 4, 5, 6, 10	100,000	—	1,923	—
Jul. 2015	3, 4, 5	199,000	—	3,166	—

* Georgetown is located in Region 4.
Source: EM-DAT (http://www.emdat.be/advanced_search/index.html)、reliefweb (http://reliefweb.int/disaster/fl-2015-000093-guy), Progress and challenges in disaster risk management in Guyana, 2014、CDC ((http://dipecholac.net/docs/files/785-guyana-cd-v38-finaldraft-all-low-res.pdf)

The main cause of inundation damage in Georgetown is inland flood. Large or small-scale inundation damage had occurred due to inland flood during/after torrential rainfall. Recently, heavy rains have caused severe damage in Georgetown. The current situation of inundation in Georgetown is as presented in **Fig. R 1.2.1**.

Flood in 2005 (Rainfall:196mm/day)
Source: Guyana News and Information (http://guyana.hoop.la/topic/g-t-has-been-renamed-to)

Flood in 2014 (Rainfall:186mm/day)
Source: News Source (http://newssourcegy.com/news/georgetown-flood-waters-heavy-rainfall-expected/)

Flood in 2015 (Rainfall:208mm/day)
Source: News Source (http://newssourcegy.com/news/georgetown-under-flood-waters-again-after-rain-batters-coastland/)

Fig. R 1.2.1 Current Situation of Inundation in Georgetown

Inland floods cause economic loss to residences, commercial facilities and infrastructure in Georgetown. Besides, transportation in Georgetown, paralyzed by inundation, negatively affects the economy and causes social damage, like functional loss of public administration, because the main method of transport for the residents in Georgetown is the wheeled vehicle like bus.

Particularly, the flood event in 2005 due to inland flood caused the severest damage in recent years and the period of inundation was three weeks. Besides, the flood event in 2005 resulted in the loss of 34 lives, and economic damage cost was estimated at approximately 60% of the GDP. A summary of damage and losses caused by the January 2005 flood is as shown in **Table R 1.2.2**.

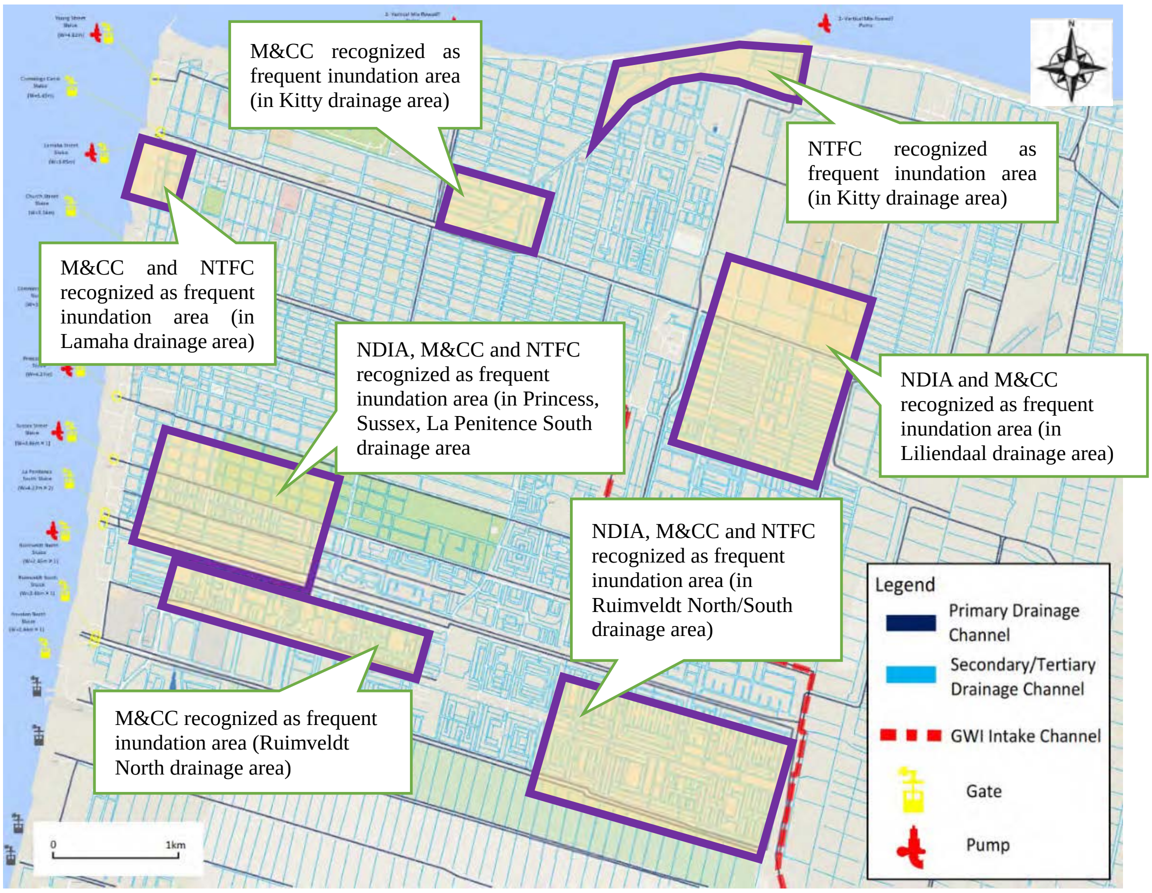
The JICA Survey Team conducted a hearing survey on the frequent inundation area in Georgetown during the first survey in Guyana. The result of the hearing survey is as follows. The results of hearing survey in the frequent inundation area in Georgetown is as shown in **Fig. R 1.2.2**.

Table R 1.2.2 Summary of Damage and Losses Caused by the January 2005 Flood

Unit: G$$10^6$

Sector and Subsector	Total	Direct	Indirect
Social Sectors	55,665.90	55,247.20	418.7
Housing	55,120.80	54,842.60	278.2
Education and culture	371.7	352.1	19.6
Health	173.4	52.5	120.9
Productive sectors	27,458.60	20,945.00	6,513.70
Agriculture	10,894.30	10,018.80	875.5
Commerce	14,476.10	10,213.10	4,263.00
Tourism	1,126.80	47	1,079.80
Manufacturing	961.5	666.1	295.4
Infrastructure	9,143.30	7,452.20	1,691.10
Drainage and irrigation	1,311.10	194.8	1,116.40
Water supply and water disposal	3,943.70	3,763.70	180
Road transport	3,529.00	3,349.00	180
Telecommunications	152.7	91.3	61.4
Electricity	206.7	53.4	153.4
Environment	15.1	15.1	
Total Emergency Relief	740		740
Grand Total	93,022.90	83,659.50	9,363.40

Source: National Integrated Disaster Risk Management Plan and Implementation Strategy for Guyana (CDC)



Source: Prepared by JICA Survey Team based on NDIA (National Drainage and Irrigation Authority), M&CC (Georgetown), NTFC (National Task Force Commission). The frequent inundations are as indicated by [purple-outlined box symbol] .

Fig. R 1.2.2 Result of Hearing Survey on the Frequent Inundation Area in Georgetown

There is a possibility that overflow from the Demerara River and tidal wave from the Atlantic Ocean will cause flood and inundation damage in Georgetown. However, as a result of hearing survey with the related agencies in Guyana, there is no record that overflow from Demerara River has caused flood and inundation in the whole of Georgetown. The coastal area of Georgetown was partially damaged by overtopping tidal wave from the existing coastal wall during the high tide in April 2013, but not the whole of Georgetown.

Source: stabroek news (http://www.stabroeknews.com/2013/news/stories/04/29/high-tides-flood-parts-of-georgetown-west-coast/)

Photo R 1.2.1 Tidal Wave Over Coastal Wall in 2013

It is said that the CDC (Civil Defence Commission) and the WSG-MPI (Work Services Group, Ministry of Public Works and Infrastructure) gather/record the data of inundation damage and tidal wave damage in Guyana, respectively. However, these data have not been collected during the Survey.

1.2.2 Climate Change Prediction

The Office of Climate Change (hereinafter called OCC) under the Ministry of the Presidency works on climate change in Guyana, and the major approaches to climate change are as shown in the following table.

Table R 1.2.3 Major Approaches to Climate Change in Guyana

Name	Year
Guyana Initial National Communication to the UNFCCC (United Nations Framework Convention on Climate Change)	2002
Guyana Climate Change Action Plan	2001
National Climate Change Adaptation Policy and Implementation Plan	2001
National Agricultural Sector Adaptation Strategy to Address Climate Change (2009-2018)	2009
Low-Carbon Development Strategy	2010
Low-Carbon Development Strategy Update	2013
Climate Resilience Strategy and Action Plan for Guyana	2015

Source: Guyana Review of current and planned adaptation action, Climate Resilience Strategy and Action Plan for Guyana

The Guyana Initial National Communication to the UNFCCC (2002) and the Guyana Climate Change Action Plan (2001) identified the priority actions for coastal zones, agriculture, fisheries, water, energy, forestry and land use, and waste as both important in socio-economic terms and vulnerable to climate variability and change. Likewise, the following activities are recommended in the Low-Carbon Development Strategy (2010) as a major adaptation to climate change.

- Upgrading infrastructure and assets (upgrading drainage system, building ocean seawalls, etc.)
- Addressing systematic and behavioural concerns (strengthening building codes, early warning systems, etc.)
- Developing financial and risk insurance measures to boost resiliency post-flooding
- Switching to flood resistant crops

- Establishing the climate change adaptation needs of Guyana's hinterland regions, including forest communities
- In the longer term, further upgrading of flood protection, seawalls and expansion of drainage and irrigation

The prediction of climate change was executed by OCC. As the first step, the OCC employed a private consultant with funds from the Japan-Caribbean Climate Change Partnership (hereinafter called JCCCP) for collecting basic data.

1.3 Basic Data for Drainage System

1.3.1 Meteorological and Hydrological Data

(1) Location of Meteorological and Hydrological Station

Location of tidal and meteorological observatory in Georgetown is as given in **Fig. R 1.3.1**.

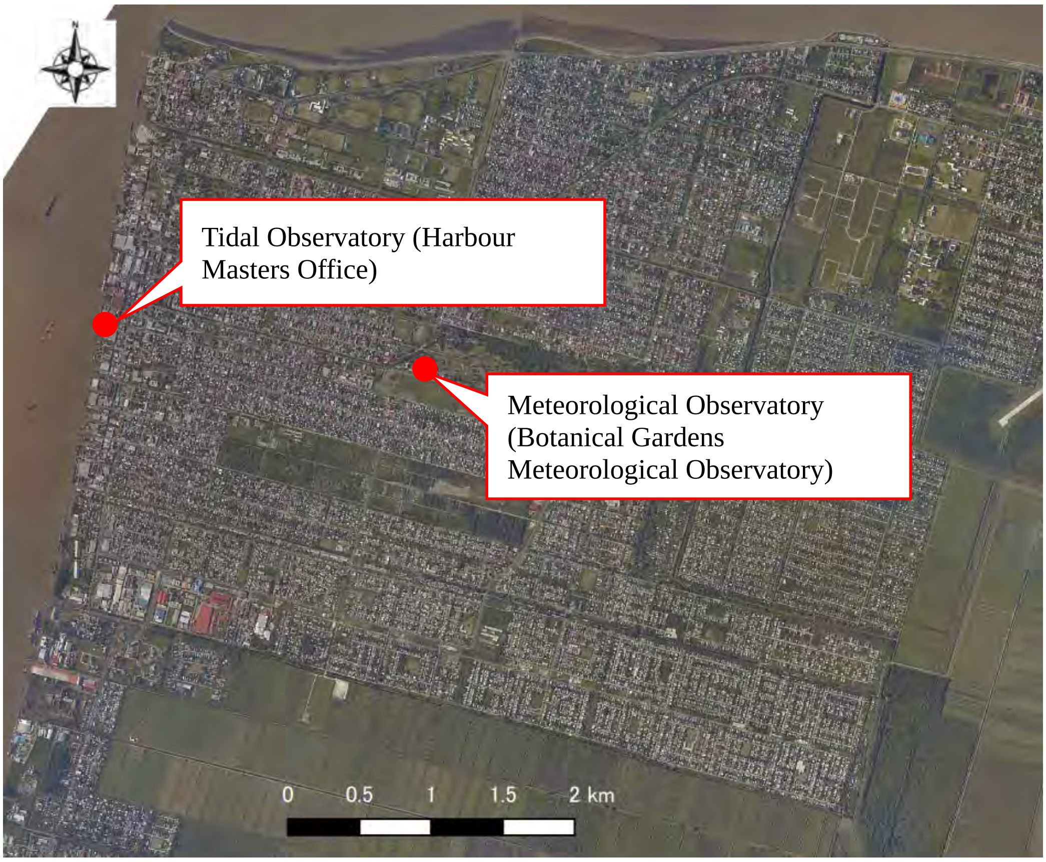


Fig. R 1.3.1 Location of Tidal and Meteorological Observatories in Georgetown

The meteorological observatory is located in the Botanical Gardens near the Ministry of Agriculture and managed/observed by the Hydro-meteorological Service, Ministry of Agriculture (hereinafter called HS-MOA). The major observatory items include rainfall, air temperature, humidity, wind direction/velocity, soil temperature, sunshine and evapotranspiration. Of these, rainfall, air temperature, humidity and soil temperature are observed by both digital and manual method. The data observed by manual method is announced officially but the digital data is utilized for only the validation of manual data since the reliability of observed digital data has not been assessed.

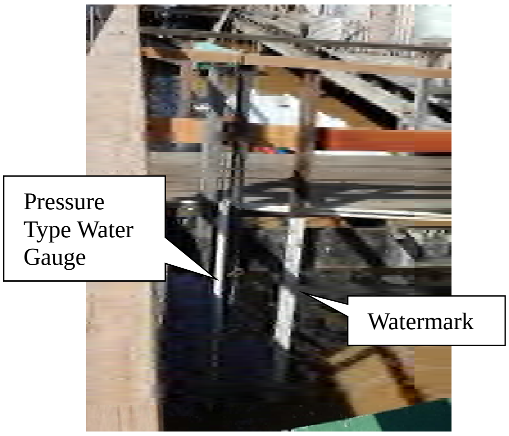
The Maritime Administration Department, Ministry of Public Works and Infrastructure (hereinafter called MARAD-MPI) observes the water level of the Demerara River and tide level along the Atlantic Ocean. However, the Harbour Masters Office is the only tidal observatory in Georgetown. HS-MOA also observes the water level of the Demerara River, not in Georgetown but at 100 miles upstream from Georgetown, for hydroelectric power generation.

Digital Type
(Data Collection by USB)

Digital Type
(Data Collection by Recorded Paper)

Manual Type

Photo R 1.3.1 Rain Gauge in Meteorological Observatory



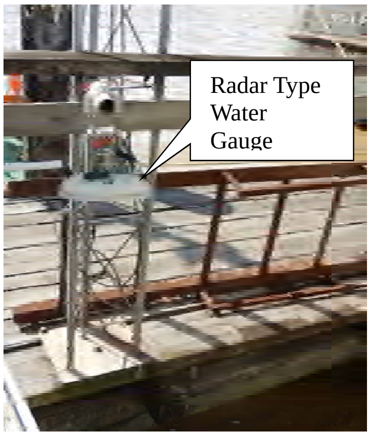


Photo R 1.3.2 Tidal Observatory

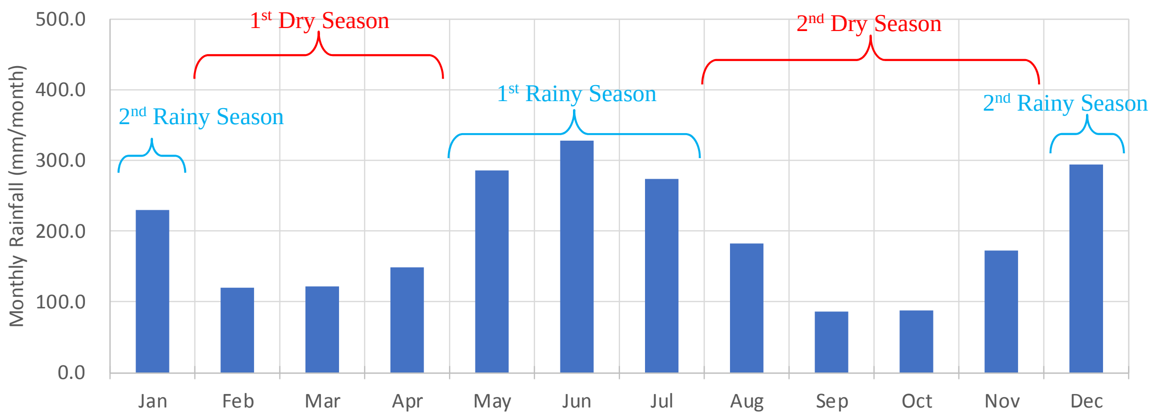
(2) Rainfall

Daily rainfall data from 1886 to 2016 at the Botanical Gardens Meteorological Observatory in Georgetown was provided by HS-MOA. Of these data, there is no data on the daily rainfall of 1890 and from 1905 to 1915. Besides, many daily rainfall data of 1903 and 1904 are deficient. However, a lot of daily rainfall data have been observed and accumulated over long periods. On the other hand, the hourly rainfall data was not organized, but provided to the Survey Team during the Survey. It is recommended that HS-MOA should observe, organize and accumulate hourly rainfall data.

Georgetown has rainy and dry seasons, each occurring two times a year, as shown in **Fig. R 1.3.2**. The dry seasons are from February to April and August to November, while the rainy seasons are from May to July and December to January.

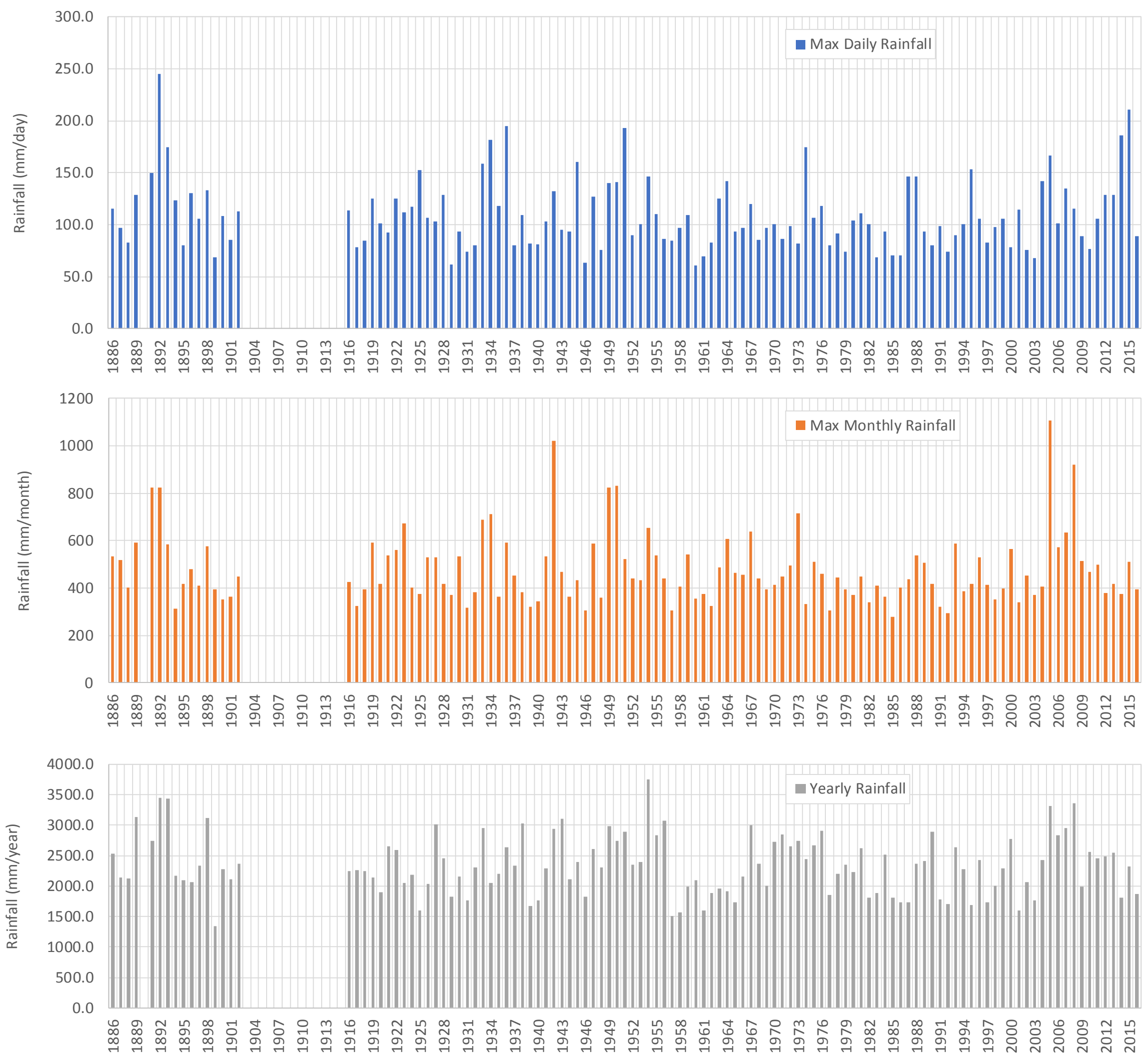
Fig. R 1.3.3 shows daily maximum, monthly maximum and annual rainfall in Georgetown from 1886 to 2016. **Table R 1.3.1** shows the ranking of daily maximum, monthly maximum and annual rainfall in Georgetown between 1886 and 2016. The trend of increasing rainfall is not indicated in **Fig. R 1.3.3**. However, the recent floods of 2005, 2014 and 2015 were caused by rainfall in the upper part of ranking during approximately 130 years of observation.

The monthly rainfall amount in January 2005 was 1,108.2 mm, which is approximately half the amount of average annual rainfall, 2,333mm.



Source: HS-MOA

Fig. R 1.3.2 Mean Monthly Rainfall in Georgetown (1886-2016)



Source: HS-MOA

Fig. R 1.3.3 Daily Maximum Rainfall, Monthly Maximum Rainfall and Annual Rainfall in Georgetown (1886-2016)

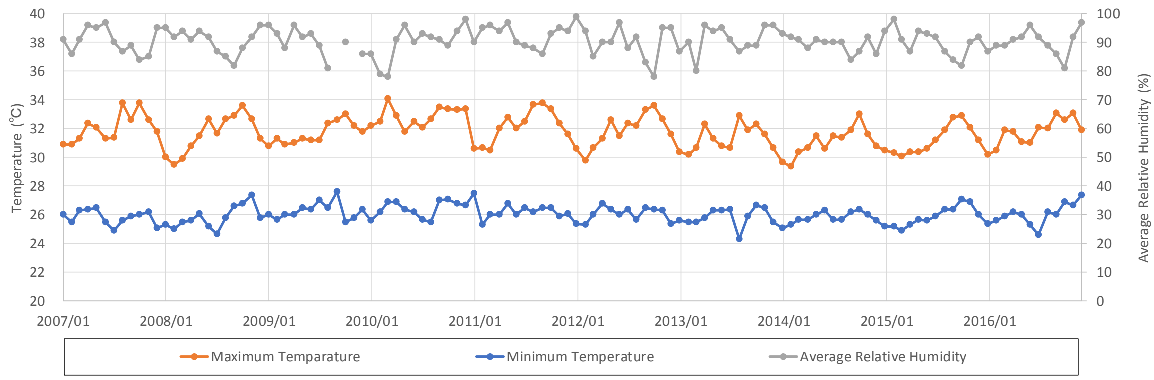
Table R 1.3.1 Ranking of Daily Maximum Rainfall, Monthly Maximum Rainfall and Annual Rainfall in Georgetown (1886-2016)

Ranking	Daily Maximum Rainfall		Monthly Maximum Rainfall		Annual Rainfall	
	mm/day	Date	mm/month	Month/Year	mm/year	Year
1	245.1	14 June, 1892	1108.2	January 2005	3749.3	1954
2	210.2	15 July, 2015	1022.0	December 1942	3454.3	1892
3	194.3	1 December, 1936	919.6	December 2008	3434.7	1893
4	192.8	8 May, 1951	831.0	January 1950	3365.2	2008
5	186.0	19 November, 2014	824.5	December 1949	3315.5	2005
6	181.9	7 January, 1934	822.7	December 1891	3137.9	1889
7	174.8	26 December, 1893	822.2	June 1892	3122.0	1898
8	174.0	1 November, 1974	716.8	December 1973	3097.4	1943
9	166.1	16 January, 2005	711.1	January 1934	3076.6	1956
10	160.0	14 May, 1945	688.5	December 1933	3022.5	1938

Source: HS-MOA (Rainfall over the past 15 years)

(3) Temperature and Humidity

Daily maximum temperature, daily minimum temperature and relative humidity data from 1954 to 2016 at the Botanical Gardens Meteorological Observatory in Georgetown were provided by HS-MOA. Of these data, there is no data of 1955, 1956 and from 1958 to 1961. However, some temperature and humidity data are deficient. Daily maximum temperature, daily minimum temperature and relative humidity data in Georgetown over the past decade are as given in **Fig. R 1.3.4**. The mean maximum temperature, mean minimum temperature and average relative humidity over the past decade are 31.8°C, 26.0°C and 90.5%, respectively. The climate is hot and humid year-round. There are no big changes in the daily maximum temperature, daily minimum temperature and relative humidity over time.

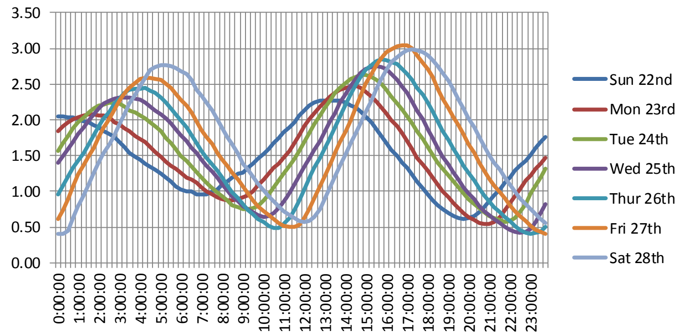


Source: HS-MOA

Fig. R 1.3.4 Daily Maximum Temperature, Daily Minimum Temperature and Relative Humidity (2007-2016)

(4) Tide Level

Tide level data in Georgetown is observed by pressure type water gauge, radar type water gauge, and watermarks. The tide data have been automatically observed every 15 minutes by pressure type water gauge and radar type water gauge since January 2007. The tide data have been observed at high tide and low tide by watermark from 1962 to 1983, during working hours of MARAD-MPI, from 8:00 AM to 4:00 PM since 1984. MARAD-MPI analyses the astronomical tide level and publishes tide tables every year.



Source: MARAD-MPI

Fig. R 1.3.5 Observed Tidal Data in Georgetown (January 22, 2017 to January 28, 2017)

As shown in **Fig. R 1.3.5**, there are usually two high and two low tides each day in Georgetown. The sluice gate is opened during low tide to drain by gravity drainage.

MARAD-MPI analysed the Mean Sea Level (hereinafter called MSL) in 1979, 1999 and 2010, and the results are as presented in **Table R 1.3.2**. The MSL had risen by 23cm from 15.52 mGD (Georgetown Datum: GD) to 15.75 mGD for 37 years from 1979 to 2016 (6.2mm/year). This rate of rise is higher than the global average of about 2-4mm/year.

The zero elevation of tidal observation is equivalent to chart datum, admiralty datum, 13.76mGD and Lowest Astronomical Tide (hereinafter called LAT). The results of analysis of tide level by MARAD-MPI using the tidal data from February 2017 to February 2017 are as given in **Table R 1.3.3**.

Table R 1.3.2 Results of Analysis of MSL by MARAD-MPI

Year	MSL（mGD）
1979	15.52
1999	15.56
2010	15.66

Source: MARAD-MPI

Table R 1.3.3 Results of Analysis of Tide Level by MARAD-MPI

Name	Elevation	Analysed year	Remarks
Highest Recorded Tide	17.39 mGD	2017	17.19 mGD on M/P*
Mean High Water Spring	16.97 mGD	2017	16.65 mGD on M/P*
Mean High Water Neap	16.51 mGD	2017	15.98 mGD on M/P*
Mean Sea Level	15.75 mGD	2017	15.52 mGD on M/P*
Mean Low Water Neap	14.83 mGD	2017	14.79 mGD on M/P*
Mean Low Water Spring	14.48 mGD	2017	14.09 mGD on M/P*

Source: MARAD-MPI
* M/P: Georgetown Water and Sewerage Master Plan (1994), Guyana Water Authority

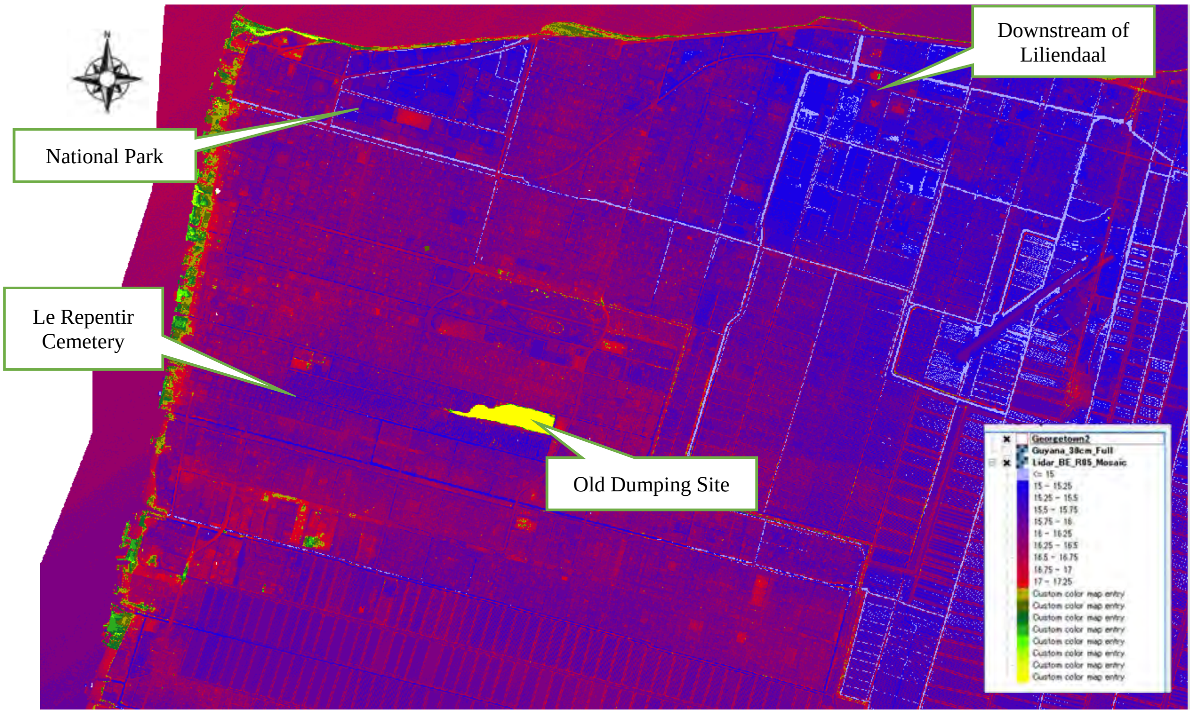
1.3.2 Geography

The Guyana Lands and Surveys Commission (hereinafter called GL&SC) works on the service for geography. The datum level in Guyana is the Georgetown Datum (hereinafter called GD). The previous standard coordinate was Provisional South American Datum of 1956 (hereinafter called PSAD56), but the present standard coordinate is World Geodetic System 1984 (hereinafter called WGS 84).

The elevation data in Georgetown (Lidar Data) is as given in **Fig. R 1.3.6**. Geographically, Georgetown consists overall of flat terrain with the elevation between 15mGD and 17mGD. The old dumping site at the centre of the city and east side of Le Repentir Cemetery is embanked and higher than the vicinity area. The elevations of the green zone at downstream of Liliendaal, National Park and Le Repentir Cemetery are relatively low.

The locations of benchmark in Georgetown are as given in **Fig. R 1.3.7**. The GL&SC's benchmarks in Georgetown includes GT1 to GT31. However, several benchmarks are not used presently, because of deterioration, buried under pavement or embankment, unidentified at site, etc.

It is desirable that GL&SC periodically conduct survey to verify the accuracy and elevation, and situationally recover and relocate the inadequate benchmarks.



Source: National Drainage and Irrigation Authority: NDIA

Fig. R 1.3.6 Elevation Data in Georgetown (Lidar Data)

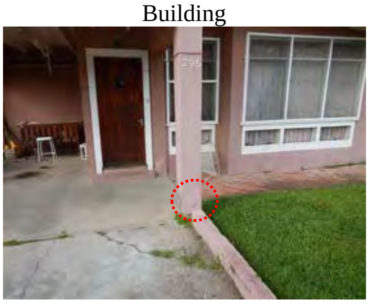
Source: Verification of Benchmark by JICA Survey Team and Local Survey Company (Surveying & Project Management Inc.) based on Information from GL&SC

Fig. R 1.3.7 Locations of Benchmark in Georgetown


GT1 on Column of Court of Appeal Building


GT2 on Seawall


GT7 on Wall of House


GT8 on Column of House

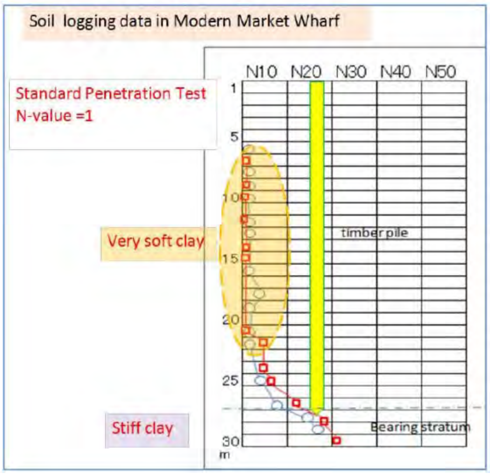

GT13 on Foundation of Former Telecom Facility


GT20 on Bridge across Church St. Channel. (GT20 is unavailable due to loss of steel rod)

Photo R 1.3.3 Condition of Existing Benchmarks

According to the Georgetown Water and Sewerage Master Plan (1994) Guyana Water Authority [hereinafter called M/P (1994)], urban development is not as influential as it is in other urban areas as the impermeable nature of the underlying clays in Georgetown means that seepage is negligible and that infiltration of rainwater is limited to the topsoil. **Fig. R 1.3.8** shows that the topsoil of Georgetown has low N-value and layer of clay.

Thus, it is supposed that rainfall penetrated into the ground poorly and run off into the channel largely in Georgetown even before the urbanization.



Source: Final Report of Mr. Tsutsui, JICA Senior Volunteer

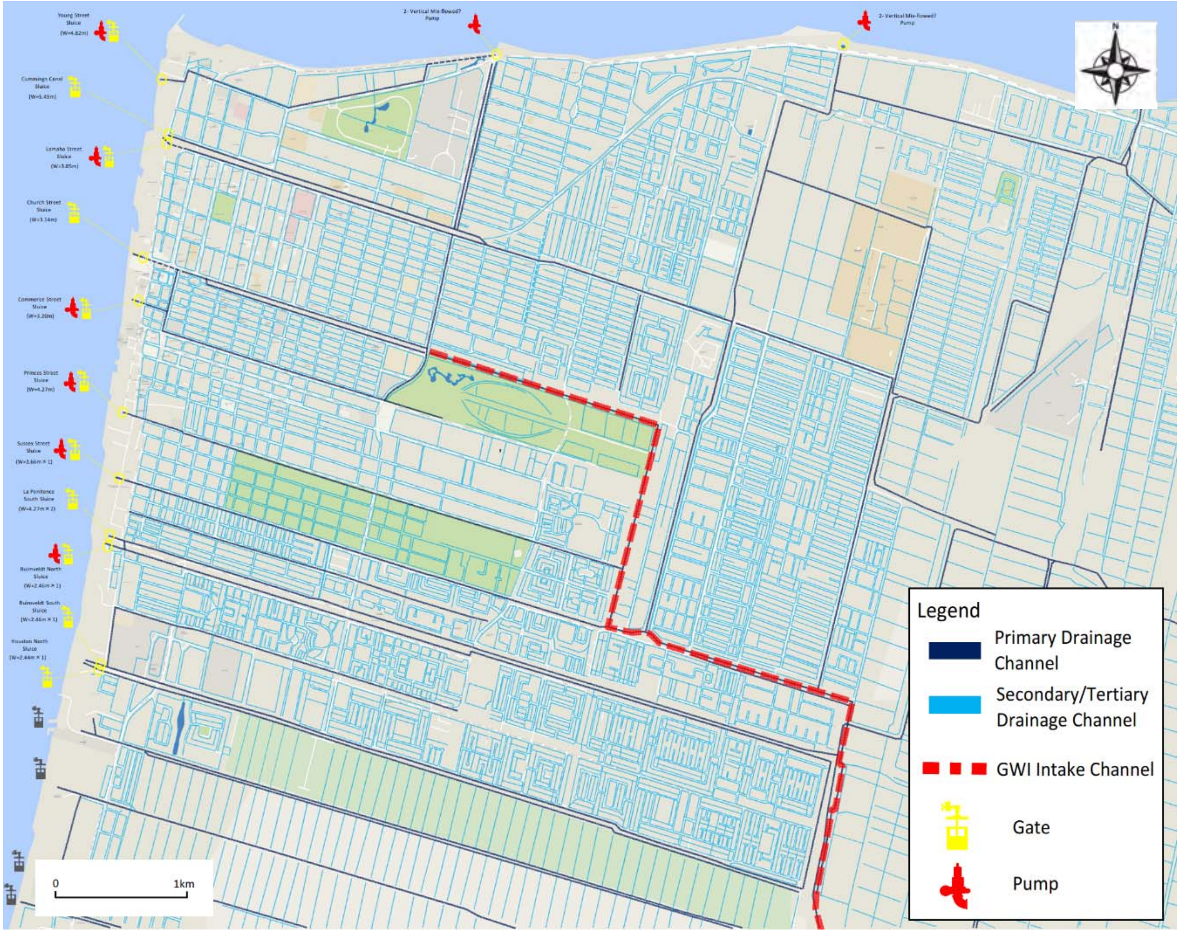
Fig. R 1.3.8 Borehole Log at Modern Market Wharf

1.3.3 Status of Existing Drainage Facilities

(1) Drainage Channel

The network of open channels was originally developed in the 17th century to irrigate and drain the sugar plantations which occupied the land on which Georgetown now stands. At the time, a drainage and irrigation channel ran in parallel. Some present drainage channels run in parallel, such as Cummings Channel and Lamaha St. Channel, and La Penitence South Channel and Ruimveldt North Channel, which trace back to the time of sugar plantation.

Drainage channels are classified into primary, secondary and tertiary drainage channels. Other than the drainage channels, there is the intake channel of Guyana Water Incorporated (hereinafter called GWI) in Georgetown. The layout plan of drainage and intake channels in Georgetown prepared by the JICA Senior Volunteer is as given in **Fig. R 1.3.9**. This layout plan was utilized by NDIA and on the report of Dutch Risk Reduction (hereinafter called DRR) Team.



Source: JICA Survey Team added to GWI intake channel based on the layout plan of JICA Senior Volunteer, Mr. Higuchi

Fig. R 1.3.9 Layout Plan of Drainage and Intake Channel in Georgetown

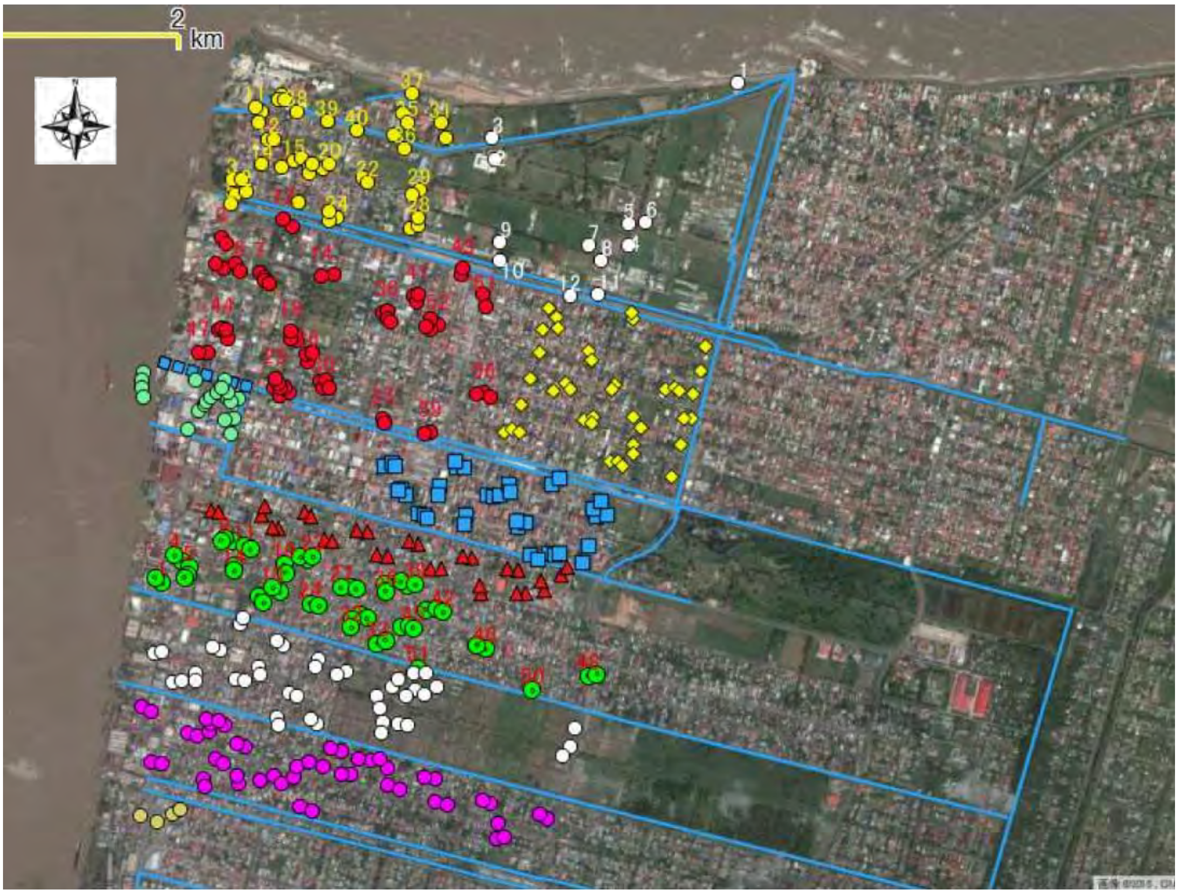
Cross-section surveys for primary drainage channels were conducted in the M/P (1994). The number of cross-sections in the M/P (1994) is as shown below.

Table R 1.3.4 Number of Cross-Sections of M/P (1994)

Primary Drainage Channels	No. of Cross-Sections	Primary Drainage Channels	No. of Cross-Sections
Young St.	3	Princes Street (North)	9
Carifesta Ave.	2	Princes Street (South)	4
Cummings Canal	3	Sussex Street (South)	6
Lamaha St.	5	Durban Backlands	1
Church St.	4	La Penitence (South)	8
North Rd.	2	Ruimveldt (North)	9
South Rd.	2	Ruimveldt (South)	3
Republic Facade	1	Sophia- Bel Air	1
		Downer Canal	1

Source: M/P (1994)

Furthermore, Mr. Tsutsui, JICA Senior Volunteer, conducted cross-section survey for a part of the secondary and tertiary drainage channels in 2016. The location of cross-section survey by the JICA Senior Volunteer is as presented in the following figure.



Source: JICA Senior Volunteer, Mr. Tsutsui

Fig. R 1.3.10 Surveyed Location Plan of Secondary and Tertiary Drainage Channels in Georgetown (350 Points) in 2016

As a result of hearing survey with the related agencies, there is no other cross-section data of drainage channel in Georgetown except the above-mentioned cross-section data. The cross-section and longitudinal section survey for primary drainage channels has been conducted, and the survey contents are as shown below.

Table R 1.3.5 Survey Contents by Outsourcing

Primary Drainage Channel	Length of Longitudinal Section（m）	Number of Cross-Section (Nos.)
Liliendaal	4,200	22
Kitty-1	1,000	6
Kitty-2	1,000	6
Young St.	1,000	6
Cummings Canal	4,387	12
Lamaha St.	2,400	23
Church St.	2,198	12
Commerce St.	4,000	21
Princess St.	3,724	22
Sussex St.	5,629	29
La Penitence South	5,036	29
Ruimveldt North	5,636	29
Ruimveldt South	5,493	28

Source: JICA Survey Team

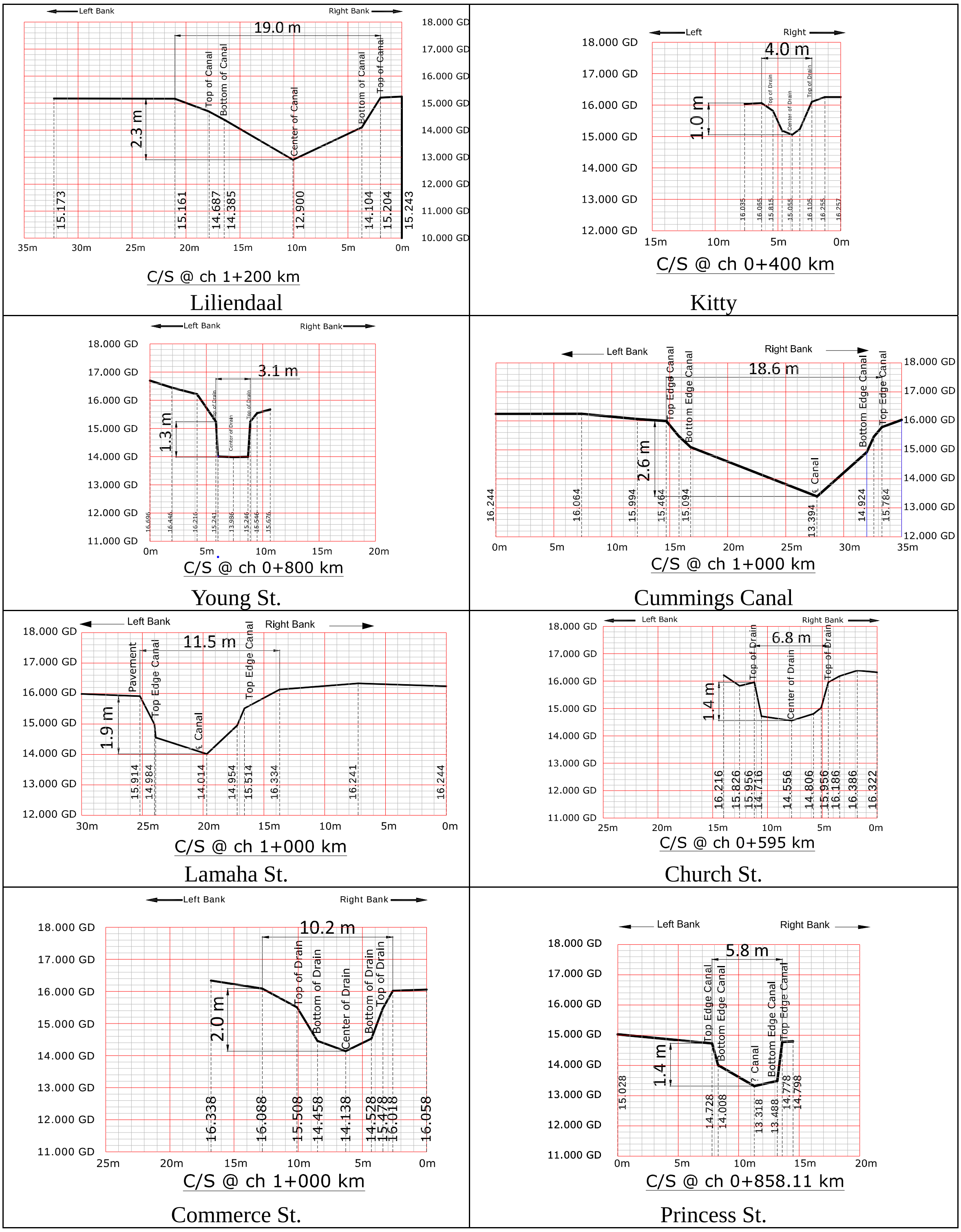


Fig. R 1.3.11 Typical Cross-Section Survey Result for Primary Drainage Channel (1)

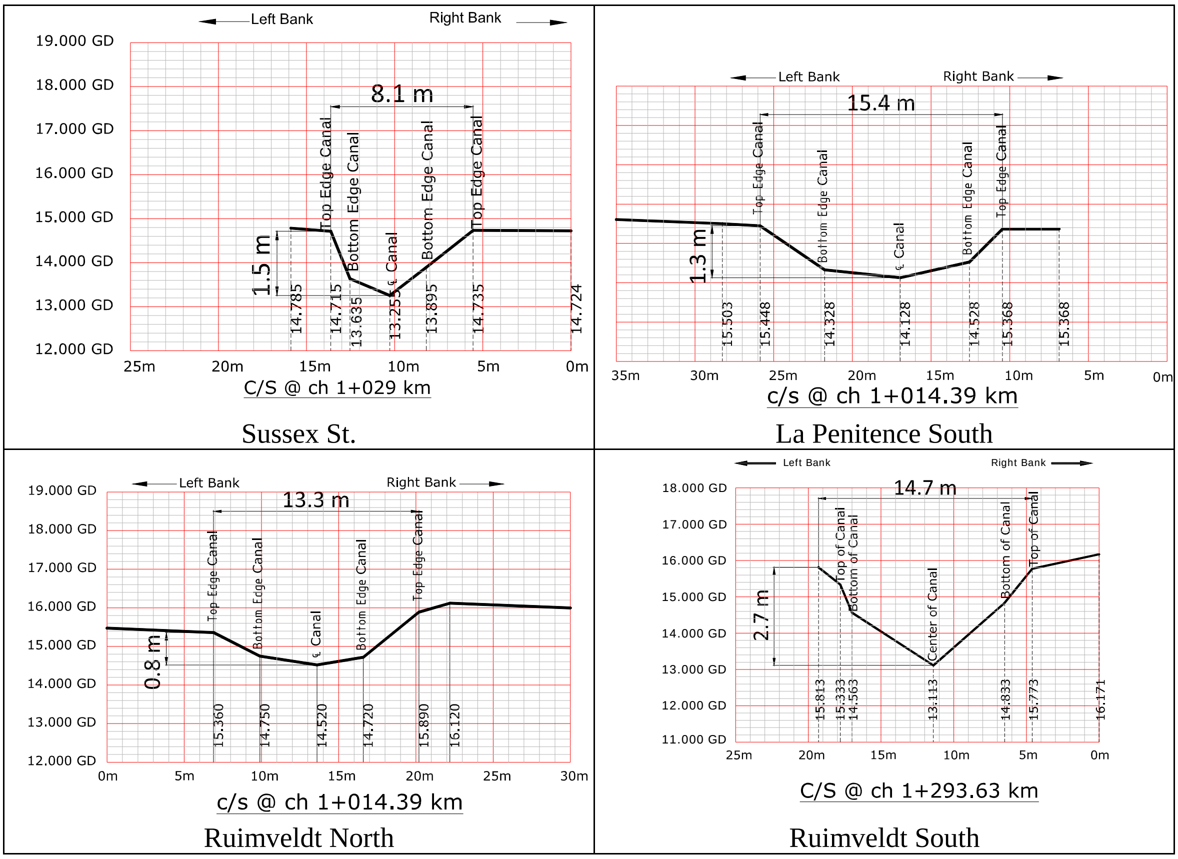


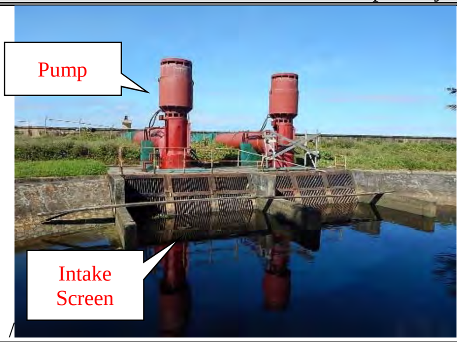
Fig. R 1.3.12 Typical Cross-Section Survey Result for Primary Drainage Channel (2)

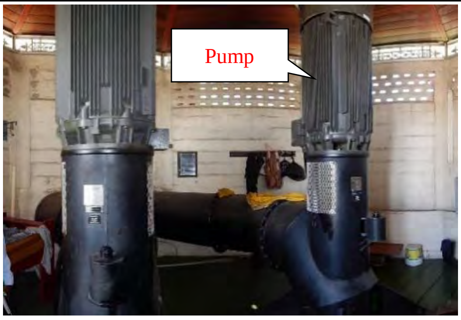
(2) Sluice and Pump Facilities

There are 2 pumping stations along the north side coastline of Georgetown, and 10 sluices and 6 mobile pumping units along the Demerara River at the west side of Georgetown.

The construction of sluice started in 1923. According to the Modelling of Floods in Georgetown in 2015 [NDIA (hereinafter called NDIA Report 2015)], the MSL at the time of sluice construction was lower than the present, and drainage capacity was secured by gravity drainage only. The Kitty pumping station and the Liliendaal pumping station were constructed in 1968 and 1973, respectively, since the drainage capacity under gravity alone is not sufficient to drain Georgetown due to narrowed drainage channels, seawater rise, etc. Additionally, mobile pumping units which have long exceeded their period of useful life with regard to operating efficiency and operation cost were installed in the 2005 heavy flood as an emergency response. Most of the mobile pumping units have not been relocated since 2005. The outline of the existing sluice and pumping facilities is as shown in **Table R 1.3.6.**

Table R 1.3.6 Outline of Existing Sluice and Pumping Facilities

<table>
<tr><th>No.</th><th>Name</th><th colspan="2">Capability/Specification</th></tr>
<tr><td rowspan="3">1</td><td rowspan="3">Liliendaal</td><td colspan="2">


</td></tr>
<tr><td>NDIA Report 2015</td><td>Drainage Area: 1,335 ha, Pump Capacity: 8.5 m^3/s</td></tr>
<tr><td>M/P (1994)</td><td>Drainage Area: 835 ha, Pump Capacity: 4.2 m^3/s×2 units (Capacity of Pump No. 2 was 3.5 m^3/s in 1993, Constructed in 1973 (Rehabilitated in 1987 and 1994)</td></tr>
<tr><td rowspan="4">2</td><td rowspan="4">Kitty</td><td colspan="2">


</td></tr>
<tr><td>NDIA Report 2015</td><td>Drainage Area: 243 ha, Pump Capacity: 4.3 (m^3/s)</td></tr>
<tr><td>M/P (1994)</td><td>Drainage Area: 243 ha, Pump Capacity: 1.2 m^3/s by 2 units, constructed in 1968 (Rehabilitated in 1993)</td></tr>
<tr><td>Hearing Result</td><td>According to the Operator of pumping station, NDIA replaced the unit of pump except building to enhance the capacity around 2009.</td></tr>
<tr><td>3</td><td>Young St.</td><td colspan="2">

Drainage Area: 65 ha, Pump Capacity: 1.1 m^3/s, Sluice Capacity: 7.8 m^3/s, Construction year remains unknown</td></tr>
<tr><td>4</td><td>Cummings Canal</td><td colspan="2">

Drainage Area: 127 ha, Sluice Capacity: 10.6 m^3/s, Constructed in 1923</td></tr>
</table>

No.	Name	Capability/Specification
5	Lamaha St.	 Drainage Area: 88 ha, Pump Capacity: 1.1 m^3/s, Sluice Capacity: 3.6 m^3/s, Constructed in 1935
6	Church St.	 Drainage Area: 146 ha, Pump Capacity: 1.1 m^3/s), Sluice Capacity: 4.0 m^3/s, Constructed in 1923 within the factory site.
7	Commerce St.	 Drainage Area: 153 ha, Pump Capacity: 1.1 m^3/s, Sluice Capacity: 2.8 m^3/s, Constructed in 1924
8	Princess St.	 Drainage Area: 211 ha, Pump Capacity: 1.1 m^3/s, Sluice Capacity: 6.2 m^3/s, Constructed in 1932

No.	Name	Capability/Specification
9.	Sussex St.	  Drainage Area: 107 ha, Sluice Capacity: 4.9 m^3/s, Construction year remains unknown
10	La Penitence South	  Drainage Area: 64 ha, Sluice Capacity: 19.1 m^3/s, Constructed in 1954
11	Ruimveldt North	  Drainage Area: 119 ha, Pump Capacity: 1.1 m^3/s, Sluice Capacity: 5.3 m^3/s, Construction year remains unknown
12	Ruimveldt South	  Drainage Area: 117 ha, Sluice Capacity: 5.0 m^3/s, Construction year remains unknown
Total		Total Drainage Area: 2,775 ha, Pump Capacity: 20.0 m^3/s, Sluice Capacity: 69.0 m^3/s

Source: JICA Survey Team based on NDIA Report 2015, M/P (1994)

1.3.4 Status of Operation and Maintenance of Drainage System

The Office of the Mayor and City Council of Georgetown (hereinafter called M&CC) mainly conducts operation and maintenance work for the existing drainage system, and MOA controls the entirety of drainage system and facilities. NDIA and MPI share the maintenance cost, if necessary. M&CC conducts maintenance work for the drainage system using both direct employment and outsourcing depending on the situation. M&CC arranges operators to conduct operation work of drainage facilities on 24-hour schedules.

The status of operation of drainage sluice and pumping facilities is as shown in the following table.

Table R 1.3.7 Status of Operation of Drainage Sluice and Pumping Facilities

No.	Name	Drainage Facility		Status of Operation
1	Liliendaal	Fixed Pump	Working Status	2 pump units are basically operated in turns but occasionally at once depending on the water level. Each operator judges the timing of operation.
			Operator	1 Operator×3 shifts (3 operators in total)
			Operator's Room	There is an operator's room with roof beside pump units.
2	Kitty	Fixed Pump	Working Status	2 pump units are basically operated in turns but occasionally at once depending on the water level. Each operator judges the timing of operation.
			Operator	1 Operator×3 shifts (3 operators in total)
			Operator's Room	Pump units, operator's room and console panel are in a building
3	Young St.	Sluice	Working Status	The sluice is normally operated 4 times a day manually, wire rope winch type. (The timing of opening is normally 3 hours after high tide and closing is normally 3 hours after low tide)
			Operator	1 Operator×3 shifts (3 operators in total)
			Operator's Room	Existing
		Mobile Pump		Pump is operated based on the instruction of superintending officer, basically. According to the operator, the operation of pump is started when the water level reaches the top of intake screen.)
4	Cummings Canal	Sluice	Working Status	The sluice is normally operated 4 times a day manually, wire rope winch type. (The timing of opening is normally 3 hours after high tide and closing is normally 3 hours after low tide.)
			Operator	2 Operators×3 shifts (6 operators in total also take charge of Lamaha St. Sluice)
			Operator's Room	No operator's room
5	Lamaha St.	Sluice	Working Status	The sluice is normally operated 4 times a day manually, chain block type. However, the gates remain closed because the chain block was broken last year. (The timing of opening is normally 3 hours after high tide and closing is normally 3 hours after low tide.)
			Operator	2 Operators×3 shifts (6 operators in total also take charge of Cummings Canal Sluice)
			Operator's Room	No operator's room
		Mobile Pump		Pump is operated based on the instruction of superintending officer, basically.
6	Church St.	Sluice	Working Status	The sluice is normally operated 4 times a day manually, chain block type. (The timing of opening is normally 3 hours after high tide and closing is normally 3 hours after low tide.)
			Operator	2 Operators×3 shifts (6 operators in total also take charge of Commerce St. Sluice)
			Operator's Room	No operator's room (Sluice is within the factory site.)
		Mobile Pump		Not functioning due to lack of battery
7	Commerce St.	Sluice	Working Status	The sluice is normally operated 4 times a day manually, chain block type. (The timing of opening is normally 3 hours after high tide and closing is normally 3 hours after low tide.) Gate has water leakage. There is mangrove at mouth.
			Operator	2 Operators×3 shifts (6 operators in total also take charge of Church St. Sluice)
			Operator's Room	Existing
		Mobile Pump		Pump is operated based on the instruction of superintending officer, basically.
8	Princess St.	Sluice	Working Status	The sluice is normally operated 4 times a day manually, wire rope winch type. (The timing of opening is normally 3 hours after high tide and closing is normally 3 hours after low tide.) There is water leakage on gate.
			Operator	1 Operator×3 shifts (3 operators in total)
			Operator's Room	Existing
		Mobile Pump		Not functioning due to damage of propeller at suction port
9	Sussex St.	Sluice	Working Status	The sluice is normally operated 4 times a day manually, chain block type. (The timing of opening is normally 3 hours after high tide and closing is normally 3 hours after low tide.)
			Operator	1 Operator
			Operator's Room	Existing
		Mobile Pump (Removed)		Mobile pump was installed in 2005 but removed in January 2017
10	La Penitence South	Sluice	Working Status	The sluice is normally operated 4 times a day manually, wire rope winch type. (The timing of opening is normally 3 hours after high tide and closing is normally 3 hours after low tide.) Two gates have separate hoist devices.
			Operator	1 Operator×3 shifts (3 operators in total also take charge of Ruimveldt North Sluice)
			Operator's Room	No operator's room

No.	Name	Drainage Facility		Status of Operation
11	Ruimveldt North	Sluice	Working Status	The sluice is normally operated 4 times a day manually, wire rope winch type. (The timing of opening is normally 3 hours after high tide and closing is normally 3 hours after low tide.)
			Operator	1 Operator×3 shifts (3 operators in total also take charge of La Penitence South Sluice)
			Operator's Room	Existing
		Mobile Pump		Pump is operated based on the instruction of superintending officer, basically.
12	Ruimveldt South	Sluice	Working Status	The sluice is normally operated 4 times a day manually, wire rope winch type. (The timing of opening is normally 3 hours after high tide and closing is normally 3 hours after low tide)
			Operator	1 Operator
			Operator's Room	Existing (House of Superintending Officer, Mr. Winston Joseph)

Source: JICA Survey Team based on site investigation and hearing survey

The operation of sluices takes time since the opening and closing of sluice is by manual operation. (According to an operator, chain block type needs 20 minutes for opening and 5 minutes for closing, while wire rope winch type needs 30 minutes for opening and 1 minute for closing.) Most sluices are not fully opened due to work saving for gate operation. Moreover, since gates are closed by gravity, it is difficult to close the gate in case of water level difference between upstream and downstream of the gate and large velocity in the channel. Therefore, the timing of opening is normally 3 hours after high tide and closing is normally 3 hours after low tide in Georgetown, experientially.

In the past, there were cases that water flow back from Demerara River to the drainage channel because the operator kept the gate open during high tide. However, there was no significant damage due to this and there is no record of physical damage to an operator during operation.

The status of maintenance for drainage channel, sluice and pumping facilities is as shown below.

Table R 1.3.8 Status of Maintenance for Drainage Channel, Sluice and Pumping Facilities

Facility	Status of Maintenance
Channel	**Dredging:** Dredging work in channel and at sluice is conducted, situationally. **Removal of Vegetation and Garbage:** Vegetation and garbage in the channel are removed once or twice a year. Regarding removal of garbage, the Engineer's Department of M&CC coordinates with the Solid Waste Department.
Sluice	**Gate:** All gates are wooden and raw materials are Greenheart Tree in Guyana. The gates are replaced every 5 to 6 years, generally. **Lubricant:** The gates are lubricated not regularly but situationally to smoothen the gate operation. **Hoist Device:** Hoist device is restored and replaced after broken. The hoist device at Lamaha St. Sluice got broken and not inactivated in 2016, but has not been restored or replaced as of March 2017.
Pump	Parts/components of pump are basically restored and replaced after broken. Garbage at screen of Liliendaal and Kitty pumping station is removed every day.

Source: JICA Survey Team based on site investigation and hearing survey

1.3.5 Outline of Existing Flood Analysis Result in Georgetown

The results of flood analysis in Georgetown are mentioned in the NDIA Report 2015, and the outline is as given below. Apart from this, the University of Guyana is updating the drainage system analysis result of the Delft University of Technology, the Netherlands.

The hearing survey results relating to the condition of flood analysis in the NDIA Report 2015 are as presented in the following table.

Table R 1.3.9 Hearing Survey Result Relating to Condition of Flood Analysis in the NDIA Report 2015

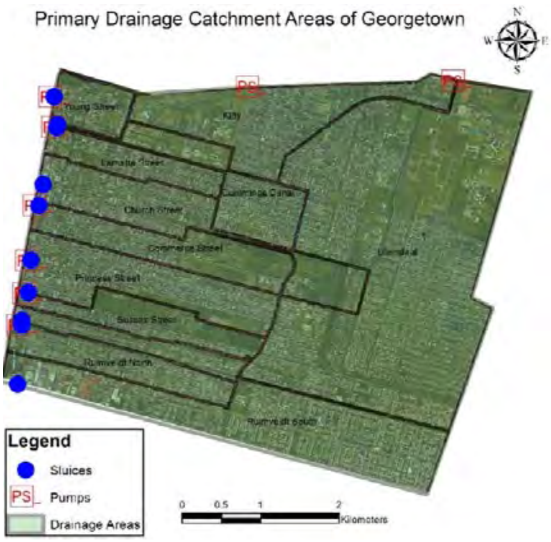
Item	Condition of Analysis	Result of Hearing Survey
Topography Data	LIDAR Data	LIDAR Data was provided on Conservancy Adaptation Project (hereinafter called CAP), WB in 2008
Flood Analysis Software	CityCAT	NDIA have used CityCAT as flood analysis software since before NDIA Report 2015 and therefore adopted it. (However, the flood analysis was actually conducted by the British Consultant, Mott MacDonald, who conducted flood analysis of East Demerara Water Conservancy (hereinafter called EDWC) on CAP.)
Existing Drainage Channel	In consideration of primary drainage channel	NDIA did not consider the secondary and tertiary drainage channels on the flood analysis because these channels are narrow and shallow. NDIA set the typical cross-section of the primary channel for flood analysis based on MP (1994). However, the calculation of drainage capacity for the existing drainage channels were not conducted.
Drainage Capacity of Sluice and Pump	Decreasing up to 75% or 95%	NDIA directly measured the drainage capacity of the existing sluice and pump at site. As a consequence, the operational efficiency of pump and sluice drainage are taken as 75% or 95%. University students under NDIA measured the drainage capacity of the existing drainage facilities by using Acoustic Doppler Current Profiler (hereinafter called ADCP) from HS-MOA.
Return Period	5-year return period	Return period was set and reviewed in consideration of drainage improvement of not only South America but also other developing countries. Reference country is unknown.
Mobile Pump	Unconsidered	The existing mobile pumps have become old and will be removed. After the removal of mobile pumps, NDIA expects to procure the additional pumps by JICA's Grant Aid.
Climate Change	Unconsidered	It is desirable that condition of flood analysis considers increase of rainfall intensity by climate change in the future. At present, flood analysis is not included as parameter of climate change in Guyana.

Source: NDIA Report 2015 and Hearing Survey Result

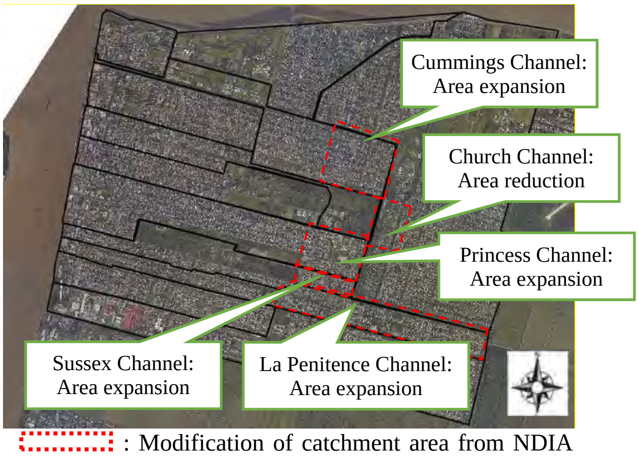
Table R 1.3.10 Summary of Drainage Facilities (Existing and Proposed by NDIA)

No.	Name	Catch-ment area (ha)	Existing Drainage Capacity				Proposed Drainage Capacity by NDIA				
			Sluice (m^3/s)	Pump (m^3/s)	Total		Additional Pump (m^3/s)*2	Sluice (m^3/s)	Pump (m^3/s)	Total	
					(m^3/day)	(mm/day)				(m^3/day)	(mm/day)
1	Liliendaal	1,335	—	8.5	550,800	20	4.2	—	12.7	822,960	30
2	Kitty	243	—	4.3	137,700	5	—	—	4.3	275,400	10
3	Young St.	65	7.8	1.1*1	253,469	9	—	7.8	—*3	210,755	8
4	Cummings Canal	127	10.6	—	286,531	10	5.6	10.6	5.6	554,659	20
5	Lamaha St.	88	3.6	1.1*1	139,392	5	—	3.6	—*3	96,678	3
6	Church St.	146	4.0	—	108,717	4	—	4.0	—	108,717	4
7	Commerce St.	153	2.8	1.1*1	117,101	4	2.2	2.8	2.2*3	179,723	6
8	Princess St.	211	6.2	1.1*1	209,988	8	2.2	6.2	2.2*3	272,610	10
9	Sussex St.	107	4.9	1.1*1	174,194	6	—	4.9	—*3	131,480	5
10	La Penitence South	64	19.1	—	514,990	19	5.6	19.1	5.6	783,118	28
11	Ruimveldt North	119	5.3	1.1*1	185,463	7	—	5.3	—*3	142,749	5
12	Ruimveldt South	117	5.0	—	133,952	5	—	5.0	—	133,952	5
Total		2,775	69.0	20.0	2,812,298	101	19.8	69.2	32.6	3,712,802	134

*1: Existing drainage capacity insofar as using mobile pump. Most of the mobile pumps remain to be installed
*2: NDIA intends to procure the additional pumps by JICA's Grant Aid
*3: NDIA does not propose/consider the mobile pump
Source: NDIA Report 2015



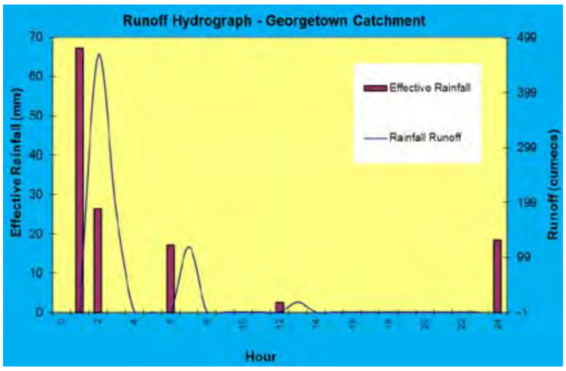
Source: NDIA Report (Modelling of Floods in Georgetown 2015)



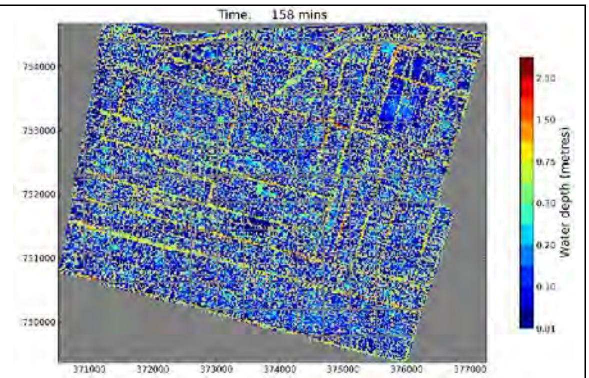
: Modification of catchment area from NDIA Report

Source: NDIA runoff analyst

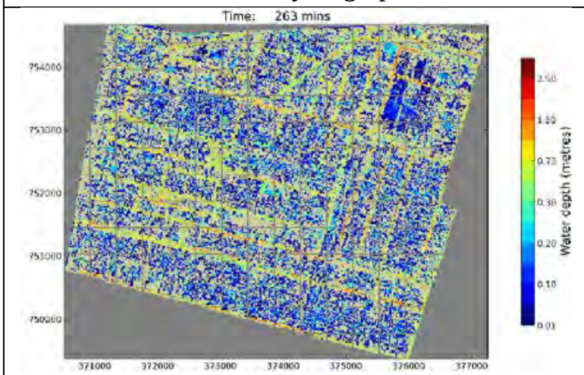
Fig. R 1.3.13 Primary Drainage Catchment Areas of Georgetown



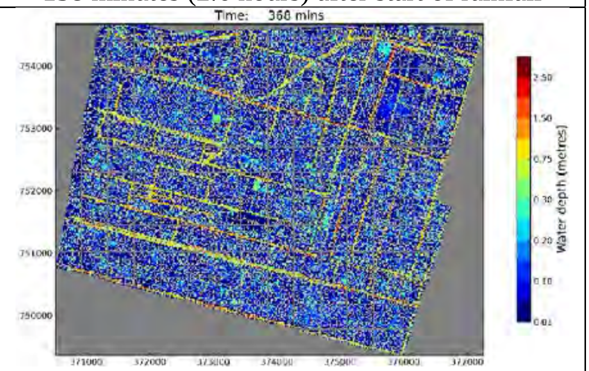
Runoff Hydrograph



158 minutes (2.6 hours) after start of rainfall



263 minutes (4.5 hours) after start of rainfall



398 minutes (6.6 hours) after start of rainfall

Source: NDIA Report 2015

Fig. R 1.3.14 Runoff Hydrograph and Flood Analysis Results (5-Year Return Period, Existing Drainage Facility)

1.4 Status of Initiatives Regarding Drainage System Improvement and Flood Mitigation

1.4.1 Policy/Strategy, Law/Institution, Plan, Framework, Guideline and Budget at National/Municipal Level

The Civil Defence Commission (hereinafter called CDC) mainly contributes to measures for natural disasters including flood mitigation at the national level with the assistance of international agencies. Besides, the roles and responsibilities for construction, operation and maintenance of drainage facilities are mentioned in the "Laws of Guyana".

Policy/strategy, law/institution, plan, framework, and guideline for drainage system improvement and flood mitigation at national/municipal level are as given in the table below.

Table R 1.4.1 Policy/Strategy, Law/Institution, Plan, Framework and Guideline for Drainage System Improvement and Flood Mitigation

Item	Name	Preparing Agency	Cooperation Agency
Policy/Strategy	National Development Strategy (2001 to 2010)	MOF	-
	A National Strategy for Agriculture in Guyana (2013 to 2020)	MOA	-
	Damage Assessment & Needs Analysis Policy Statement (2010)	CDC	-
	National Integrated Disaster Risk Management Implementation Strategy for Guyana (2013)	CDC	IDB
	Disaster Risk Management Policy (2013)	CDC	UNDP
	Strategic Plan for the Civil Defence Commission of Guyana (2014 to 2017)	CDC	-
	Sea and River Defence Sector Policy (2015)	MPI	-
Law/Institution	Laws of Guyana (Chapter 28-01), Municipal and District Councils Act (1998)	MOLA	-
	Laws of Guyana (Chapter 30-01) Water and Sewerage Act (2012)	MOLA	-
	Laws of Guyana (Chapter 64-02) Sea Defence Act (2012)	MOLA	-
	Laws of Guyana (Chapter 64-03) Drainage and Irrigation Act (2012)	MOLA	-
Plan	Georgetown Water and Sewerage Master Plan (1994)	GWA	-
	Damage Assessment & Needs Analysis Plan (2010)	CDC	-
	Flood Preparedness & Response Plan (2011)	CDC	UNDP
	National Integrated Disaster Risk Management Plan for Guyana (2013)	CDC	IDB
	Multi-hazard Disaster Preparedness & Response Plan (2013)	CDC	UNDP
Framework	Damage Assessment & Needs Analysis Framework (2010)	CDC	-
	Early Warning System Framework (2013)	CDC	UNDP
Guideline	Guideline for Incorporating Integrated Disaster Risk Management in Agricultural Planning (2013)	CDC	-
	Guideline for Incorporating Integrated Disaster Risk Management in Environmental Management (2013)	CDC	-

Source: MOLA (Ministry of Legal Affairs) (http://mola.gov.gy/information/laws-of-guyana)
CDC (http://cdc.gy/wp-content/uploads/2016/05/Document-for-Website/)
MPI (http://publicworks.gov.gy/files/docs/Policy_Final_GoG_Cover_Cabinet_December_8_2015.pdf)
National Development Strategy (http://www.ndsguyana.org/downloads/annex15.pdf)
MOA (http://cms2.caricom.org/documents/11264-moa_agriculture_strategy_2013-2020_-_cd.pdf)
M/P (1994)
*GWA (Guyana Water Authority), *IDB (Inter-American Development Bank), *MOF (Ministry of Finance)

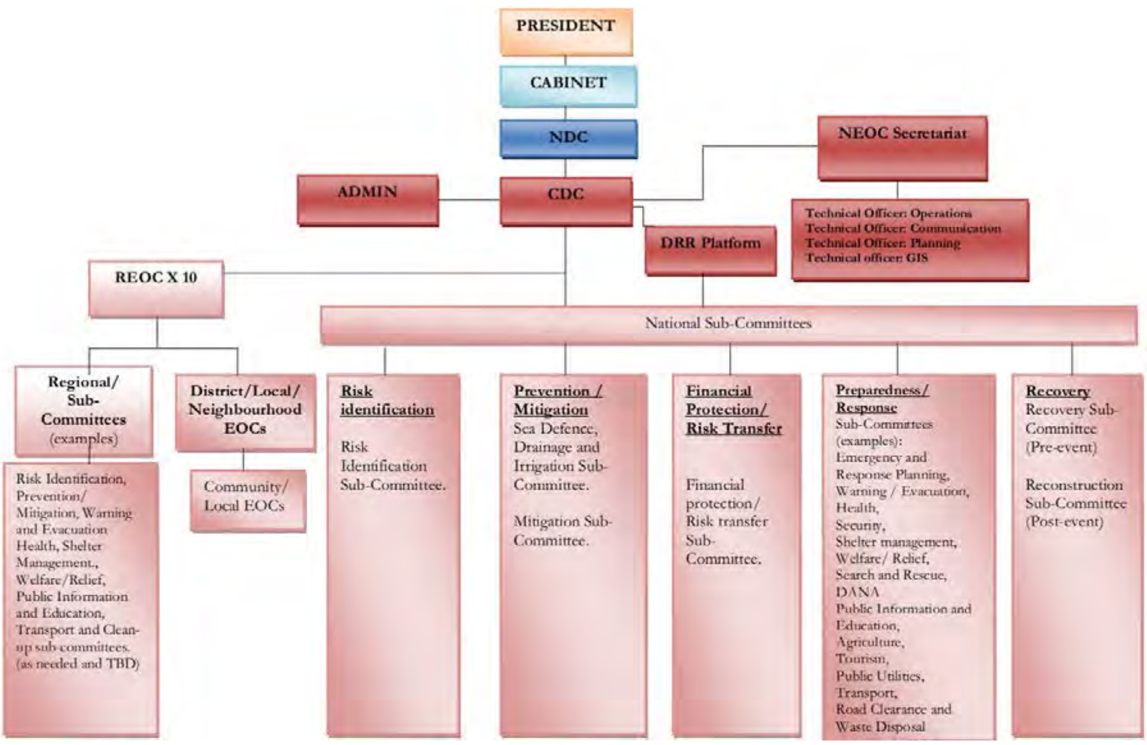
(1) Policy/Strategy

Flood mitigation at the national level is mentioned in the "National Integrated Disaster Risk Management Plan" which includes drainage improvement as part of flood mitigation. The "National Development Strategy (2001 to 2010) (ANNEX 15 Water)" and the "A National Strategy for Agriculture in Guyana (2013 to 2020)" mention that drainage improvement is a national issue. Policy/strategy for drainage system improvement and flood mitigation is as presented in the table below.

Table R 1.4.2 Policy/Strategy for Drainage System Improvement and Flood Mitigation

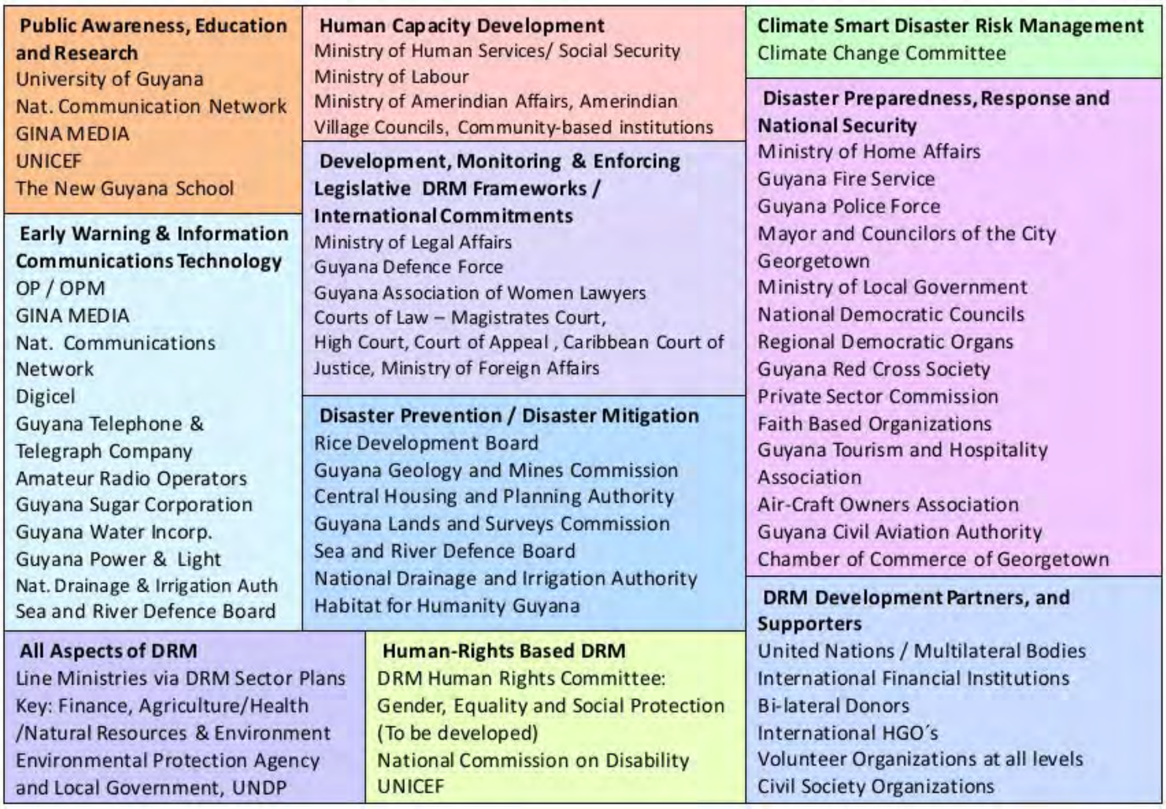
Name	Outline
National Development Strategy (2001 to 2010)	The present and future activities at national level for "Sea Defences", "Drainage and Irrigation", "Hydro-meteorological Service" are mentioned in "ANNEX 15, Water" which includes long-term plan and recommendation for drainage improvement.
A National Strategy for Agriculture in Guyana (2013 to 2020)	"Guyana's Vision for Agriculture 2020 – Twenty-Five Priorities for "Success" is shown. The priority activity "Priority 3 reaffirms that Water Security and, therefore, Water Management is crucial for success." includes vulnerability of the existing drainage system and necessity of the drainage improvement.
Damage Assessment & Needs Analysis Policy Statement (2010)	The Damage Assessment and Needs Analysis (DANA) Committee under CDC mainly assesses damage and needs including flood disasters. This statement does not specify flood mitigation and drainage improvement but mentions a role of public and private agencies in damage assessment, and establishment of database for natural disasters.
National Integrated Disaster Risk Management Implementation Strategy for Guyana (2013)	Activities and projects for disaster risk reduction for the decade from 2013 are proposed. Disaster risk management system in Guyana is as described in **Fig. R 1.4.1.** Risk Identification: Identification of risk and preparation of hazard map. Prevention/Mitigation: Assessment of vulnerability to flood and poor drainage and execution of countermeasures for drainage improvement. Financial Protection/Risk Transfer: Engage regional insurance with the Caribbean Catastrophe Risk Insurance Facility (hereinafter called CCRIF). Preparedness/Response: Cooperation among all related agencies in disaster responses. Development of required law and guideline Recovery: Cooperation among all related agencies in disaster recovery; Operation of National Contingency Fund.
Disaster Risk Management Policy (2013)	This policy includes 12 goals, 14 Key Strategic Objectives and 20 Key Approaches in Disaster Risk Management. This policy was prepared and referred to the experience of flood in 2005 and Hyogo Framework for Action. The structural organization for disaster risk management system in Guyana is as given in **Fig. R 1.4.2**.
Sea and River Defence Sector Policy (2015)	This policy mentions that the Sea and River Defence Division (hereinafter called SRDD) under MPI is in charge of planning, design and construction of coastal and river structures, and NDIA manages and maintains drainage and irrigation structures, including outlets and sluices in sea defence.

Source: CDC (http://cdc.gy/wp-content/uploads/2016/05/Document-for-Website/)
MPI (http://publicworks.gov.gy/files/docs/Policy_Final_GoG_Cover_Cabinet_December_8_2015.pdf)
National Development Strategy (http://www.ndsguyana.org/downloads/annex15.pdf)
MOA (http://cms2.caricom.org/documents/11264-moa_agriculture_strategy_2013-2020_-_cd.pdf)



Source: National Integrated Disaster Risk Management Implementation Strategy for Guyana

Fig. R 1.4.1 Disaster Risk Management System in Guyana



Source: Disaster Risk Management Policy

Fig. R 1.4.2 Structural Organization for Disaster Risk Management System in Guyana

(2) Law/Institution

The “Laws of Guyana” have been promulgated. The “Laws of Guyana” include “Chapter 64-03, Drainage and Irrigation Act,” for drainage system improvement at the national level and “Chapter 28-01, Municipal and District Councils Act (Part IX Drainage and Irrigation),” for drainage improvement at the municipal level. Laws/institutions for drainage system improvement and flood mitigation is as presented in the table below.

Table R 1.4.3 Laws/Institutions on Drainage System Improvement and Flood Mitigation

Name	Outline
Laws of Guyana (Chapter 28-01, Municipal and District Councils Act), 1998	It is mentioned that the Municipal and District Council (M&CC) has the responsibility for the maintenance of drainage facilities in "Part IX Drainage and Irrigation".
Laws of Guyana (Chapter 30-01, Water and Sewerage Act, 2012)	Regulation on water supply and sewerage, and institution and mandate of HS-MOA is mentioned.
Laws of Guyana (Chapter 64-02, Sea Defence Act, 2012)	It is mentioned that the owner and municipal and district council have the responsibility for drainage facilities along the sea (like sluices and channels) in "Part III: Maintenance, Management and Construction of Sea Defences". The owner and the municipal and district council are requested adequate response including expenses if drainage facilities are an obstacle in construction or management of coastal protection works.
Laws of Guyana (Chapter 64-03, Drainage and Irrigation Act, 2012)	NDIA has the role for planning, cost estimation and implementation of drainage improvement works in "Part VI Construction, Acquisition and Maintenance of Works". Besides, the Minister of MOA may approve the construction of new drainage improvement works which shall be published in the gazette and at least one daily newspaper. NDIA shall pay due regard to the cost of operation and maintaining the drainage and irrigation systems on a national and regional basis and by locality where appropriate. The area within twelve feet shall be kept free for maintenance work by NDIA and continue to be the property of the NDIA. Moreover, "Flood Control" is defined as the tapping of potential floodwaters by conservancy but does not include sea and river defence areas covered by the Sea Defence Board in this Act.

Source: Ministry of Legal Affairs (MOLA) (http://mola.gov.gy/information/laws-of-guyana)

(3) Plan

There is no national plan for drainage system improvement. M/P (1994) is the only authorized drainage improvement plan in Georgetown. The national flood mitigation plan is prepared by CDC with the assistance of international agencies, like UNDP and IDB.

The plan for drainage system improvement and flood mitigation is as presented in the following table.

Table R 1.4.4 Plan for Drainage System Improvement and Flood Mitigation

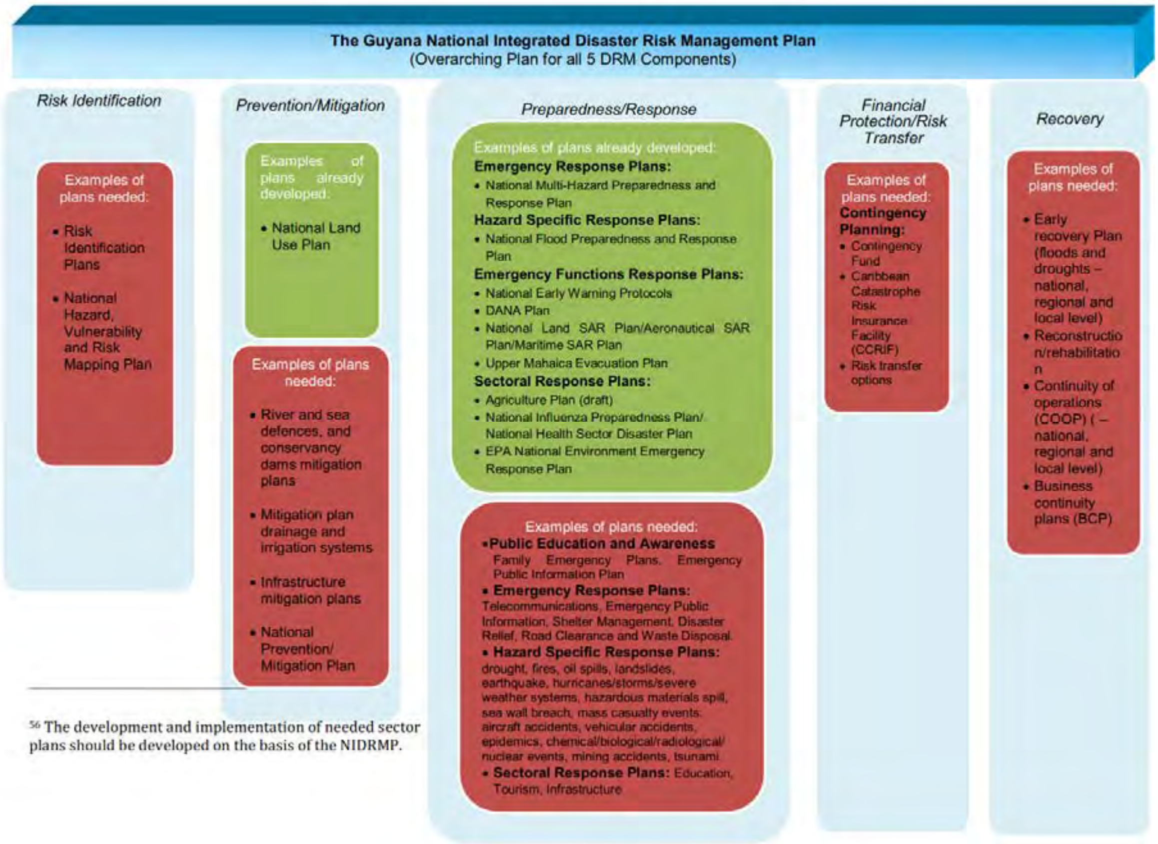
Name	Outline
Georgetown Water and Sewerage Master Plan (1994)	There are Volume 1, Existing Services, and Volume 2, Future Services, in Part IV, Primary Drainage System and the current condition and future plan of primary drainage channel, sluice and pumping station are mentioned. As a future plan, dredging at drainage channel, three sides concrete lining, dredging at sluice, widening of culvert, rehabilitation of pumping station/ sluice/ culvert, and procurement of equipment for maintenance work are proposed.
Damage Assessment & Needs Analysis Plan (2010)	This plan mentioned that the following damage assessment teams are composed based on the disaster type and scale. • Rapid Damage Assessment Team • National Damage Assessment Team • Regional Democratic Council Damage Assessment Team • Sector Assessment Team The outline of type of assessment report is as given in **Table R 1.4.5**.
Flood Preparedness & Response Plan (2011)	The followings are mainly mentioned in this plan. • Profile of Guyana • Disaster Management Systems in Guyana • Disaster Management Functions • Disaster Response Function • Early Recovery Frameworks • Flood Mitigation: Approaches and Strategies • Flood Safety Measure Also, the following countermeasures against flood are mentioned. <u>Structural Measures</u>: Embankment, Water Shed Management, Reservoirs, Natural Water Retention Basins and Buildings on Elevated Area <u>Non-Structural Measures</u>: Flood Plain Zoning, Flood Forecasting and Warning and Preparedness Planning
National Integrated Disaster Risk Management Plan for Guyana (2013)	The plans for disaster risk management for the decade from 2013 are proposed based on the disaster situation, approach, role of each organization and issues in Guyana. • Risk Identification • Prevention/Mitigation • Financial Protection/Risk Transfer • Preparedness/Response • Recovery
Multi-hazard Disaster Preparedness & Response Plan (2013)	The target disaster types include natural disasters like flooding and landslides, man-made disasters like fires and oil spill, other disaster like seawall breach and conservancy breach. The National Emergency Operation Centre (NEOC) set up by CDC is mentioned in this plan. All the agencies will be coordinated by the NEOC during disaster.

Source: CDC (http://cdc.gy/wp-content/uploads/2016/05/Document-for-Website/), M/P（1994）

Table R 1.4.5 Outline of Assessment Report at Each Stage

Stage of Assessment	Time Period	Purpose
Stage 1	4–8 hours after the disaster has occurred and the All Clear given	To determine the extent and scope of the disaster and the need for outside assistance
Stage 2	7 days after the disaster has occurred and the All Clear given	To provide information on the overall damages (the extent, severity and location) to facilitate the needs analysis process and the allocation of critical supplies
Stage 3	From 21 days after the disaster has occurred.	To provide information for recovery of services and the physical stock on the country

Source: Damage Assessment & Needs Analysis Plan (2010)



Source: National Integrated Disaster Risk Management Plan for Guyana (2013)

Fig. R 1.4.3 Links between National Integrated Disaster Risk Management Plan and Other Plans

Table R 1.4.6 Members of Disaster Risk Reduction Platform

National Drainage and Irrigation Authority	Guyana Red Cross
United Nations Development Programme	Guyana Lands and Survey Commission
Ministry of Communities	Ministry of Public Health
United Nations Children's Fund	Ministry of Finance
Sea and River Defence, Ministry of Public Infrastructure	Hydro-meteorological Services, Ministry of Agriculture
Guyana Fire Service	Guyana Police Force
Environmental Protection Agency	Guyana Defence Force
Private Sector Commission	Inter-American Development Bank

Source: Multi-hazard Disaster Preparedness & Response Plan (2013)

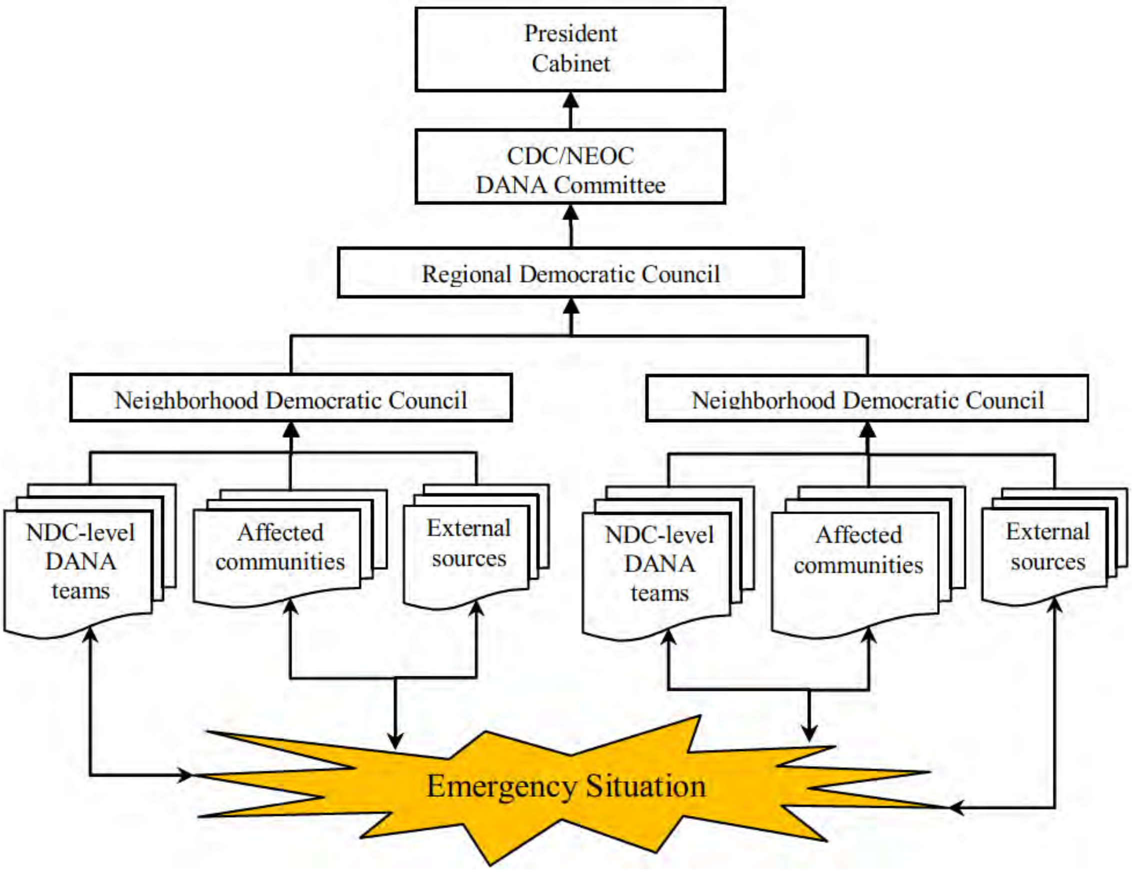
(4) Framework

There is no framework for specified drainage system improvement in Guyana. The framework for flood and natural disasters including damage assessment and early warning system has been established, as presented in the following table.

Table R 1.4.7 Framework for Flood and Natural Disasters

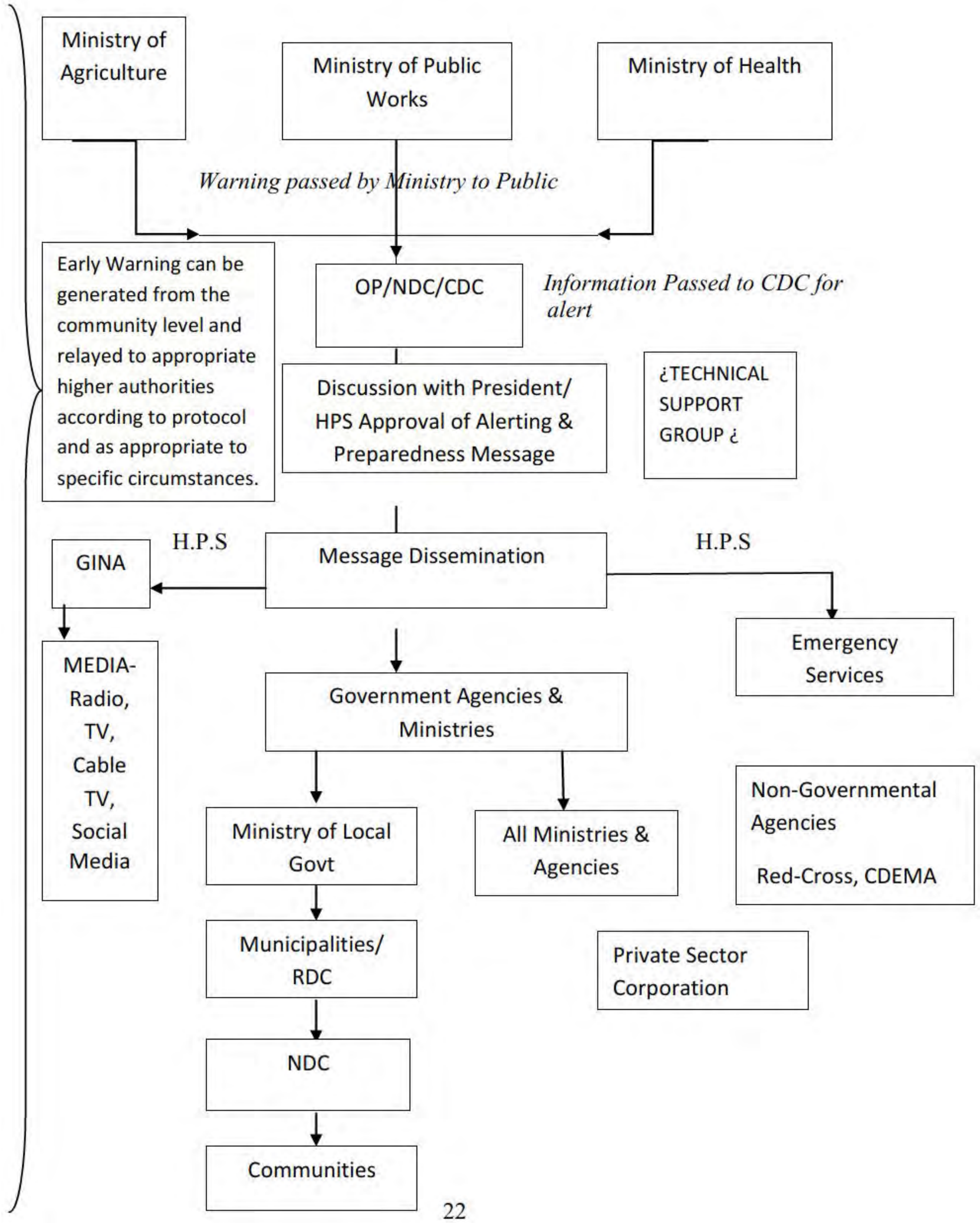
Name	Outline
Damage Assessment & Needs Analysis Framework (2010)	This framework includes the following methods of damage assessment. • Stage 1: 4–8 hours after the disaster has occurred and the All Clear given (Data collection form including affected person, housing infrastructure with comment are defined) • Stage 2: 7 days after the disaster has occurred and the All Clear given (Rough damage amount including affected housing, infrastructure, lifeline, agriculture-livestock and crops are estimated) • Stage 3: From 21 days after the disaster has occurred (Preparation of DANA (Damage Assessment & Needs Analysis), estimation of direct costs from impact of the event and estimation of the medium to long term needs) Damage assessment data flow is as shown in **Fig. R 1.4.4**
Early Warning System Framework (2013)	The framework of National Early Warning System is mentioned. As a structure, Technical Support and National Emergency Operations Centre are under the National Early Warning System Sub Committee and cooperated respectively. • Member of National Early Warning System Sub-Committee: MOH, MOA, MPI, MOC, CDC, OCC, etc. • Member of Technical Support: Sea and River Defence Division, MPI, MARAD-MPI, NDIA, HS-MOA, GL&SC, EPA, GWI, etc.

Source: CDC (http://cdc.gy/wp-content/uploads/2016/05/Document-for-Website/)



Source: Damage Assessment & Needs Analysis Framework (2010)

Fig. R 1.4.4 Damage Assessment Data Flow



Source: Early Warning System Framework (2013)

Fig. R 1.4.5 National Early Warning System Protocol (Draft)

Source: Early Warning System Framework (2013)

Fig. R 1.4.6 National Early Warning System Management Structure

(5) Guideline

There is no specific guideline for drainage system improvement and flood mitigation. The guidelines for natural disaster are as given in the table below.

Table R 1.4.8 Guidelines for Natural Disaster

Name	Outline
Guideline for Incorporating Integrated Disaster Risk Management in Agricultural Planning (2013)	This guideline shows the following steps to execute integrated disaster risk management in agricultural planning. • Step 1: Get Started • Step 2: Identify Risks and Consequences • Step 3: Assess and Prioritize Consequences of Risks • Step 4: Prepare a Draft Action Plan for Integrated Disaster Risk Management (IDRM) • Step 5: Implement IDRM for Agricultural Planning Draft action plan for integrated disaster risk management in agricultural planning is as shown in **Table** R 1.4.9. A "short term" time frame for implementing actions is between 1 and 5 years, a "medium term" between 6 and 15 years and a "long term" time frame means an action will need more than 15 years to be completed.
Guideline for Incorporating Integrated Disaster Risk Management in Environmental Management (2013)	This guideline shows the following steps to execute integrated disaster risk management in environmental management. • Step 1: Get Started • Step 2: Identify Risks and Consequences • Step 3: Assess and Prioritize Consequences of Risks • Step 4: Prepare a Draft Action Plan for IDRM • Step 5: Implement IDRM for Environmental Management Draft action plan for integrated disaster risk management in environmental management is as shown in **Table** R 1.4.10. A "short term" time frame for implementing actions is between 1 and 5 years, a "medium term" between 6 and 15 years and a "long term" time frame means an action will need more than 15 years to be completed.

Source: CDC (http://cdc.gy/wp-content/uploads/2016/05/Document-for-Website/)

Table R 1.4.9 Action Plan for Integrated Disaster Risk Management in Agricultural Planning (Draft)

Consequence in Priority Order	Prevention Action(s)	Mitigation / Adaption Action(s)	Financial Risk Management Action(s)	Rehabilitation / Reconstruction Action(s)	Agency Responsible	Time Frame
Washed out road	Not applicable	Raise road elevation	Not applicable	Replace road at same elevation	Public Works	Short term
Increased costs for farm inputs	Change crop varieties	Breed new varieties of same crop	Crop insurance	Not applicable	Ministry of Agriculture and Agricultural Research Institute	Long term
Community abandonment	Build dikes	Relocated to higher ground	Disaster relief fund	Not applicable	Civil Defense Commission	Long term
Contamination of farm wells	Not applicable	Berm well-heads	Public / private sector contributions	Drill new wells	Farmers and Ministry of Agriculture	Short term
Destruction of irrigation infrastructure	Not applicable	Develop flood proof pumps	Disaster relief fund	Replace infrastructure	Civil Defense Commission	Medium term
Destruction of farm buildings	Improved construction standards	Improved construction standards	Public / private sector contributions	Farmers rebuild	Farmers and Ministry of Agriculture	Medium term
Crop Destruction	Not applicable	Not applicable	Crop insurance	Replant when possible	Farmers and Ministry of Agriculture	Short term
Current Crops become uneconomic	Not applicable	Change crop varieties	Crop subsidization	Not applicable	Ministry of Agriculture	Medium term

Source: Guideline for Incorporating Integrated Disaster Risk Management in Agricultural Planning (2013)

Table R 1.4.10 Action Plan for Integrated Disaster Risk Management in Environmental Management (Draft)

Consequence in Priority Order	Prevention Action(s)	Mitigation Adaption Action(s)	Financial Risk Management Action(s)	Rehabilitation Reconstruction Action(s)	Agency Responsible	Time Frame
Loss of timber production from fire	Early detection of forest fires	Enhanced fire fighting capacity	Not applicable	Replanting or natural regeneration	Guyana Forestry Commission	Long term
Threat to Amerindian villages	Early warning and creation of buffer areas	Relocation of village to safer area	Establish insurance program(s)	Rebuild village in same location	CDC	Short term
Destruction of mangrove swamps	Prohibition of logging and enforcement	Not applicable	Establish national mangrove restoration fund	Mangrove restoration program	Ministry of Agriculture (Mangrove Restoration Project)	Medium term
Destruction of coastal wetlands	Prohibit development on wetlands	Continuous rehabilitation	Not applicable	Not applicable	MNR&E	Medium term
Destruction of forest access roads	Build higher and better roads	Improve road drainage	Not applicable	Rebuild road	Forestry Commission and Public Works	Short term
Damage to national parks	Not applicable	Flood proof park buildings	Private fundraising (naming rights)	Rebuild buildings, equipment and restore park en	National Parks Commission	Short term
Stream contamination from runoff	Not applicable	Reduce fertilizer use	Not applicable	Clean up stream	EPA	Short term
Loss of certain tree species	Spray for pests	Replant to different species	Allow rapid harvesting	Not applicable	Forestry Commission	Long term

Source: Guideline for Incorporating Integrated Disaster Risk Management in Environmental Management (2013)

Other than the above, there is the operation manual for EDWC. However, there is no specific and general manual/guideline for operation and maintenance of drainage facilities.

There is no specific design guideline for drainage facilities. However, the American Society for Testing and Materials (ASTM), American Concrete Institute (ACI), Europe Standard and British Standard are used as the criteria for concrete quality in Guyana, situationally. Concrete material test is conducted in the laboratory of a university and MPI. The Guyana National Bureau of Standards is mainly used as the building code, and the Indian Standard is partially used for building construction.

For the design of infrastructure, there is no specific guideline or standard in Guyana. However, the American Association of State Highway and Transportation Officials (AASHTO) and the American Society for Testing and Materials (ASTM) are utilized depending on the project. Seismic condition is not considered for structural designs in Guyana, usually.

(6) Budget

The collected budget data from the agencies related to drainage system improvement and flood mitigation are as shown in the following table.

Table R 1.4.11 Budget for Major Agencies Related to Drainage System Improvement and Flood Mitigation

Unit: G$

Year	NDIA	WSG-MPI	EPA-MONR
2012	6,625,874,000	17,795,798,530	192,037,000
2013	3,970,923,500	14,410,992,076	229,381,000
2014	4,613,618,331	18,686,132,000	248,282,000
2015	4,294,856,317	11,353,831,488	285,557,000
2016	3,698,055,000	24,782,268,565	357,773,000

Source: NDIA, WSG-MPI and EPA-MONR

1.4.2 Roles and Responsibilities of Related Agencies

The roles and responsibilities of related agencies are as given in the table below.

Table R 1.4.12 Role and Responsibility of Related Agency

Agency	Role and Responsibility
National Drainage and Irrigation Authority (NDIA)	NDIA is a subsidiary of the Ministry of Agriculture (MOA) and member of the Georgetown Drainage Authority. The mandate of NDIA includes planning, cost estimation and implementation of drainage and irrigation projects, and holistic maintenance work for drainage facilities. In Georgetown, NDIA works on the installation of mobile pump and rehabilitation of pumping station, and defray a part of maintenance cost. In the Laws of Guyana, the "Drainage and Irrigation Act" mentions the role and responsibility of NDIA.
Hydrometeorological Services (HS)	HS is a subsidiary of the Ministry of Agriculture (MOA) and works on hydro-meteorological services in Guyana. Meteorological observation is conducted at the Botanical Gardens in Georgetown. HS observes water level at the hydroelectric power plant and conservancy but there is no water gauge station in Georgetown. HS conducts flood forecasting based on the meteorological data but does not conduct flood analysis and early warning at present. In the Laws of Guyana, the "Water and Sewerage Act" mentions the role and responsibility of HS. However, its functions for national monitoring systems for groundwater and climate change are not still performed by HS at present even though these are mentioned in the Act.
Work Services Group (WSG)	WSG is a subsidiary of the Ministry of Public Infrastructure (MPI) and member of Georgetown Drainage Authority. WGS comprehensively manage river and coastal protection facilities except drainage channels, sluice and pumping stations at connection points with river/coastal facilities, such as dike and revetment. Basically, WSG does not directly have a role and responsibility for drainage system improvement, but indirectly contributes to drainage system improvement by supporting NDIA, M&CC and CDC during/after flood. WSG provides mobile pump and cleaning devices for drainage channel based on the request of M&CC. Besides, WSG carried out rehabilitation work for the drainage pipe connecting to Kitty pumping station because the impact on road traffic has been severe and urgent.
Maritime Administration Department (MARAD)	MARAD is a subsidiary of the Ministry of Public Infrastructure (MPI) and works on tidal observation and analysis. The Harbour Masters Office is the only tidal observatory at the river mouth of Demerara River in Georgetown. Tidal level data in Georgetown is observed by pressure type water gauge, radar type water gauge, watermarks. MARAD-MPI analyse astronomical tide level and publish tide tables every year.
Ministry of Communities (MOC)	MOC is a member of Georgetown Drainage Authority but does not have a role and responsibility of drainage system improvement and flood mitigation, directly. However, MOC has a role to promote the development of local government units. Thus, MOC financially supports M&CC, like cleaning of drainage channels and procurement of equipment for cleaning in accordance with the Memorandum of Understanding (MOU). Accordingly, MOC indirectly contributes to the drainage system improvement in Georgetown but does not directly support the construction of drainage facilities and provide personnel.
Central Housing & Planning Authority (CHPA)	CHPA is a subsidiary of the Ministry of Communities (MOC). CHPA prepared the land use plan for Georgetown on the "Greater Georgetown Development Plan 2001-2010" in March 2002.
Mayor and City Council of	MOC is a member of Georgetown Drainage Authority and works on routine maintenance of drainage facilities in Georgetown. Infrastructure including drainage facilities are planned, designed and constructed by the central government, and then turned over to M&CC which

Agency	Role and Responsibility
Georgetown (M&CC)	operate and maintain the drainage facilities. In the Laws of Guyana, the "Municipal and District Councils Act" mentions the role and responsibility of M&CC. However, the central government financially supports the maintenance work of M&CC since M&CC does not have enough budget. Informal settlers along drainage channels shall be relocated by M&CC based on the Drainage and Irrigation Act. It is necessary for the Ministry of Social Protection and MOC to provide support for the relocation of informal settlers. The relocation activity is currently delayed due to the difficulty of obtaining consensus with residents and securement of relocation site. (The Ministry of Social Protection takes care of persons who relocate and MOC prepares the land for relocation.)
Geospatial Information Management Unit (GIMU)	GIMU is a subsidiary of the Permanent Secretary of the Ministry of Natural Resources (MONR) that has not the role and responsibility for drainage improvement and flood mitigation works. Since staff of GIMU have the skill of water resource and run-off analysis using GIS, they are requested to work by several other organizations, like ministries, international donors, and so on.
Environmental Protection Agency (EPA)	EPA is a subsidiary of the Ministry of Natural Resources (MONR) and does not have the role and responsibility for drainage system improvement and flood mitigation, directly. However, EPA reviews and approves Environmental Impact Assessment (EIA) for the construction of drainage facilities. The Law of Guyana, "Environmental Protection Act", mentions the role and responsibility of EPA.
Office of Climate Change (OCC)	OCC was established as subsidiary of the Ministry of the Presidency (MOP) in 2009 and works on climate change adaptation/mitigation in Guyana with assistance from international organizations. The National Climate Change Policy is in preparation by OCC with assistance from the Caribbean Development Bank (CDB). The Law on Carbon Development Strategy (LCDS) was prepared in 2009 and revised in 2013. Based on the LCDS, the Climate Resilience Strategy and Action Plan was prepared in 2015. The prediction of climate change will be executed by OCC. As the first step, the OCC has been collecting basic data as of May 207.
Guyana Lands and Surveys Commission (GL&SC)	GL&SC is a subsidiary of the Ministry of the Presidency (MOP) and works on geodetic, topographic, hydrographic and cadastral survey. GL&SC does not prepare flood hazard maps but provide basic map and topography data to the related agencies. In the Laws of Guyana, "Chapter 59-05, Guyana Lands and Surveys Commission," mentions the role and responsibility of GL&SC. The elevation at Georgetown and its adjacent area are irregularly surveyed by GL&SC. As a result, there is no notable change of the elevation data, and ground subsidence is not recognized at Georgetown.
Civil Defence Commission (CDC)	CDC is a subsidiary of the Ministry of the Presidency (MOP) and works on the preparation of comprehensive disaster mitigation plans, and coordination with the related agencies, like NDIA, MPI, etc., during/after disasters. Specific activities include the preparation of the "National Integrated Disaster Risk Management Plan", as well as setting up and operation of the "National Emergency Operation Centre". Flood disaster is one of the major challenges in Guyana, but target disasters of CDC includes natural disasters like droughts and landslides, as well as man-made disasters like fires, and epidemics.
Guyana Water Incorporated (GWI)	The GWI was established as a result the merger of the Guyana Water Authority (Guywa) and the Georgetown Sewerage and Water Commissioners (GS&WC) in 2002. The purpose of the GWI is centralization of water projects and supply of safe/enough water to Guyanese as a modernization program of the water sector. GWI is a state-run company owned by the government that owns all the company's stocks. In the Laws of Guyana, the "Water and Sewerage Act" mentions the role and responsibility of GWI. Besides, 24 sewage pumping stations in Georgetown are managed by GWI in addition to the water supply project.
National Task Force Commission (NTFC)	NTFC was established in 2015 to carry out the "Project Restore Guyana" based on the appointment by the Cabinet of Guyana. There are several committees on each development subject under the Secretariat of NTFC. These committees work on each development subject in cooperation with ministries. NTFC directly has a close relation to MPI. However, NTFC does not conduct drainage improvement or provide financial support due to budgetary constraints. NTFC coordinates with GDA. GDA specializes on drainage improvement in Georgetown while NTFC works on the maintenance plan of drainage improvement at the national level. On the other hand, the mandate of CDC that works on emergency countermeasures for general natural disasters is different from NTFC that works on 6 development subjects at the national level. At present, NTFC is preparing the map of drainage system in Georgetown including the location and size of drainage channels (primary, secondary and tertiary), sluice, pump and culvert. The University of Guyana is updating and developing the drainage system analysis result of Delft University of Technology, the Netherlands, based on NTFC's request. The hydraulic drainage model is under formulation at present.
Georgetown Drainage Authority (GDA)	GDA was established in January 2017 to execute adequate maintenance work for drainage facilities in Georgetown. Members of GDA include the representatives of NDIA, M&CC, MPI and MOC.

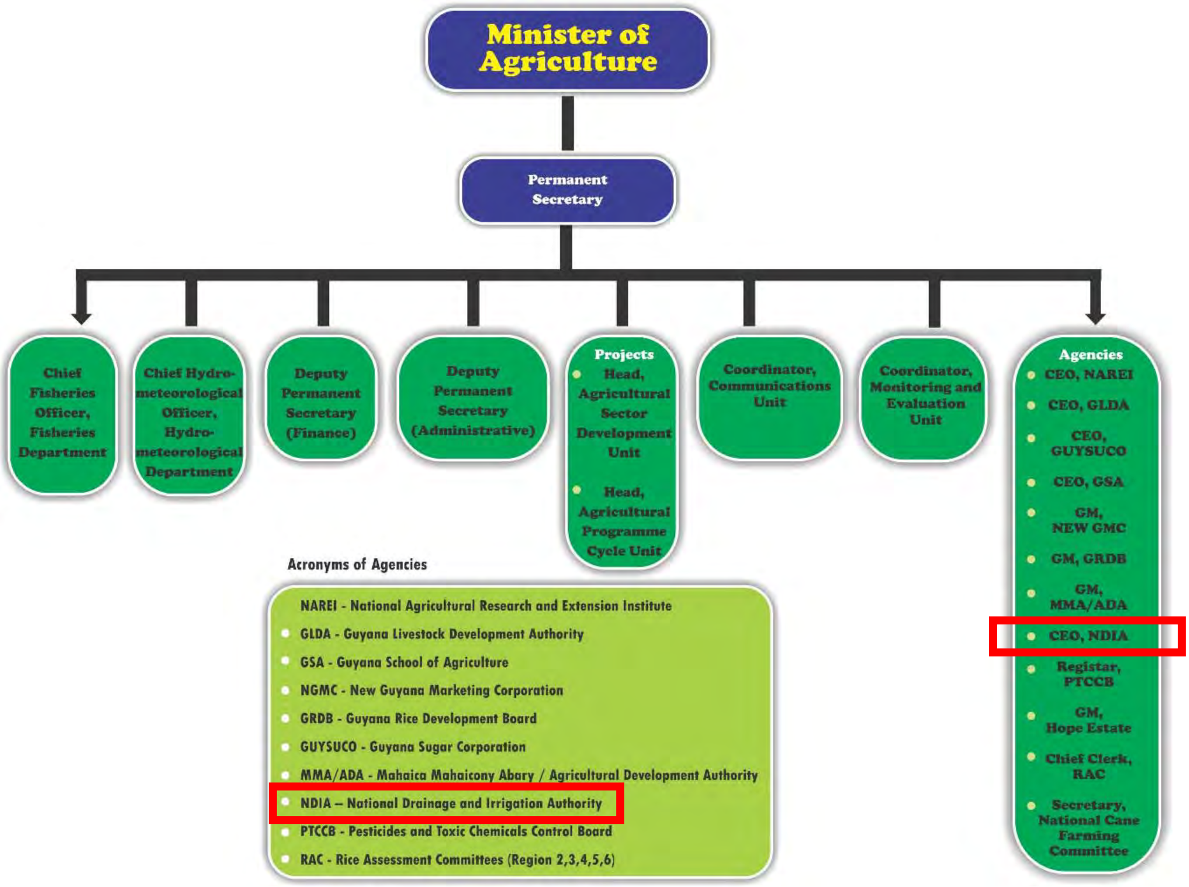
Source: JICA Survey Team based on hearing survey

(1) MOA (Ministry of Agriculture)

(a) NDIA-MOA (National Drainage and Irrigation Authority, MOA)

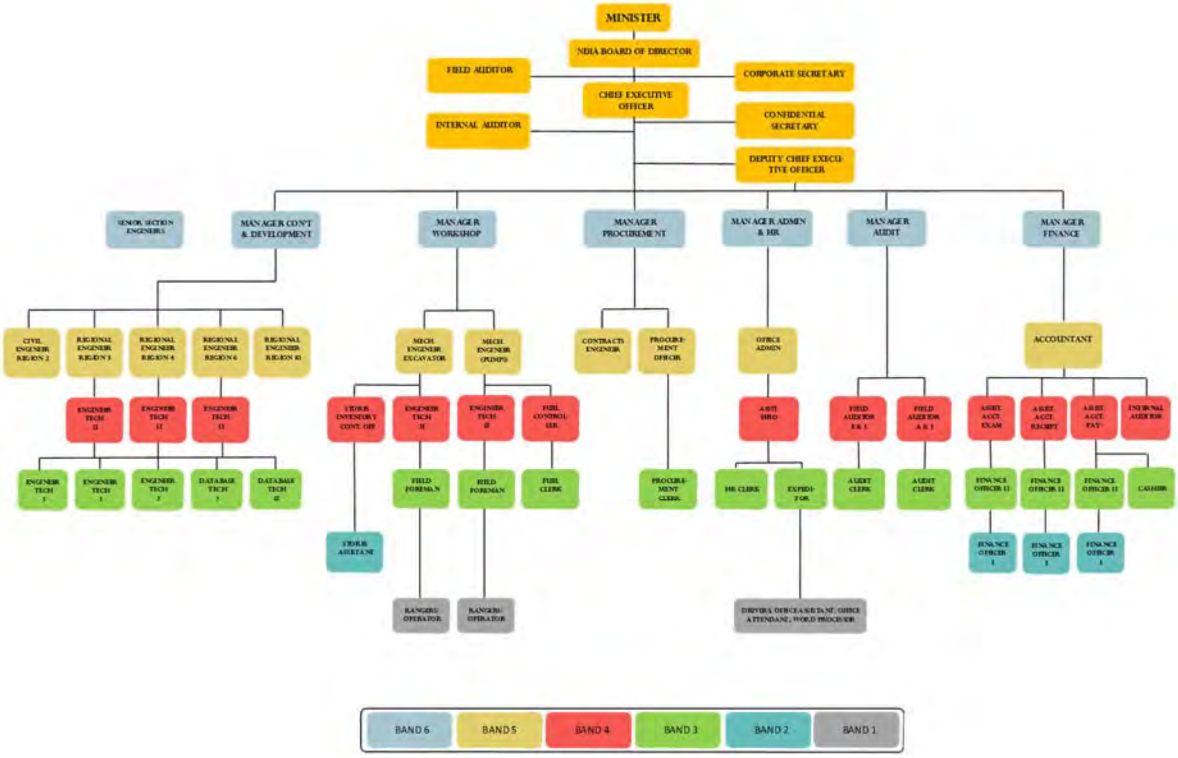
NDIA, established in 2004, is a subsidiary of MOA as shown in **Fig. R 1.4.7**.

The number of administration staff is 31, while there are 13 drivers, finance department is 12, mechanical engineering department is 9, engineering department is 25 and procurement department is 4. The organizational chart of NDIA is as given in **Fig. R 1.4.8**.



Source: http://agriculture.gov.gy/organization-structure/

Fig. R 1.4.7 Organizational Chart of MOA

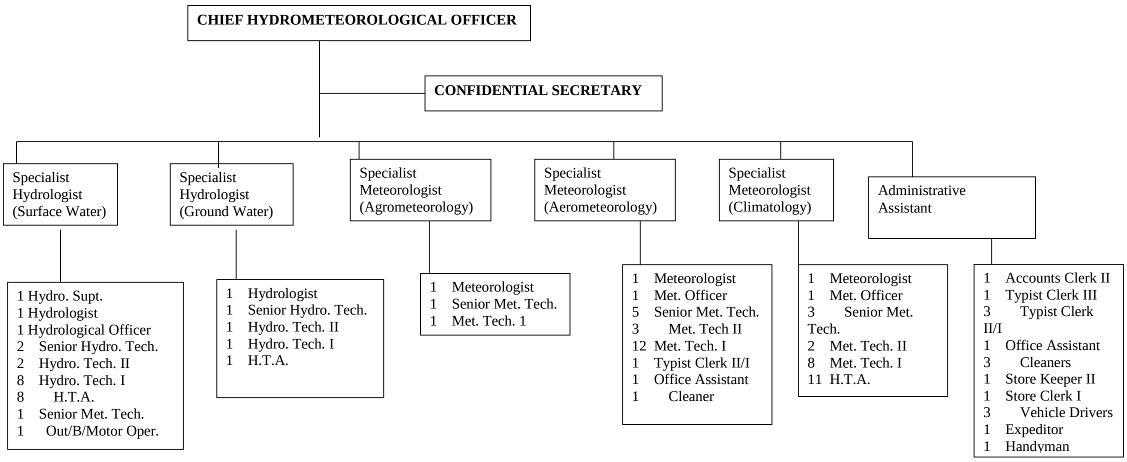


Source: NDIA

Fig. R 1.4.8 Organizational Chart of NDIA

(b) HS-MOA (Hydrometeorological Services-MOA)

The HS-MOA was established in 1965 based on the recommendation of a World Meteorological Organization's representative and overseen by MOA in 1992. The total number of staff in HS-MOA is 32, including staff with doctorate degree (1), Master's degree (4), and Bachelor of Science or BS (9). The organizational chart of HS-MOA is as given in **Fig. R 1.4.9.**



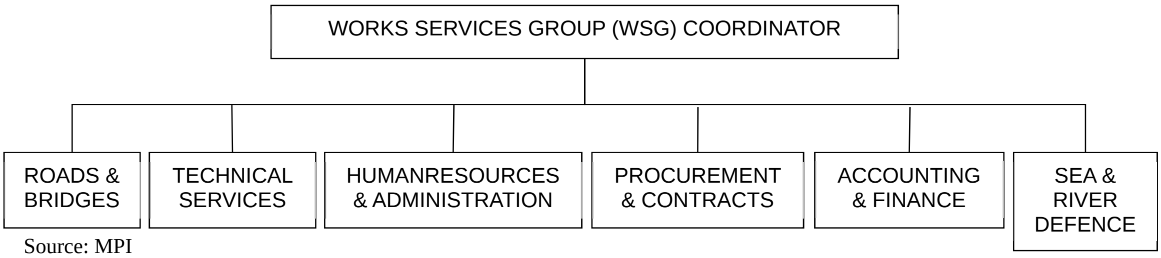
Source: HS-MOA

Fig. R 1.4.9 Organizational Chart of HS-MOA

(2) MPI (Ministry of Public Infrastructure)

(a) WSG-MPI (Work Services Group-MPI)

The WSG-MPI that has 59 engineers was established in 2002 and incorporated with the Sea and River Defences Division (SRDD) in 2008. The organizational chart of WSG-MPI is as given in **Fig. R 1.4.10**.



Source: MPI

Fig. R 1.4.10 Organizational Chart of WSG-MPI

(b) MARAD-MPI (Maritime Administration Department-MPI)

MARAD-MPI was established in 2003 in conformity with the 1997 Merchant Shipping Act and managed in line with the International Maritime Organization.

(3) MOC (Ministry of Communities)

MOC has the role to promote the development of local government units. Thus, MOC financially supports M&CC activities, like cleaning of drainage channels and procurement of equipment for cleaning, in accordance with the Memorandum of Understanding (MOU). Accordingly, MOC indirectly contributes to the drainage system improvement in Georgetown. Recent financial support for drainage improvement from MOC to M&CC is as presented in the following table.

Table R 1.4.13 Recent Financial Support for Drainage Improvement from MOC to M&CC

Year	Amount of Allocation	Contents of Execution
2011	G$20,000,000	Rehabilitation of City Hall Building
2012	G$20,000,000	Acquisition of Two Compactors Purchase of One Hook Lift Truck
2013	G$20,000,000	Purchase of Two used ten-ton DAF trucks (2006) Repairs to Daewood Slid Steer Loader 0.22210
2014	G$22,000,000	Purchase of One new Hyundai Excavator on wheels and slush bucket
2015	G$24,000,000	Purchase of Fogging Machine Purchase of Skip Bin Truck Purchase of Tow Truck Purchase of Pick-Up Truck

Source: MOC

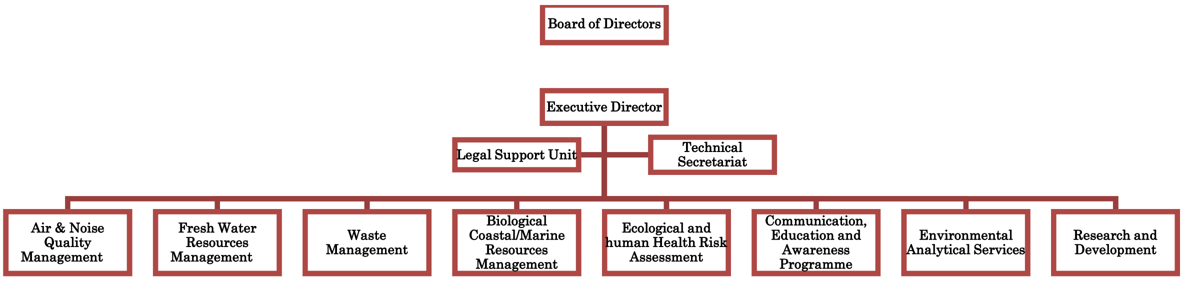
(4) M&CC (Mayor and City Council of Georgetown)

The MOC is a member of the Georgetown Drainage Authority and works on routine maintenance for drainage facilities in Georgetown. Infrastructures including drainage facilities are planned, designed and constructed by the central government, and then turned over to M&CC which operates and maintains the drainage facilities. In the Laws of Guyana, the "Municipal and District Councils Act," mentions the role and responsibility of M&CC. However, the central government financially supports the maintenance work of M&CC since M&CC does not have enough budget.

(5) MONR (Ministry of Natural Resources)

(a) EPA-MONR (Environmental Protection Agency-MONR)

The organizational chart of EPA-MONR is as given in **Fig. R 1.4.11**. The total number of staff in EPA-MONR is 97 including general and technical staff. Most of the staff are university graduates in Guyana. There is a doctorate (1 staff) and masters (12 staff),and most of them graduated and passed through the Faculty of Environmental Concerns.



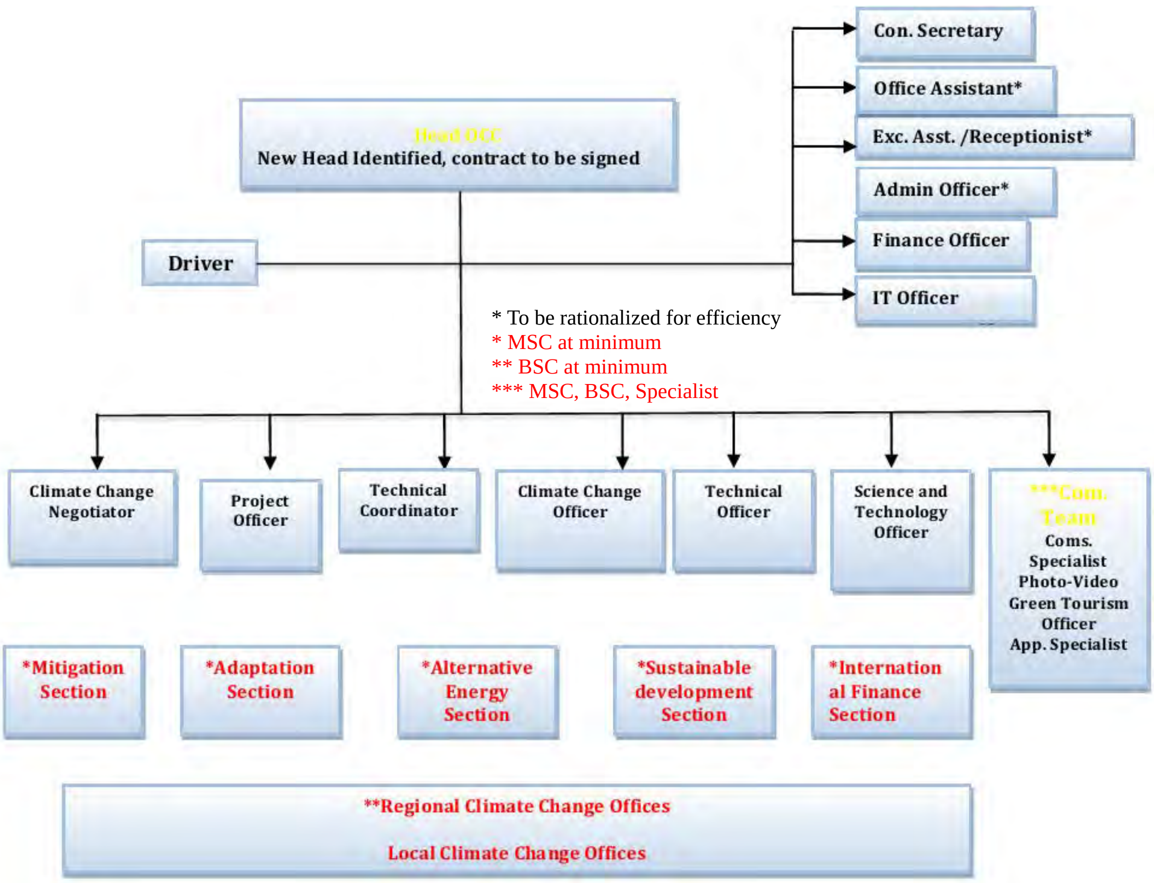
Source: EPA-MONR

Fig. R 1.4.11 Organizational Chart of EPA-MONR

(6) MOP (Ministry of the Presidency)

(a) OCC-MOP (Office of Climate Change, MOP)

The organizational chart of OCC-MOP is as given in **Fig. R 1.4.12**. The total number of staff in OCC-MOP is 12 including masters (3 staff) and BS (8 staff).

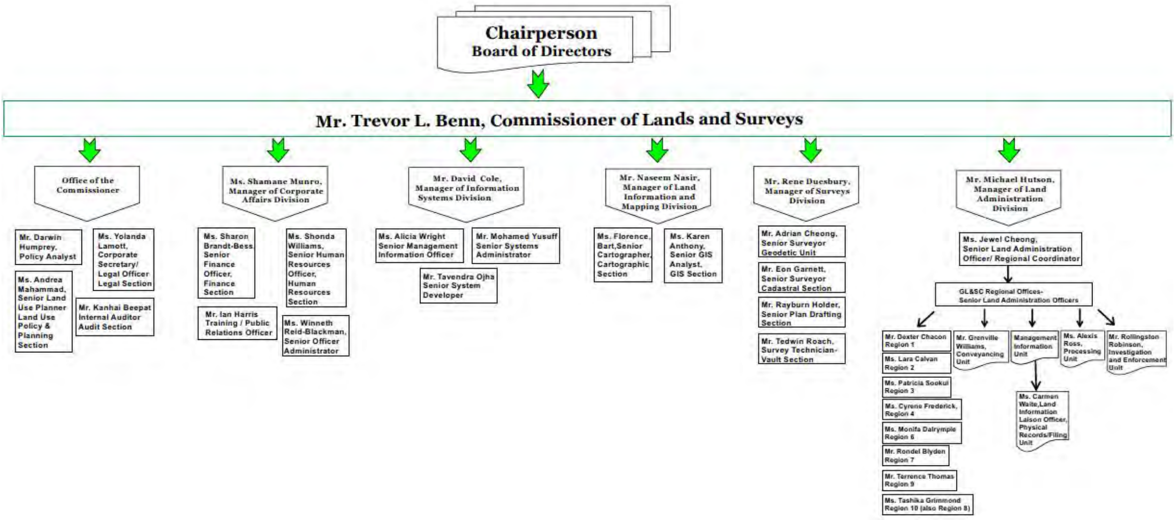


Source: OCC-MOP

Fig. R 1.4.12 Organizational Chart of OCC-MOP

(b) GL&SC-MOP (Guyana Lands and Surveys Commission, MOP)

The organizational chart of GL&SC-MOP is as given in **Fig. R 1.4.13**. The total number of staff in GL&SC-MOP is 232 including masters (8 staff), BS (18 staff) and qualified surveyor (3 staff). There are 11 regional offices of GL&SC-MOP in Guyana.

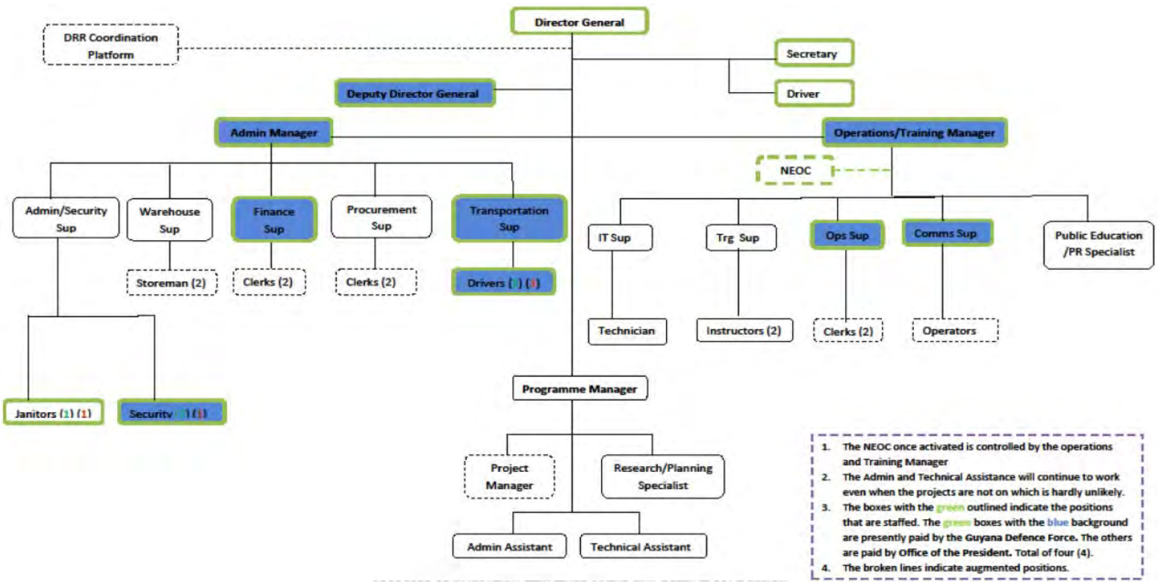


Source: GL&SC-MOP

Fig. R 1.4.13 Organizational Chart of GL&SC-MOP

(c) CDC-MOP (Civil Defence Commission-MOP)

The organizational chart of CDC-MOP is as given in **Fig. R 1.4.14**. The total number of staff in CDC-MOP is 15 including masters (2 staff) and BS (5 staff). There is no civil engineer and most of the staff have acquired skills in Disaster Management.

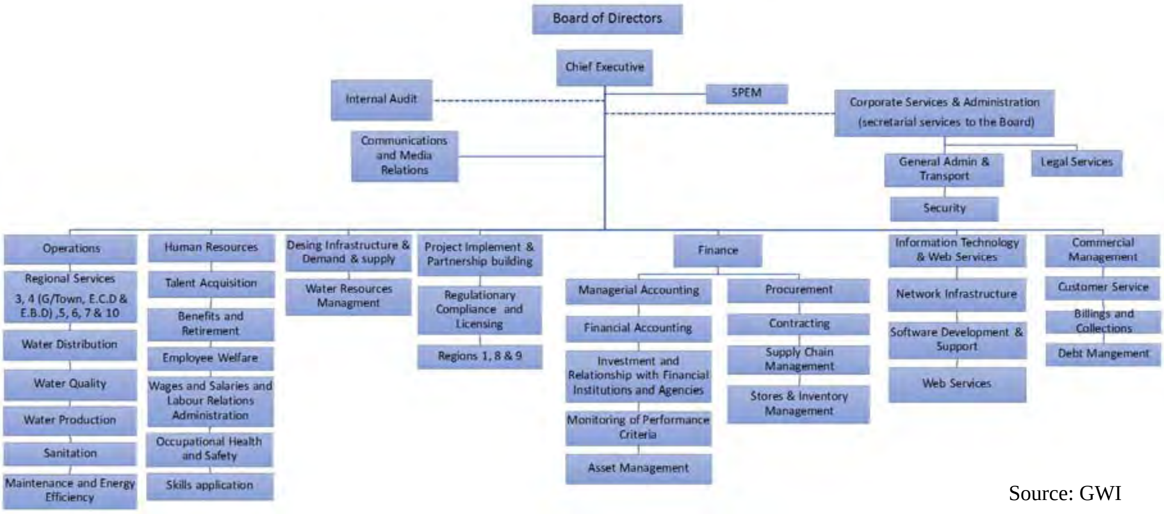


Source: National Integrated Disaster Risk Management Plan for Guyana (2013)

Fig. R 1.4.14 Organizational Chart of CDC-MOP

(7) GWI (Guyana Water Incorporated)

The organizational chart of GWI is as given in **Fig. R 1.4.15**. The total number of staff in GWI is 856 (Male: 569, Female: 287), including permanent staff (807) and contract employees (49).

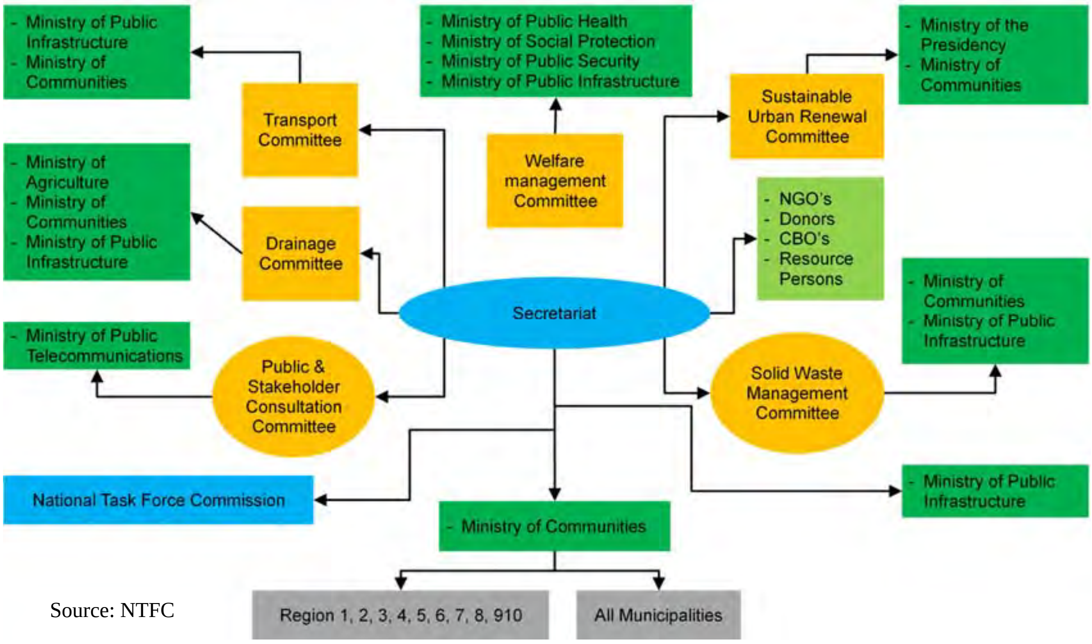


Source: GWI

Fig. R 1.4.15 Organizational Chart of GWI

(8) NTFC (National Task Force Commission)

The organizational chart of NTFC is as given in **Fig. R 1.4.16**.



Source: NTFC

Fig. R 1.4.16 Organizational Chart of NTFC

A short-term program (within a year) for drainage improvement in Georgetown is currently being implemented by NTFC. However, most of the activities in the program have not yet started. The major activity is the enhancement of drainage capacity for channel including maintenance work, like dredging of drainage channel and removal of vegetation in channel using chemical products. M&CC has the role and responsibility for maintenance work of drainage facilities. Several ministries, such as the Ministry of Agriculture, the Ministry of

Communities, and the Ministry of Public Infrastructure, cooperate in budgetary, technical, and human resources with M&CC. NTFC does not conduct drainage improvement and/or provide financial support due to budgetary constraints.

Table R 1.4.14 Short-Term Program of NTFC for Drainage Improvement in Georgetown

Theme	What	Why	Where	When	Who Leads	Support	Cost	Present Status
Drain	Desilting	Increase reservoir capacity & the rate of flow	Railway Embankment	Immediate	M&CC	MOC, MPI and NDIA	G$25M	Commenc ed
		Clear inlet channel	Meadow bank	Immediate	M&CC	MOC, MPI and NDIA	G$5M	Not started yet
			Sussex St. from Cemetery Rd. to the outfall	Immediate	M&CC	MOC, MPI and NDIA	G$20M	Not started yet
			Agricola/ Rome	Immediate	M&CC	MOC, MPI and NDIA	G$5M	Not started yet
	Desilting	Provide temp. relief to North Ruimveldt	South Ruimveldt Gardens	Immediate	MPI	M&CC, MOC and NDIA		Commenc ed
		Clear drains	Newtown	10-Apr.	MPI	M&CC, MOC and NDIA	G$13.7M	Commenc ed
Sluice	Repair Door& Winch	Make operational	Meadow bank	Immediate	M&CC	MOC, MPI and NDIA	G$5M	Not started yet
	Total rehab.	Make operational	Agricola/Rom e, South	Immediate	M&CC	MOC, MPI and NDIA	G$8.5M	Not started yet
	Repair winch& door	Make operational	Lamaha St.	Immediate	M&CC	MOC, MPI and NDIA	G$5.2M	Not started yet
Outfall	Desilting	To ensure that water is discharge quickly	All	17-Apr.	NDIA	M&CC, MOC and NDIA		Not started yet

Source: NTFC

(9) GDA (Georgetown Drainage Authority)

Funds for GDA are allocated to the executing agencies based on the Cabinet's approval of the project. The committee of GDA unanimously agreed to the following Terms of Reference to steer the committee of GDA in executing its mandate:

- Identify the critical needs for drainage within the City.
- Make recommendations for scheduling short and long-term maintenance of sluices, pumps and outfall channels within the City.
- Determine priority Drainage Works within the City.
- Schedule site visits to monitor and evaluate ongoing drainage and/or related works, and to assess the need for remedial works to drainage infrastructures.
- Formulate a national policy for drainage within the City, in terms of determining the standard for desilting, cleaning, dredging, constructing, covering or the revetment of primary and secondary drains, trenches and canals within the City.

1.4.3 Cooperation from International Donor

Various international donors cooperate with GCRG. Particularly, the cooperation on drainage system improvement and flood mitigation have been carried out by an international donor starting from the 2005 flood, as outlined below.

(1) Government of the Netherlands

The Government of the Netherlands dispatched a DRR Team in 2015 to conduct a study to improve the drainage system and mitigate flood disaster in Georgetown. The DRR Team rounded up the results of the study as "DRR-Team Mission Report" in 2016. The following activities are recommended based on the site investigation and hearing survey from related agencies.

(a) Upgrade Modelling Capacity

- Make a long-term project plan to gradually develop the hydraulic drainage model for Georgetown
- Set up a simple spreadsheet type of network model for the entire drainage system of Georgetown and use it to better understand the flow of water
- Start selecting two or three engineers with passion for computers and modelling and train them on the subject of hydraulic modelling

(b) Improve Flood Resiliency of People

- Develop a communication plan aiming to increase the understanding of the public about what it means to live with water
- Make a flood hazard map of Georgetown and use it to explain to the public
- Prepare a simple explanation (for example, YouTube) on how the drainage system works, why water needs space, and why it is important to keep the drainage system free from constructions and waste

(c) Upgrade Small-Scale Floating Dredging Capacities

- Specify the requirements for small scale floating dredgers for the City of Georgetown and justify the investment based on cost/benefit calculation. Decide on whether it should be a public or a private entity to run the "City Dredging Operations"
- Purchase dedicated equipment and start operations

(d) Develop and Apply Rational Risk Approach

- Prepare a first set of flood hazard maps
- Set up the framework for analysis for the sea defence risk assessment

(e) Pilot "Living with Water"

- Develop a pilot "Living with Water" in which all elements of an integrated long-term and holistic "Drainage System Management" are specified and made applicable to Guyanese situations
- Develop a similar pilot for an existing highly urbanized catchment area in Georgetown

(f) Asset Management

- Consider the suggestions, like making an inventory of all assets, allocate the responsibility for the maintenance of all assets, etc.

(g) Data Management

- Start collecting all available data on the drainage system including data on locations, their dimensions, capacities, etc.
- Start collecting all relevant hydro-meteorological data required for risk assessment of drainage system as well as the sea defence system
- Use geo-informatics to collect data on land use, long-term shoreline dynamics, and flood events
- Start analysing the data in a consistent manner and contributing to better understanding of the flood risk

(h) Technical Short-Term Improvements

- Consider the technical upgrade options, like provision of stop-logs, replacing wooden gates by stronger steel gates, keeping available materials and equipment in case of failure, etc.
- Consider improving the hydraulic efficiency by streamlining corners of drainage canals

The list of recommendations and associated cost estimates by the DRR Team is as shown in the following table.

Table R 1.4.15 List of Recommendations and Associated Cost Estimates by DRR Team

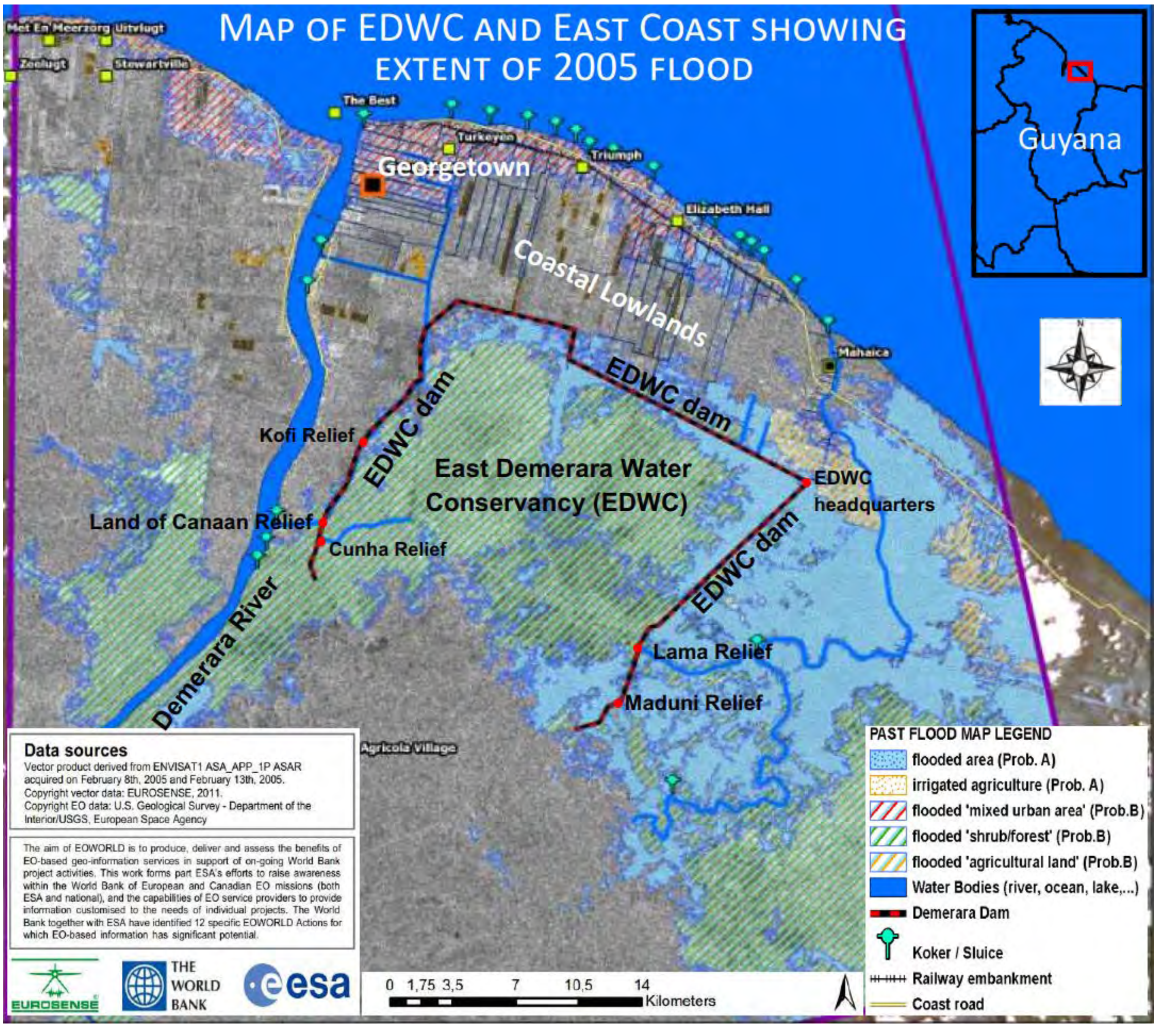
		first tentative estimate - only meant for rough indication			
	topic	personnel costs foreign experts [kEUR]	material costs (incl travel and materials) [kEUR]	duration of activity (weeks abroad to prepare)	duration of activity (weeks in Guyana)
R1a	Roadmap to develop hydraulic drainage model	8 - 20	4 - 8	0 - 1	1 - 2
R1b	Spreadsheet-type of first model (Georgetown)	15 - 25	8 - 10	0 - 1	2 - 3
R1c	Training Guyanese hydraulic experts	14 - 25	4 - 8	1 - 2	1 -2
R2a	Communication plan on flood resiliency	25 - 40	8 -10	2 - 3	2 - 3
R2b	Flood hazard map catchment area Georgetown	8 - 20	4 - 8	0 - 1	1 - 2
R2c	Youtube video on the drainage system	10 - 25	0 - 5	1 - 2	0 - 1
R3a	Business plan floating mini urban dredgers	20 - 32	4 - 8	2 - 3	1 - 2
R3b	Purchase equipment and guidance operations	t.b.d.	t.b.d.	-	-
R4a	Flood hazard mapping	25 - 40	8 -10	2 - 3	2 - 3
R4b	Rational Risk Approach and National Debate	45 - 80	12 - 22	3 - 4	4 - 6
R5a	Pilot Living Water rural arean	25 - 40	5 - 10	2 - 3	2 - 3
R5b	Idem, highly urbanised area (Georgetown)	25 - 40	5 - 10	2 - 3	2 - 3
R6a	Develop asset management instruments	14 - 25	4 - 8	1 - 2	1 -2
R7a	Collect and digitise data on current drainage	15 - 35	8 - 14	0 - 1	2 - 4
R7b	Idem, for hydraulic extremes analysis	15 - 35	8 - 14	0 - 1	2 - 4
R7b	Idem, on land use using geo-informatics	15 - 25	8 - 10	0 - 1	2 - 3
R7d	Analyse data to get data for risk assessment	30 - 50	12 - 22	1 - 2	3 - 6
R8a	Elaborate on technical suggestions Section 3.9	6 - 12	4 - 8	0 -1	1
R8b	Idem, streamlining options	6 - 12	4 - 8	0 -1	1

Source: DRR-Team Mission Report

(2) WB (The World Bank)

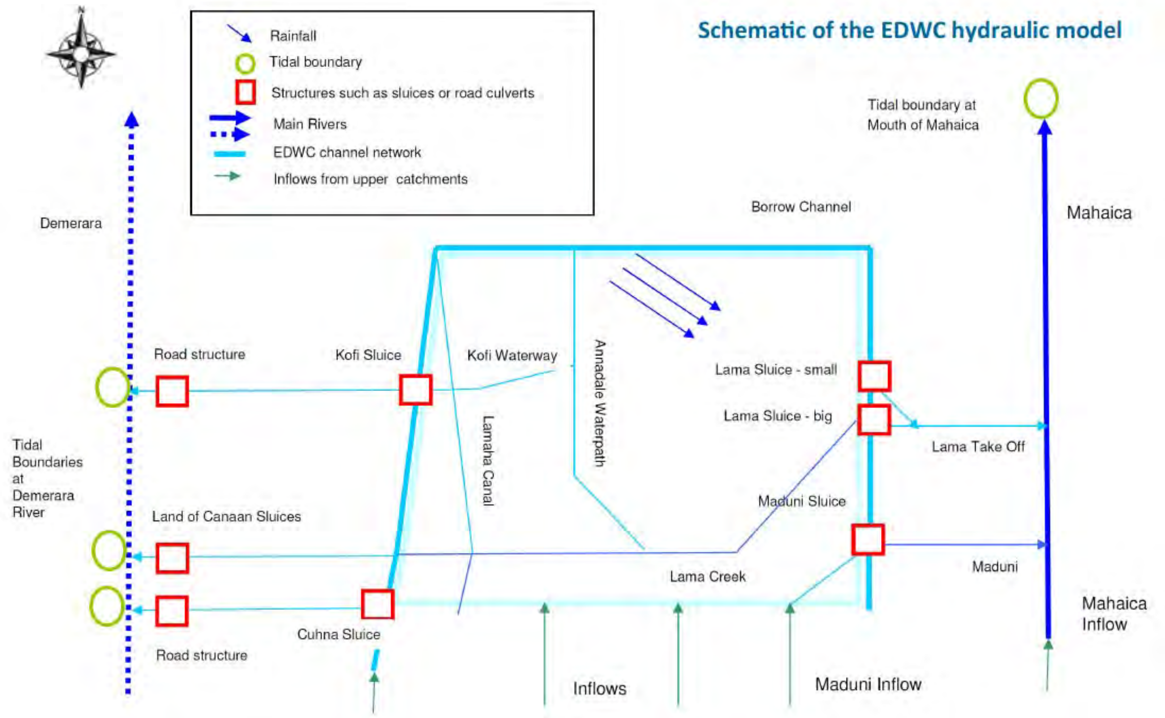
The WB conducted "The Conservancy Adaptation Project (CAP)" using approximately 3.8 million USD in total project expense from 2008 to 2013. This project included the review/evaluation of flood mitigation and improvement of the functions of EDWC which has the role of water resource and flood mitigation system for Georgetown and surrounding area along coastal line. The implementation agency for this project was MOA and the outline is as presented in below.

- Collection of hydro-meteorological data (8 rainfall gauges, 29 water level gauges and 18 flowmeters)
- Conduct of topographic survey (Lidar data)
- Hydrological modelling at EDWC and east coast
- Stability analysis of embankment of EDWC
- Rehabilitation of 2 sluices at Lama, procurement of long-boom excavator, design/construction of floating punt and pontoon, procurement of hydrological observation instrumentation, survey equipment and computing equipment.
- Institutional Strengthening



Source: CAP

Fig. R 1.4.17 Inundation Map of 2005 Flood Event by CAP



Source: CAP

Fig. R 1.4.18 Schematic Diagram of EDWC Hydraulic Model

Table R 1.4.16 Outline and Cost Estimate of Proposed Project in CAP

Description of Proposed Interventions	Cost US$
EDWC Interventions:	**45,000,000**
Excavations within EDWC (widening of channel from Flagstaff to Kofi, connectivity channels)	40,000,000
Optimization of Demerara drainage (works, dredging, channel upgrading)	5,000,000
EDWC dam upgrading:	**54,002,500**
Reconstruction of the Northeast dam	12,780,000
Reconstruction of North dam	9,220,000
Reconstruction of East dam	10,800,000
Reconstruction of West dam	9,200,000
Heavy Earth Moving Plant equipment	12,000,000
Dam inspection & maintenance equipment	2,500
East Coast drainage interventions:	**20,048,000**
Liliendaal: Additional pumping capacity	1,130,000
Ogle: Additional pumping capacity	2,328,000
Embankment raising between pump station & outfall koker	21,000
Mon Repos/Annandale	
Additional pumping capacity at Good Hope	2,019,000
Additional pumping capacity at Lusignan	2,052,000
Additional pumping capacity at Annandale	2,062,000
Enterprise/Strathspey/Paradise	
New pump station 1 + culverts + channel widening	1,189,000
New pump station 2 + culverts + channel widening	7,190,000
Additional pumping capacity at Hope + culverts + channel widening	2,057,000
East Coast drainage interventions (separation of urban & agricultural drainage):	**4,735,000**
Mon Repos/Annandale	1,200,000
Enterprise/Strathspey/Paradise	1,600,000
Beehive/Clonbrook	435,000
Montrose/Sparendaam	1,500,000
Safety improvements to existing water control structures	**730,000**
Total	**123,385,500**

After CAP, the "Flood Risk Management Project" and "Cunha Canal Rehabilitation Project" are being conducted with WB assistance to enhance the drainage capacity of EDWC and MOA is the implementation agency

The Flood Risk Management Project includes three components as shown in the following table.

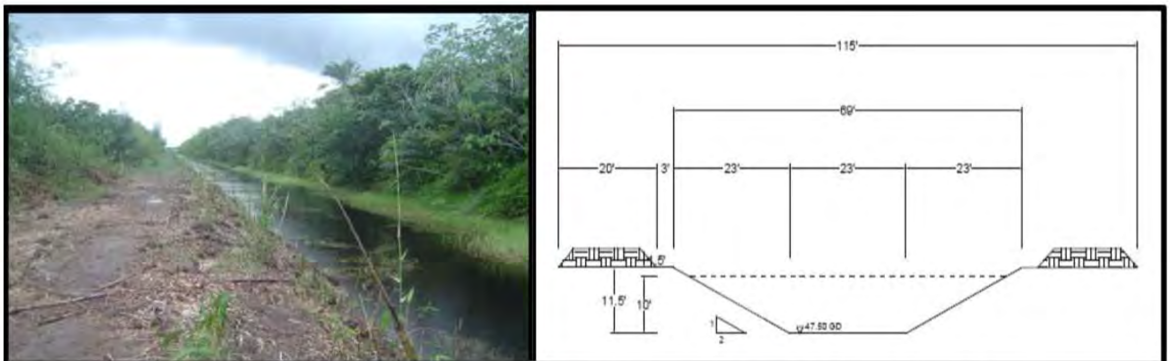
Table R 1.4.17 Outline and Cost of Each Component in Flood Risk Management Project

No.	Component	Content	Cost
1.	Priority Works for Flood Risk Reduction	• Rehabilitation of Northeast Dam (USD 2.0 x 10^6) • Purchase of equipment for earth work (USD 2.0 x 10^6) • Pumping Station at East Coast (3 locations: Lusignan, Buxton, Hope) (USD 5.5 x 10^6) • Consulting Services (Construction Supervision and Quality Assurance) (USD 0.8 x 10^6)	USD 10.3 x 10^6
2.	Institutional Strengthening for Flood Risk Reduction	• Preparation and implementation of Construction Supervision, Quality Assurance Plan and Operation and Maintenance Plan • Purchase and installation of instrumentation for expansion of the system of hydro-meteorological data in the EDWC • Preparation of Emergency Preparedness Plan • Support to Flood Modelling	USD 0.5 x 10^6
3.	Project Management and Implementation Support	• Support to MOA to strengthen and develop their institutional capacity to conduct project management and implementation	USD 1.2 x 10^6

The Cunha Canal Rehabilitation Project include three components as shown in the following table.

Table R 1.4.18 Outline and Cost of Each Component in Cunha Canal Rehabilitation Project

No.	Components	Contents	Costs
1.	Cunha Canal Rehabilitation Works	• Rehabilitation Head Regulator at EDWC (USD 0.17 x 10^6) • Rehabilitation of Existing Drainage Sluice at Cunha Canal (USD 0.21 x 10^6) • Construction of Bridge (USD 1.5 x 10^6) • Purchase of Hydrologic Monitoring Equipment, etc. (USD 0.03 x 10^6) • Rehabilitation Work for Cunha Canal is funded by GCRG (USD 0.27 x 10^6)	USD 1.91 x 10^6
2.	Resettlement (Compensation)	• Land Acquisition and Compensation Cost for Barama Company Limited (Approx. 20,000m^2)	USD 0.57 x 10^6
3.	Project Management	• Consulting Services, etc.	USD 0.52 x 10^6



Existing Cunha channel | Typical Cross Section

Source: Cunha Canal Rehabilitation Project (WB)

Fig. R 1.4.19 Cross-Section of Cunha Canal Rehabilitation Project

(3) UNDP (United Nations Development Programme)

UNDP supports CDC in disaster risk management including flood mitigation in Guyana. Mainly, policy and planning of disaster risk management in Guyana is supported, and the outline is as shown in the following.

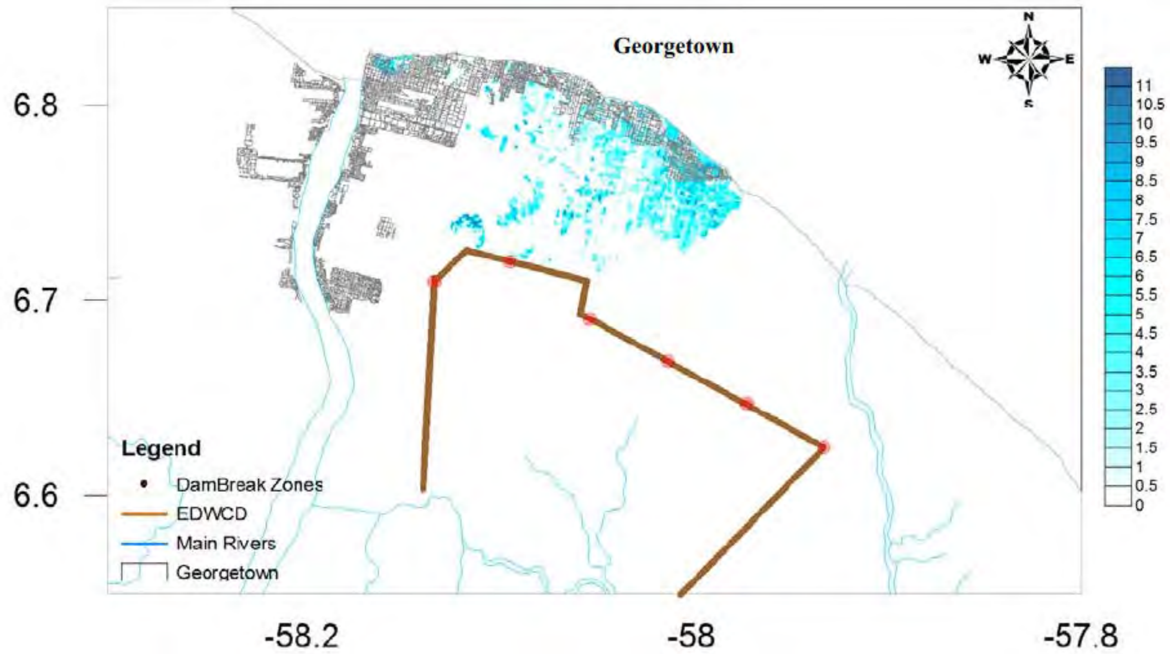
- Disaster Risk Management Policy (2013)
- Flood Preparedness & Response Plan (2011)
- Multi-hazard Disaster Preparedness & Response Plan (2013)
- Early Warning System Framework (2013)

(4) IDB (Inter-American Development Bank)

IDB also supports CDC in disaster risk management including flood mitigation in Guyana, as shown below.

- National Integrated Disaster Risk Management Implementation Strategy for Guyana (2013)
- National Integrated Disaster Risk Management Plan for Guyana (2013)

The "Disaster Risk Indicators and Flood Risk Evaluation", which received assistance from the IDB was conducted in 2012. This included flood simulation in case of dike breach at EDWC with several scenarios. A sample of flood simulation result by IDB is as shown in the following figure.



Source: CAP

Fig. R 1.4.20 Sample of Flood Simulation Result by IDB

(5) Export-Import Bank of India

The loan agreement for the "Design and Supply of Nine (9) Fixed Drainage Pumps and Five (5) Mobile Drainage Pumps" with the Export-Import Bank of India was signed in

February 2017. The nine fixed drainage pumps will be installed in Region 2 (Hampton Court、Devonshire Castle), Region 3 (Den Amstel), Region 4 (Hope, Nooten Zuil), Region 5 (Mora Point), Region 6 (Rose Hall), and the five mobile drainage pumps will be utilized in Georgetown during floods. The contractor for this project was under the selection process as of March 2017.

(6) Others

(a) Cooperation in Climate Change (Adaptation and Mitigation)

OCC is receiving technical and financial cooperation on climate change (adaptation and mitigation) from international donors, as tabulated below.

Table R 1.4.19 Cooperation from International Donor to OCC

Project Title	Project Partner(s)	Project Cost (USD)	Duration	Beneficiaries	Geographic Location
Institutional Strengthening Project (ISP)	Guyana REDD Investment Fund (GRIF) through Partner Entity IDB	3,073,904	2012-2017	Government of Guyana	National
Technology Needs Assessment Project under the UN Framework Convention on Climate Change (TNA)	United Nations Environment Programme Department of Management Engineering – Technical University of Denmark Partnership (UDP)	134, 800	2015-2017	Government of Guyana	National
Japan-Caribbean Climate Change Partnership Project (JCCCP)	Government of Japan through UNDP	600,000	2016-2018	Government of Guyana	National
Republic of Guyana: Preparation of the Third National Communication under the UN Framework Convention on Climate Change (TNC)	United Nations Environment Programme (UNEP)	564,000	2013-2019	Government of Guyana	National
Guyana: Initial Biennial Update Report (BUR1) under the United Nations Framework Convention on Climate Change	United Nations Environment Programme (UNEP)	372,000	2016-2018	Government of Guyana	National
Technical Assistance - Capacity Strengthening for the Office of Climate Change through preparation of National Climate Change Policy and Strategic Plan	Caribbean Development Bank (CDB)	150,000	2017-2018	Office of Climate Change	National
Climate Change Adaptation Program (CCAP)	The United States Agency for International Development (USAID) with the Caribbean Community Climate Change Centre (CCCCC)	1,000,000	2016-2020	Government of Guyana	National
Caribbean Climate Online Risk and Adaptation Tool (CCORAL)	Caribbean Community Climate Change Centre (CCCCC)		ongoing	Government of Guyana	National
Reporting for Results-Based REDD+ Actions (RRR+) project	Norwegian Agency for Aid Development (NORAD) with partner Coalition of Rainforest Nations (CfRN)		2016-2019	Government of Guyana	National
A Proposal for the Institutional Arrangement to implement a MRVS System in Energy Efficiency in the Public Buildings	Latin American Energy Organisation (OLADE)	30,000	4 months	Government of Guyana	National

Project Title	Project Partner(s)	Project Cost (USD)	Duration	Beneficiaries	Geographic Location
Transitioning to National Energy Security: Bartica as a Model Green Town	Government of Italy in collaboration with Caribbean Community Climate Change	650,000	4 months	Government of Guyana	Bartica
Mainstreaming Low-emission Energy Technologies to build Guyana´s Green Economy	Global Environment Facility (GEF) through UNDP	2,000,000	48 months	Government of Guyana	National

Source: OCC

(b) Cooperation in Infrastructure Project

The other cooperation in infrastructure projects like the construction of coastal banks are supported for MPI.

1.5 Relationship between Urban Development Plan and Drainage System

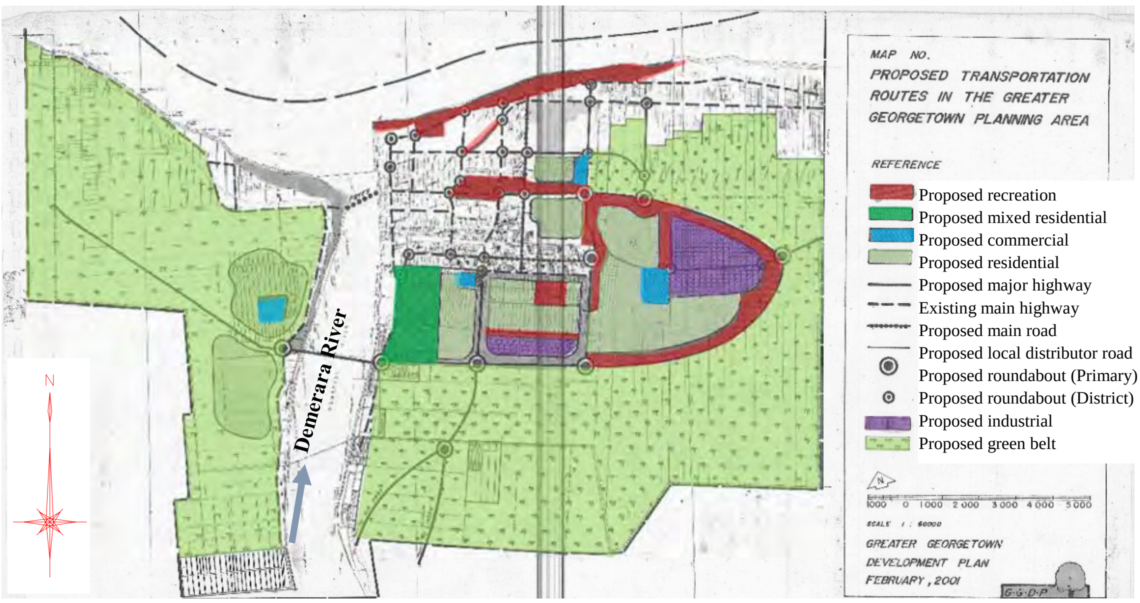
1.5.1 Urban Development Plan

Summaries of the recent development plans in Georgetown are given in the following table. The latest development plan in Georgetown is the "Greater Georgetown Development Plan 2001-2010" which was prepared by the Central Housing & Planning Authority (CHPA) in March 2002.

Table R 1.5.1 Summary of Recent Development Plans in Georgetown

Name	Outline
Greater Georgetown Planning Area Scheme	This plan was approved in October 1951. Camp Street is recommended as the main arterial thoroughfare of the town to join the East Bank Road.
The Draft Varying Scheme (1961)	In response to the fire of 1962, the improvement of Stabroek Market was recommended including wider pedestrian pavements along shopping streets by CHPA.
Georgetown Planning Area (Development Plan) -1982	This plan was prepared in June 1982 by UN and local planners. However, the plan never reached the approval stage.
Greater Georgetown Development Plan 2001-2010	This plan was prepared in March 2002 by CHPA.

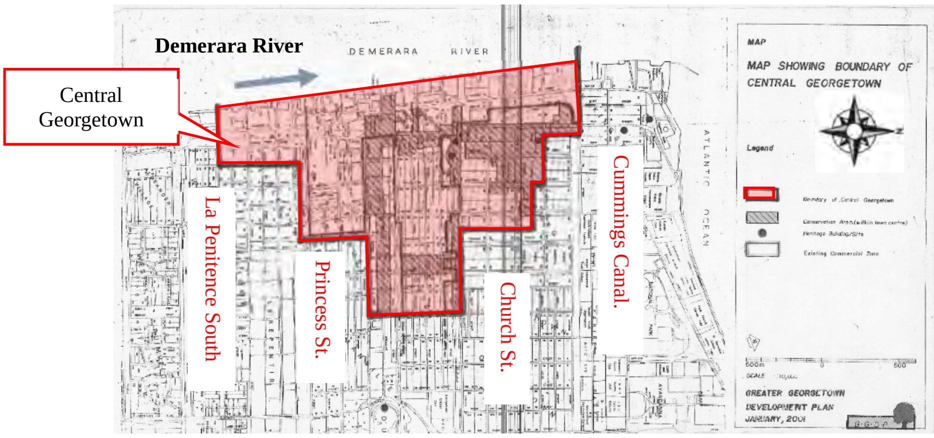
Source: Greater Georgetown Development Plan 2001-2010



Source: CHPA

Fig. R 1.5.1 Development Plan in Georgetown (Greater Georgetown Development Plan 2001-2010)

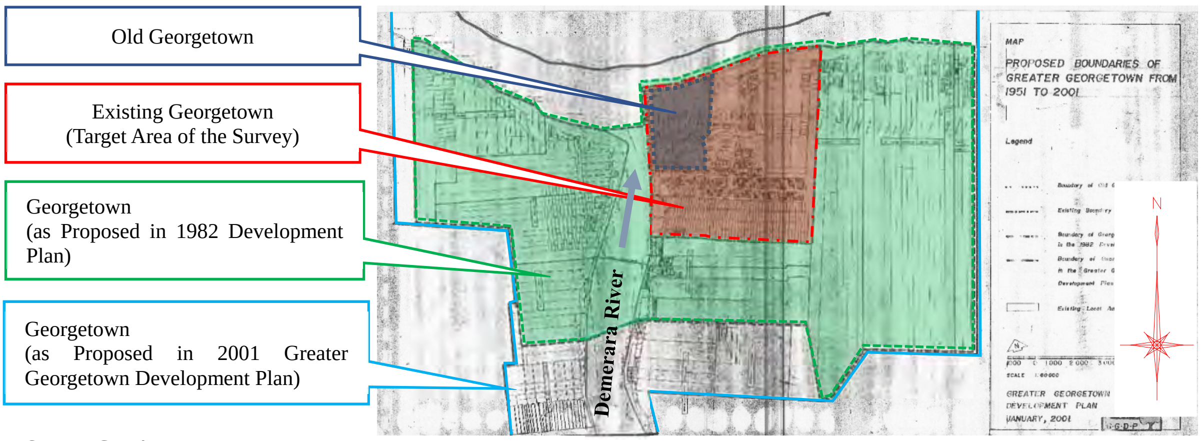
According to the Greater Georgetown Development Plan of 2001-2010, the central place of public administration and commerce in Georgetown is positioned as “Central Georgetown”. A modern commercial area focusing on Stabroek and Bourda market will be developed in this plan and this might increase the value of assets in Central Georgetown. The boundaries of Central Georgetown are as shown in **Fig. R 1.5.2**. The whole area of Central Georgetown is the target area of this Survey.



Source: CHPA

Fig. R 1.5.2 Boundaries of Central Georgetown

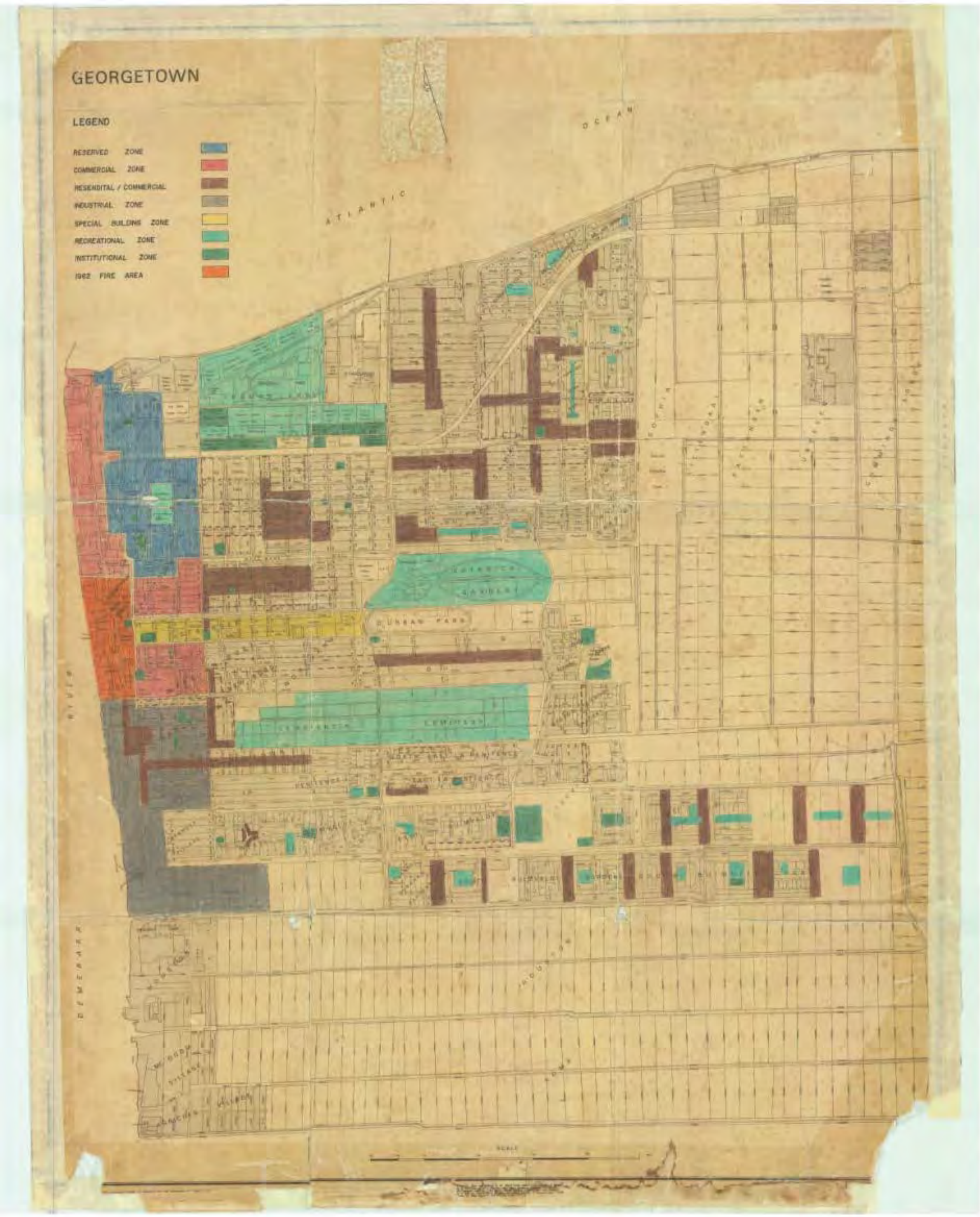
The existing Georgetown is a small city of 5 square kilometres. The area of Georgetown is proposed to be expanded in the urban development plans of 1982 and 2001. The boundaries of the old Georgetown, the presently existing Georgetown (Target Area of the Survey), and the proposed Georgetown are as shown in **Fig. R 1.5.3**.



Source: CHPA

Fig. R 1.5.3 Boundaries of Georgetown

Georgetown is proposed to be expanded up to the above-indicated areas in the Greater Georgetown Development Plan of 2001-2010. The residential area is to be expanded to the east side of the existing Georgetown and the others are planned as green zones, as shown in **Fig. R 1.5.1**.



Source: CHPA

Fig. R 1.5.4　　Previous Development Plan of Georgetown

The “National Land Use Plan” was prepared with support of the EU (European Union) in 2013 and implemented by GL&SC. The sample is as shown in **Fig. R 1.5.5**.

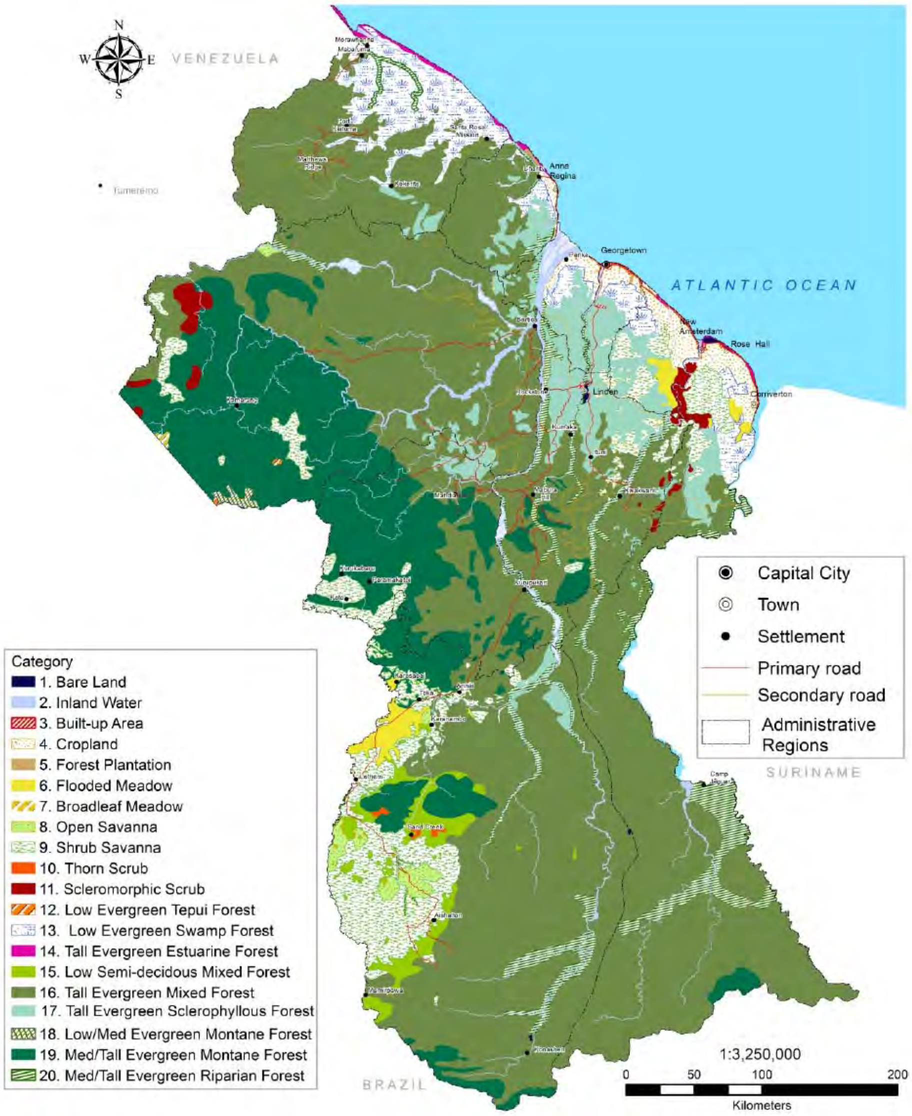


Fig. R 1.5.5 Sample of National Land Use Plan under the Development of Land Use Planning Project

At this point, there is no relation between the drainage improvement plan and the development plan of Georgetown and thus the plans do not reflect each other.

1.5.2 Road Plan

In Georgetown, road pavement rehabilitation, road widening and intersection improvement have been conducted; however, they are not as planned but as required without plan. Besides, there are no short-term and long-term plans for road construction in Georgetown. On the other hand, there is a road construction plan financed by the Indian Government to serve as the access road to Georgetown or ring road to the city suburban area to mitigate traffic, because traffic congestion occurs in the city during commuting hours.

There is no urban development plan in Georgetown. Recently, the west side of Georgetown (opposite shores of Demerara River) and the south side of Georgetown have developed due to rapid population increase in Georgetown and suburbs.

Moreover, Georgetown does not have a road plan but there is a “Traffic Development Plan” focusing on the movement of people and vehicles.

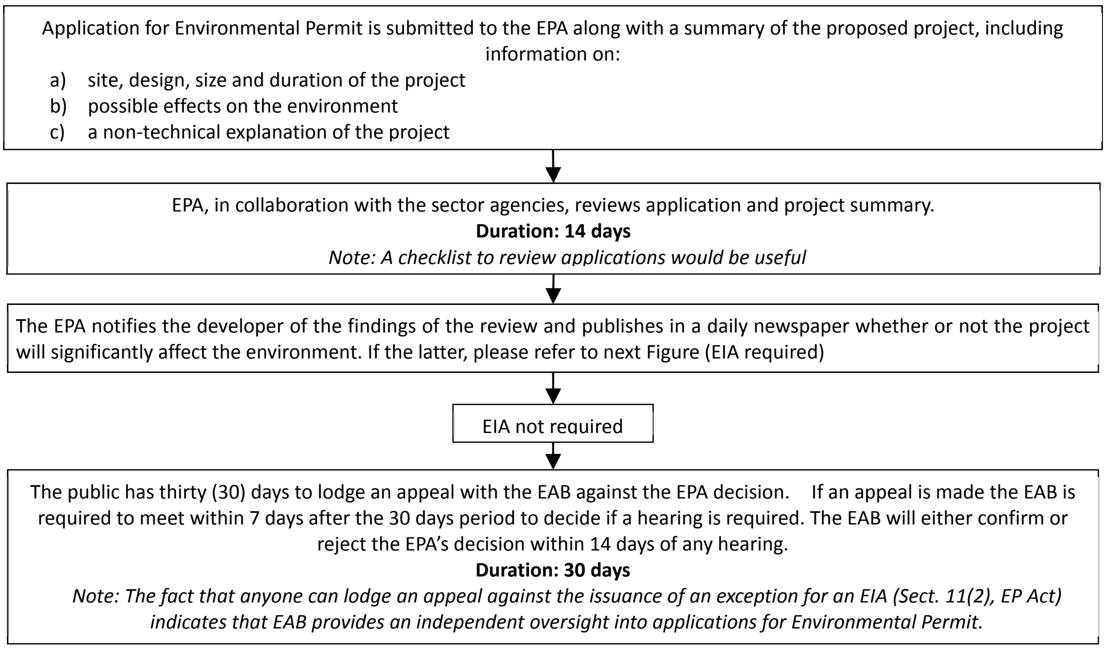
1.5.3 Environmental Impact Assessment

The LAWS OF GUYANA (Chapter 20-05, Environmental Protection Act) stipulate Regulations (Noise Management, Air Quality, Water Quality, Hazardous Waste management, etc.) and Guidelines (Environmental Management Plan, etc.).

The normal procedure of EIA is as described below.

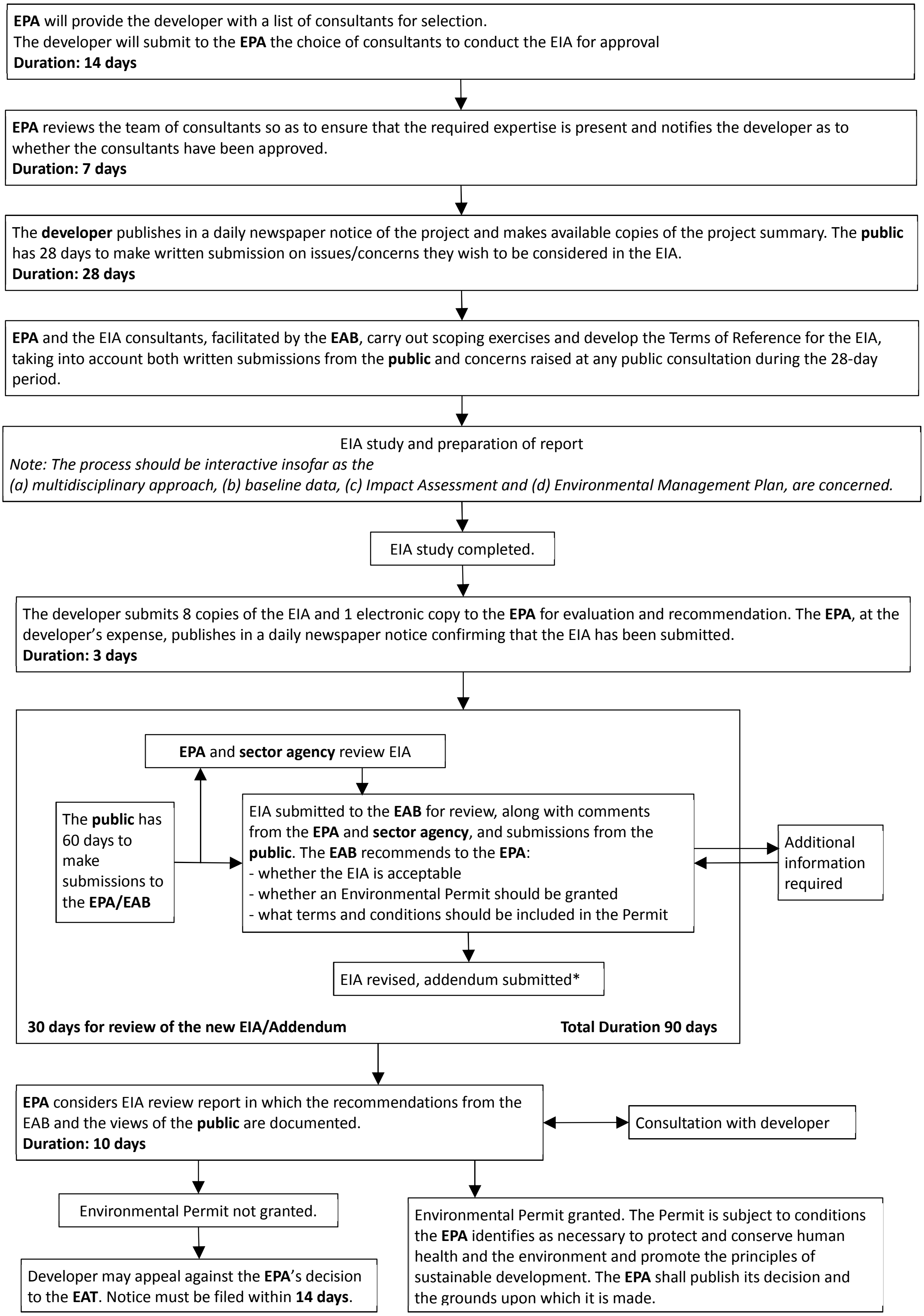
- Application for environmental permit is submitted to the EPA
- EPA reviews the application as to whether or not an EIA is required
- Business conducts an EIA study and submits the results to EPA, if necessary
- EPA reviews the result of EIA study and permits the EIA documents, if applicable. (The outline of the project is opened to the public and public comments are accepted.)

The procedure to obtain an environmental permit as to whether or not an EIA is required are as diagrammatically shown in the following figures. It takes about 2 months for the paper procedure if without EIA, and 1 year from submission of EIA documents to permission of the document if with EIA.



Source: EPA

Fig. R 1.5.6 Procedure for Obtaining Environmental Permit – EIA not required (about 2 months)



*Depending on the significance of the information requested, the EIA may need to be re-submitted either as a revised document or as an addendum to the EIA.

Source: EPA

Fig. R 1.5.7 Procedure for Obtaining Environmental Permit – EIA required (about 1 year)

The standards of EIA in Guyana comply with the Environmental Protection Act. EIA does not require Initial Environmental Examination (IEE) and Initial Environmental Impact Assessment (IEIA). The EIA standards refer to Canadian standards with assistance from IDB and other international standards although it is not quoted verbatim.

The points of attention in case of the project with cooperation from Japan are as mentioned below.

- "Application Form for Environmental Authorisation" of EPA shall be filled up and the documents submitted together with the required attachments to EPA in case of general civil engineering works, such as construction of drainage pumping station.
- "Application Forms for Research" often is not required to be submitted in case of general services for survey and design. However, it is necessary to confirm this with EPA in case that chemical is discharged into river as a part of survey. Likewise, there is a possibility to require the submittal of "Application Forms for Research" to EPA in case of geological survey with boring test.
- "Application Form for Registration of Environmental Consultants" shall be submitted by the company that will conduct the EIA to obtain environmental permission. Besides, the company should pass the screening and registration. (JICA consultant should confirm with the environmental outsourcing company whether the company has been registered prior to the execution of contract.)

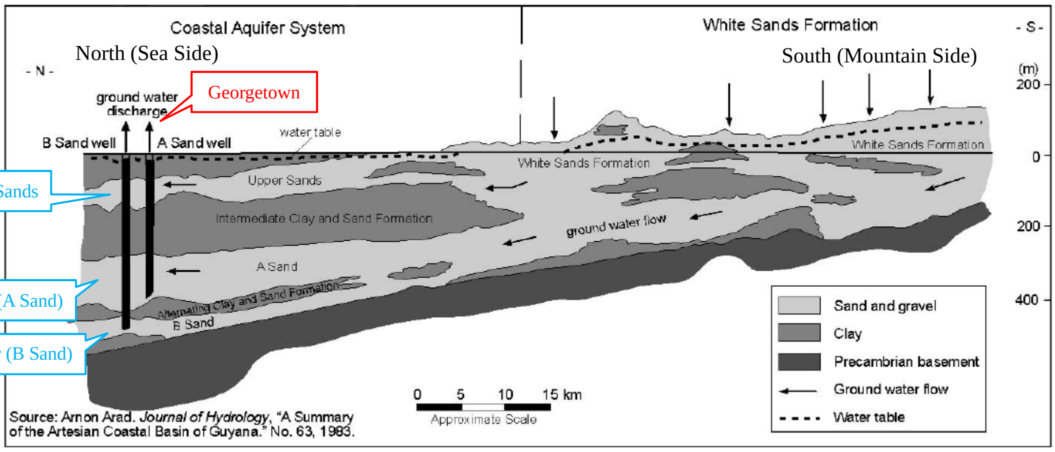
1.6 Relationship between Groundwater/Ground Subsidence and Flood

1.6.1 Status of Groundwater Use and Control

GWI manages water supply in Georgetown. Although relatively large hotels and factories possess their own groundwater intake facility, GWI basically supply water from the water-treatment facility of GWI.

The 60% of water supply in water treatment plant within the compound of the Head Office of GWI is surface water from intake channel originated in East Demerara Water Conservancy, and 40% is groundwater. There are 7 groundwater wells within the compound of the Head Office of GWI. Other than this, there are 2 water treatment plans at Ruimveldt Central and Sophia in Georgetown, and all these water resources are from groundwater.

The geological profile around Georgetown is as shown in **Fig. R 1.6.1**. The groundwater system comprises three aquifers beneath Georgetown and the coastal plain. The "upper" sand is the shallowest of the three aquifers and its depth varies between 30m to 60m from Ground Level (GL.), with thickness ranging from 15m to 120m. It is not used as a source of water because of its high iron content and salinity. Most potable water is obtained from the two deep aquifers. The "A" sand is typically encountered between 200m and 300m below the surface with thickness ranging from 15m to 60m. Water from the "A" aquifer requires treatment for the removal of iron. The "B" sand is found at about 300m to 400m with thickness of between 350m and 800m. Water from this aquifer has very little iron, high temperature, and trace of hydrogen sulphide which can be treated with aeration. GWI mainly takes groundwater from "A" sand and "B" sand. The groundwater level at "A" sand have been observed every month since 1997. According to GWI, the results of the observation of groundwater level in Regions 3 and 4 was EL -16m and EL -30m in 1997 and 2017, respectively. Thus, the groundwater is considerably lower than before.



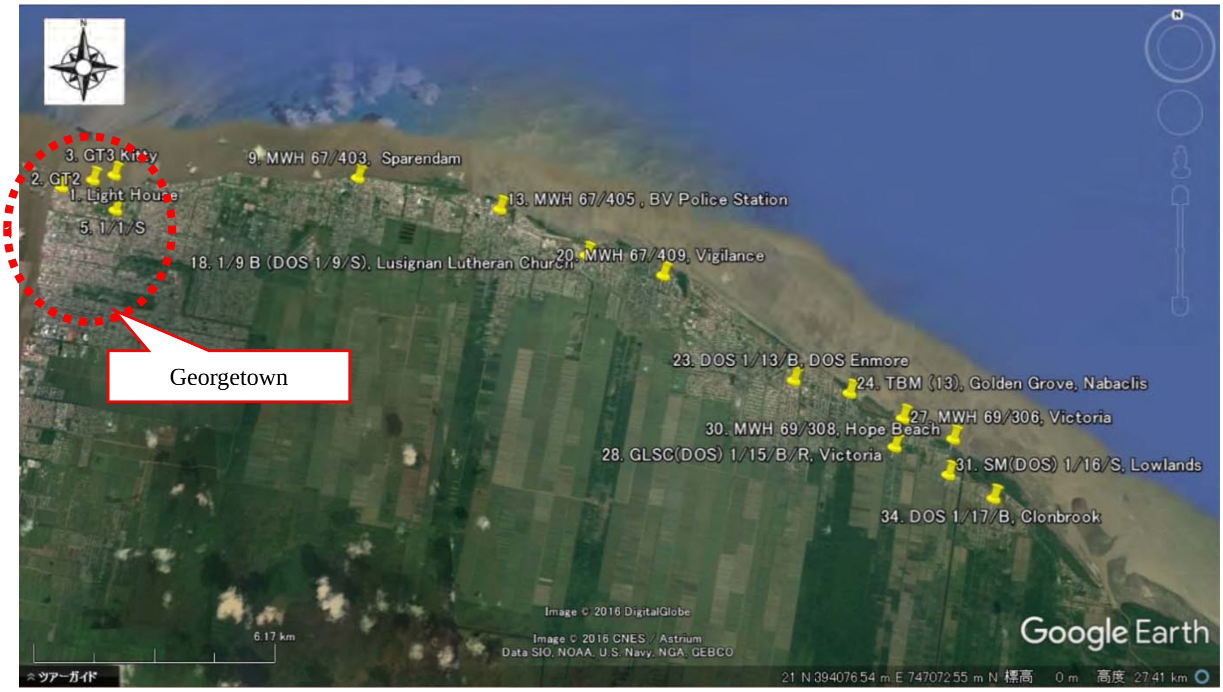
Source: Water Resources Assessment of Guyana、US Army Corps in 1998

Fig. R 1.6.1 Geological Profile around Georgetown

The groundwater level observation data was not organized but provided to the Survey Team during the Survey. It is recommended that GWI should observe, organize and accumulate the data of groundwater level.

1.6.2 Ground Elevation

The ground elevation data is as mentioned in "1.3.2, Geography". As a result of the first survey in Guyana, all related agencies and engineers do not take cognizance of ground subsidence in Georgetown. GL&SC irregularly conducts survey of elevation at national benchmarks along the coastal line including a part of Georgetown. The location and levelling result is as given in **Fig. R 1.6.2** and **Table R 1.6.1**, respectively.



Source: JICA Survey Team prepared, based on the benchmark coordinate provided from GL&SC

Fig. R 1.6.2 Location of National Benchmarks Provided from GL&SC

Table R 1.6.1 Result of Levelling of National Benchmarks

National Benchmark	1974		1997		2010	
	Foot GD	mGD	Foot GD	mGD	Foot GD	mGD
LH	57.11	17.41	57.11	17.41	56.9793	17.37
GT2	61.58443	18.77	61.4078	18.72	61.2886	18.68
GT3 (Kitty PS)	58.1538	17.73	57.4664	17.52	57.1623	17.42
1/1/S	54.4588	16.60	-	-	54.0552	16.48
MWH 67/403	50.412	15.37	50.3758	15.35	50.2105	15.30
MWH 67/405	50.144	15.28	50.2494	15.32	50.1436	15.28
DOS 1/9/S	50.1913	15.30	50.1834	15.30	49.8667	15.20
MWH 67/409	52.411	15.97	52.1848	15.91	52.0712	15.87
DOS 1/13/B	51.3663	15.66	51.3209	15.64	51.271	15.63
TBM Grove/N	55.635	16.96	-	-	55.6961	16.98
MWH 69/306	50.167	15.29	50.2431	15.31	50.2352	15.31
DOS 1/15/B	50.9328	15.52	50.7734	15.48	50.7196	15.46
MWH 69/308	55.995	17.07	-	-	55.7663	17.00
DOS 1/16/S	55.71654	16.98	-	-	55.7601	17.00
DOS 1/17/B	49.3085	15.03	-	-	49.3328	15.04

Source: GL&SC (: National Benchmark in Georgetown)

Based on the above result of levelling of national benchmarks, the difference of levelling result is as shown in the following table. The difference at GT3 (Kitty PS) is about 30cm for 36 years from 1974 to 2010. Other than the national benchmark of GT3, there are small differences in elevation of approximately 10cm for 36 years.

Table R 1.6.2 Difference of Levelling Results of National Benchmark

National Benchmark	1974→1997 (m)	1997→2010 (m)	1974→2010 (m)
LH	0.00	-0.04	-0.04
GT2	-0.05	-0.04	-0.09
GT3 (Kitty PS)	-0.21	-0.09	-0.30
1/1/S	-	-	-0.12
MWH 67/403	-0.01	-0.05	-0.06
MWH 67/405	0.03	-0.03	-0.00
DOS 1/9/S	-0.00	-0.10	-0.10
MWH 67/409	-0.07	-0.03	-0.10
DOS 1/13/B	-0.01	-0.02	-0.03
TBM Grove/N	-	-	0.02
MWH 69/306	0.02	-0.00	0.02
DOS 1/15/B	-0.05	-0.02	-0.06
MWH 69/308	-	-	-0.07
DOS 1/16/S	-	-	0.01
DOS 1/17/B	-	-	0.01

Note: Minus sign "-" indicates downward in a vertical direction, : National Benchmark in Georgetown

1.6.3 Draft of Observation Plan

There is no noticeable information about ground subsidence in Georgetown based on the hearing survey and the existing data except the small difference in elevation of approximately 10cm for 36 years. However, there is a possibility that ground subsidence will be subject to inundation and poor drainage in the future since the water supply in Georgetown have been heavily relying on groundwater over the years, and the result of GWI's observation of groundwater level shows drawdown over time. Hence, it is necessary to continuously observe ground elevation and groundwater level, accumulate data and monitor the ground subsidence in Georgetown. The observation plan for ground elevation and groundwater level are drafted as follows.

(1) Draft of Observation Plan for Ground Elevation

GL&SC irregularly conducts survey of elevation at national benchmarks along the coastal line including a part of Georgetown. The tendency of ground subsidence cannot appropriately be grasped by the existing system for ground elevation observation because the observation is irregular and not in the whole Georgetown.

Therefore, periodical ground elevation observation by using the existing national benchmarks is recommended to grasp the tendency of ground subsidence. Proposed locations of ground elevation observation are as shown in **Fig. R 1.6.3**. Likewise, the outline of ground elevation observation is as given in **Table R 1.6.3.**

(2) Draft of Observation Plan for Groundwater Level

A new observation well is not required because GWI has been observing the groundwater level in Georgetown every month since 1997. It is recommendable that GWI will continue the observation of groundwater level and to share the observed data with the related agencies, like MOA, MPI, MOC, MONR, and so on.

Source: JICA Survey Team and Survey Company (Surveying & Project Management Inc.) checked the location of national benchmark at site based on the GL&SC data.

(⭕ is proposed location of future's observation point for the ground elevation)

Fig. R 1.6.3 Proposed Locations of Ground Elevation Observation

Table R 1.6.3 Outline of Ground Elevation Observation

<table>
<tr><td colspan="3">Observation Frequency: Once a year*
Observation Method: Ground elevation is observed by levelling based on the national benchmark LH</td></tr>
<tr><td>Name: LH (Lighthouse)

Elevation: 17.37 mGD
(Based on levelling in 2010)</td><td>Name: GT3 (Kitty PS)

Elevation: 17.42 mGD
(Based on levelling in 2010)</td><td>Name: GT10

Elevation: 16.35 mGD
(List of benchmarks of GL&SC)</td></tr>
<tr><td>Name: GT13

Elevation: 16.22 mGD
(List of benchmarks of GL&SC)</td><td>Name: GT17

Elevation: 16.61 mGD
(List of benchmarks of GL&SC)</td><td>Name: GT26

Elevation: 16.59 mGD
(List of benchmarks of GL&SC)</td></tr>
</table>

*Source: Guideline for Monitoring of Ground Subsidence (https://www.env.go.jp/houdou/gazou/6132/6914/2356.pdf)
(: Recommended location of ground elevation observation)

- DRR (Dutch Risk Reduction) Team Mission Report (2016)
- On the technical level, the CDC is the lead coordinator. Assistance and guidance in programming is given to the CDC by the Disaster Risk Reduction Platform.

CHAPTER 2 MAJOR CHALLENGES TO THE DRAINAGE SYSTEM IN GEORGETOWN

2.1 Major Causes of Flood

The major causes of flood based on the hearing survey with the related agencies in Guyana and the collected data are as discussed below.

2.1.1 Sea Level Rise

Table R 2.1.1 shows that the MSL near Georgetown have risen to 23cm in 23 years from 1994 to 2017. The rate of sea level rise in the coastal areas of Guyana is approximately 10mm/year, which is much more than the global average of about 2-4mm/year in IPCC (Intergovernmental Panel on Climate Change) Fifth Assessment Report, 2013. Gravity drainage can only take place for about 8 to 10 hours per day. The sea level rise shortens the duration of gravity drainage, which causes the reduction of drainage capacity in Georgetown. Thus, it is assumed that sea level rise causes the frequent flood and inundation damage in Georgetown.

Table R 2.1.1 Sea Level Rise

Name	1979 [mGD]	M/P (1994) [mGD]	1999 [mGD]	2010 [mGD]	2017 [mGD]	Sea Level Rise [m]
Highest Recorded Tide	—	17.19	—	17.19	17.39	+0.20
Mean High Water Spring	—	16.65	—	16.65	16.97	+0.32
Mean High Water Neap	—	15.98	—	15.98	16.51	+0.53
Mean Sea Level	15.52	15.52	15.56	15.66	15.75	+0.23
Mean Low Water Neap	—	14.79	—	14.79	14.83	+0.04
Mean Low Water Spring	—	14.09	—	14.09	14.48	+0.39

Source: MARAD-MPI

As shown in “1.6.2, Ground Elevation,” the gap of elevation between the results of levelling in 1974 and 2010 is approximately 10 cm for 36 years. If the reason of gaps is not surveying error but ground subsidence, the rate which omits ground subsidence from the rate of sea level is 3.27mm/year (refer to **Table R 2.1.2.**) The rate of rise (3.27mm/year) is within the range of global annual average rate of sea level rise (2-4mm/year).

Table R 2.1.2 Rate of Sea Level Rise in Consideration of Ground Subsidence in Georgetown

<table>
<tr><th>Item</th><th>Observed Year</th><th>Vertical Displacement</th><th colspan="2">Annual Average Vertical Displacement</th></tr>
<tr><td>Average Tidal Level in Georgetown</td><td>1979~2017 (for 38 years)</td><td>+230mm</td><td>+6.05mm/year</td><td rowspan="2">+3.27mm/year</td></tr>
<tr><td>National Benchmark in Georgetown</td><td>1974~2010 (for 36 years)</td><td>-100mm</td><td>-2.78mm/year</td></tr>
<tr><td>Global Annual Average Rate of Sea Level Rise</td><td>—</td><td>—</td><td colspan="2">+2~4mm/year</td></tr>
</table>

Source: JICA Survey Team

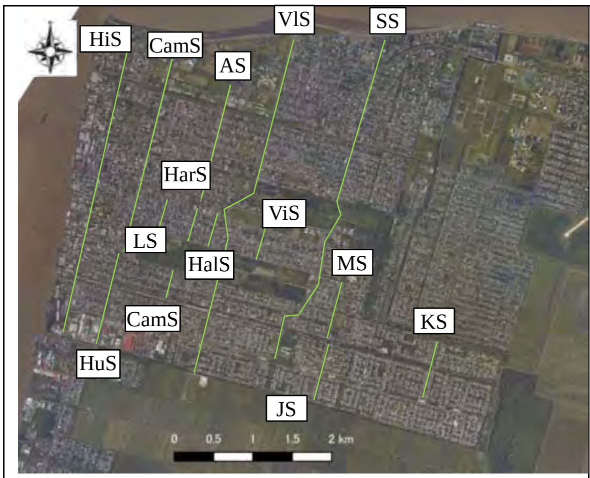
Therefore, there is a possibility that ground subsidence all over Georgetown will cause a relative sea level rise. To support these data, it is useful that periodical ground elevation observation based on “1.6.3, Draft of Observation Plan,” and the verification of ground subsidence phenomenon in Georgetown is conducted.

2.1.2 Human-induced Interference and Narrowing of Drainage Channel due to Urbanization, Development and Informal Settlers

Some stretches of drainage channel have narrowed along with urbanization, and underdrainage have increased along with the development of traffic network. Anchored ships block the channel at the outfall, which may be causing reduction of the drainage capacity and furtherance of siltation.

Particularly, the drainage channels were originally open-channel type but now some of them have become closed conduits due to the construction of factories and road crossings. Moreover, several underground drains are extremely narrow compared to the width of the original open channel. There are many road crossings across drainage channels, and these points are narrower compared to the width of the original open channel.

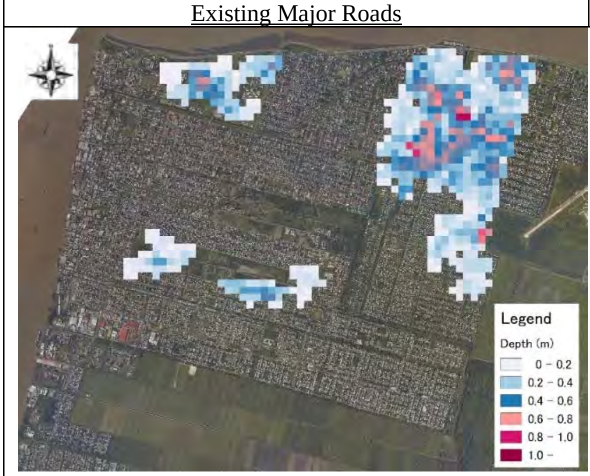
To analyse the impact on flood due to human-induced interference/narrow drainage channel, flood simulation in case of reduction of drainage channel width at a bridge by 25% is conducted. Besides, inundation area due to overflow from drainage channel is extracted. The result of flood analysis is as given in **Fig. R 2.1.1**.



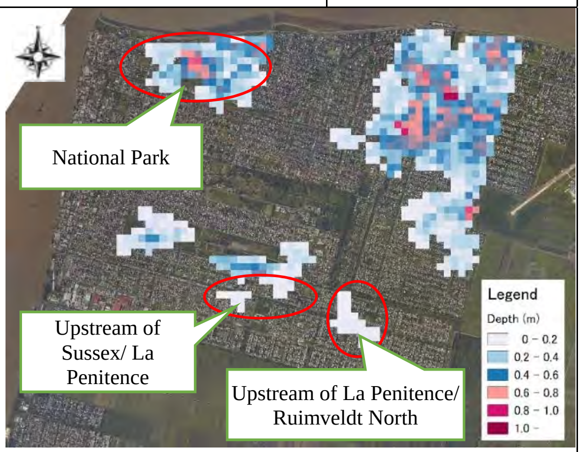
Existing Major Roads

Major Road:
- HiS: High Street
- CamS: Camp Street
- AS: Albert Street
- VlS: Vlissengen Street
- SS: Sheriff Street
- LS: Louisa Street
- HarS: Hardina Street
- HalS: Haley Street
- ViS: Victor Street
- HuS: Hunter Street
- CalS: Callender Street
- MS: Macaw Street
- JS: Jackson Street
- KS: Kaikan Street

(red circle): New inundation or deeper inundation point in case of reduction of width of drainage channel at the point of major road crossing by 25%



In case of no reduction of width of drainage channel (Cross-section survey result as it is)



In case of reduction of width of drainage channel at the point of major road crossing by 25%

Condition of Flood Analysis:
- Lidar data from NDIA is used as topographical information
- Drainage facilities (such as sluice, pumping station) are as-is. The primary drainage channel is modeled. The width of drainage channel at the point of major road crossing is reduced by 25%.
- Probable rainfall is 5-year return period

Fig. R 2.1.1 Result of Flood Analysis (Extraction of Inundation Area due to Overflow from Drainage Channel)

As the result of flood simulation in **Fig. R 2.1.1**, the National Park, the upstream side of Sussex/La Penitence and the upstream side of La Penitence/Ruimveldt North are inundated or have deeper inundations due to human-induced interference/narrowing of drainage channel at the points of road crossing.

Thus, it is assumed that the reduction of drainage capacity due to human-induced interference/narrowing of drainage channel causes the frequent flood and inundation damage in Georgetown. (Refer to **Photo R 2.1.1**)

Lamaha St. Channel (within T&HD): Open channel becomes culvert

Princess St. Channel: Insufficient height of under girder

Secondary Drainage Channel: Narrowed drainage channel and insufficient height of under girder

Photo R 2.1.1 Human-induced Interference and Narrowing of Drainage Channel

As mentioned in "1.4.1, Policy/Strategy, Law/Institution, Plan, Framework, Guideline and Budget at National/Municipal Level," plenty of policies, institutions and legal framework for flood mitigation and drainage system improvement have been developed.

On the other hand, the legal system in Guyana for drainage has the "Laws of Guyana (Chapter 64-03, Drainage and Irrigation Act"). According to this Act, the area within twelve feet shall be kept free for maintenance work by NDIA and continue to be the property of the NDIA. In fact, however, there are many facilities and buildings along the existing drainage channel.

Church St. Sluice (Factory was constructed at the surrounding of the sluice and drainage channel)

Downstream of Ruimveldt North Sluice (Buildings are on right bank)

Princess St. Channel (Houses are built at the vicinity of the channel, and wooden access bridge are installed)

Photo R 2.1.2 Facilities/Buildings along Drainage Channel

Although the "Drainage and Irrigation Act" mentions that NDIA comprehensively manages the surroundings of drainage facilities, M&CC practically works on the relocation of informal settlers along drainage channels in cooperation with the Ministry of Social Protection and MOC. The relocation activity is currently delayed due to the difficulty of coordination.

Additionally, a building and facility which were constructed at the vicinity of the drainage facility before this Act is statutorily not able to be relocated. Hence, drainage improvement work is difficult in Georgetown which is an urbanized and densely populated area along drainage facilities.

The rehabilitation of road pavement, road widening and improvement of intersection have been conducted in Georgetown as required, but there is no Road Development Plan in Georgetown. Several underground drains are extremely narrow at the point of crossing road compared to the width of original open channel. CHPA has a development plan for Georgetown; however, the plan has not gotten across the related agencies and has not been carried out.

Thus, it is assumed that urban development without consideration of drainage capacity causes the frequent flood and inundation damage in Georgetown.

2.1.3 Reduction of Drainage Capacity due to Siltation and Vegetation

There are silt and vegetation in many drainage channels in Georgetown, and these factors might cause the reduction of drainage capacity of the existing drainage facilities. There is a tendency that sedimentation is generated at the downstream side of channel and vegetation is propagated at the upstream side. The main reason of generated siltation and vegetation might be the low flow velocity in the drainage channel because the channel bed gradient is gentle or inverse draft as shown in **Fig. R 2.1.2**.

Besides, since Georgetown lies marginally below mean sea level, gravity drainage can only take place for about 8 to 10 hours per day. Thus, the flow velocity in a drainage channel is zero for almost the whole day. This also encourages siltation and vegetation in the drainage channel and is one of the reasons for the reduction of drainage capacity.

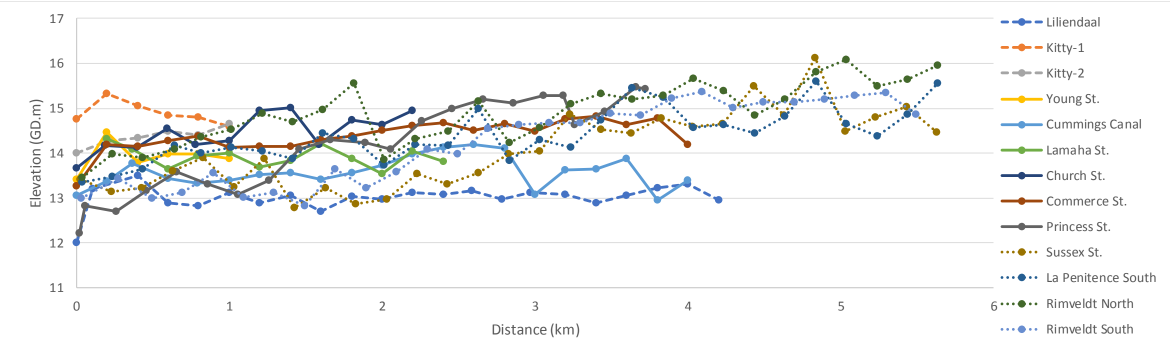


Fig. R 2.1.2 Longitudinal Profile of Primary Channels

As a mentioned above, it is assumed that the reduction of drainage capacity due to siltation and vegetation causes the frequent flood and inundation damage in Georgetown. The siltation and vegetation in drainage channels are as shown in **Photo R 2.1.3** and **Photo R 2.1.4**, respectively.

Drainage Channel at Downstream Side of Cummings Sluice

Drainage Channel at Downstream Side of La Penitence South Sluice

Drainage Channel at Downstream Side of Sussex St. Sluice

Photo R 2.1.3 Examples of Siltation in Drainage Channel

Church St. Channel

Commerce St. Channel

Princess St. Channel

Sussex St. Channel

La Penitence South Channel

Ruimveldt North Channel

Photo R 2.1.4 Examples of Vegetation in Drainage Channel

2.2 Challenges on the Existing Drainage System

The challenges on the existing drainage system based on the hearing survey with the related agencies in Guyana and the collected data are as briefly discussed below.

2.2.1 Lack of Capability of Existing Drainage System

NDIA had proposed in the NDIA Report in 2015 to develop the drainage facilities in Georgetown with a 5-year return period in the short-term plan, and 10-year return period in the long-term plan.

However, as mentioned in **Table R 1.3.10,** "Summary of Drainage Facilities (Existing and Proposed by NDIA)," the existing drainage capacity is totally 101 mm/day, with approximately 2-year return period.

Therefore, the capacity of the existing drainage system does not cope with the rainfall events of up to 5-year return period, and might cause frequent flooding and inundation damage in Georgetown.

2.2.2 Decrepit and Insufficient Maintenance of Drainage Facilities (Channel, Sluice, Pump)

The construction and rehabilitation record of the existing drainage facilities is as presented in **Table R 2.2.1**. More than 300 years, 40 years and 60 years have passed after the construction of drainage channels, pumping stations and sluice in Georgetown, respectively. The period for usage of these drainage facilities is over the guide of expected lifetime as shown in **Table R 2.2.2**. Particularly, these drainage facilities and the parts have intensely deteriorated and became decrepit because the drainage facilities in Georgetown are operated every day.

Table R 2.2.1 Construction and Rehabilitation Record of Existing Drainage Facilities

Facility	Name	Construction and Rehabilitation Record
Drainage Channel		The open channel network was originally developed to irrigate and drain the sugar plantations which occupied the land on which Georgetown now stands in the 17th century. The type of channel is unlined open-channel, but there are many interference and narrowing of underground drains along with urbanization.
Fixed Pumping Station	Liliendaal	Constructed in 1973 (Rehabilitated in 1987 and 1994)
	Kitty	Constructed in 1968 (Rehabilitated in 1993, replaced the units of pump except building around 2009)
Mobile Pump		The mobile pumps were installed beside the existing sluice in 2005 as emergency response in heavy floods. The manufacturing year of the mobile pumps remains unknown. As of March 2017, mobile pumps are located beside Young St. sluice, Lamaha St. sluice, Church St. sluice (Not functioning due to lack of battery), Commerce St. sluice, Princess St. sluice (not functioning due to damage of propeller at suction port), Ruimveldt North sluice.
Sluice	Common Subject Matter	All gates are wooden and the raw materials are Greenheart Tree in Guyana. The gates are replaced every 5 to 6 years, generally. The gates are lubricated not regularly but situationally to smoothen them. Hoist device is restored and replaced after broken.
	Young St.	Constructed year remains unknown
	Cummings Canal	Constructed in 1923
	Lamaha St.	Constructed in 1935 (The hoist device (Chain Block Type) was broken and not restored. The gate remains closed as of March 2017)
	Church St.	Constructed in 1923 in the factory
	Commerce St.	Constructed in 1924 (Water leakage at gate)
	Princess St.	Constructed in 1932 (Water leakage at gate)
	Sussex St.	Construction year remains unknown
	La Penitence South	Constructed in 1954
	Ruimveldt North	Construction year remains unknown
	Ruimveldt South	Construction year remains unknown

Source: JICA Survey Team prepared based on site investigation and hearing survey

Table R 2.2.2 Guide of Expected Lifetime for Drainage Facilities

Japanese Standards	Facility/Part	Expected Lifetime	
		Reliable Period of Replacement/Reconstruction	Average Period of Replacement/Reconstruction
Ministerial Order on Expected Lifetime for Depreciable Asset*1	Channel	30	
	Sluice	25	
	Pump	15	
Manual for Inspection, Maintenance, Renewal of Gate Facilities*2	Structural part of gate	32	56
	Roller part of gate	23～32	49～55
	Wire rope	14 (regular use), 17 (waiting)	35
	Brake, deceleration device	27～30	41～43
Manual for Inspection, Maintenance, Renewal of Pump Facilities *3	Main pump (vertical)	12～26	20～32
	Main pump (horizontal)	12～25	30～36
	Diesel	14～26	37
	System device	6～15	23～35

Source:
*1 http://www.soumu.go.jp/main_sosiki/kenkyu/chikoujiken/pdf/070730_1_1_2_04_B02.pdf
*2 https://www.mlit.go.jp/common/000014193.pdf
*3 https://www.mlit.go.jp/common/000014194.pdf

Regarding the maintenance of drainage channels, manual desilting and mowing in the channel are carried out in Georgetown (refer to **Photo R 2.2.1.**) Although M&CC cleans and desilts the drainage channels with assistance from related agencies, the maintenance work is not executed at enough frequency due to the long extent of the drainage channel.

Photo R 2.2.1 Mowing at Drainage Channel

Regarding maintenance of sluice and pumping station, the device and parts are basically restored and replaced after broken as needed. Some rehabilitation work for the drainage facilities are delayed even though gate operation and water interception are problematic.

2.2.3 Operational Restriction by Manual Operation for Sluice and Pump Facilities

The drainage facilities are frequently operated manually since Georgetown is located on a poorly-drained area, topographically. Hence, the operational delay of drainage facilities causes the flood and inundation damage in Georgetown. In the past, there were cases of water flowing back from Demerara River to the drainage channel because the operator kept the gate open during high tide. However, there has been no significant damage due to this and there is no record of physical damage to an operator during operation. Adequate operators are deployed since operators are stationed at the sluice in three shifts to operate the gate and pump.

However, the operation of sluice takes time since the opening and closing of sluice is done manually. (According to the operator, the chain block type needs 20 minutes for opening and 5 minutes for closing, wire rope winch type needs 30 minutes for opening, 1 minute for closing). Moreover, since gates are dropped by gravity, it is difficult to close a gate in case of water level difference between upstream and downstream of gate and large velocity in the channel. The existing gate system is not able to immediately response in emergency situations, and the operational period per day is restricted.

Wire Rope Winch Type (Princess St. Sluice)

Chain Block Type (Commerce St. Sluice)

Photo R 2.2.2 Types of Hoist Device of Existing Sluice

CHAPTER 3 PRELIMINARY DRAINAGE IMPROVEMENT PLAN

3.1 Recommendation for Drainage Improvement in Georgetown

3.1.1 Functional Recovery of Existing Drainage Facilities

(1) Existing Drainage Channel

As mentioned in Chapter 2, the challenges on the existing drainage channel are as given below.

- Human-induced Interference and Narrowing of Drainage Channel due to Urbanization, Development and Informal Settlers
- Reduction of Drainage Capacity due to Siltation and Vegetation

(a) Recovery and Securement of Channel Width and Flow Section

There are some obstructed and narrowed sections of drainage channels by human-induced activities due to the urbanization, development and informal settlers. These sections require the widening of drainage channels at road crossing sections and heightening of existing bridges to recover the function of the existing drainage channel, as shown in the following figures.

Need to Widen Drainage Channel at Road Crossing Section (Extension of Bridge)

Need to Heighten Existing Bridge so as not to Reduce the Area of Drainage Channel

Source: JICA Survey Team

Fig. R 3.1.1 Widening and Expansion of Narrowed Sections of Drainage Channel

There are many decrepit bridges. It is required to secure the sectional area at road crossing sections as large as the section of the existing channel to keep the drainage capacity at the timing of bridge reconstruction or upgrade. Hence, it is important for NDIA to cooperate with M&CC, MPI, and CHPA.

On the other hand, the Laws of Guyana "Chapter 64-03, Drainage and Irrigation Act", prohibits construction works within 12 ft. from the existing drainage facilities. Dissemination of this Act to related agencies/companies/residents and legal compliance are important in order to secure adequate maintenance space and to prevent narrowing of drainage channels due to human-induced interference like urbanization, development and informal settlers.

Inlet Culvert of Liliendaal Pumping Station

Liliendaal pumping station has 8.5m^3/s of discharge capacity by two pumps. On the other hand, width of box culvert at inlet of Liliendaal pumping station is 7m, and its flow capacity is estimated as 2~6m^3/s (varied by the water depth).

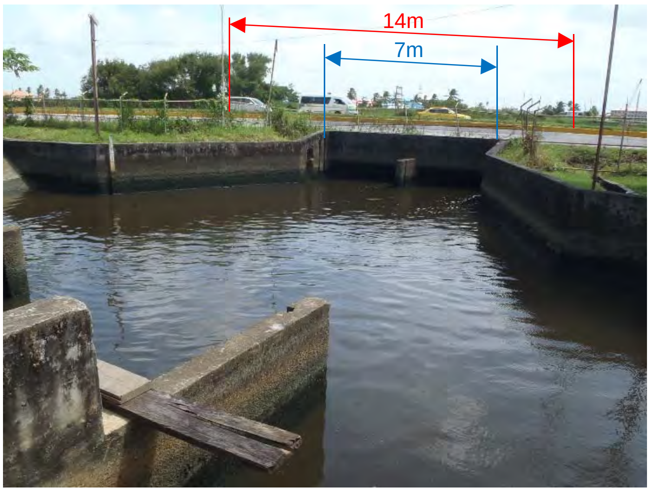


Fig. R 3.1.2 Widening Inlet Culvert of Liliendaal Pumping Station

Flow capacity of box culvert at inlet of Liliendaal pumping station is smaller than discharge capacity of pump. Thus, Liliendaal pumping station cannot exert its designed drainage performance. Width of box culvert at inlet of Liliendaal pumping station shall be not smaller than 14m.

(b) Maintenance Work for Drainage Channel

The capacity of drainage channels is reduced due to siltation and vegetation. Thus, periodic dredging work for siltation and removal work for vegetation in the drainage channels are required to recover the function of the existing drainage channel, as illustrated in **Fig. R 3.1.3**.

Removal of Silt in Drainage Channel

Removal of Vegetation in Drainage Channel

Source: JICA Survey Team

Fig. R 3.1.3 Removal of Silt and Vegetation in Drainage Channel

Presently, M&CC situationally conducts dredging of silt and removal of vegetation in the drainage channels once or twice a year by manual maintenance work. However, this maintenance work is not sufficient since the total distance of drainage channels including primary, secondary and tertiary drainage channels are long and the expense, manpower and working efficiency (by manpower) are restricted.

Therefore, the points of attention in maintenance work for functional recovery of the existing drainage channels are as described in the following:

- Efficient maintenance work (Dredging work by heavy equipment like backhoe and proper disposal by dump trucks in consideration of hauling cycle)
- Effective maintenance work (Prioritization of dredging work at/in noteworthy area of siltation/vegetation, gentle longitudinal gradient of drainage channel, flood-prone area, inundation area by flood simulation, etc.)

Flood-prone areas based on the hearing survey, overflow points from drainage channel by the flood simulation result, primary drainage channels and drainage catchment areas are as shown in **Fig. R 3.1.4**. Based on this, the prioritized area for dredging work is as given in **Table R 3.1.1**.

Table R 3.1.1 Prioritized Area for Dredging Work

Liliendaal : From midstream to downstream	Princess St : From midstream to downstream
Kitty1, 2 : From upstream to downstream	Sussex St. : From midstream to downstream
Young St. : At upstream side	La Penitence South : From upstream to downstream
Cummings Canal : At upstream and downstream side	Ruimveldt North : At upstream and downstream side
Lamaha St. : At midstream and downstream side	Ruimveldt South: At upstream

Source: JICA Survey Team

: Flood-prone area based on hearing survey, : Overflow point from drainage channel by flood simulation result

Source: JICA Survey Team

Fig. R 3.1.4 Flood-Prone Area, Overflow Point from Drainage Channel, Primary Drainage Channel and Drainage Catchment Area

(2) Existing Drainage Sluice

As mentioned in "2.2.2, Decrepit and Insufficient Maintenance of Drainage Facilities (Channel, Sluice, and Pump)", more than 60 years have passed after the construction of drainage sluice in Georgetown, and un-exchangeable parts like gatepost have become decrepit. All gates are made of Greenheart Tree which is a tough and specialty wood product of Guyana. The wooden gates are normally replaced every five to six years. M&CC conducts the maintenance work for the sluice. Although the gates are lubricated situationally to smoothen gate operation, the lubricant is intensely wasted due to the frequent operation, on average, 2 times opening and closing per day. Hence, it is desirable to rebuild all the existing sluices to recover the designed functions.

Reconstruction of all sluices require considerable time and cost. Thus, emergency repair of at least the following parts of sluice is required to recover their original functions.

Table R 3.1.2 Required Emergency Repair for Parts of Sluice

Sluice	Emergency Repair
Lamaha St.	Repair of hoist device (Chain Block Type)
Princess St.	Repair of gate at water leakage portion

Source: JICA Survey Team

In the gate at Princess St. the sluice requires repair at the water leakage portion as mentioned in the table above. It is noteworthy that there is a small amount of water leakage at all the existing gates based on the hearing survey.

Moreover, it is necessary to desilt and remove vegetation at the upstream and downstream of each sluice, periodically.

(3) Existing Drainage Pump

As mentioned in "2.2.2, Decrepit and Insufficient Maintenance of Drainage Facilities (Channel, Sluice, and Pump)", more than 40 years have passed after the construction of drainage pumping stations at Liliendaal and Kitty, which have been broken repeatedly and not restored until now. The impeller and draft tube at the Liliendaal pumping station were rehabilitated in 2014. Pumping facilities except the building were replaced at Kitty pumping station around 2010. Hence, the function of these fixed pumping stations is maintained because these parts have been recently rehabilitated or replaced.

On the other hand, mobile pumps have been installed beside the existing drainage sluice as a stopgap measure in the flood event of 2005. The production date of mobile pumps is unknown but already decrepit. Mobile pumps were installed beside the sluices at Young St., Lamaha St., Church St., Commerce St., Princess St., and Ruimveldt North as of 2017.

Propeller of mobile pump at Princess St. Sluice had been damaged and under restoration by M&CC in February 2017. The Survey Team confirmed that damaged pump at Princess St. Sluice had been restored and re-installed at its original position in August 2017.

At present, following repair of mobile pump is required as an emergency repair to recover its designed function.

Table R 3.1.3 Emergency Repair Required for Parts of Mobile Pump

Mobile Pump	Emergency Repair
Vicinity of Church St. Sluice	Installation of new battery

Source: JICA Survey Team

Moreover, it is necessary to desilt and remove vegetation at the vicinity of each drainage pumping station/facilities, periodically.

(4) Operation and Maintenance Work

M&CC and/or NDIA have not prepared the operation and maintenance (O&M) plan for drainage facilities as well as cost estimation for O&M and the budget. The preparation of short/long term plan of O&M for drainage facilities is the role and responsibility of GDA. It is necessary for GDA to prepare the O&M plan to periodically conduct the O&M for drainage facilities and to procure the O&M equipment by M&CC.

The measurement of drainage capacity at the existing facilities may be indicators to evaluate the efficacy of function of the existing drainage facilities. As a result of hearing survey, NDIA has an experience of measurement of drainage capacity at the existing sluice and pumps. It is desirable to conduct periodic measurements of drainage capacity at the existing facilities in order to recover their designed functions.

3.1.2 Drainage Improvement Plan (Draft)

3.1.2.1 Basic Policy

(1) Protection Level of Drainage Facilities

The protection level of drainage facilities in Georgetown is set at 5-year return period. Generally, the protection level of drainage facilities in an urban area is set between 5 and 10-year return period. The rainfall characteristic of Georgetown is that rainfall intensity at peak time is high and rainfall duration of high-intensity is short. Thus, the protection level is set at 5-year return period, consistent with the NDIA Report (2015) and to avoid excessive drainage facility planning. The protection level of drainage facilities in the NDIA Report (2015) is also set at 5-year return period. Some degree of inundation should be allowed in case of excessive rainfall over the protection level (over 5-year return period).

(2) Selection of Countermeasures for Flood Mitigation and Drainage Improvement

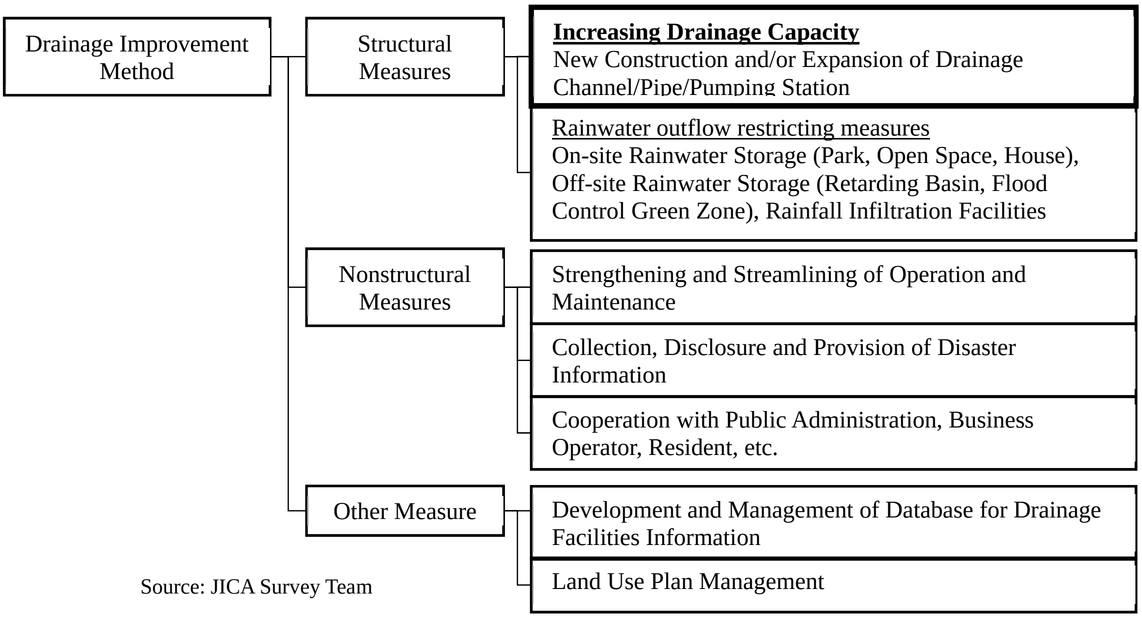
Proposed countermeasures for flood mitigation and drainage improvement are as shown in the following table.

Table R 3.1.4 Proposed Countermeasures for Flood Mitigation and Drainage Improvement

Item	Major Cause/Challenges	Proposed Countermeasures
Major Causes of Flood	Sea Level Rise	• Increasing drainage capacity (Speeding up gate operation, increasing capacity of drainage pump)
	Human-induced Interference and Narrowing of Drainage Channel due to Urbanization, Development and Informal Settlers	• Increasing drainage capacity (Improvement of drainage channel) • Rainwater outflow restricting measures • Cooperation with public administration, business operator, resident, etc. • Land use plan management
	Reduction of Drainage Capacity due to Siltation and Vegetation	• Increasing drainage capacity (Improvement of drainage channel) • Strengthening and streamlining of operation and maintenance
Challenges to Existing Drainage System	Lack of Capability for Existing Drainage System	• Increasing drainage capacity (Improvement of drainage channel, reconstruction of sluice and increasing capacity of drainage pump)
	Decrepit and Insufficient Maintenance of Drainage Facilities (Channel, Sluice, Pump)	• Increasing drainage capacity (Improvement of drainage channel and reconstruction of sluice) • Strengthening and streamlining of operation and maintenance
	Operational Restriction by Manual Operation for Sluice and Pump Facilities	• Increasing drainage capacity (Speeding up gate operation)
Other Countermeasures for Flood Mitigation and Drainage Improvement		• Promotion of disaster resilient city • Collection, disclosure and provision of disaster information • Development and management of database for drainage facilities information

Source: JICA Survey Team

The above countermeasures were sorted out and the classifications of drainage improvement method in Georgetown are as given in the following figure.



Source: JICA Survey Team

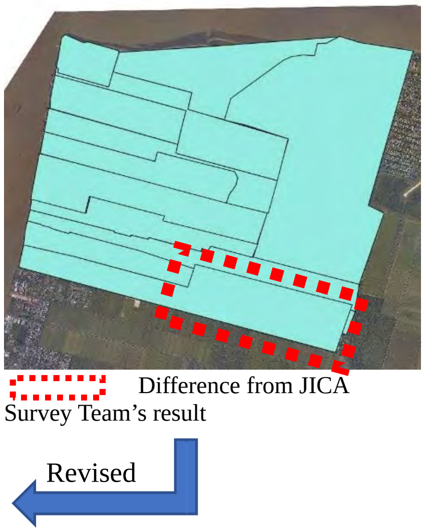
Fig. R 3.1.5 Classification of Drainage Improvement Method

Structural measures are basically major countermeasures for drainage improvement to achieve a target. The objective of non-structural measures is to conduct efficient operation and maintenance and to mitigate the damage in the case of occurrence of excessive rainfall over the protection level.

3.1.2.2 Natural Condition for Drainage Improvement Plan

(1) Drainage Catchment Area in Georgetown

Based on the drainage catchment area and Lidar data collected from the NDIA runoff analyst, the Survey Team reviewed the drainage catchment area in Georgetown. As a result, the drainage catchment areas of Ruimveldt North and Ruimveldt South are modified to the following figure due to inconsistency between the drainage catchment area and the drainage channel.



Prepared by JICA Survey Team   Provided by NDIA runoff analyst

Source: Prepared by JICA Survey Team based on the collected drainage catchment area and Lidar data from NDIA runoff analyst

Fig. R 3.1.6 Drainage Catchment Area in Georgetown (JICA Survey Team)

Table R 3.1.5 Drainage Catchment Area of Primary Drainage Channel (JICA Survey Team)

Primary Drainage Channel	Catchment Area (km^2)	Length of Channel (km)
Liliendaal	8.19	4.37
Kitty-1	0.81	1.53
Kitty-2	1.59	1.10
Young St.	0.63	1.10
Cummings Canal	1.88	3.25
Lamaha St.	1.36	2.24
Church St.	1.33	4.07
Commerce St.	1.53	3.54
Princess St.	2.42	3.87
Sussex St.	1.30	3.93
La Penitence South	1.97	5.74
Ruimveldt North	2.30	5.72
Ruimveldt South	2.25	5.62

(2) Rainfall Condition

(a) Probable Rainfall

Based on the daily rainfall data from 1886 to 2016 at the Botanical Gardens Meteorological Observatory in Georgetown which was provided by HS-MOA, the JICA Survey Team conducted rainfall analysis and the results show that there is not much difference in the probable rainfall results of NDIA and the JICA Survey Team. The rainfall frequency analysis results are as given in the following table.

Table R 3.1.6 Rainfall Frequency Analysis Results

Return Period	Rainfall Intensity (mm/day)	
	Estimated by NDIA (Rainfall data from 1886 to 2015)	Estimated by JICA Survey Team (Rainfall data from 1886 to 2016)
2	102	102.7
3	116	116.5
5	132	132.4
10	151	153.3
50	194	203.0
100	225	225.8

Source: NDIA and JICA Survey Team

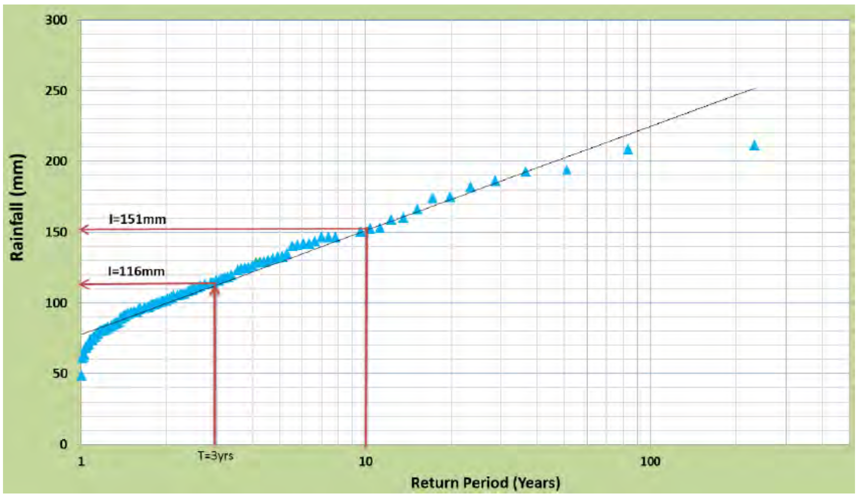


Fig. R 3.1.7 Rainfall Frequency Analysis Result by NDIA (1886 to 2015)

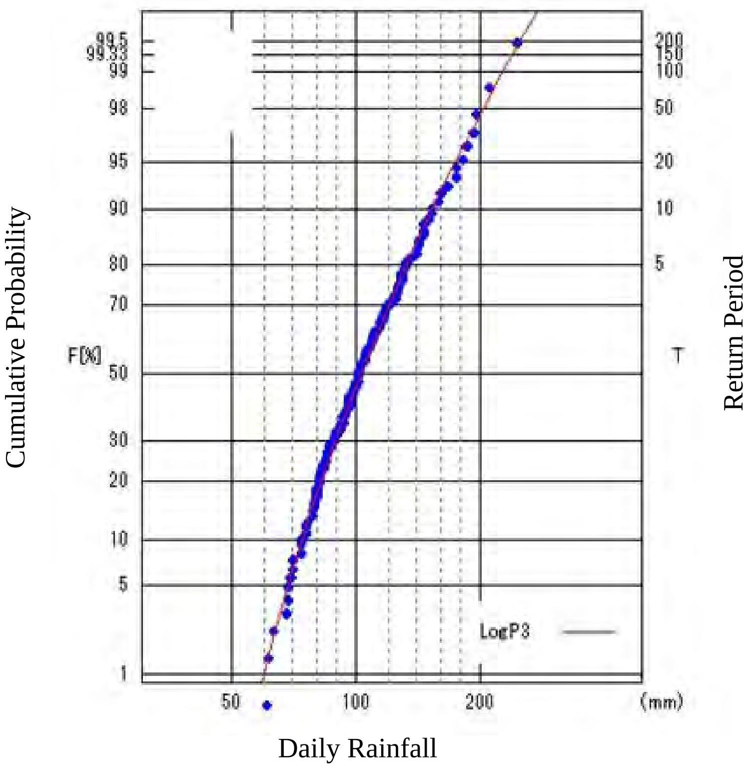


Fig. R 3.1.8 Rainfall Frequency Analysis Results of JICA Survey Team (1886 to 2016)

(b) Hyetograph

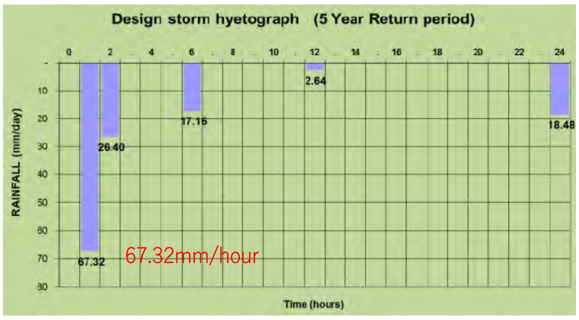


Fig. R 3.1.9 Design Storm Hyetograph of 5-Year Return Period (NDIA Report 2015)

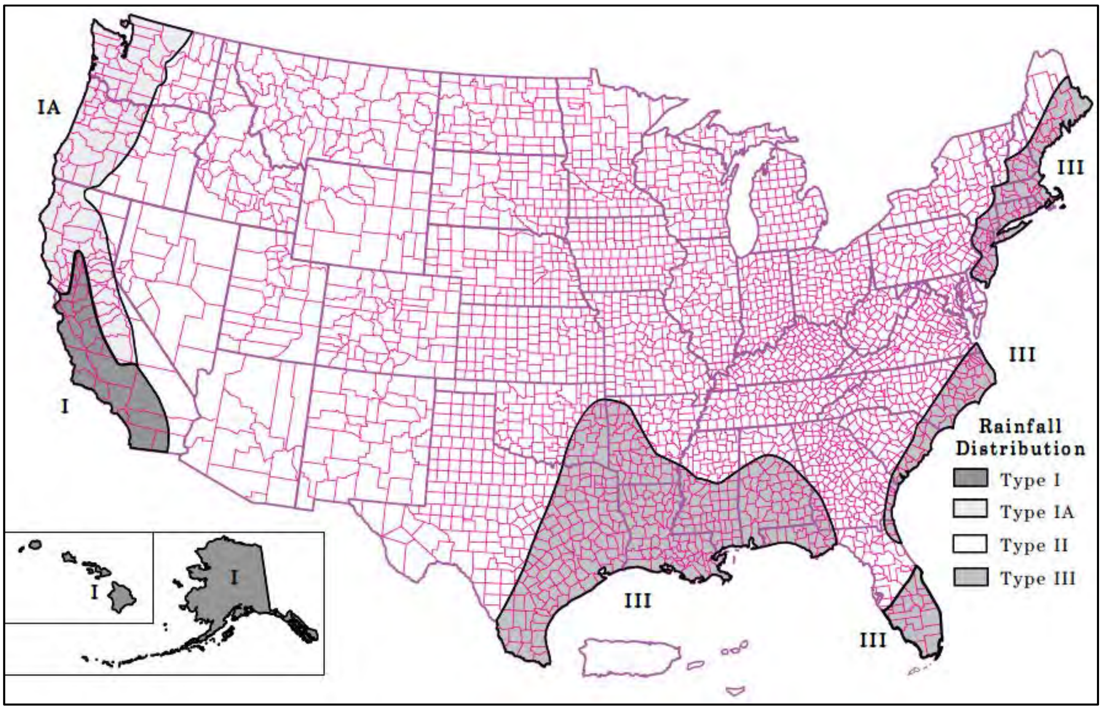
Hyetograph of design storm is assumed by collected daily rainfall data from HS-MOA since hourly rainfall data were not collected.

The hyetograph which is adopted in the NDIA Report (2015) on runoff analysis is as shown in **Fig. R 3.1.9**.

This hyetograph is unexampled and the adequacy cannot be assessed due to no hourly rainfall data in Georgetown. Thus, the hyetograph in the NDIA Report (2015) is not adopted but a general centralized model rainfall is adopted in the Survey. However, it should be noted that the peak rainfall intensity of the hyetograph in the NDIA Report is relatively high (67.32 mm/hour). The higher peak rainfall intensity is, the larger runoff volume per hour and the larger impact on drainage channel become.

The preparation of hyetograph used the SCS (Soil Conservation Service) hypothetical storm which is commonly used in HEC-HMS (The Hydrologic Engineering Centre - Hydrologic Modelling System), and the centralized model rainfall is adopted as a type of hyetograph.

To represent various regions of the United States, NRCS (Natural Resources Conservation Service) developed four types of 24-hour rainfall distributions (I, IA, II, and III) from the storm data. The type of 24-hour rainfall and applied area in the USA is as given in **Fig. R 3.1.10**, and accumulated curve of 24-hour rainfall in SCS hypothetical storm is as shown in **Table R 3.1.7**.



Source: Urban Hydrology for Small Watersheds TR-55

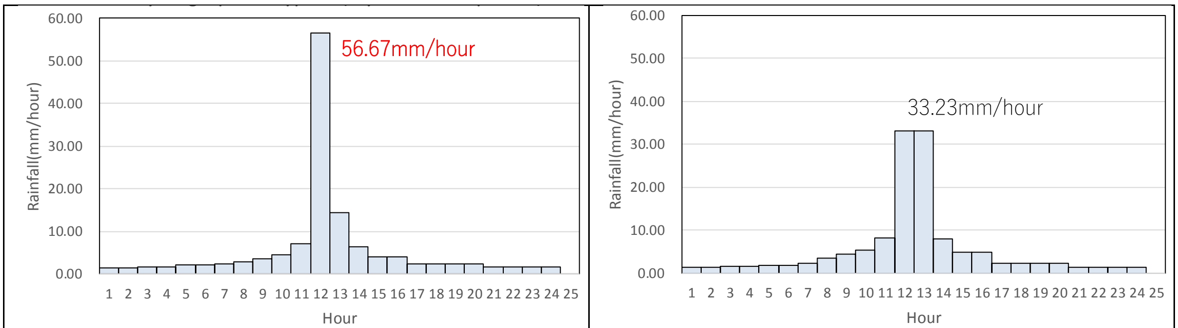
Fig. R 3.1.10 Types of 24-Hour Rainfall and Applied Area in USA

Table R 3.1.7 Accumulated Curve of 24-Hour Rainfall in SCS Hypothetical Storm

Time(hr)	24hr precipitation temporal distribution			
	Type I	Type IA	**Type II**	Type III
0.00	0.000	0.000	**0.000**	0.000
2.00	0.035	0.050	**0.022**	0.020
4.00	0.076	0.116	**0.048**	0.043
6.00	0.125	0.206	**0.080**	0.072
7.00	0.156	0.268	**0.098**	0.089
8.00	0.194	0.425	**0.120**	0.115
9.00	0.254	0.520	**0.147**	0.148
10.00	0.515	0.577	**0.181**	0.189
11.00	0.624	0.624	**0.235**	0.250
12.00	0.682	0.664	**0.663**	0.500
13.00	0.727	0.701	**0.772**	0.751
14.00	0.767	0.736	**0.820**	0.811
16.00	0.830	0.800	**0.880**	0.886
20.00	0.926	0.906	**0.952**	0.957
24.00	1.000	1.000	**1.000**	1.000

Source: NRCS (https://www.wcc.nrcs.usda.gov/ftpref/wntsc/.../SCSrainfallDistTimeTransformations.xlsx)

The applicable type of 24-hour rainfall is Type-II or Type-III since Guyana is located on the southwestern area of the USA. As shown in **Fig. R 3.1.11**, the peak rainfall intensity of the Type-II hyetograph is 56.67mm/hour and relatively high. In the Survey, the Type-II hyetograph is applied because the feature of hyetograph is similar to the hyetograph in the NDIA Report.



Hyetograph of Type II (5-year return period)

Hyetograph of Type III (5-year return period)

Source: JICA Survey Team

Fig. R 3.1.11 Comparison between Type-II and Type-III Hyetographs (5-Year Return Period)

3.1.2.3 Recommendation of Future Plan for Drainage Improvement

(1) Increasing Drainage Capacity (Improvement of Drainage Channel, Sluice and Pumping Station)

The improvement of existing primary drainage channels, sluices and pumping station and the construction of new pumping stations are recommended as the future plan of the most effective structural measure on drainage improvement.

The target improvement level of major drainage facilities is designed as to be able to drain the peak run-off of 5-year probable rainfall promptly by drainage channel under gravity flow and the pumping station.

(a) Design Rainfall

Design rainfall was prepared by model pattern of centre-concentrated type. Design rainfall pattern of 5-year probable rainfall was applied to plan main drainage channels and pumping stations. Hourly rainfall and daily rainfall are shown in the table below.

Table R 3.1.8 Design Rainfall

Item	unit	5-year Probable Rainfall	10-year Probable Rainfall
Daily Rainfall	mm/day	**132.4** (Refer to Table R 3.1.6)	153.3
Hourly Rainfall (Peak)	mm/hour	**56.67** (Refer to Fig. R 3.1.11)	65.61

Source: calculated by JICA Survey Team

(b) Calculation of Run-off (Run-off Analysis: Rational Formula)

(i) Run-off Model

Run-off in the target area was calculated by the rational formula. Inundation in urban area usually occurs due to insufficient drainage capacity for peak flow caused by high-intensity rainfall in short-time duration. Therefore, the rational formula, with which run-off discharge can be computed on the safe side, is employed in consideration of the present land-use in the target area, as shown below. The rational formula is as follows.

Rational formula $$Q = \frac{1}{360} \cdot C \cdot I \cdot A$$

Where,

Q : Run-off (m^3/s)
C : Run-off coefficient
I : Rainfall intensity (mm/h)
A : Drainage area (ha)

(ii) Run-off Coefficient

Run-off coefficient was set based on the condition of present land-use. Overall run-off coefficient was set based on the run-off coefficient by land use in consideration of the urban development plan and/or the existing land use on the drainage catchment area.

≪Overall Run-off Coefficient≫

$$C = \sum_{m=1}^{m} Ci \cdot Ai / \sum_{m=1}^{m} Ai$$

where;
C : Overall Run-off Coefficient
Ci : Run-off coefficient by land use
Ai : Area by land use
m : Number of land use

Table R 3.1.9 Run-off Coefficient by Land Use

Land Use		Run-off Coefficient
Residential Area	Residential area with little unused area	0.80
Suburban Area 1	Suburban area with small gardens	0.65
Suburban Area 2	Suburban area with large gardens	0.40
Industrial Area		0.65
Agricultural Area		0.30
Park		0.25

Source: JICA Survey Team based on Guideline for Sewerage Facilities Plan and Design (Japan Sewage Works Association)

Green areas, such as the National Park, Botanical Gardens and Le Repentir Cemetery, are substantially functioning as On-site Rainwater Storage. Run-off coefficient was calculated on the precondition that rainwater outflow restricting the function of green areas will be kept in the future, and future land use is the same as the present land use. Therefore, these green areas need to be conserved as the present condition in the future.

(iii) Calculation of Run-off

Calculation results of run-off of each sub-catchment area are as shown in the following table.

Table R 3.1.10 Calculation Results of Run-off

No.	Name of Sub-Catchment Area	Catchment Area (A) [km^2]	Runoff Coefficient (C)	Rainfall Intensity (I) [mm/hr]	Design Discharge (Q) [m^3/s]
1	Liliendaal	8.19	0.35	13.8	11.0
2-1	Kitty1(West)	0.81	0.25	27.9	2.0
2-2	Kitty2(East)	1.59	0.60	24.9	7.0
3	Young Street	0.63	0.60	48.8	6.0
4	Cummings Canal	1.88	0.65	22.1	8.0
5	Lamaha Street	1.36	0.65	23.1	6.0
6	Church Street	1.33	0.60	30.2	7.0
7	Commerce Street	1.53	0.35	18.7	3.0
8	Princess Street	2.42	0.60	23.1	10.0
9	Sussex Street	1.30	0.60	21.0	5.0
10	La Penitence South	1.97	0.50	22.0	7.0
11	Ruimveldt North	2.30	0.50	22.1	8.0
12	Ruimveldt South	2.25	0.50	19.8	7.0

Source: JICA Survey Team

(c) Increasing Drainage Capacity (Improvement of Drainage Channel, Sluice and Pumping Station)

Based on the calculation results of run-off, the future improvement plan of drainage facilities is as shown in the following table.

All the existing drainage channels are required to improve, and pumping station is needed to be installed at the outfall of each primary drainage channel. The development of pumping stations includes the construction of sluice for gravity drainage during low tide and to prevent backward flow during high tide.

Table R 3.1.11 Future Improvement Plan of Drainage Facilities

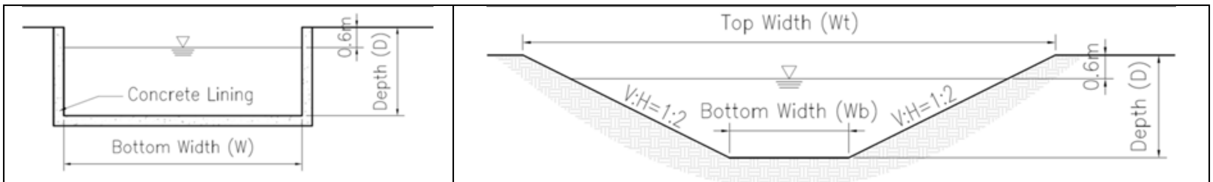
No.	Name of Sub-Catchment Area	Catchment Area [km^2]	Design Flow Q [m^3/s]	Proposed Facilities: Pumping Station Discharge Capacity [m^3/s]	Proposed Facilities: Improvement of Drainage Channel
1	Liliendaal	8.19	11.0	11.0 + Sluice	- Widening of Existing Earth Channel or - Change to Concrete Lining Channel
2-1	Kitty1(West)	0.81	2.0	2.0 + Sluice	
2-2	Kitty2(East)	1.59	7.0	7.0 + Sluice	
3	Young Street	0.63	6.0	6.0 + Sluice	
4	Cummings Canal	1.88	8.0	8.0 + Sluice	
5	Lamaha Street	1.36	6.0	6.0 + Sluice	
6	Church Street	1.33	7.0	7.0 + Sluice	
7	Commerce Street	1.53	3.0	3.0 + Sluice	
8	Princess Street	2.42	10.0	10.0 + Sluice	
9	Sussex Street	1.30	5.0	5.0 + Sluice	
10	La Penitence South	1.97	7.0	7.0 + Sluice	
11	Ruimveldt North	2.30	8.0	8.0 + Sluice	
12	Ruimveldt South	2.25	7.0	7.0 + Sluice	

Source: JICA Survey Team

Table R 3.1.12 Dimensions of Drainage Channel for Improvement

No.	Name of Sub-Catchment Area	Catchment Area	Design Flow	Length of Main Channel	Longitudinal Gradient	Channel Depth	Channel Width		
							Concrete Channel	Earth Channel	
		[km^2]	Q [m^3/s]	L [km]	-	D [m]	W [m]	Wb [m]	Wt [m]
1	Liliendaal	8.19	11.0	4.37	1/7,000	2.6	10.0	10.0	18.0
2-1	Kitty1(West)	0.81	2.0	1.53	1/8,000	2.6	3.0	1.0	9.0
2-2	Kitty2(East)	1.59	7.0	1.10	1/2,000	2.6	4.0	2.0	10.0
3	Young Street	0.63	6.0	1.10	1/2,500	2.6	4.0	2.0	10.0
4	Cummings Canal	1.88	8.0	3.25	1/10,000	2.6	9.0	8.0	16.0
5	Lamaha Street	1.36	6.0	2.24	1/6,000	2.6	6.0	4.0	12.0
6	Church Street	1.33	7.0	4.07	1/3,000	2.6	5.0	3.0	11.0
7	Commerce Street	1.53	3.0	3.54	1/4,000	2.1	4.0	2.0	8.0
8	Princess Street	2.42	10.0	3.87	1/2,000	2.6	6.0	4.0	12.0
9	Sussex Street	1.30	5.0	3.93	1/4,000	2.6	4.0	2.0	10.0
10	La Penitence South	1.97	7.0	5.74	1/3,000	2.1	7.0	6.0	12.0
11	Ruimveldt North	2.30	8.0	5.72	1/3,000	2.6	6.0	3.0	11.0
12	Ruimveldt South	2.25	7.0	5.62	1/4,000	2.6	6.0	3.0	11.0

Source: JICA Survey Team



In case of Concrete Channel

In case of Earth Channel

Source: JICA Survey Team

Fig. R 3.1.12 Typical Cross Sections of Drainage Channel

(d) Issues on the Future Improvement Plan of Drainage Facilities

The future improvement plan of drainage facilities might include the following challenges:

- A part of the drainage channel in Georgetown has become a culvert due to urbanization. Land acquisition for the expansion of drainage channel might be difficult because of the urbanization of Georgetown. Thus, there is an option on the installation of concrete lining channel instead of unlined existing channel to reduce the roughness and to increase the drainage capacity of the channels. However, the construction cost of concrete-lined channel is approximately 5 to 6 times as much as the unlined channel.
- Sufficient space for the construction of pumping station cannot be secured at Lamaha Street channel and Church Street channel.
- There is a vacant land at the downstream side of Liliendaal, and the vacant land might be developed for effective utilization of land. In this case, it is necessary to increase the drainage capacities of channel and pump because the run-off volume will increase due to urbanization.
- Sewer water flows in the drainage channel. Water contamination and mal-odour might emerge in the future.

(e) Rough Cost Estimation of Improvement of Drainage Channel, Sluice and Pumping Station

Table R 3.1.13 Rough Cost Estimation of Increasing Drainage Capacity

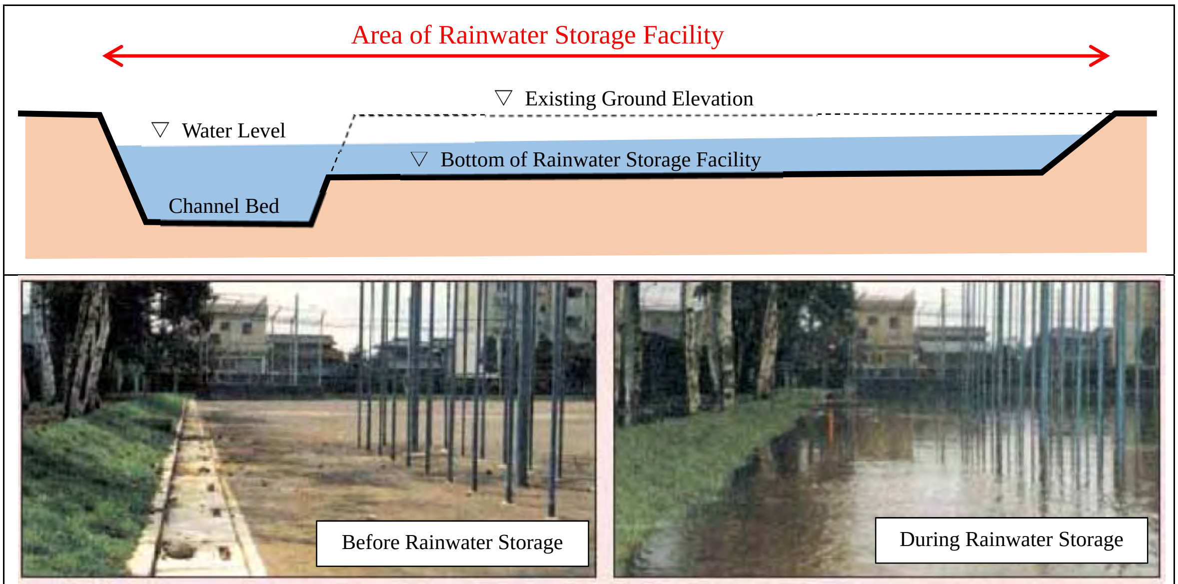
No.	Name of Sub-Catchment Area	Design Flow	Pumping Station + Sluice	Drainage Channel					
				Length	Depth	Concrete Channel		Earth Channel	
		Q [m^3/s]	[x 10^6 USD]	L [km]	D [m]	W [m]	[x 10^6 USD]	Wt [m]	[x 10^6 USD]
1	Liliendaal	11.0	9.7	4.37	2.6	10.0	14.0	18.0	4.0
2-1	Kitty1(West)	2.0	3.5	1.53	2.6	3.0	2.7	9.0	0.5
2-2	Kitty2(East)	7.0	7.4	1.10	2.6	4.0	2.1	10.0	0.4
3	Young Street	6.0	6.8	1.10	2.6	4.0	2.1	10.0	0.4
4	Cummings Canal	8.0	8.0	3.25	2.6	9.0	9.7	16.0	2.5
5	Lamaha Street	6.0	6.8	2.24	2.6	6.0	5.3	12.0	1.2
6	Church Street	7.0	7.4	4.07	2.6	5.0	8.8	11.0	1.8
7	Commerce Street	3.0	4.5	3.54	2.1	4.0	6.2	8.0	0.9
8	Princess Street	10.0	9.2	3.87	2.6	6.0	9.2	12.0	2.0
9	Sussex Street	5.0	6.1	3.93	2.6	4.0	7.7	10.0	1.5
10	La Penitence South	7.0	7.4	5.74	2.1	7.0	13.5	12.0	2.5
11	Ruimveldt North	8.0	8.0	5.72	2.6	6.0	13.5	11.0	2.6
12	Ruimveldt South	7.0	7.4	5.62	2.6	6.0	13.3	11.0	2.5
Total			92.2				108.1		22.8

Source: JICA Survey Team

(2) Rainwater Outflow Restricting Measures

On-site rainwater storage restricts the outflow of rainwater. This facility temporarily stores rainwater with relatively shallow depth at open space like park and athletic field so that the function of original land use classification is not impaired.

The outline of rainwater storage facility is as illustrated in **Fig. R 3.1.13**. The main candidates for rainwater storage facility in Georgetown are as given in **Fig. R 3.1.14**.



http://www.tokyo-sougou-chisui.jp/shishin/shishin-siryou.pdf

Source: JICA Survey Team

Fig. R 3.1.13 Outline of Rainwater Storage Facility

Source: JICA Survey Team

Fig. R 3.1.14 Main Candidates for Rainwater Storage Facility in Georgetown

These candidates are currently green spaces and might have water-retaining functions. Besides, digging down the existing ground level contributes to the increase of storage capacity and the mitigation of inundation damage in the city. However, the effect must be noted on the existing facilities and the setting of excavation and water storage depth when the rainwater storage facility is planned/designed.

Table R 3.1.14 Result of Rough Cost Estimation for Rainwater Storage Facility

Name	Quantity	Unit Cost	Total Amount	Remarks
Excavation and Hauling at National Park	850,000 m^3	5 USD/m^3	4.3 x 10^6 USD	1m depth excavation
Excavation and Hauling at Botanical Gardens	570,000 m^3	5 USD/m^3	2.9 x 10^6 USD	1m depth excavation
Excavation and Hauling at Downstream of Liliendaal	1,700,000 m^3	5 USD/m^3	8.5 x 10^6 USD	1m depth excavation
Sub-Total			15.7 x 10^6 USD	
Construction Cost of Appurtenant Structures	30 %		5.0 x 10^6 USD	30% of Excavation and Hauling Cost
Total			20.7 x 10^6 USD	

Source: JICA Survey Team

(3) Cooperation with Public Administrations, Business Operators, Residents, etc.

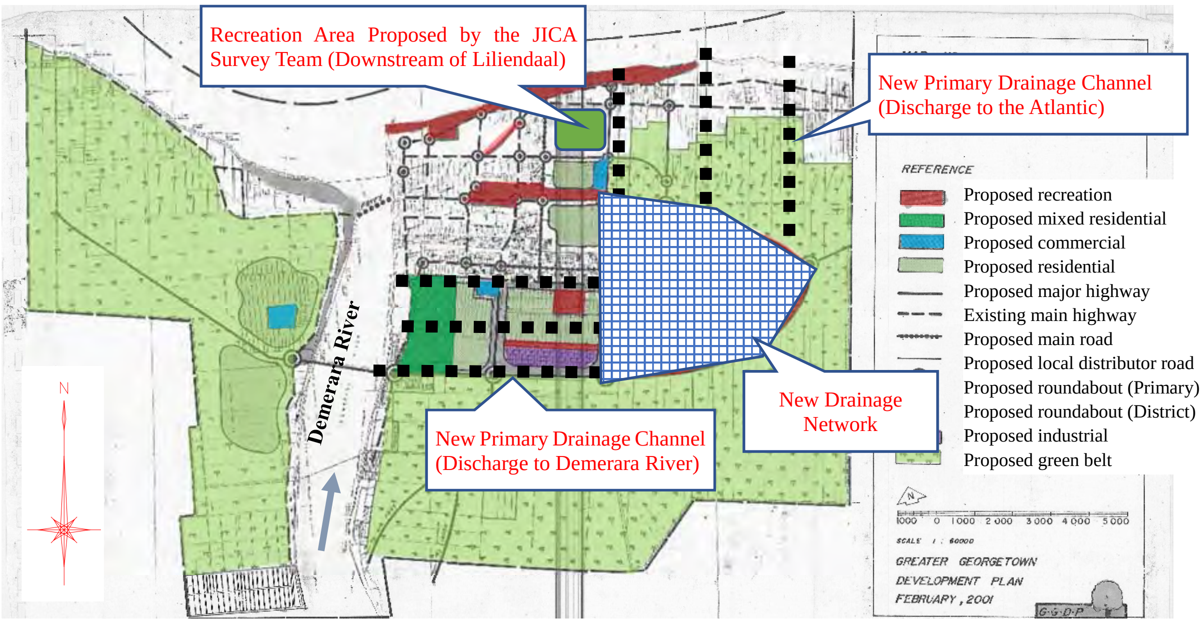
In the "Laws of Guyana (Chapter 64-03, Drainage and Irrigation Act") prohibit construction works within 12 ft. from existing drainage facilities. Dissemination of this Act to related agencies/companies/residents and legal compliance is important to secure adequate maintenance space and to prevent narrowing of drainage channel from human-induced interference like urbanization, development and informal settlers. Additionally, a building and facility constructed at the vicinity of the drainage facility before the effectivity of this

Act is statutorily not able to be relocated. Hence, drainage improvement work is difficult in urbanized and densely populated areas along drainage facilities in Georgetown.

To promote the drainage channel improvement, revision of this Act, including relocation of the existing building constructed at the vicinity of drainage facility before the effectivity of this Act and a new ordinance on the relocation of all buildings at the vicinity of drainage facilities shall be effected by the GDA.

(4) Land Use Plan Management

CHPA had prepared the Greater Georgetown Development Plan of 2001-2010 including the land use plan, but this plan is not widely known by the related agencies and not executed.



Source: Prepared by JICA Survey Team based on information from CHPA

Fig. R 3.1.15 Proposed Drainage Plan for Greater Georgetown Development Plan 2001-2010

Urban development planning in consideration of drainage improvement shall be executed in cooperation with the related agencies like GDA, including information sharing, consultation and coordination. Construction of drainage network, primary drainage channel toward to the Atlantic Ocean/Demerara River, on-site/off-site rainwater storages are required at new development sites. For the construction of on-site/off-site rainwater storage (measures to reduce rainwater discharge), the required land shall be designated and secured based on the urban development plan, and development action in the designated area shall be restricted by regulation of Georgetown, situationally.

(5) Strengthening and Streamlining of Operation and Maintenance

M&CC and/or NDIA have not prepared an operation and maintenance (O&M) plan for drainage facilities as well as the cost estimate for O&M and budget. The preparation of short/long term plan of O&M for drainage facilities is the responsibility of GDA. It is necessary for GDA to prepare the O&M plan to periodically conduct the O&M for drainage facilities and to procure the O&M equipment by M&CC.

To conduct appropriate O&M, it is important that the O&M cost for drainage facilities in Georgetown is expended not only by M&CC but also by GDA members like NDIA, MPI and MOC as needed. Following table shows roughly estimated cost of O&M work.

Table R 3.1.15 Result of Rough Cost Estimate for Annual Operation and Maintenance Cost of Drainage Facilities

Name	Quantity	Unit Cost	Total Amount	Remarks
Dredging of Outlet Fall of Drainage Channel (1.4 km in total)	2,800 m^3	30 USD/m^3	84 x 10^3 USD/Year	$2m^2$ excavation per channel length
Dredging and Hauling of Primary Drainage Channel (46 km in total)	46,000 m^3	7 USD/m^3	322 x 10^3 USD/Year	$1m^2$ excavation per channel length
Maintenance Cost of Pump and Sluice	0.5%		460 x 10^3 USD/Year	0.5 % of Construction Cost of Pump and Sluice (USD92 x 10^6)
Total			0.9 x 10^6 USD/Year	

Source: JICA Survey Team

Excavation and/or dredging of sediment in drainage channel shall be categorised in two sections, namely outfall of drainage channel (downstream of sluice) and drainage channel (upstream of sluice). Section of outfall of drainage channel (downstream of sluice) can be accessed from Demerara river. Other section of drainage channel can be accessed from land.

Therefore, excavation and/or dredging work at outfall of drainage channel (downstream of sluice) shall be work on the water. and excavation and/or dredging work at drainage channel (upstream of sluice) shall be land-based work.

Considering working condition at outfall of drainage channel, suction dredger or backhoe dredger is applicable. Dredging efficiency of suction dredger is higher than backhoe dredger, but cost of equipment is also higher. Annual work volume of dredging work at outfall of drainage channel is estimated 2,800m^3. Taking this work volume into consideration, backhoe dredger is suitable.

Following table gives the list of equipment required for O&M work at each section of drainage channel.

Table R 3.1.16 List of Equipment for Operation and Maintenance

Section	Equipment	Purpose	Q'ty (Unit)	Unit Cost USD x 10^6	Amount USD x 10^6	Remarks
Outfall of Drainage Channel (Downstream of sluice)	Excavator with Long Boom	Excavation/Dredging of sediment	1	0.3	0.3	
	Pontoon	Working platform for excavator	1	0.1	0.1	
	Tug Boat	Towing pontoon and barge	2	0.3	0.6	
	Barge	Conveying excavated sediment	2	0.25	0.5	
Drainage Channel (Upstream of sluice)	Excavator with Long Boom	Excavation/Dredging in primary and secondary drainage channel	2	0.3	0.6	Proposed in M/P (1994)
	Sludge Pump	Excavation/Dredging in secondary and tertiary drainage channel	4	0.025	0.1	
	Drainage Pump Vehicle	Emergency drainage work	6	0.8	4.8	
	Dump Truck	Hauling of excavated/dredged soil	6	0.15	0.9	Proposed in M/P (1994)
				Total Cost	7.9	

Source: JICA Survey Team
Note: Self-propelled suction dredger costs about USD 2 x 10^6 /unit.

(6) Promotion of Disaster Resilient City

Traditionally, the "pilotis-type" of building is popular in Georgetown due to the frequent flood disasters (refer to **Photo R 3.1.1**). This type of building is effective in avoiding flood damage since the first floor is open ceiling space.

Promotion of a disaster resilient city encourages the "pilotis-type" of building including subvention for the construction of "pilotis-type" of building and favourable treatment with regards to tax and casualty insurance.

	
Pilotis-Type of Building along Ruimveldt South Drainage Channel	Pilotis-Type of Building along Princess St. Drainage Channel

Source: JICA Survey Team

Photo R 3.1.1 Pilotis-Type of Building in Georgetown

(7) Collection, Disclosure and Provision of Disaster Information

Collection, disclosure and provision of disaster information include the preparation and provision of hazard map. However, the flood hazard map in Georgetown is not yet completed.

The Geospatial Information Management Unit (GIMU) under MONR is preparing an inundation map of Georgetown. On the other hand, according to the "National Integrated Disaster Risk Management Implementation Strategy for Guyana (2013)," the preparation of flood hazard map is the role and responsibility of GL&SC in cooperation with related agencies such as CDC and CHPA.

Flood hazard maps shall be prepared by related agencies like GL&SC, CDC, CHPA, and GDA based on the inundation map prepared by GIMU.

(8) Development and Management of Database for Drainage Facilities Information

Information about the existing drainage facilities has not been fully managed.

Based on the result of hearing survey, NTFC is preparing a GIS map of the existing drainage system in Georgetown. This GIS map will include information about location and size of primary, secondary and tertiary drainage channels, sluices, pumps and culverts.

Updated information including construction year, damage record, rehabilitation record, improvement plan and maintenance plan for drainage facilities by using the database will contribute to the improvement of integrated information management for drainage system in Georgetown.

3.1.2.4 Priority of Draft Drainage Improvement Plan

Draft drainage improvement plan is prepared based on the above-cited countermeasures for flood mitigation and drainage improvement. Outlines of evaluation items as well as priority of draft drainage improvement plan are given in **Table R 3.1.17** and **Table R 3.1.18**, respectively.

Table R 3.1.17 Outline of Evaluation Items

Evaluation Item	Description	Evaluation Score
Urgency	Countermeasures which are promptly required for flood mitigation and drainage improvement in Georgetown	0 point ↔ 5 points Low Urgency — High Urgency
Effectivity	Countermeasures effective for flood mitigation and drainage improvement in Georgetown	0 point ↔ 5 points Less Effective — More Effective

Source: JICA Survey Team

Table R 3.1.18 Urgency and Effectivity of Draft Drainage Improvement Plan

Measures	Urgency	Effectivity
Increasing Drainage Capacity (Improvement of Drainage Channel)	Urgency is high because the existing drainage capacity is insufficient and human-induced narrowing of drainage channel causes flood damage. Score: 5	The width and longitudinal gradient of the existing drainage channel is non-uniform and a part of longitudinal gradient is inverse. This effectivity is high because the drainage channel improvement contributes to increasing drainage capacity, mitigation of flood damage and improvement of drainage Score: 5
Increasing Drainage Capacity (Improvement of Sluice and Pump)	Urgency is high because more than 60 years have passed since construction of drainage sluice and sluices which are now decrepit. The existing drainage capacity is low due to insufficient pumping station in Georgetown. Thus, drainage pumps are required promptly. Score: 5	Effectivity is high because the development of sluices and pumps directly contributes to mitigation of flood damage and improvement of drainage Score: 5
Rainwater Storage Facility	The available area for rainwater storage facilities utilized by the existing park, athletic field and open space will be reduced due to urbanization. This urgency is relatively high. Score: 4	Depending on the area and/or depth of rainwater storage facility, the storage effect might mitigate the flood damage within the limited area. This effectivity is relatively high. Score: 4
Revision of “Drainage and Irrigation Act”	Revision of law/act might require sufficient discussion and a lot of procedure. The urgency is low. Score: 2	Revision of the Act will promote drainage channel improvement work and contribute to securement of space for maintenance work. However, the effectivity is low because revision of the Act does not directly contribute to mitigation of flood damage and improvement of drainage Score: 2
Execution of Land Use Plan with Drainage Plan	Mutual consultation and arrangement with related agencies are required for the urban development plan. The relationship to the drainage plan is high but urgency is low. Score: 3	Effectivity is not high because execution does not directly contribute to mitigation of flood damage and improvement of drainage even though relationship to drainage plan is high Score: 3
Planning and Conducting Adequate Operation and Maintenance	The current operation and maintenance work is not well-planned but ad hoc within restricted budget. The planning and executing for operation and maintenance is required. This urgency is high. Score: 5	Effectivity is high because dredging and cleaning of drainage channel directly contribute to mitigation of flood damage and improvement of drainage in Georgetown. Score: 5
Utilization of Equipment for Operation and Maintenance	The current dredging and cleaning works for drainage channel is inefficient because it is conducted manually. Utilization of equipment contributes to efficient operation and maintenance work. The urgency is relatively high. Score: 4	Effectivity is relatively high because the removal of sediment and cleaning of drainage channel will keep flow capacity of drainage channel, and it is directly contributing to mitigation of flood damage in Georgetown. Score: 5

Measures	Urgency	Effectivity
Promotion of Pilotis-Type of Building	Modernistic designed house is recently increasing although pilotis-type building is traditional in Georgetown. The urgency is not high. Score: 3	Promotion of pilotis-type building protects individual assets from flood damage. However, the effectivity is not high because this measure does not contribute to mitigation of flood damage and improvement of drainage, fundamentally. Score: 3
Preparation of Flood Hazard Map	The risk analysis for flood is important and the preparation of flood hazard map is mentioned in national disaster risk management plan. However, the flood hazard map is not yet completed. The urgency is relatively high. Score: 4	The flood hazard map contributes to grasping location of hazardous area of flood and utilizing the evacuation plan. However, the effectivity is not high because this measure does not contribute to mitigation of flood damage and improvement of drainage, fundamentally. Score: 2
Development and Management of Database for Drainage Facilities Information	Grasping information of the existing drainage facilities is important for the planning and execution of operation and maintenance. Particularly, positional information about the existing drainage channel network is not grasped sufficiently. Inventory of drainage channel network and drainage ledger is required. The urgency is high. Score: 5	Effectivity is relatively high because the database can be sufficiently utilized for drainage improvement plan and operation and maintenance plan though this measure does not contribute to mitigation of flood damage and improvement of drainage, fundamentally. Score: 4

Source: JICA Survey Team

Based on the above comparisons, the priorities of structural and non-structural measures for drainage improvement are as given in the following table.

Table R 3.1.19 Priorities of Measures for Drainage Improvement

Priority	Measures	Implementation Agency
1st Priority (Indispensable Measures)	- Improvement of Drainage Channel	NDIA
	- Improvement of Sluice and Pump	NDIA
	- Planning and Conducting Adequate Operation and Maintenance	GDA
	- Development and Management of Database for Drainage Facilities Information	GDA
	- Utilization of Equipment for Operation and Maintenance	GDA
2nd Priority	- Rainwater Storage Facility	NDIA
	- Preparation of Flood Hazard Map	GL&SC
	- Execution of Land Use Plan with Drainage Plan	CHPA
	- Promotion of Pilotis-Type Building	M&CC
	- Revision of “Drainage and Irrigation Act”	GDA

Source: JICA Survey Team

It is important that adequate operation and maintenance plan, including work plan, institutional and organizational reinforcement plan, and budget allocation and disbursement plan, shall be established and executed prior to the further structural drainage development. Effect of structural measures, such as construction of drainage facilities, might be limited if adequate operation and maintenance work would not be executed.

It is recommended that the GCRG shall establish the adequate operation and maintenance plan and execute it prior to the further structural drainage development.

Recommended facilities, work items, equipment and estimated costs of future plan for drainage improvement described in **3.1.2** are summarized in “**Appendix 4. Summary of Future Plan for Drainage Improvement**” of this report.

3.2 Flood Analysis of Georgetown

Flood analysis has been conducted in the Survey. The condition and results of flood analysis are as described below.

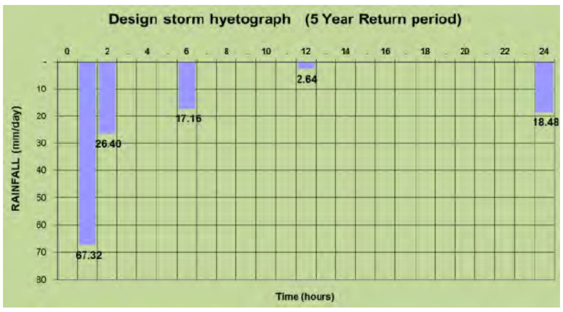
(1) Condition of Flood Analysis

The comparison table of flood analysis condition between the NDIA Report (2015) and the Survey is as follows.

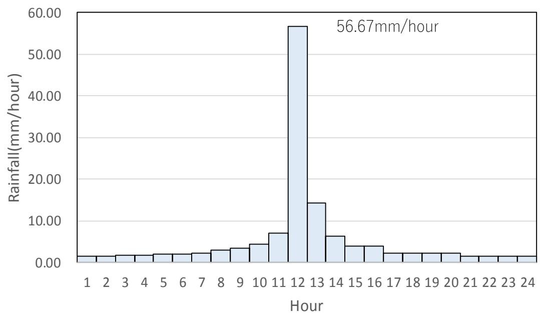
Table R 3.2.1 Comparison Table of Flood Analysis Condition between NDIA Report (2015) and the Survey

Item	NDIA Report (2015)	JICA Survey
Drainage Catchment Area	Refer to **Fig. R 3.1.6** and **Table R 3.1.5**	
Probable Rainfall	5-Year Return Period	
Hyetograph	Refer to **Fig. R 3.2.1**	
Topography Data	LIDAR Data (2008)	
Existing Drainage Channel	In consideration of primary drainage channel surveyed in the M/P (1994)	In consideration of primary drainage channel surveyed in 2017
Flood Analysis Software	CityCAT	MIKE FLOOD

Source: NDIA and JICA Survey Team



NDIA Report (2015)



JICA Survey Team (Centralized Distribution)

Fig. R 3.2.1 Design Storm Hyetographs (5-Year Return Period)

As a result, there is not much difference in the results of probable rainfall between NDIA and the JICA Survey Team. The design rainfall pattern of 5-year probable rainfall is applied in conformity with the NDIA Report (2015)

(2) Result of Flood Analysis

Cases of flood analysis and results are summarised as follows.

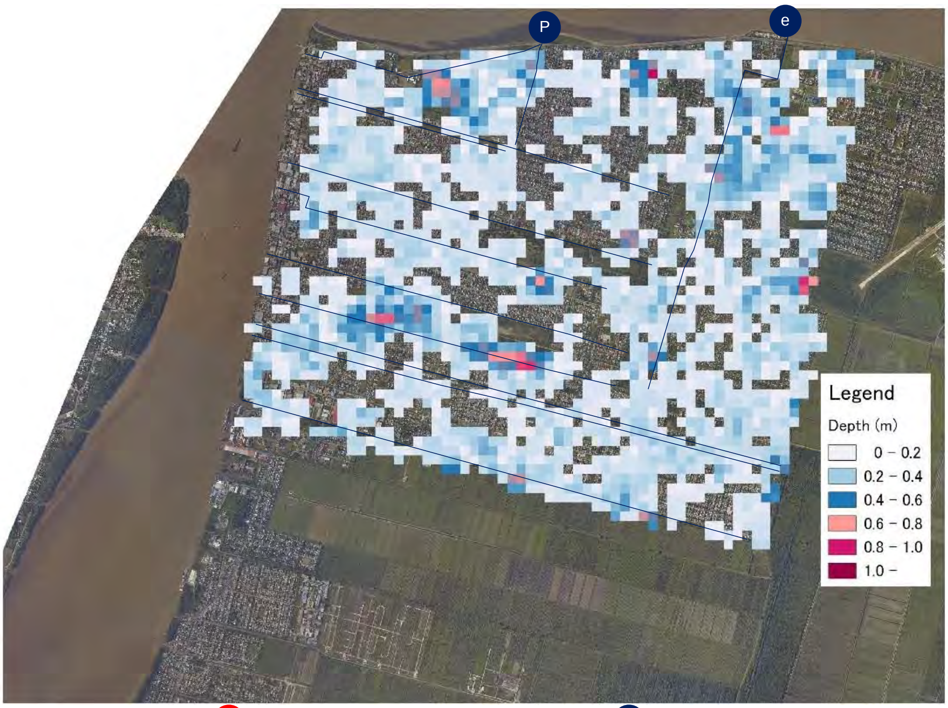
Table R 3.2.2 Summary of Flood Analysis Case

Case	Description	Discharge Capacity of each Pumping Station
Case-1	<u>Existing Condition</u> (Both peak of rainfall and high tide is simultaneously occurred.)	[Existing] Liliendaal: 8.5m^3/s, Kitty: 4.3m^3/s
Case-2	<u>Construction of New Pumping Stations (based on the Request)</u> (Drainage Improvement by Construction of pumping stations at Cummings, Commerce, Princess and La Penitence South, only)	[Existing] Liliendaal: 8.5m^3/s, Kitty: 4.3m^3/s [New Construction] Cummings: 6.0m^3/s, Commerce: 1.5m^3/s, Princess: 3.5m^3/s, La Penitence South: 6.0m^3/s
Case-3	<u>Future Condition with Full Improvement</u> (Construction of Drainage Channels and Pumping Stations as Future Improvement Plan of Drainage Facilities) Ref.: **Table R 3.1.11**	[Expansion] Liliendaal: 11.0m^3/s (8.5+2.5), Kitty: 9.0m^3/s (4.3+4.7) [New Construction] Young: 6.0m^3/s, Cummings: 8.0m^3/s, Lamaha: 6.0m^3/s, Church: 7.0m^3/s, Commerce: 3.0m^3/s, Princess: 10.0m^3/s, Sussex: 5.0m^3/s, La Penitence South: 7.0m^3/s, Ruimveldt North: 8.0m^3/s, Ruimveldt South: 7.0m^3/s

Source: NDIA and JICA Survey Team

(a) Case-1: Existing Condition

Almost whole area of Georgetown is inundated in this case.



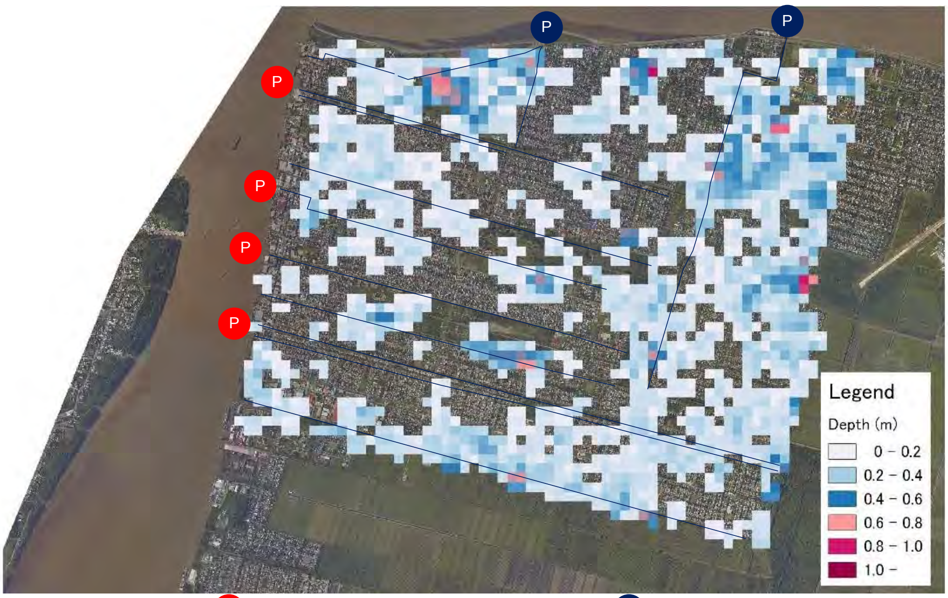
Source: JICA Survey Team P: Expansion/New Construction of Pump, P: Existing Pump

Fig. R 3.2.2 Result of Flood Analysis (Case-1: Existing Condition)
(Inundation Area: 19.3km^2)

(b) Case-2: Construction of New Pumping Stations (based on the Request)

In this case, pumping stations at Cummings, Commerce, Princess and La Penitence South are newly constructed. Considering flow capacity of existing drainage channels, pumping capacity are modified as same as present flow capacity of drainage channel. At Liliendaal pumping station, flow capacity of inlet culvert is smaller than existing pumping capacity. Therefore, expansion of Liliendaal pumping station is not necessary, unless otherwise inlet culvert is expanded.

If proposed pumping stations are constructed, some of inundation will be mitigated at downstream part of drainage channels where pumping station would be newly constructed.



Source: JICA Survey Team P: Expansion/New Construction of Pump, P: Existing Pump

Fig. R 3.2.3 Result of Flood Analysis (Case-2: Construction of New Pumping Stations) (Inundation Area: 15.9km^2)

Table R 3.2.3 Components of Drainage Improvement based on the Request by Guyana

Type	Requested by GCRG (2015)		Modification of Components by the Survey Team	
	Description	Capacity	Modification of Pumping Capacity	Capacity
Construction Work	Expansion of Liliendaal pumping station	4.2 m^3/s	Because flow capacity of inlet culvert is smaller than existing pumping capacity, expansion is not necessary.	-
	Construction of new pumping station and sluice at Cummings Channel	5.6 m^3/s	Pumping capacity shall be same as present flow capacity of drainage channel.	6.0 m^3/s
	Construction of new pumping station and sluice at Commerce St. Channel	2.2 m^3/s	Pumping capacity shall be same as present flow capacity of drainage channel.	1.5 m^3/s
	Construction of new pumping station and sluice at Princess St. Channel	2.2 m^3/s	Pumping capacity shall be same as present flow capacity of drainage channel.	3.5 m^3/s
	Construction of new pumping station and sluice at La Penitence South Channel	5.6 m^3/s	Pumping capacity shall be same as present flow capacity of drainage channel.	5.0 m^3/s

Source: JICA Survey Team

(c) Case-3: Future Condition with Full Improvement (Construction of Drainage Channel and Pumping Station as Future Improvement Plan of Drainage Facilities)

In this case, future inundation condition is analysed on the premise that drainage facilities, which consists of construction of pumping stations and improvement of drainage channels, are improved with full capacity of future development plan. Specifications of drainage facilities are shown in the **Table R 3.1.11**.

Inundation area is decreased in the whole area of Georgetown in this case.

The National Park functions as on-site rainwater storage. Lowland area at the immediate upstream of Liliendaal pumping station is inundated since this area is not connected to primary drainage channel on this flood analysis model.

In other inundation areas, there is no connection channel to primary drainage channel or detailed situation of existing drainage network is not reflected on this flood analysis model. If such inundation areas have no connection to primary drainage channel at present condition, drainage network (such as new drainage channel or pipe) shall be developed.

Source: JICA Survey Team (P): Expansion/New Construction of Pump, (P): Existing Pump

Fig. R 3.2.4 Result of Flood Analysis (Case-3: Future Condition with Full Improvement) (Inundation Area: 8.8km^2)

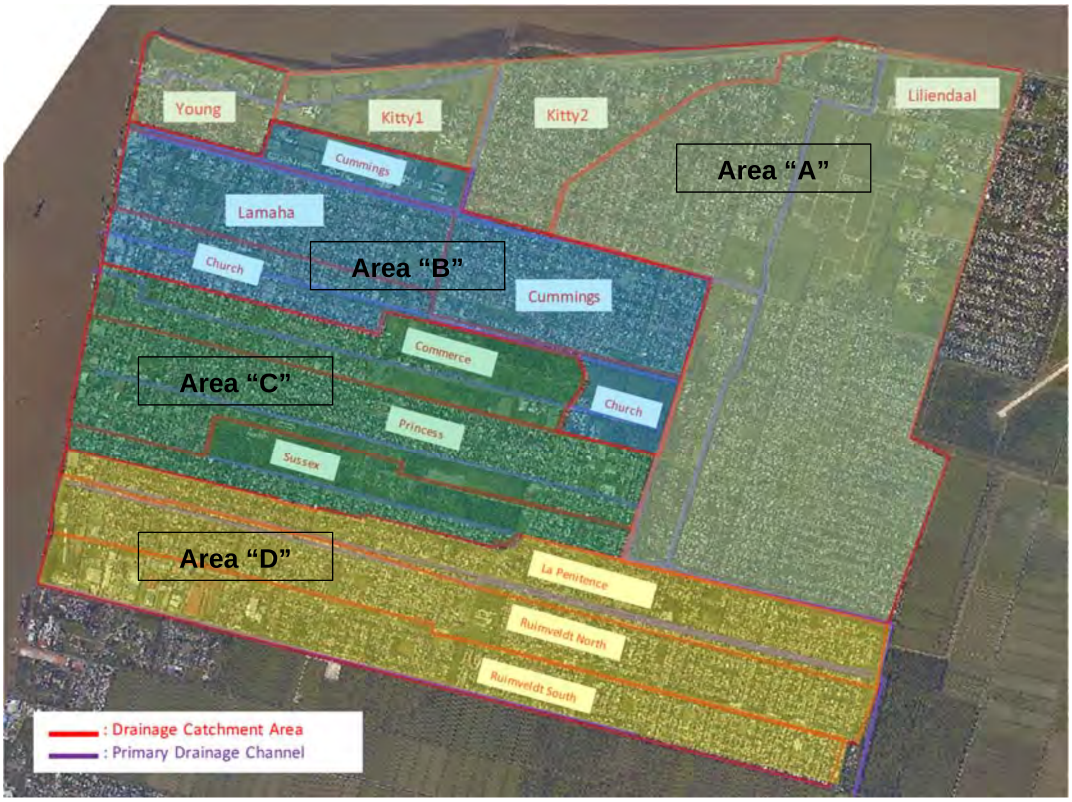
3.3 Priority Area for Improvement of Drainage Channel, Sluice and Pumping Station in Georgetown

Prioritized and recommended facilities, work items, equipment and estimated costs of future plan for drainage improvement described in “3.1.2.4 Priority of Draft Drainage Improvement Plan” are summarized in "Appendix 4. Summary of Future Plan for Drainage Improvement" of this report. Among these drainage improvement measures, the highest-prioritized measures are improvement of the drainage channel, sluice and pumping station. Drainage channel, sluice and pumping station shall be improved simultaneously maximize the effectiveness of investment.

To implement these drainage improvement measures, huge amount of budget is required. Therefore, drainage improvement may be implemented in phases on a long-term basis by financing from international donor or GCRG's fund.

In this paragraph, the survey area divided into four areas, and then the priority area for improvement of drainage channel, sluice and pumping station in Georgetown is recommended.

The target area of this survey divided into four areas, namely Area "A" to "D" as shown in Fig. R 3.3.1. Area "B" and "C" are located in the city center and Area "A" and "D" are located in the outer area of Georgetown. The priority is determined by the existence of flood-prone area, influence of flood/inundation and scale of economic loss due to flood.



Source: JICA Survey Team

Fig. R 3.3.1 Classification of Drainage Area in Georgetown

Area "C" consists of the sub-catchment area of Commerce Street, Princess Street and Sussex Street, and flood-prone area in Albouystown is included. Area "C" is determined the 1st priority area since it is located in the city center of Georgetown with the large scale of economic loss due to flood.

Area "A" and "D" includes flood-prone area. However, it is assumed that the scale of economic loss is smaller than Area "C" because these areas are located in the outer area of Georgetown. Priority of drainage improvement at Area "A" might be higher than Area "D" since catchment area of Area "A" is much larger than Area "D". Thus, Area "A" and "D" is determined the 2nd and 3rd priority area, respectively.

Area "B" is located in the city center of Georgetown and includes small flood-prone area. However, Area "B" is determined the 4th priority area because the economic loss in this area might be smaller than the others due to the small flood damage.

Classification of priority of drainage improvement area in Georgetown is summarised in Table R 3.3.1. Recommended specification for improvement of sluice and pumping station, and drainage channel in Georgetown is presented in Table R 3.3.2 and Table R 3.3.3, respectively.

Table R 3.3.1 Classification of Priority of Drainage Improvement Area in Georgetown

No.	Name of Sub-Catchment Area	Classified Area	Catchment Area[km^2]		Priority
1	Liliendaal	Area "A" North and East part of outer area of Georgetown	8.19	11.22	**2nd Priority** There is flood-prone area. This area has a profound effect on drainage improvement due to the large catchment area.
2	Kitty		2.40		
3	Young Street		0.63		
4	Cummings Canal	Area "B" North part of city center of Georgetown	1.88	4.57	**4th Priority** Area of flood-prone area is small and the emergency is lower.
5	Lamaha Street		1.36		
6	Church Street		1.33		
7	Commerce Street	Area "C" South part of city center of Georgetown	1.53	5.25	**1st Priority** There is flood-prone area. Flood damage is enormous because this area is located in the city center of Georgetown.
8	Princess Street		2.42		
9	Sussex Street		1.30		
10	La Penitence South	Area "D" South part of outer area of Georgetown	1.97	6.52	**3rd Priority** There is flood-prone area. This are located around the outer edge of Georgetown.
11	Ruimveldt North		2.30		
12	Ruimveldt South		2.25		
Total			27.56		

Source: JICA Survey Team

Table R 3.3.2 Recommended Specification of Sluice and Pumping Station

No.	Name of Sub-Catchment Area	Specification	Estimated Cost [US$ x 10^6]		Priority
1	Liliendaal	Expansion: Q=2.5m^3/s (Total: 11.0 m^3/s)	4.0	16.6	Area "A" **2nd Priority**
2	Kitty	Expansion: Q=4.7m^3/s (Total: 9.0 m^3/s)	5.8		
3	Young Street	New Construction: Q=6.0 m^3/s	6.8		
4	Cummings Canal	New Construction: Q=8.0 m^3/s	8.0	22.2	Area "B" **4th Priority**
5	Lamaha Street	New Construction: Q=6.0 m^3/s	6.8		
6	Church Street	New Construction: Q=7.0 m^3/s	7.4		
7	Commerce Street	New Construction: Q=3.0 m^3/s	4.5	19.8	Area "C" **1st Priority**
8	Princess Street	New Construction: Q=10.0 m^3/s	9.2		
9	Sussex Street	New Construction: Q=5.0 m^3/s	6.1		
10	La Penitence South	New Construction: Q=7.0 m^3/s	7.4	22.8	Area "D" **3rd Priority**
11	Ruimveldt North	New Construction: Q=8.0 m^3/s	8.0		
12	Ruimveldt South	New Construction: Q=7.0 m^3/s	7.4		
Total			81.4		

Source: JICA Survey Team

Table R 3.3.3 Recommended Specification of Drainage Channel

No.	Name of Sub-Catchment Area	Specification	Estimated Cost [US$ x 10^6]		Priority
1	Liliendaal	Earth Channel: L=4.37km, W=18.0m	4.0	9.2	Area "A" **2nd Priority**
2-1	Kitty1(West)	Concrete Channel: L=1.53km, W=3.0m	2.7		
2-2	Kitty2(East)	Earth Channel: L=1.10km, W=10.0m	0.4		
3	Young Street	Concrete Channel: L=1.10 km, W=4.0m	2.1		
4	Cummings Canal	Earth Channel: L=3.25km, W=16.0m	2.5	12.5	Area "B" **4th Priority**
5	Lamaha Street	Earth Channel: L=2.24km, W=12.0m	1.2		
6	Church Street	Concrete Channel: L=4.07km, W=5.0m	8.8		
7-1	Commerce Street 下流	Concrete Channel: L=1.0km, W=4.0m	1.8	19.4	Area "C" **1st Priority**
7-2	Commerce Street 上流	Earth Channel: L=2.54km, W=8.0m	0.7		
8	Princess Street	Concrete Channel: L=3.87km, W=6.0m	9.2		
9	Sussex Street	Concrete Channel: L=3.93km, W=4.0m	7.7		
10	La Penitence South	Earth Channel: L=5.74km, W=12.0m	2.5	7.6	Area "D" **3rd Priority**
11	Ruimveldt North	Earth Channel: L=5.72km, W=11.0m	2.6		
12	Ruimveldt South	Earth Channel: L=5.62km, W=11.0m	2.5		
Total			48.7		

Note: If there is an enough construction space for expansion of channel, earth channel is applied; otherwise, concrete lining channel is applied.
Source: JICA Survey Team

Although improvement of drainage channel requires land acquisition, house relocation and resettlement of residents along the existing drainage channel, construction work of drainage channel doesn’t require special construction techniques. On the other hand, construction work of pumping station requires special construction techniques and machinery of pumping station shall be imported from other country.

Hence, there is a way of cooperation that GCRG shall be responsible to improvement of drainage channel, and international donors financially and technically take charge of improvement of drainage sluice and pumping station which is needed advanced technology of construction, mechanical and electrical works.

[APPENDICES]

Appendix 1. Member List of the Survey Team

1. Field Survey in Guyana (February 12 to March 13, 2017)

Name	Designation	Affiliation
Mr. Tsuyoshi MATSUSHITA	Chief Consultant /Urban Drainage Planning	CTI Engineering International Co., Ltd.
Mr. Hirofumi TANAKA	Drainage Channel Planning	CTI Engineering International Co., Ltd.

2. Explanation of Draft Final Report in Guyana (September 20 to September 26, 2017)

Name	Designation	Affiliation
Mr. Katsuhiro SHINO	Leader	Senior Deputy Director of Central America and Caribbean Division, JICA
Mr. Tsuyoshi MATSUSHITA	Chief Consultant /Urban Drainage Planning	CTI Engineering International Co., Ltd.
Mr. Hirofumi TANAKA	Drainage Channel Planning	CTI Engineering International Co., Ltd.

Appendix 2. Survey Schedule

1. Field Survey in Guyana (February 12 to March 13, 2017)

No	Date			Destination to Visit	Team of Consultants	
					Mr. Tsuyoshi MATSUSHITA	Mr. Hirofumi TANAKA
1	2017/2/12	Sun	PM		*19:30 JL 0004 Narita →New York JFK 18:25*	
2	2017/2/13	Mon	AM		*1:25 BW 0527 New York JFK →Georgetown 7:55*	
			AM		Preparation of the Survey. Meeting with Mr. Morita (JICA Expert)	
			PM	**NDIA/ Georgetown**	Courtesy call to NDIA and Georgetown: Explanation of the Survey outline, interview of the existing condition and data collection (including groundwater/ground elevation monitoring for subsidence, cross-section of drainage channel, and recomendable sub-contractor.	
			PM		Site Visit: Investigation of the existing drainage facilities (Lilliendaal and Kitty Pumping Station)	
			PM		Meeting with Sub-contractors (Drainage Channel Survey, Elevation Observation)	
3	2017/2/14	Tue	AM	**HS-MOA**	Meeting with HD-MA: Explanation of the Survey outline, interview of the existing condition and data collection (particularly, collection of meteorological/rainfall, and tide level data)	
			PM		Site Visit: Investigation of the existing drainage sluice gate and mobile pump	
4	2017/2/15	Wed	AM		Office work, internal meeting and confirmation of schedule with ASDU	
			PM		Site Visit: Investigation of the existing drainage channel	
5	2017/2/16	Thu	AM		Site Visit: Investigation of the existing drainage channel	
			PM		Analysis of collected data/information	
6	2017/2/17	Fri	AM	**NDIA**	Meeting with engineer who prepared NDIA Report 2015: Explanation of the Survey outline, interview of the existing condition and data collection based on the questionnaire	
			PM		Site Visit: Investigation of the existing meteorological observatory station	
7	2017/2/18	Sat	-		Site Visit: Investigation of the existing drainage channel	
8	2017/2/19	Sun	-		Analysis of collected data	
10	2017/2/20	Mon	AM	**ASDU**	Meeting with ASDU: Explanation of the Survey outline, interview of the existing condition and data collection based on the questionnaire	
			AM		Request for Quotation for topographic survey (Longitudinal Profile and Cross Section Survey of Primary Drainage Channel) in Georgetown	
			PM	**CDC**	Meeting with CDC: Explanation of the Survey outline, interview of the existing condition and data collection based on the questionnaire	
11	2017/2/21	Tue	AM		Site Visit: Investigation of the existing drainage channel	
			PM		Analysis of collected data/information	
9	2017/2/22	Wed	AM		Site Visit: Investigation of the existing drainage channel	
			PM	**GWI**	Meeting with GWI: Explanation of the Survey outline, interview of the existing condition and data collection based on the questionnaire, and tour of inspection at water treatment plant of GWI	
			PM		Collection of quotation for topographic survey (Longitudinal Profile and Cross Section Survey of Primary Drainage Channel) in Georgetown	
12	2017/2/23	Thu	-		(National Holiday in Guyana)	
			-		Site Visit: Investigation of the existing drainage channel and sluice	
13	2017/2/24	Fri	AM	**GL&SC**	Meeting with GL&SC: Explanation of the Survey outline, interview of the existing condition and data collection based on the questionnaire.	
			PM		Negotiation with sub-contractor for topographic survey (Longitudinal Profile and Cross Section Survey of Primary Drainage Channel) in Georgetown	
14	2017/2/25	Sat	AM		Site Visit: Investigation of the existing drainage channel after heavy rain	
			PM		Execution of agreement with sub-contractor for topographic survey (Longitudinal Profile and Cross Section Survey of Primary Drainage Channel) in Georgetown	
15	2017/2/26	Sun	-		Analysis of collected data	
16	2017/2/27	Mon	AM		Site Visit: Investigation of the existing drainage channel	
			PM		Analysis of collected data/information	
17	2017/2/28	Tue	AM		Site Visit: Investigation of the existing drainage channel	
			PM	**MARAD-MPI**	Meeting with MARAD-MPI: Explanation of the Survey outline, interview of the existing condition and data collection based on the questionnaire	
18	2017/3/1	Wed	AM	**MONR**	Meeting with MONR: Explanation of the Survey outline, interview of the existing condition and data collection based on the questionnaire	
			PM		Analysis of collected data/information	
19	2017/3/2	Thu	AM	**Georgetown, M&CC**	Meeting with M&CC: Interview about the existing condition and data collection based on the questionnaire.	
			PM		Analysis of collected data/information	
20	2017/3/3	Fri	AM		Site Visit: Investigation of the existing drainage channel	
			PM	**EPA**	Meeting with EPA: Explanation of the Survey outline, interview of the existing condition and data collection based on the questionnaire	
21	2017/3/4	Sat	-		Site Visit: Investigation of the existing benchmarks	
22	2017/3/5	Sun	-		Preparing site survey report/Analysis of collected data/information	
23	2017/3/6	Mon	AM		Meeting with National Task Force: Explanation of the Survey outline, interview about the existing condition and data	
			PM		Preparing site survey report/Analysis of collected data/information	
24	2017/3/7	Tue	AM		Preparing site survey report/Analysis of collected data/information	
			PM		Site Visit: Investigation of the existing drainage channels, pums and sluices with JICA Expert Mr. Morita	
25	2017/3/8	Wed	AM		Preparing site survey report/Analysis of collected data/information	
			PM	**MPI**	Meeting with MPI: Explanation of the Survey outline, interview of the existing condition and data collection based on the questionnaire	
26	2017/3/9	Thu	AM	**OCC**	Meeting with OCC: Explanation of the Survey outline, interview of the existing condition and data collection based on the questionnaire	
			PM	**MC**	Meeting with MC: Explanation of the Survey outline, interview of the existing condition and data collection based on the questionnaire	
27	2017/3/10	Fri	-		Preparing site survey report/Analysis of collected data/information	
28	2017/3/11	Sat	AM		Preparing site survey report	
			PM		*17:25 BW 0526 Georgetown →New York JFK 22:25*	
29	2017/3/12	Sun	-		*12:15 JL 0005 New York JFK → Narita*	
30	2017/3/13	Mon	-		*Narita 16:35*	

MOA	:	Ministry of Agriculture	HS-MOA	:	Hydrometeorological Service, Ministry of Agriculture
NDIA	:	National Drainage and Irrigation Authority, MOA	MARAD-MPI	:	Maritime Administration Department, MPI
ASDU	:	Agriculture Sector Development Unit, MOA	MONR	:	Ministry of Natural Resources
GL&SC	:	Guyana Lands and Surveys Commission	M&CC	:	Mayor and City Council
GWI	:	Guyana Water Incorporated	EPA	:	Environmental Protection Agency
MC	:	Ministry of Communities	WB	:	World Bank
MPI	:	Monistry of Public Infrastructure	IDB	:	Inter-American Development Bank
CDC	:	Civil Defence Commission	OCC	:	Office of Climate Change

2. Explanation of Draft Final Report in Guyana (September 20 to September 26, 2017)

No	Date			JICA	Team of Consultants	
				Mr. Katsuhiro SHINO	**Mr. Tsuyoshi MATSUSHITA**	**Mr. Hirofumi TANAKA**
1	2017/8/20	Sun	PM	－	*Tokyo (Narita Airport), JAPAN → New York (JFK Airport), USA*	
2	2017/8/21	Mon	AM	*Arrive at GUYANA*	*New York (JFK Airport), USA → Georgetown (Roraima Airport), GUYANA*	
			PM		Preparation of Explanation of the Draft Final Report and Internal Meeting	
3	2017/8/22	Tue	AM	Site Visit: Investigation of the existing Pumping Station, Drainage Sluice Gate, Mobile Pump and Drainage Channel		
			PM			
4	2017/8/23	Wed	AM	Explanation and Discussion of the Draft Final Report with Related Agencies		
			PM			
5	2017/8/24	Thu	AM	*Leave GUYANA*	Preparing survey report and Revision of Draft Final Report	
			PM	－	*Georgetown, GUYANA → New York, USA*	
6	2017/8/25	Fri	-	－	*New York, USA → Tokyo, JAPAN*	
7	2017/8/26	Sat	-	－	*Tokyo, JAPAN*	

Appendix 3. List of Parties Concerned in Guyana

Organization	Name	Title / Position
Ministry of Agriculture (MOA)	Hon. Noel Holder	Minister
	Mr. George Jervis	Permanent Secretary
National Drainage and Irrigation Authority (NDIA), MOA	Mr. Fredrick Flatts	Chief Executive Officer (CEO)
	Mr. Dave Hicks	Deputy CEO
	Ms. Cristal Conway	GIS Engineer
Agriculture Sector Development Unit (ASDU), MOA	Mr. Raymond Latchman	Civil Engineer
	Mr. Trevaughn Waldron	Civil Engineer
	Mr. Benedict Yhap	Civil Engineer
Hydrometeorological Service (HS-MOA), MOA	Mr. Garvin Cummings	Deputy Chief Hydrometeorological Officer
	Mr. Komalchand Dhiram	Head of Climatology
	Ms. Vivianna Critchlow	Specialist / Hydrologist
	Ms. Vidayshree Misir	Specialist / Hydrologist
Ministry of Foreign Affairs	Ms. Vanessa Dickenson	Director
	Ms. Rosshanda Bagot	Foreign Service Officer
Caribbean Community Secretariat (CARICOM) / JICA	Mr. Tatsuya Morita	JICA Expert / Adviser, Regional Development Planning
Georgetown Mayor and City Council Engineer's Department	Mr. Colvern Venture	City Engineer
	Mr. Kenson Boston	Assistant City Engineer
	Mr. Winston Joseph	Supervisor of Gate/Pump Operators
	Mr. Horrings Worth	Gate Operator at Sussex Sluice
Ministry of Public Infrastructure (MPI)	Mr. Carmichael Thorne (former NDIA Staff)	Project Manager of Airport Expansion
	Mr. Maitland Stewart	Senior Engineer
Maritime Administration Department (MARAD), MPI	Mr. Troy Clarke	Superintendent of Surveys (Ag)
	Ms. Thandi McAllister	Legal Officer
	Mr. Darrell Fraser	Hydrographer
Works Services Group (WSG), MPI	Mr. Kevin Samad	Chief Sea and River Defence Officer
	Mr. Jermaine Braithwaite	Senior Engineer
Transport Planning Office, MPI	Mr. Patrick Thompson	Chief of Transport Planning Officer
	Ms. Ramona Duncan	Economist
Civil Defence Commission (CDC)	Mr. Chabilall Ramsarup	Director General / Colonel (Retired)
Guyana Water Incorporated (GWI)	Dr. Richard Van West-Charles	Chief Executive
	Mr. Lancelot Mars	Head of Strategic Planning
	Mr. Aubrey Roberts	Director of Procurement
	Mr. Orin Browne	Water Resources Manager
	Ms. Angelina Franklin	Hydrologist
	Ms. Melissa Benjamin	Statistician
Guyana Lands and Surveys Commission (GLSC)	Mr. Trevor L. Benn	Commissioner / Chief Executive Officer
	Mr. Nseem Nasir	Manager of Land Information and Mapping Division
	Ms. Alaira Murphy-Goodman	Executive Assistant
	Mrs. Jewel Cheong	Senior Land Administration Officer / Regional Coordinator
	Mr. Durwin Humphrey	Policy Analyst
	Mr. Hilton Cheong	Senior Surveyor (Geodetic)
	Ms. Andrea Mahammad	Senior Landuse Planner
Ministry of Natural Resources Geospatial Information Management Unit	Mr. Haimwant Persaud	Manager / Spatial Solution Specialist
Environmental Protection Agency (EPA)	Mr. Kemraj Parsram	Executive Director
	Ms. Felicia Adams	Senior Environmental Officer
	Mr. Colis Primo	Senior Environmental Officer
	Ms. Teijvarti Persaud	Senior Environmental Officer
	Ms. Diana Fernandes	Environmental Officer
	Mr. Frank Grogan	Environmental Officer
	Mr. Imole Mcdonald	Environmental Officer
National Task Force Commission (NTFC)	Dr. Sewnauth Punalall	Head of NTFC Secretariat
	Mr. Lennox Lee	Research Engineer
Ministry of the Presidency	Ms. Janelle Christian	Head of Office
Office of Climate Change (OCC)	Ms. Carolyn Foo	Community Outreach Officer / Assistant
	Mr. Shane Singh	Technical Officer
Ministry of the Presidency	Mr. Rafael Gravesande	Project Manager, Project Management Office
Ministry of Communities (MOC)	Mr. Emil Mcgarrell	Permanent Secretary
	Mr. Puran Persaud	Senior Regional Development Officer
	Ms. Nandranie J. Harrichan	Principal Municipal Services Officer
	Ms. Denis Hodge	Legal Officer
Central Planning and Housing Authority (CHPA)	Mr. Anthony Ragnauth	Civil Engineer

Appendix 4. Summary of Future Plan for Drainage Improvement

All of specifications of facilities, work items and estimated costs shown in the following tables are preliminary assumed by the Survey Team based on data acquired though the Survey. Therefore, accuracy is rougher than master plan study.

1. Improvement of Drainage Channel, Sluice and Pumping Station

No.	Sub-Catchment Area	Facility	Specification	Estimated Cost
1	Liliendaal	Pumping Station	New: Q=2.5m^3/s (Existing 8.5m^3/s, Total 11.0m^3/s)	USD 4.0 x 10^6
		Drainage Channel	Earth Channel: L=4.37km, W=18.0m	USD 4.0 x 10^6
2	Kitty	Pumping Station	New: Q=4.7m^3/s (Existing 4.3m^3/s, Total 9.0m^3/s)	USD 5.8 x 10^6
		Drainage Channel (West)	Concrete Channel: L=1.53km, W=3.0m	USD 2.7 x 10^6
		Drainage Channel (East)	Earth Channel: L=1.10km, W=10.0m	USD 0.4 x 10^6
3	Young Street	Pumping Station + Sluice	New: Q=6.0 m^3/s	USD 6.8 x 10^6
		Drainage Channel	Concrete Channel: L=1.10 km, W=4.0m	USD 2.1 x 10^6
4	Cummings Canal	Pumping Station + Sluice	New: Q=8.0 m^3/s	USD 8.0 x 10^6
		Drainage Channel	Earth Channel: L=3.25km, W=16.0m	USD 2.5 x 10^6
5	Lamaha Street	Pumping Station + Sluice	New: Q=6.0 m^3/s	USD 6.8 x 10^6
		Drainage Channel	Earth Channel: L=2.24km, W=12.0m	USD 1.2 x 10^6
6	Church Street	Pumping Station + Sluice	New: Q=7.0 m^3/s	USD 7.4 x 10^6
		Drainage Channel	Concrete Channel: L=4.07km, W=5.0m	USD 8.8 x 10^6
7	Commerce Street	Pumping Station + Sluice	New: Q=3.0 m^3/s	USD 4.5 x 10^6
		Drainage Channel	Downstream: Concrete Channel: L=1.0km, W=4.0m	USD 1.8 x 10^6
		Drainage Channel	Upstream: Earth Channel: L=2.54km, W=8.0m	USD 0.7 x 10^6
8	Princess Street	Pumping Station + Sluice	New: Q=10.0 m^3/s	USD 9.2 x 10^6
		Drainage Channel	Concrete Channel: L=3.87km, W=6.0m	USD 9.2 x 10^6
9	Sussex Street	Pumping Station + Sluice	New: Q=5.0 m^3/s	USD 6.1 x 10^6
		Drainage Channel	Concrete Channel: L=3.93km, W=4.0m	USD 7.7 x 10^6
10	La Penitence South	Pumping Station + Sluice	New: Q=7.0 m^3/s	USD 7.4 x 10^6
		Drainage Channel	Earth Channel: L=5.74km, W=12.0m	USD 2.5 x 10^6
11	Ruimveldt North	Pumping Station + Sluice	New: Q=8.0 m^3/s	USD 8.0 x 10^6
		Drainage Channel	Earth Channel: L=5.72km, W=11.0m	USD 2.6 x 10^6
12	Ruimveldt South	Pumping Station + Sluice	New: Q=7.0 m^3/s	USD 7.4 x 10^6
		Drainage Channel	Earth Channel: L=5.62km, W=11.0m	USD 2.5 x 10^6
Total				USD 130.1 x 10^6

2. Equipment for Operation and Maintenance

Location	Equipment	Purpose	Q'ty (Unit)	Estimated Cost
Outfall of Drainage Channel (Downstream of sluice)	Excavator with Long Boom	Excavation/Dredging of sediment	1	USD 0.3 x 10^6
	Pontoon	Working platform for excavator	1	USD 0.1 x 10^6
	Tug Boat	Towing pontoon and barge	2	USD 0.6 x 10^6
	Barge	Conveying excavated sediment	2	USD 0.5 x 10^6
Drainage Channel (Upstream of sluice)	Excavator with Long Boom	Excavation/Dredging in primary and secondary drainage channel	2	USD 0.6 x 10^6
	Sludge Pump	Excavation/Dredging in secondary and tertiary drainage channel	4	USD 0.1 x 10^6
	Drainage Pump Vehicle	Emergency drainage work	6	USD 4.8 x 10^6
	Dump Truck	Hauling of excavated/dredged soil	6	USD 0.9 x 10^6
			Total	USD 7.9 x 10^6

3. Annual Operation and Maintenance Work of Drainage Facilities

Work Item	Work Quantity	Estimated Cost
Dredging of Outlet Fall of Drainage Channel	2,800 m^3	USD 84 x 10^3 /Year
Dredging and Hauling of Primary Drainage Channel (46 km)	46,000 m^3	USD 322 x 10^3 /Year
Maintenance Cost of Pump and Sluice (0.5 % of Construction Cost of Pump and Sluice)		USD 460 x 10^3 /Year
Total		USD 0.9 x 10^6 /Year

4. Rainwater Storage Facility

Location	Work Item	Work Quantity	Estimated Cost
National Park	Excavation and Hauling	850,000 m^3	USD 4.3 x 10^6
Botanical Gardens	Excavation and Hauling	570,000 m^3	USD 2.9 x 10^6
Lowland Area at Downstream of Liliendaal	Excavation and Hauling	1,700,000 m^3	USD 8.5 x 10^6
Appurtenant Structures for All Site	30 % of Construction Cost		USD 5.0 x 10^6
Total			USD 20.7 x 10^6