Kingdom of the Netherlands

DRR-Team Mission Report

Guyana

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[DRR - Team Guyana]

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EXECUTIVE'S SUMMARY

In July 2015, extreme rainfall caused severe disruption of daily life in Georgetown as well as in several agricultural coastal areas. According to the Ministry of Public Infrastructure, the losses due to this event in the agricultural sector alone were more than 100 M US$. In addition to the direct damage city flooding also causes serious health threats due to potential spread of water-borne diseases. Flooding is not an unusual situation for the low-lying areas of Guyana with typical topographic heights around Mean Sea Level (MSL). Inundations occurred many times in the past, with sometimes devastating effects, such as in 1934 and 2005.

The Government of Guyana has requested the Government of the Netherlands to advise on their drainage situation, both for Georgetown and the low-lying agricultural coastlands. The official request from the Guyanese Ministry of Public Infrastructure was sent to the Netherlands Embassy in Suriname on 03-08-2015. In this letter, it was also requested to comment on the coastal defence strategy, but it was decided during the preparatory telecons and the kick-off meeting to focus on the drainage problems. It was decided by the Dutch Government to follow-up the request by means of a scoping DRR – Team mission addressing the flood risk management in the northern coastline of Guyana, and Georgetown in particular.

Dutch Risk Reduction (DRR) Teams, in general, aim to reduce the risk of water related disasters. Many countries around the world face severe water threats. Often, these countries are in urgent need of expert advice on how to prevent a disaster or how to recover from a calamity.

The DRR - Team visited Guyana in the period 22 – 26 November 2015. The various components of the Georgetown drainage system were visited, a fly-over across the entire coastline was made and interviews were held with leading representatives from governing agencies, potential funding agencies (EC) and relevant stakeholders.

The DRR - Team accompanied by Guyanese experts during the fly-over

The objective of the mission was to specify what can be done to better operate and manage the drainage system of Georgetown and the low-lying coastal areas. Annex A gives the names of the DRR - Team members, as well as those of the attendants of the inception meeting (23 November, Georgetown). Some highlights of the wrap-up meeting (26 November, Georgetown) are given in Annex B.

Considering the economic situation of Guyana and the relatively mild character of the flooding events under normal conditions, it is not recommended to consider new large scale, expensive infrastructure. Instead, it is advised to take a large number of small steps over a period of several years that will increase the knowledge and the collective ownership of the drainage infrastructure among local experts, Guyanese governments, and the people of Guyana. By increasing trust, cooperation and local expertise Guyana can become a South-American example of effective and efficient water management

This report provides concrete suggestions to make the Guyana approach towards water management in general and drainage in particular more integrated and more *proactive.* The suggestions cover a wide palette of topics and include:

1 Upgrade modelling capability

- Make a long-term project plan to gradually develop the hydraulic drainage model for Georgetown, with the design requirements mentioned in Section 3.2.
- 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. Use this understanding to support project proposals (for example increasing the pumping capacity of the most northern outfall sluice along the Demerara River).
- Start selecting two or three engineers with a passion for computers and modelling and train them on the subject of hydraulic modelling.

2 Improve flood resiliency of people

- Develop a communication plan with the aim to increase the understanding of the people about what it means to live with water (in terms of potentials and challenges) and execute this plan. It has to be clear that the flood risk will never be reduced to zero. Consider to use a shared symbol, for example the water lily.
- Make a flood hazard map of Georgetown and use it to explain to the people why it is important to build their properties (houses and businesses) flood-proof.
- Prepare a simple explanation (for example, a Youtube video) on how the drainage system works, why water needs space, and why it is important to keep the drainage system free from constructions and solid waste.

3 Upgrade small-scale floating dredging capabilities

- Specify the requirements for small scale floating dredgers for the city of Georgetown and justify the investment based on a 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. Evaluate the performance on a regular basis.

4 Develop and apply rational risk approach

- Prepare a first set of flood hazard maps for a region yet to be chosen (for example one isolated catchment area in Georgetown). Next steps are to prepare flood hazard maps for other areas as well, including rural areas.
- Set up the framework for analysis for the sea defence risk assessment using the Rational Risk Approach briefly described in Section 3.5. The items mentioned under 'national debate' in Section 4.1 should be part of this activity.

5 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. One pilot location could be chosen in consultation with GuySuCo (low-lying coastal area with planned or unplanned urban development on formerly rural lands). Involve different governmental agencies to develop structural ways of cooperation;
- Idem, but now for an existing highly urbanized catchment area in Georgetown.

6 Asset Management

- Consider the suggestions given in the Table in Section 3.7 on Asset Management.

7 Data Management

- Start collecting all available data on the drainage system (Georgetown and elsewhere), digitise, and apply gap analysis to see what misses. Start collecting and digitising these missing data. This includes data on locations of canals, sluices and pumps, their dimensions, capacities, flow velocities, bed composition, embankment composition, etc).
- Start collecting all relevant hydro-meteorological data that is required for a risk assessment (of the drainage system as well as the sea defence system – see Section 3.5). Use a pre-set format for such data collection and store it in a national central data base. Apply gap-analysis to see which data is missing.
- Use geo-informatics to collect data on land use, long-term shoreline dynamics (mudbanks), and flood events. Store these data in a fixed format in the central database.
- Start analysing the data in a consistent manner and contributing to better understanding of the flood risks. Lidar data in combination with land use data can be used to prepare flood hazard maps. Long-term rainfall data (GuySuco) can be used to determine the frequency of occurrences of extreme rainfall events, which serves as input for the risk assessment.

8 Technical short-term improvements

- Consider the technical upgrade options listed in Table 3.2;
- Consider improving the hydraulic efficiency by streamlining corners of drainage canals

The above recommendations have been split up into short-term (2016), medium-term (2016 – 2018) and long-term (beyond 2018) measures in Section 4.2.

No ranking has been applied to recommendation, since it is up to the Guyana government to discuss, prioritize and decide on the relevance of the measures. Final choices will depend on their funding opportunities and/or possible matching funds from other running or expected initiatives.

Probably the most obvious running initiative to consider co-funding is the Budget Support programme from the European Union (EDF), even though this focusses on the sea defence. The outfall structures that cross the sea defence, however, can be considered an integral part of the sea defence and could logic-wise become part of the upcoming 11th EDF. Preliminary discussions on this subject with the EU representative in the preparation of the mission indicated that this could indeed be an option. In that case, in principle, some of the above recommendations may be considered under the framework of the 11th EDF.

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1 INTRODUCTION

1.1 Background

The Cooperative Republic of Guyana (hereafter referred to as Guyana) has experienced numerous inundations, especially in the low lying coastal areas and the capital city of Georgetown. Just recently, in July 2015, extreme rainfall of 220 mm in just one day (with 2300 cm on average per annum), caused severe disruption of daily life in Georgetown as well as in several agricultural coastal areas. According to the Ministry of Public Infrastructure, the losses due to this event in the agricultural sector alone were more than 100 M US$. In addition to the direct damage flooding also causes serious health threats due to potential spread of water-borne diseases. Since these types of flood (from rainfall) generally move slowly in time, no casualties occurred, but the impact on daily life and negative impact on the economy is evident.

Although the July-event was extreme, it was not an unusual situation for the low-lying areas of Guyana with typical topographic heights around Mean Sea Level (MSL). Floodings occurred many times in the past, as described in an article from Kandasammy (2006). For example, devastating floods occurred in 1934 when excessive rainfall flooded all low-lying coastal areas. The situation worsened considerably after a series of breaches in the coastal defence, so that each tide significant volumes of (salt) ocean water entered the flooded areas. 2005 was another year with serious floods which reminded the people of Guyana again of the vulnerability of their low-lying land.

The city of Georgetown is drained by an interconnected network of open channels which discharge rainfall water into the ocean by a system of pumps or gravity-operated sluices (kokers). This system was originally developed to irrigate and drain the sugar plantations which occupied the land on which Georgetown now stands. Urbanization over the years had a large impact on the hydraulic functioning of the system as some channels were blocked and previously pervious surfaces were paved resulting in increased rates of run-off (less retention capacity). A detailed description of the components of the water and sewerage system of the city of Georgetown (channels, pumping stations along the northern sea wall and gravity-operated sluices towards the Demerara river) is given in Halcrow (1994).

Outside the built up areas, land use in the coastal zone is still predominantly agricultural. (sugar, rice, cattle and some cash crops like coconut). Here, the original functioning of the irrigation and drainage channels, including discharge sluices, has largely been preserved. The irrigation channels obtain their water from so-called conservancies where water is being collected and retained during wet season with a system of dams and discharge structures. This delicate but effective system of channels and hydraulic structures is of paramount importance for the agricultural sector, and as such for the national income of Guyana.

However, increasing pressure on space, urbanization, conflicting interests and in some cases poor maintenance have also led to a deterioration of the drainage system in the rural areas, leading to an increase in serious flooding events.

The current state of the drainage systems in Georgetown is likely not adequate anymore to effectively cope with rainfall conditions that may occur on average each year, and the situation is expected to worsen due to the effects of global warming. It is expected that the so-called eustatic part of sea level rise will accelerate, which reduces the time span during which water can flow out under gravity. This will necessitate the use of more pumps to get the (rainfall) water out of the city.

Global warming may also lead to more frequent storms (potentially even hurricanes – so called 'grey swans'), which increases the hydraulic attack on the river and sea defenses. Further, more intense rainfall is expected which will also increasingly challenge the current drainage systems.

The Government of Guyana acknowledges the importance of building and maintaining an adequate drainage system for both Georgetown and the agricultural areas. In view of the situation described above, the Government of Guyana has recently established a National Task Force, appointed by the Cabinet, to address the problem and to develop an implementable strategy to make the country future-proof.

Guyana has been and continues to be assisted in its sea and river defense efforts by several International Funding Institutions (IFI's). These programs and projects are increasingly funded by allocating funds to the government of Guyana, rather than standalone projects overseen for example by the European Union. This shows confidence in the government's sense of urgency on the matter and their ability to manage and execute these works.

1.2 Dutch Risk Reduction

Dutch Risk Reduction Teams in general aim to reduce the risk of water related disasters. Many countries around the world face severe water threats. Often, these countries are in urgent need of expert advice on how to prevent a disaster or how to recover from a calamity.

For example, when a country has been struck by severe flooding and the first emergency relief workers are gone, the need for advice on how to build a sustainable and safer water future arises. To meet these needs with a swift response, the Dutch government has initiated the Dutch Risk Reduction Team (DRR - Team). This team of experts advises governments on how to resolve urgent water issues related to flood risks, water pollution and water supply, to prevent disasters or to rebuild after water related disasters. With climate change and a fast growing world population, water issues are becoming more urgent.

The Netherlands has brought its best water experts together in the Dutch Risk Reduction Team. It consists of high level advisors supported by a broad base of technical experts who can provide top quality and tailor made expertise to governments that are confronted with severe and urgent water challenges. The Dutch are experts in adapting to water in a changing world; from delta management to water technology, from urban planning to governance, public private partnerships and financial engineering.

1.3 Terms of Reference for this mission

The government of Guyana has requested the DRR - Team to advise on their drainage situation, both for Georgetown and the low-lying agricultural coastlands. The official request from the Guyanese Ministry of Public Infrastructure was sent to the Netherlands Embassy in Suriname on 03-08-2015. It was decided by the Dutch government to follow-up the request by means of a DRR - Team scoping mission addressing the flood risk management in the northern coastline of Guyana, Georgetown in particular.

The objective of the DRR - Team mission is to provide advice and on-spot capacity building on short-, medium and long-term flood risk management. More specifically:

- The mission will explore technical possibilities with the Guyana government regarding short-term, medium- and long-term measures that can be taken and look into a sustainable strategy for the water management and drainage problems in Georgetown and the coastal lowlands.
- The mission will review how flood risk management is currently being managed / governed.
- The mission will assess the current (technical) state of a number of hydraulic structures (in particular the gravity-operated discharge sluices).
- The mission will provide advice and recommendations regarding possible improvements of the operating and maintenance of the various elements of the drainage system of Georgetown.
- The mission will describe existing programmes on flood management and look for opportunities to implement the recommendations.

The planning of the DRR - Team mission was as follows:

10 – 20 November:	Team mobilisation and preparations
22 November:	Travelling, arrival,
23 November:	Kick-off meeting, inspection drainage works Georgetown (pumps, sluices, channels), sharing expertise and ideas
24 November:	Fly-over west coast to Pomeroon River and fly-over east coast to Corentyn River; three interview sessions
25 November:	Seven interview sessions
26 November:	Two interview sessions, analysing visual observations and lessons learned from interview sessions, preparing for presentation, wrap-up session.
27, 28 November:	Travelling back to Netherlands
30 Nov – 31 Dec:	Reporting, feedback to DRR management team;
Mid Jan 2016:	Finalisation of report;
End of Jan 2016:	Formal delivery of final report to Government of Guyana, start follow-up activities and feedback to Dutch Water Sector.

1.4 Reader's guide and Acknowledgements

Sections 2.1 and 2.2 give a summary of the observations that were made during the field inspections (Georgetown and fly-over). It describes the locations that were visited, what the local issues were, as well as tentatively the technical state of the inspected hydraulic structures.

More than ten interview sessions were held with senior management and leaders of involved stakeholders. These interviews provided the team with lots of insight on how water management issues are being dealt with and how the effectiveness of it is being perceived. The lessons taken from these interviews are mentioned in Section 2.3.

Based on the observations from the field visits and the interviews, it became clear that some aspects of the current water management are definitely worth maintaining. These good things about the current practices are mentioned in Section 2.4.

Improvements, both technically and governance-wise, are possible and given the importance of a well-functioning drainage system for the future of the country, in fact necessary. The Team's suggestions for improvement have been grouped under the following items:

- Upgrade Modelling capability (Section 3.2);
- Increase flood resilience of people and business (Section 3.3);
- Upgrade dredging capabilities / improve flow efficiency (Section 3.4);
- Develop long-term plan with investment programme based on risk approach (Section 3.5);
- Develop and test pilot Living with Water (Section 3.6);
- Develop and apply a life cycle approach for the drainage assets (Section 3.7);
- Data management (digitise) (Section 3.8).
- Technical improvement options (section 3.9)

Recommendations on how to proceed are given in Chapter 4. This includes an estimate of costs and planning for the proposed follow-up activities.

The names of the Dutch team members, as well as those of the interviewed experts and authorities, are given in Annex A. All accompanying experts have put a lot of effort in making the mission a success and are warmly acknowledged for their hard work.

Picture taken after the wrap up meeting (from left to right: Major General Joe Singh Ret'd – Chairman NTFC; Mr Frederick Flatts – CEO NDIA, Mr Ernst Noorman – Ambassador of the Kingdom of the Netherlands, Mrs Judith Klostermann – DRR - Team expert on social sciences, Mr. Rob Steijn – DRR - Team leader and principal coastal engineer, Mr. Fokke Westebring – DRR – Team expert on hydraulic structures, and Mr. David Patterson – Hon. Minister of Public Infrastructure.)

2 OBSERVATIONS AND ANALYSIS

2.1 Georgetown

Elements of the drainage system

The current drainage system of Georgetown is based on the historic irrigation, transportation and drainage system, which was developed centuries ago for the sugar plantations:

- Straight typically 6 m wide irrigation channels running in east-west direction terminated at the Demerara River at sluice gates called 'kokers". These channels obtain their water from the East Demerara Water Conservancy where rainfall water is collected and stored.
- Similar drainage channels running in the same direction with similar widths usually dug in pairs at the boundaries of the former sugar estates. Typical distance between the various channels is around 400 m.
- In addition to the primary drainage system, in Georgetown, there is a system of smaller secondary drainage channels perpendicular to the primary channels, as well as tertiary drainage channels perpendicular to the secondary channels see Figure 2.1). These roadside drains are generally of concrete construction in central Georgetown.

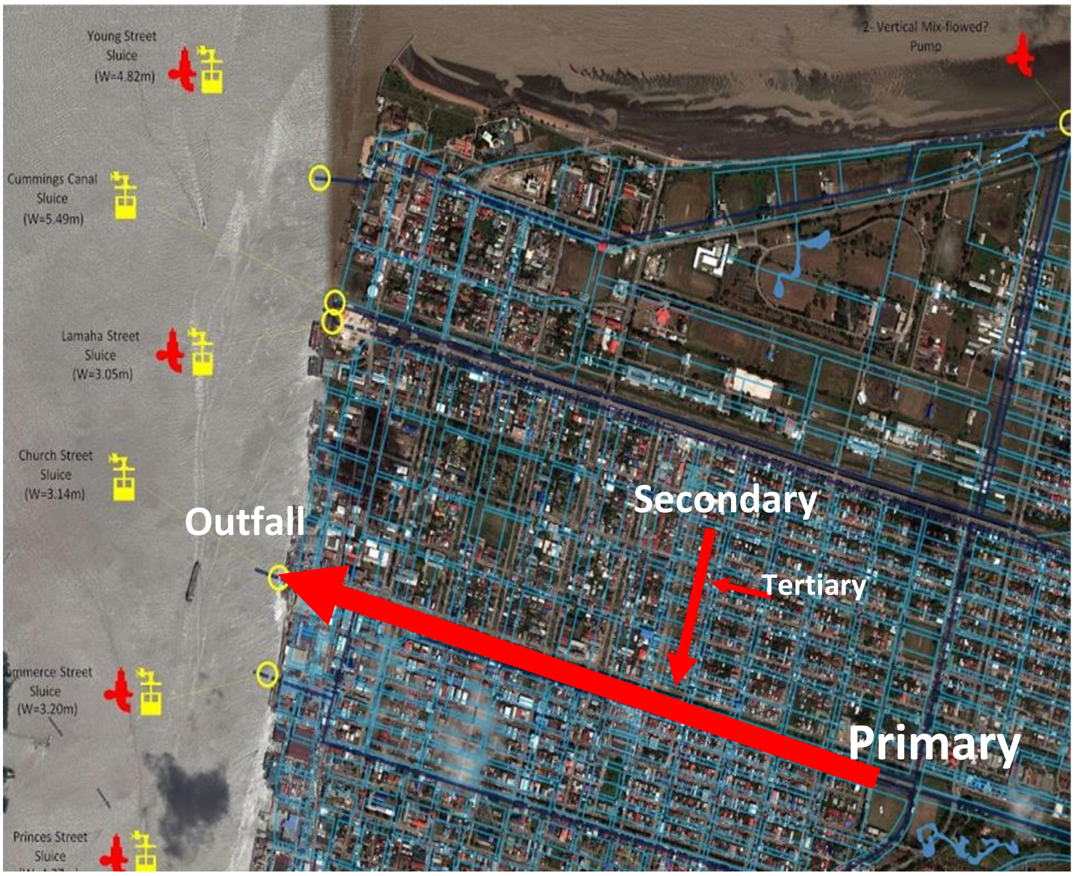

Figure 2.1 System of primary, secondary and tertiary drainage channels

- Free flow outfalls (gravity) into the river or (in some areas) the ocean, where discharge is possible only during low tide (below MSL). Within the Georgetown area there are 13 of these kokers, of which 11 are operational today.
- Outfalls consisting of a concrete structure and a single wooden vertical gate with counter weight, manually operated by a simple winch. Most of the operational structures were built during the Nineteen Twenties and Thirties.
- Since water discharge capacity under gravity alone is not sufficient to drain the area, pump stations were constructed since the Sixties. The first one was the Kitty pumping station with a reported capacity of 1.2 m^3/s (Halcrow, 1994) installed in 1968; the second was Liliendaal with a reported capacity of 4.2 m^3/s, installed in 1973.

The urban development of Georgetown followed the historical 'rectangular' pattern of the sugar estates drainage systems. This has resulted in 16 principal drainage systems varying in size between 64 hectares (Number 8: bounded by Independence Boulevard in the North and by Laing Avenue in the South) and 835 hectares (number 15: western boundary at Sheriff Street, southern boundary by Caneview Avenue – this catchment area is drained by the Liliendaal pumping station).

The various catchment areas are interconnected, but only at a few locations and primarily with relatively small (1 m diameter) culverts.

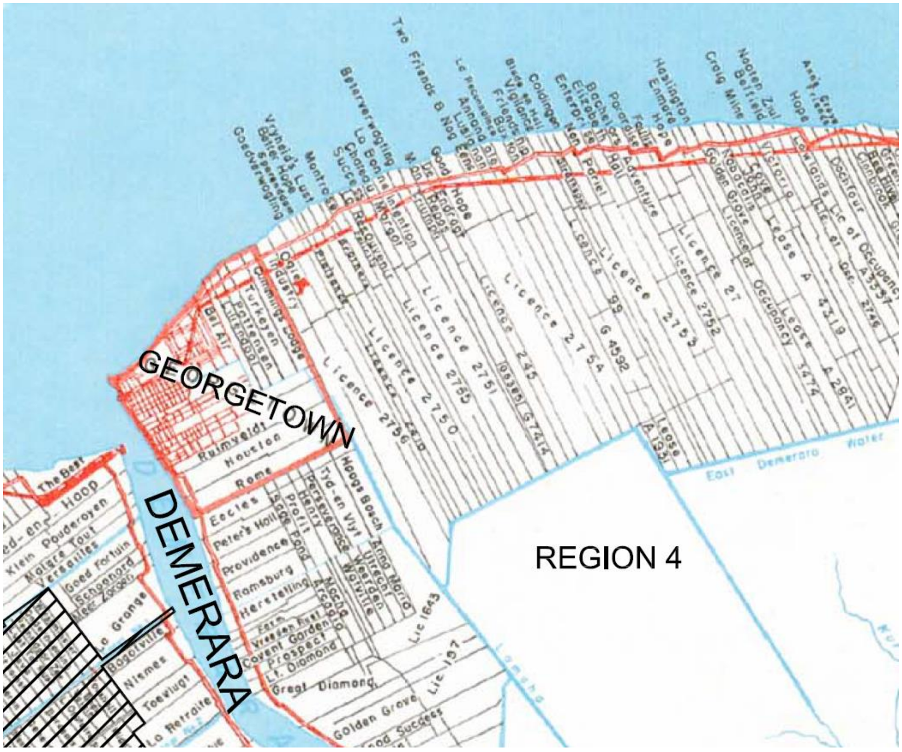

Figure 2.2: Georgetown in relation to the coastline drainage structure (source: part of "Map of the seacoast of Guyana" by the lands department of the ministry of agriculture March 1972)

A detailed description of the various elements of the Georgetown drainage system is given in Halcrow (1994), but some of the information will probably be outdated by now.

The system of irrigation and drainage channels with their water intake points at the Conservancies and outfall structures at rivers or the Ocean, is the same system as what is still used in the agricultural areas of Guyana. This becomes clear when the (primary) drainage pattern of Georgetown is shown altogether with the irrigation and drainage pattern of its surroundings (see Figure 2.2).

Field observations (26 November 2015)

The two pumping stations Liliendaal and Kitty were inspected as well as the four most northern outfall sluices along the Demerara River. The two most northern outfall sluices were equipped with temporary pumps. These mobile pumps were intended to operate only temporarily, but in reality they are operational for years now.

Figure 2.3: Typical examples of outfall structures 'Cummings Sluice' and 'La Penitence Sluice'.

Besides the various outfall structures the team also visited sections of the different drainage channels (Figures 2.4 and 2.5 below).

Figure 2.4: Typical examples of primary drainage channels


Figure 2.5: Typical examples of secondary and tertiary drainage channels

Man-made and natural changes that influence conveyance capacity (m^3/s)

In the last decades the basic drainage system has been modified as a result of the continuous urbanisation of Georgetown. Adjustments such as:

- Filling in of drainage channels (artificial);
- Illegal construction;
- Concrete lining of drainage channels, leading to much less seepage of water into the soil (Figure 2.6);
- Tunnelling of drainage channels (especially along the Demerara River, so near the outfall structures as a result of industrial development along the riverside – Figures 2.7 and 2.8);
- Increased bridging of channels due to increased traffic, often reducing the flow with a culvert;
- Additional interconnection culverts between drainage areas; and
- Choking of water exits (mooring of ships in the outfall channel, sediment deposits).


Figure 2.6 Concrete lining of drainage channels due to urban pressure

These adjustments all resulted in an increase in the hydraulic resistance and therefore decrease of the conveyance capacity. There are no quantitative data on how much the conveyance capacity (in m^3/s per cross-section) has decreased in each part of the overall drainage system. It is however very likely that due to the (unplanned) modifications, the flood probability in certain urban areas has increased as a result of this.

Figure 2.7 Tunnelling of drainage channels due to urban pressure

Figure 2.8: Blocking of the outfall channel by industrial activity

On the other hand, measures have been taken to increase the conveyance capacity or to increase the redundancy of the drainage system:

- Installation of 'mobile' (or 'temporary') pump capacity next to the two most northern sluices along the Demerara River (Figure 2.9);
- Installation of permanent pump capacity instead of gravity outfall structures (1968 and 1973: Kitty and Liliendaal along the Ocean side – Figures 2.10 and 2.11);
- Adding culverts to improve interconnectedness between primary drainage catchment areas (Figure 2.12).
- Removing solid waste from the channels (note: during the mission, most solid waste was removed. It was reported that this happened just a few months before the mission and that in the past years solid waste disposal in the channels was a serious threat to the conveyance capacity of the drainage system).

Figure 2.9 : 'Mobile' pump (in operation for a few years)

Figure 2.10: Permanent pump station 'Liliendaal' at the ocean side

Figure 2.11: Permanent pump station 'Kitty' at the ocean side

Figure 2.12 connection pipe between two catchment areas

Apart from these 'man made' adjustments to the drainage system (both improvement and worsening of conveyance capacity), there are also changes due to natural causes. The most import ones are:

- Siltation and overgrowing of the outfall channels (Figure 2.13);
- Vegetation in the drainage channels (Figure 2.14).

Figure 2.13: Siltation and overgrowth at outfall channels

Figure 2.14: Vegetation in drainage channels

All these changes together have led to a complicated system of drainage. Figure 2.15 below gives an overview of the total Georgetown drainage system, with the channels indicated with blue lines and the sluices and pump stations indicated with yellow circles.

Some catchment areas are interconnected resulting in some redundancy in the system. This redundancy results in levelling of the water between catchment areas. This has a positive effect because the outfall or pump of one catchment area can help when there is a problem with the capacity in another area. However, it can also have a negative effect when flooding in one area leads to extra water in the adjacent areas.

The installation of pump capacity makes the drainage system less dependent of the tide level in the river. In the (near) future, with expected higher sea levels (possibly combined with some land subsidence) it will be necessary to increase the pump capacity. On the longer term (decades) pumping is the only way to discharge excessive precipitation.

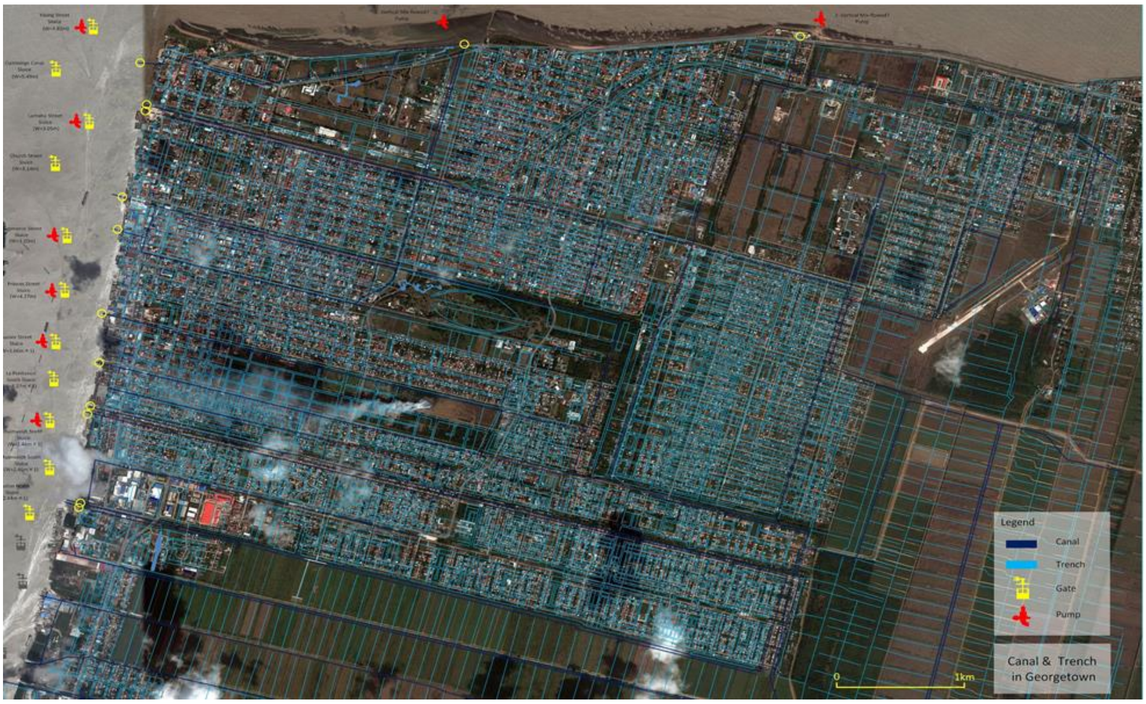

Figure 2.15 Drainage map of Georgetown

Available discharge capacity model

There is a basic model of the total system of sluices and pumps that is used to predict the total capacity of the outfall structures (illustrated in Figure 2.16 below). The model does not take into account the hydraulic effects of the drainage channels, nor does it take into account the hydraulic losses due to all structures and human and natural interferences (as indicated above). It is merely based on experience and observations made in the past. It has for example been assumed that all pumps and sluices are 75% operational as a consequence of maintenance and repair works (as indicated under 'notes' in the right column).

The model has been used to better understand the maximum rainfall discharge capacity of the current system, assuming that all elements function according to expectations. The model at least gives some quantitative data about discharge capacity of the system.

According to this model, the total capacity of the Georgetown drainage system is a maximum rainfall intensity of ca 100mm/day. If this figure is correct, then higher rainfall will automatically lead to (temporary) flooding of parts of the city. The extreme rainfall intensity of 220 mm/day that occurred in July 2015 was clearly above this critical level and led to large-scale flooding (said to be up to 0.5 m inundation depths).

It is likely that some local inundations will occur with rainfall even below the 'critical' level of 100 mm/day, as not all elements of the system will always be fully operational (due to human and natural causes mentioned above), and there are differences in land heights between the 16 different catchment areas.

No	Location	Drainage Area (ha)	Existing Capacity				Notes
			Sluice	Pump	Total	Total	
			(m3/sec)	(m3/sec)	(m3/day)	(mm/day)	
1	Pump Station – Liliendaal	1335		8,5	550.800	20	Pump availability taken at 75% due to dependence on unreliable electricity supply.
2	Pump Station - Kitty	243		4,25	137.700	5	Only one pump functions at a time due to basin constaints. Pump availability taken at 75% due to dependence on unreliable electricity supply.
3	Young st	65	7,8	1,13	253.469	9	Sluice and pumps are only 75% efficient due to poor state of maintenance.
4	Cummings Canal	127	10,6		286.531	10	Sluice is only 75% efficient due to poor state of maintenance.
5	Lamaha Street	88	3,6	1,13	139.392	5	Sluice and pumps are only 75% efficient due to poor state of maintenance.
6	Church Street	146	4,0		108.717	4	Sluice is only 75% efficient due to poor state of maintenance.
7	Commerce Street	153	2,8	1,13	117.101	4	Sluice and pumps are only 75% efficient due to poor state of maintenance.
8	Princess Street	211	6,2	1,13	209.988	8	Sluice and pumps are only 75% efficient due to poor state of maintenance.
9	Sussex Street	107	4,9	1,13	174.194	6	Sluice and pumps are only 75% efficient due to poor state of maintenance.
10	La Penitence South	64	19,1		514.990	19	Sluices are only 75% efficient due to poor state of maintenance.
11	Rimveldt North	119	5,3	1,13	185.463	7	Sluice and pumps are only 75% efficient due to poor state of maintenance.
12	Ruimveldt South	117	5,0		133.952	5	Sluice are only 75% efficient due to poor state of maintenance.
	Total	2.775	69	20	2.812.298	101	

Figure 2.16: Overview of the capacity of the Georgetown outfall structures (model)

Figure 2.17 shows how the model is used to compute the long-term averaged frequency of occurrence of inundation. The blue triangles show recorded rainfall intensities in the region, with the straight line as a best fit. Assuming a discharge capacity of 101 mm/day (red rectangular box in Figure 2.16), the recurrence interval equals two years.

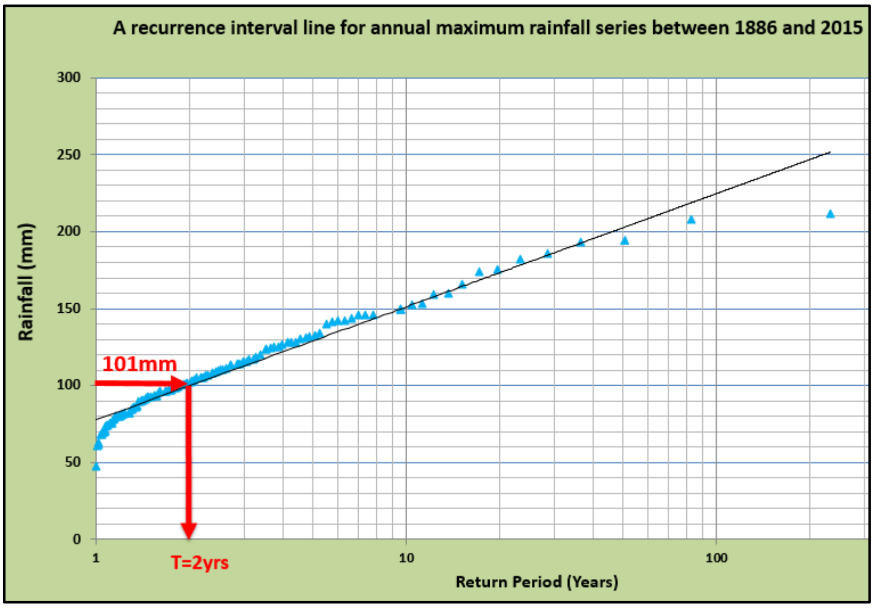

Figure 2.17 Computation of the flood recurrence interval in Georgetown

It is generally felt that in the last couple of years, inundation occurred more often than once per two years. This is possible if the drainage system is not functioning according to the assumptions listed in Figure 2.16. According to the team, this is likely one of the reasons, because conveyance capacity of the channels may not be sufficient to bring enough water towards the outfall structures (so the discharge rates used in Figure 2.16 cannot be 'delivered').

Another possible explanation for the general perception that flood frequency increases, is a change in rainfall intensities (climate change effect). When analysing the rainfall records from 1886 to 2015 (see table below), it was found that three (3) of the top ten highest ranked annual maximum daily rainfall events, took place in the last decade and two (2) within the last two years. Similar trends of more frequent 'extreme weather events' occur all over the world and are generally associated with the consequences of global warming. It shows once again that climate change is not a threat for the future but that its effects are already manifested in more extreme weather conditions today.

Year	I(mm)/day	Rank
1890	211	1
2015	208	2
2005	196	3
1936	194	4
1951	192	5
2014	186	6
1934	181	7
1893	174	8
1974	174	9
1945	160	10

Coastal high water defence scheme

The team focussed their observations on the drainage system (channels, outfall structures), but also looked at the sea defence. After all, Georgetown lies at or slightly below MSL, so flooding from the seaside may also be a threat to the city.

The typical coastline behaviour as will be described in Section 2.2, has resulted in the construction of sea defences, which largely cover the northern borders of Georgetown. The Georgetown high water defence on the ocean side consists of a reinforced coast line as illustrated with the pictures below (Figure 2.18).

During the field inspections it was noticed that even though the wind was relatively calm (perhaps 3-4 Beaufort), wave overtopping of the seawall occurred at several places (estimated to be around 0.1 l/m/s). During more extreme wind conditions, significant volumes of water will overtop the seawall and will flow into the northern catchment areas of Georgetown. This additional volume of (salt) water needs to be discharged through the drainage system as well.

Figure 2.18 : Georgetown sea defence (upper: concrete seawall and rock revetment; lower: geotube groyne and concrete outfall for sewerage).

River high water defence scheme

On the Demerara river side, the spatial situation is more complex. The original dike has over the years been extended into the river with all kinds of port related structures including buildings, shipyards, mooring sites, etc. (Figure 2.19).

The exact line of the high water defence along the river could not be recognised in the field; nor could it be drawn on a map. This makes inspection or managing the river embankment (important to keep river water out of the city during high river water levels) very difficult, if possible at all.

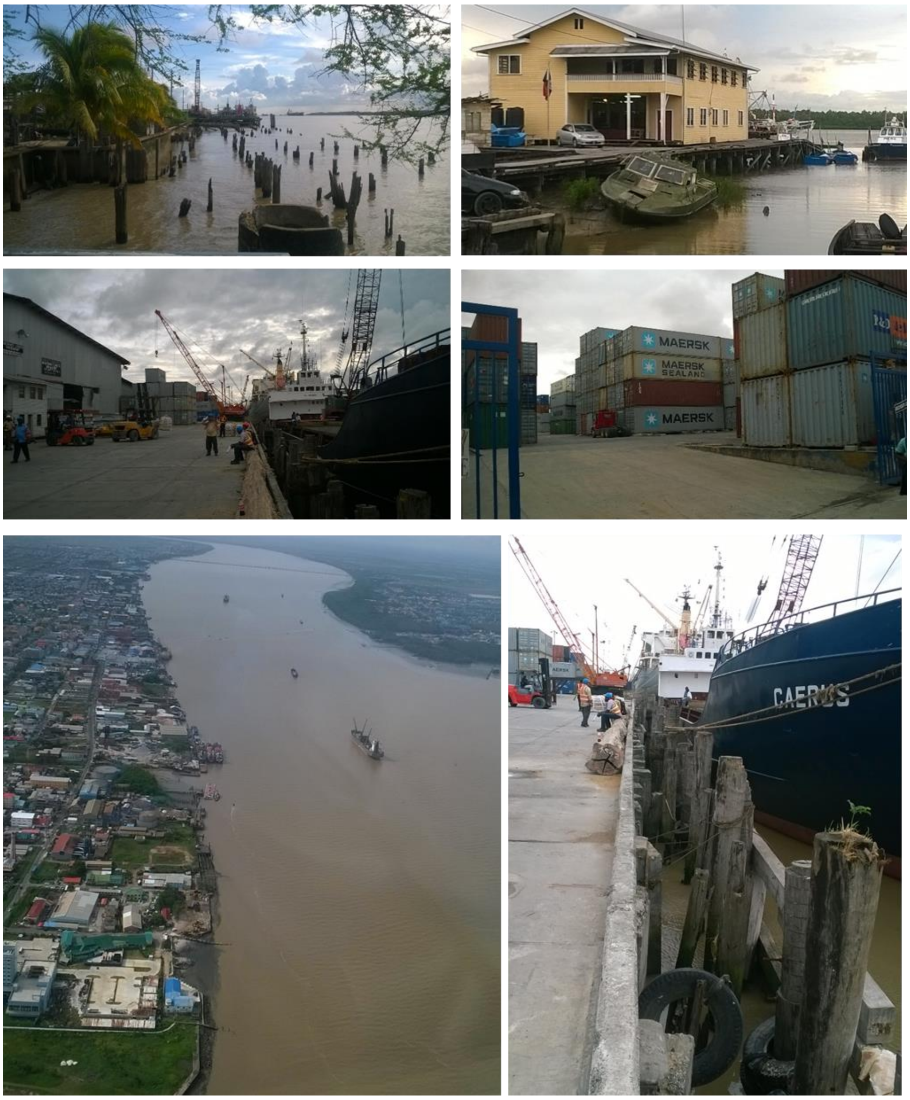

Figure 2.19 : Use of the river side high water defence

It is important to understand that the drainage system's outfall structures are integrated with the high water defence schemes. The single wooden flood gates are manually closed when the river water level rises above the water level in the interior drainage channel. The gates are opened when the water level outside drops below the drainage channel level.

If the doors are not closed in time (manually), then water will flow into the city until the turn of the tide allows water discharge again. For this important task, 24/7 labour shifts are present at each of the outfall structures.

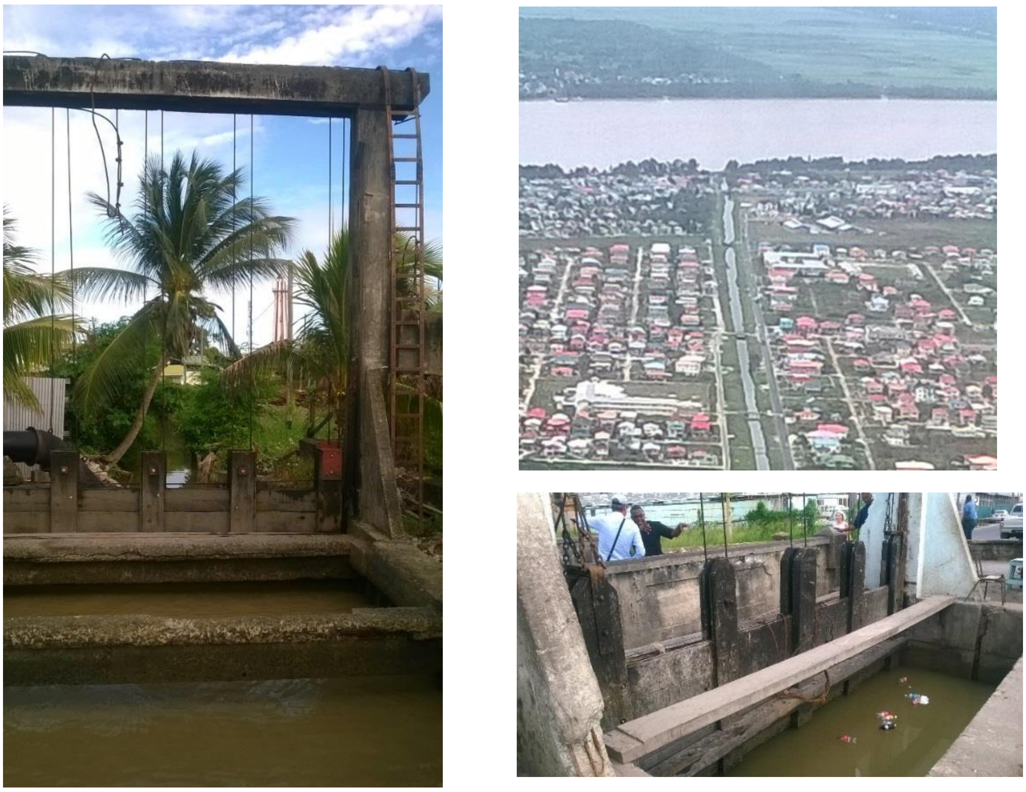

Figure 2.20: Sluices are part of drainage and high water defence system

2.2 Coastal area

The Guyanese coastline extends some 450 km from the border of Surinam to the border of Venezuela. The low-lying coastal plain is a narrow strip of fertile land bordered on its south side by an old mountainous area known as the Guyana Shield (Figure 2.21 below).

The coastal area with a typical width of several tens of km's, has been built up from young marine sediments, which mainly consist of clay. Transport of fine sediments along the coastline is estimated at 100 million tons per year, mainly originating from the Amazon River (Nedeco, 1968). Huge mud banks spaced at average distances of tens of kilometres migrate along the coast from east to west, with a velocity in the order of 1-2 km/y. Mud banks crossing the various estuaries lead to temporary shallowing of river mouths. Concurrent with these mud banks and the troughs between them, the coast shows a pattern of alternating accretion and erosion, which moves westward with a velocity of some 1 km/y. At one specific location the coast can alternate from erosion to accretion in a period of several decades. Over such period of time the shoreline position at one specific location can fluctuate with 100-200 m.

This pattern can be recognised from the pattern of mangroves along the Guyanese shoreline. Mangroves tend to grow in areas where accretion occurs (mud bank) or where erosion is not too intense. They tend to wash away in areas where erosion becomes too strong or where people start to cut the trees.

The process of mud bank migration is not only evidenced with shoreline movements, but also causes the depth contours along the coast to shift northward and southward periodically. The greatest movement with a range of several kilometres are observed within a belt of depths of 3 to 6 m.

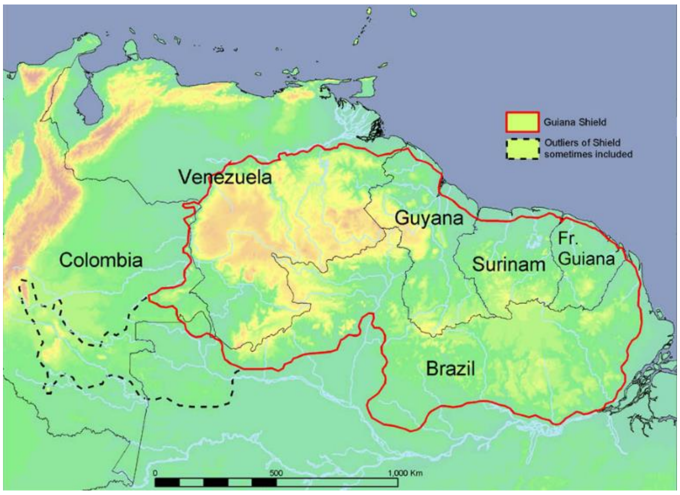

Figure 2.21 Guyana Shield

The team made a fly-over across the entire coastal zone of Guyana. This gave an excellent impression of the impressive dimensions of the many irrigation and drainage systems, the interaction with urban development as well as the coastal challenges due to the movement of the mud banks.

There is a cyclical behaviour of the shoreline, so a continuing process where either the trough or the top of a mud bank is in front of a specific location. When the trough passes, the coastline is receding and a manmade defence is required to keep the land safe from ocean flooding. At locations where the top of the mud bank moves by, the coast is expanding and the natural defence by mangroves takes over.

Figure 2.22: Example of a receding coastline with relocated outfall structures (note the old outfall sluice standing in the water)

High water defence is as strong as its weakest link. The team considers the outfall structures (man-operated, weak structures) as the weakest links in the river and sea defence. However, data on failure mechanisms are not available and no safety levels are applied (such as for instance a safety level able to withstand once per 100 years event at most).

Both the receding and the expanding coast line also have an effect on the drainage system. When the coast is receding drainage outfalls sometimes have tobe relocated land inwards (Figure 2.22). With an expanding coast line problems with siltation in front of the outfalls occurs reducing the drainage capacity (Figure 2.23).

Figure 2.23: Example of an expanding coast line with siltation of drainage outfall structures (these channels are regularly excavated)

Besides the natural movements on the ocean side of the coastline there is also a 'man made' effect on the land side of the coast. Along the coast a ribbon of residential areas has developed over the last decades. This development takes place along the road that follows the coastline.
The width of the residential development varies between 500 and 2000m and stretches almost along the entire coast of Guyana east from Georgetown. West of Georgetown this development is mainly present between the Demerara River and the Essequibo River. Figure 2.24 below shows the names of the various major rivers of Guyana, while Figure 2.25 shows an example of urban development along the shoreline.

Figure 2.24: Major rivers of Guyana.

Figure 2.25: Example or ribbon development along the coastal road

The original agricultural water management system is greatly influenced by this residential development. Some former irrigation channels have been filled and changed into roads. Drainage channels get squeezed by housing that take more and more space; channels are narrowed, blocked or even filled (Figure 2.26 below). The team understands that the consequences of any of the developments on the water drainage systems have not been taken into account.

Figure 2.26: Example of changes in water management system due to housing development

During the fly-over and subsequent discussions (Section 2.3) it became clear that not only urban growth interferes with the (old) drainage systems, but that also the behaviour of farmers changed over time. This is particularly the case in the rice production areas where more and more land is owned by private farmers, in contrast to the historic situation when most of the land was owned and farmed by a few large (state) companies. These independent farmers have to coordinate their actions related to the water cycle of rice production, but this does not seem to function well in some places as illustrated in the following example.

In the Mahaica Mahaicony Abary conservancy area (Region 5) an infrastructure was created in the Eighties that could irrigate all rice fields with gravity flow. It is announced when the rainy season starts. If the announcement is there, farmers should secure their land, and if they don't it gets flooded. If a farmer has finished his dry land preparation he will take in water to start wetland preparation. But if a neighbouring farmer is later and the early farmer opens the gate, then the land of the late farmer land is flooded too. Out of anger the late farmer may break the mechanism and gets out the water because he still needs to do the dry phase preparations. Then the wetland farmer is angry and he blocks it again. In this way, the farmers have destroyed most of the mechanisms and structures; of the 88 structures in that area, only 9 still have mechanisms to close and open the gates.

With so many sluices destructed, a lot of water from the Mahaica Mahaicony Abary conservancy is lost because the water is flowing all the time. This compromises the resilience of the water conservancy seriously. When there is a future drought, there will for this reason likely not be enough water to complete a rice season. To make farmers aware of the shortage the water is now for the first year provided to a level where they have to pump it up to the fields. Farmers are not able to waste water anymore because then they will waste their own money on fuel.

A new development is the creation of water user associations of which farmers can become a member. So far eleven water user associations have been established, mostly for rice and cash crop farmers in Regions 3 and 6. The associations pay for water use from the primary system and maintain the secondary system.

2.3 Interviews

Interviews were held with managers and senior staff from a variety of organisations (names listed in Annex A). All of the interviewees play an important role in the operation, control, upgrade or maintenance of the drainage system (both for Georgetown and the low-lying coastlands). Each interview took about one hour and was generally very informative for the team.

Below, we extract some of the lessons-learned from these interviews under the items 'water legislation', 'enforcement of legislation', 'plans and policies related to water', 'spatial planning and space for water', 'organisation and maintenance issues', 'resiliency of the population against flooding', and 'financing instruments'.

Water legislation

Table 2.1 below gives an overview of the water legislation relevant for drainage and irrigation. The Drainage and Irrigation Act is the most important law for this topic. It provides adequate guidelines and rights for good management of drainage and irrigation issues, if there are enough resources to follow it up. There is no mention of flooding or norms for what kind of flooding is unacceptable. The law does not differentiate between rural (agricultural) areas and urbanized areas.

The water laws contain general rules to safeguard the overall purpose (e.g. main goals, rights and responsibilities) and mention by-laws as a layered structure. The main laws also include very detailed sections such as the amount of a fine or a levy, or the precise tasks of certain officers. This may make it harder to adapt legislation to new developments and insights over time.

Law	Purpose and structure	Questions and comments
Guyana Water Authority Act	The purpose is to create a public body that coordinates creation and maintenance of infrastructure for drinking water supply and discharge of sewage. The act creates a monopoly position for the Authority to provide water and sewage services but also opens the possibility to delegate works and services to other organizations. The Authority has the right to charge users for the services. Assets and income are subject to the influence of the Ministry under which the Authority functions. The Authority has to report on performance (water quality, finance) to the Ministry. There is a licence and permit structure for activities that influence the water infrastructure (plumbers, large scale water users, drilling wells etc). The Act provides rights to perform water related activities on streets and roads and to inspect water infrastructure on the premises of the users. The act also contains sanctions for specific offences.	Twelve to fifteen members are appointed, but it is unclear if they are supported by a secretariat. The Authority falls under the Ministry of Works, Hydraulics and Supply, but the structure of the Ministries has now changed.
Water Commissioners Act	The purpose is to protect freshwater quality and supply to plantations, farmers and other water users. The act enables Commissioners to regulate proper freshwater supply. The act contains sanctions for water pollution or destruction of water works. The act regulates access of canals and dams for transport purposes.	It is not stated who the Commissioners are. Maybe the Commissioners of the East Demerara Water Conservancy Board. It is not clear which Ministry issued this act (most likely the Ministry of Agriculture)
East Demerara Water Conservancy Act	Purpose of the act is to organize the construction, management and regulation of the East Demerara Water Conservancy. The Act describes the establishment of a Board of Commissioners for the overall management, consisting of ten members from government and water users. Proprietors of land can vote for the commissioners. The Board appoints a Superintendent, a Secretary and an Auditor (for	Who has sovereignty over the affairs of the Board: the meeting of proprietors or the Ministry? Is this the Ministry of Agriculture?

	auditing finances) and further employees as deemed necessary The Board can charge local authorities and owners of plantations and other properties for the freshwater and maintenance services they provide. In times of water shortage, the Board decides on the water distribution. The Ministry has to approve construction plans for the dam, large scale loans for construction works, and acquisition of land by the Board. The Ministry also has to approve the financial management of the Board. The proprietors meet every year to approve the report, financial statement and other important affairs of the Board. A register is kept of the proprietors. The Act lists the plantations in two districts. The Act lists offences such as pollution of water and damage to works and contains sanctions.	
Drainage and Irrigation Act	The purpose of the Act is to establish the National Drainage and Irrigation Authority (NDIA) with the responsibility to manage all water resources to the greatest national advantage, to coordinate drainage and irrigation systems and to ensure participation of water users in the decision making process. The Ministry can give directions to NDIA and has to approve general plans and financial affairs. NDIA has to report yearly to the Ministry on its functioning. There are a CEO, a Board of Directors (consisting of 17 members) and a Management Board. NDIA can also establish regional offices. NDIA can hire personnel but can also involve the private sector for management and operation of drainage and irrigation infrastructure. NDIA supports water users associations and farmers associations and can delegate tasks to these associations. NDIA can also install working groups. NDIA makes plans and published them for comments by persons, bodies and local authorities. NDIA monitors, evaluates and supervises drainage and irrigation activities. The NDIA Act overrides the MMA act; NDIA and the Sea Defence authorities have to cooperate; and consultation needs to take place with three other regional water management acts (including the East Demerara Conservancy). NDIA has to separate private and public categories of water users and ensure that each	Implementation of water policy and inspection is done by the same organization.

	category is charged for what it costs. The act contains many detailed rules on financial affairs (loans, charges, payments etc). All land up to twelve feet adjacent to drainage and irrigation infrastructure has to be remain free for access by NDIA. Transport over such areas is allowed but not permanent structures like fences. In the case of a threatening flood NDIA can take measures in a dialogue with the Ministry. If land is needed for works the owners will be compensated. The act also contains detailed sanctions for various offences such as obstruction, damaging and trespassing of cattle.	
Drainage and Irrigation Act – Declaration of Areas	The purpose of the act is to regulate irrigation and drainage in the areas owned by the GuySuCo corporation. The act amends the principal Drainage and Irrigation Act. It specifies in what areas GuySuCo has rights to manage drainage and irrigation systems and when GuySuCo has to pay for services provided by NDIA.	The act contains a long list of precise amounts to be paid to NDIA for different areas. Due to complicated sentences and archaic language the Act is difficult to understand.
Sea Defence Act (CAP 64)	Dates back till 1883 ("an Act to secure the maintenance of the sea, river, and outer dams of estates"). Re-issued and updated in 1973 and 1998. Two Acts: 64.01 and 64.02. The government appointed Chief Officer is empowered to instruct owners to carry out any improvement or maintenance works he deems necessary. If owner fails, work can be carried out on behalf of the Chief Officer and costs will be deferred to the owner. The Minister is empowered to protect and conserve the foreshore and prohibits cutting of trees and removal of shells and sand. Act 64.02 has six parts and makes provision for the establishment of a river and sea defence board (SRDB).	Both Acts are generally considered to be sufficient to meet the responsibilities of the Chief Officer and the SRDB. Penalties seem to be out of date and a lack of law enforcement occurs. A review of the coastal defence act is given in Sturm et.al (2014)

Table 2.1: Overview of water legislation

Enforcement of legislation

The interviews and the Georgetown field observations indicated that the enforcement of the Drainage and Irrigation Act is a problem. The banks of drainage canals are often occupied by squatters and by private companies, and the legally required 12 feet (3,7 meter) are not kept free for maintenance (as can be seen in Figure 2.27).

Squatting obstructs maintenance of canals

Private companies occupy the space along the canals

Figure 2.27: Poor access for maintenance of channels

Some quotes from the interviews show examples of a lack of enforcement of the Drainage and Infrastructure Act:

- "We can do a lot better when we keep our infrastructure clear, and we have to enforce the laws. We are not doing it".
- "Poor people squat along canals, literally for kilometres. Squatters sometimes build a house overnight. Squatters are also voters so politicians sometimes choose their side".
- "Rich people build huge structures on the reserves, there are endless battles to remove people from the reserves, it is lawlessness. It exploded in the last 15 years. People are now even given title to the land they have started to occupy illegally".
- "We ask someone to move their fence so we can dredge, it is not a permanent fence, and they say no".
- "A company at the Demerara embankment blocked the outfall and they had to open it again, which they didn't".
- "The government itself built on the embankment. We said stop building and then we received a phone call by a politician: please let us proceed. Politicians have friends and can go against the rules".
- "People throw their solid waste and building waste into the drainage canals. Household garbage has been cleaned from streets and canals by the new government in the last 2 months".

These examples show that the space for water that is needed for good drainage is not respected by a large majority of the involved people: politicians, governments, private companies, rich and poor people all contribute to occupation of reserves and blocking of drainage canals. The people involved in water management do not succeed in convincing the Guyanese people that space is needed for water in order to reduce flooding.

Plans and policies related to water

Table 2.2 gives an overview of relevant water plans. The IDRM plan is the most relevant plan for the reduction of flooding, and especially steps 1 (risk identification) and 2 (prevention/mitigation). As for step 1, risk identification, the plan lists fifteen steps to come to a comprehensive, state of the art overview of national risks. The last steps, 14 and 15, suggest education of governments and communication to the stakeholders, which is rather late in the process, especially when steps 1 to 13 may include some insurmountable barriers. Maybe it is better to start with steps 14 and 15 and create a first rough risk map together with stakeholders. Improving the map with scientific data such as satellite data and LIDAR data can be the second phase.

For step 2, prevention and mitigation, the plan suggests 18 activities, among which a thorough assessment, renovation and maintenance of sea walls, conservancy dams and drainage and irrigation infrastructure (based on priorities as defined in step 1). Next to the technical improvement of these assets, the activities also include spatial planning and revision of the building code. Enforcement of both the land use plan and the building code are also mentioned.

The Guyana Land Use Plan contains insights on which better planning for water management can be based, but the dots are not connected yet. The plan lacks insight in the planning-related causes of flooding problems.

The Georgetown Water and Sewerage Master Plan (1994) includes a detailed analysis of the drainage system of Georgetown of which many aspects are still relevant today.

Plan	**Purpose and structure**	**Questions and comments**
Guyana National Integrated Disaster Risk Management Plan (IDRM) (2013)	The plan follows the commonly used steps 1) Risk identification (including risk maps), 2) Prevention/mitigation (reducing vulnerability of communities and strengthening water infrastructure), 3) Financial protection (mandatory insurance), 4) Preparedness/response (crisis plans and exercises for emergency services) and 5) Recovery (including a National Contingency Fund).	Are all the proposed steps feasible in the context of Guyana, and if not, can the process be split up in a 'quick and dirty' round and a more scientific and thorough second round?
Guyana National Land Use Plan (2013)	The land use plan explores options for more intensive use of the land surface of Guyana. Although the majority of the land is still covered with forest, there are many forestry concessions and mining concessions, as well as mining exploration areas. Abandoned and unused land is more a problem than pressure on land although multi-use hotspots are also identified in the plan. Demand for space is high on the coastal plain, which is driven by transport costs. "Past urban development in Guyana has been linear or 'ribbon development' along transport routes i.e. rivers or roads. If there is to be a policy of further urban expansion on the coastal plain then it should be one of 'nuclearisation' of settlements." "The future development of Guyana needs to consider increased and planned urbanisation inland." Regarding the Coastal Plain Drainage and irrigation is mentioned in relation to	To reduce flooding two measures are mentioned: no settlement in flood prone areas; and better drainage. However, most of the coastal plain is flood-prone, and still most of the settlement takes place in that plain. The plan does not explain what constitutes better drainage; and it does not make the connection between better drainage and planning for more space for water. The plan contains elements for better water management (changing ribbon development into nuclearisation and

	agriculture: • Rehabilitation of D&I system and dams • Provision of new D&I for new areas but beware of draining acid sulphate soils Priorities for housing in the Coastal plain are: • Squatter regularisation • Improve planning – no development on areas liable to flood • Improve drainage from housing developments	building more inland) but these are not connected to the flooding problems. A building code is not mentioned in the plan.
Georgetown Water and Sewerage Master Plan (1994) Part IV Primary Drainage System Vol 1: Existing services	The report concludes that upgrading to one in 2 years rain events is feasible but one in 5 years events not. The report lists the following problems regarding drainage: • An increase of impermeable areas • The infilling of drains • A reduction in maintenance • The use of drains for waste disposal • A rise in sea level due to global warming • The inadequacy of secondary and roadside drains • The establishment of illegal development on the drain reserves. Proposed solutions: • Excavation of outfall channels • Excavation of primary channels to design cross channels • Concrete lining of particular channels • Construction of culverts to link adjacent drainage basins • Rehabilitation of pumping stations and outfall sluices	Most of today's problems are already mentioned in this report. Which recommendations are implemented? Why are some of the listed problems not addressed in the recommendations (such as illegal development)?
Georgetown Water and Sewerage Master Plan (1994) Part IV Primary Drainage System Vol 2: Future services	The plan contains hydraulic design of Georgetown drainage infrastructure and detailed plans (including cost calculations) for a number of solutions mentioned in vol. 1 such as: • Design of drains in the Liliendaal catchment • Linked Young street Kitty catchments • Excavation of drains and culverts • Clearing of embankments • Concrete lining of drains in 6 locations • Rehabilitation of pumping stations and sluices	What solutions have been implemented since then?
Water Safety Plan Linden Guyana (2009)	The plan contains an assessment of the drinking water infrastructure for the town of Linden in Region 10 of Guyana. Linden was	Not relevant for the coastal plain

	chosen as a pilot project. Recommendations are made for improved watershed management and improved drinking water quality through the development of a Water Safety Plan (WSP). It provides an opportunity for a drinking-water supplier to assess, modify, and build upon existing good management practices.	

Table 2.2: Overview of water related plans

Spatial planning and space for water

The team observed a lack of space for water in urban areas. In Georgetown, the space becomes more and more economically valuable going closer to the Demerara River side where channels become narrower and narrower; even to be reduced to tunnels (see Figure 2.28).

Tunnels are difficult to clean up from siltation and solid waste; there are all kinds of structures on top. From a hydraulic point of view, the canals should become wider and wider towards the outfall structures as more and more water is conveyed.

Closer to the coast space becomes more valuable

Less and less space for water, to the point it goes underground

Figure 2.28: the space for water becomes more and more narrow towards the coast.

From the air, the urbanization process could be observed as different stages could be discerned along the coast. New developments often take place on former sugar cane plantations. These plantations have a drainage system that is regularly maintained. When a development is started on such a field, the drainage channels left and right of the development are maintained while the irrigation channel in the middle is often closed and changed into a road.

Most of the secondary channels (perpendicular to the main channels towards the coastline) are also closed to become roads (see Figure 2.26). These are routine measures and there are no calculations made for the drainage capacity that is needed on this location. This way, the drainage capacity is structurally reduced while the drainage needed likely increases due to a higher amount of impermeable surface.

In principle, all roads could be accompanied by a canal; however, many bridges are needed for crossing all that water, and this infrastructure would also have to be drainage-proof. In Georgetown bridges can also reduce the conveyance when the water is forced through a culvert (Figure 2.29).

Figure 2.29: Georgetown bridge that reduces water conveyance, and the 'Kissing Bridge' with space for water.

Another pattern that could be observed from the air is the ribbon-like development of housing areas as already mentioned in Section 2.2 (Figure 2.25). The developments are driven by road building, and as the main roads run along the coast, a ribbon of developments is created that seals the inland areas off from the coast.

If the housing areas were alternated with open, green areas, this would create a breathing space for water and would allow for flexibility in the future. A problem with this kind of planning may be that to make it feasible it would have to be connected to several other policy fields (road building, public transport, economic policy).

Organisation and maintenance issues

Different organizations are involved in the maintenance of the drainage and irrigation infrastructure. This is a historically grown situation that has to be dealt with carefully, as a lot of knowledge on the water system tends to be in the heads of the people involved.

Of course it is necessary that all efforts are coordinated and in fact NDIA was created exactly with this aim in 2008. NDIA is part of the Ministry of Agriculture and has drainage and irrigation of agricultural areas as its first priority; next to that it assists with the drainage of communities. Communities are in between the agricultural lands and the pumps and sluices that are needed to drain the agricultural lands. In the board of NDIA all important organizations are represented as indicated above. The board meets every three months. The Board has a CEO and a management committee to make daily decisions.

The most important organizations involved in drainage and irrigation are:

- NDIA: Coordinating and overseeing all construction works and maintenance efforts throughout the country;
- Georgetown Council responsible for maintenance of drainage canals within city borders;

- Community Councils (with the exception of Georgetown) are responsible for maintenance of drainage canals but the system has collapsed, new elections in the near future should re-establish this government layer;
- GuySuCo: responsible for irrigation and drainage of sugar cane fields (they clean primary canals every 3 years and secondary canals every 5 years) but also of many communities in between the sugar cane fields and the coast or the rivers (where cleaning with this frequency has become impossible);
- Organizations related to water conservancies such as the Mahaica Mahaicony Abary development authority (MMA) organize irrigation and drainage in agricultural areas e.g. for rice and cattle farmers.
- The Ministry of Public Infrastructure works at the national level and is responsible for the sea wall.
- The Ministry of Communities plans and builds the drainage infrastructure in new developments but is not involved in the maintenance.

There is no long term inspection and maintenance plan for existing drainage infrastructure and no overall future plan for the upgrading or reconstruction of watersheds. Instead there is a 'wish list' of smaller scale separate technical plans all over the country that NDIA has to approve and provide financial support for.

Everyone who wants to develop something affecting the water system has to write to the Ministry of Agriculture. If the development is judged by the regional engineer to be simple, a quick decision is made by the CEO and/or the management committee. Only complex matters with conflicting interests are discussed in the NDIA Board.

At the same time, there is a continuous inflow of small crises that the above organizations respond to by asking help from each other. For example, NDIA will lend excavation equipment to the City Council of Georgetown. The Ministry of Public Infrastructure assisted the Council of Georgetown with cleaning silted tunnels.

Fortunately, no one complains that it is not in their job description to solve other organization's problems. This cooperative attitude is something that should be preserved. However, a continuous crisis mode is exhausting and likely inefficient. A learning process should take place to reduce the number of crises over time.

Resilience of the population against flooding

From the inception meeting, the interviews and also the Georgetown Water and Sewerage Master Plan of 1994, it became clear that the ambition is to lower the number of flood events in Georgetown from 3-4 times per year to once every 2-5 years. Further reduction of flooding events is considered too costly. This is still a high frequency of flood events making it necessary for the people of Georgetown to be structurally adapted to floods or inundations.

Flood resilience is built into the traditional houses of Georgetown already (see figure 2.30). After the flood of 2005, a building advisory was issued of building four feet above the ground (1.2 meter). Actually it would be better to relate this figure to the Georgetown ordnance datum.

The advisory is not part of the Building Code yet and can therefore not be enforced. Insurance companies and banks providing loans require this advisory to be implemented.

Apparently, not all property developers are aware that larger inundation depths can occur, as one-storey houses are sometimes built and sold. The Civil Defence Commission had to open shelters some time ago for owners of one-storey buildings.

Figure 2.30: Traditional Georgetown two-storey house and new style, one storey house from an advertisement.

Many companies have built their own localised protection measures, such as mobile blockades, after the last major flood in 2005 to keep the water out of their business.

Hydromet provides a daily weather forecast of which the expected amount of rain is an important part. A flood warning is based on rainfall expectations above two inches (50 mm), as experience shows that the drainage system cannot cope entirely with anything above that amount (note that Figure 2.16 suggests that precipitation up till 100 mm/day can still be dealt with).

A flood map of the 2005 event is available and the Ministry of Agriculture has recent LIDAR maps, but these have not been converted into a detailed flood risk map yet. With such a map communities could work on their resilience to flooding.

A building code for flood-proof housing will only work in legal housing areas. The many people who are squatting have little or no protection from flooding. For these households an early warning system would be of help.

Financial management

Lack of funds for maintenance is a structural problem for all Guyanese organizations involved in water management:

- NDIA has problems with receiving taxes from farmers and is now funded with national taxes;
- The Council of Georgetown has problems with receiving taxes from households and has not fully been paid for lease contracts of the companies along the Demerara river; presently the Council is working on getting paid by the companies;
- Other community councils did not succeed in getting taxes from their inhabitants; they need the taxes for waste collection, maintenance of drainage canals, sewage systems, etc.
- GuySuCo is operating at a loss due to low sugar prices and wants a solution for the significant financial effort they put in taking care of the drainage for the residential areas in their areas (which is formally not their task).

When budgets are available, it is not always clear how these are spent:

- NDIA approves regional development plans for the water system in advance but does not always inspect how the money is spent; sometimes the budget meant for infrastructure or maintenance is spent on something else;
- When works on water infrastructure are proposed this is not accompanied by a cost-benefit analysis, which makes it harder to prioritize between plans and to justify expenditures. If a competing sector can provide proper justification, the water sector loses.

The Ministry of Finances plays a crucial role in funding water drainage related projects. They urge for the development of cost-effective measures, which means that costs and benefits are both considered and in the right balance. Only from a holistic (systems-driven) approach, based on cost-benefit analysis as well as flood risk computations, it will be possible to select those measures that contribute most to lowering the flood risks. This is further worked out in Chapter 3.

2.4 Good things to maintain

This DRR - Team mission is focused on finding implementable ways to improve the current technical and managerial ways of flood management. Consequently, most sections of this report address topics that can or need improvement. It is important, however, to note that many operations and policies, both technical and managerial, are adequate and do not need to be changed. In summary these are:

- The Drainage and Irrigation Act provides a comprehensive framework for creating a well-functioning drainage and irrigation infrastructure.
- The IDRM plan (2013), the Guyana Land Use Plan (2013) and the Georgetown Water and Sewerage Master Plan (1994) contain many valuable recommendations and ideas for improvement that are still relevant.
- The same is true for the recommendations made in Sturm et.al (2014) for the sea defences.
- NDIA and other water organizations have a dedicated and knowledgeable staff. With the limited resources available they generally understand the technical issues very well and act responsibly.
- The informal cooperation between all organizations in the water sector in the interest of the community at large should be maintained and encouraged. If the sometimes very rigid and detailed legislation doesn’t work under certain conditions it is a great advantage that people know each other and help each other in their joined responsibility of dealing with water.
- A good start has been made with some deferred maintenance issues such as waste collection and lease payments.
- The typical Georgetown type of house with the main functions on the second floor is a good example for future building projects.

3 RECOMMENDATIONS

3.1 Introduction

This mission's objectives were (Section 1.3):

1. The mission will explore technical possibilities with the Guyana government regarding short-term, medium- and long-term measures that can be taken and look into a sustainable strategy for the water management and drainage problems in Georgetown and the coastal lowlands.
2. The mission will review how flood risk management is currently being managed / governed.
3. The mission will assess the current (technical) state of a number of hydraulic structures (in particular the gravity-operated discharge sluices).
4. The mission will provide advice and recommendations regarding possible improvements of the operating and maintenance of the various elements of the drainage system of Georgetown.
5. The mission will describe existing programmes on flood management and look for opportunities to implement the recommendations.

In the previous Chapter 2, the emphasis was put on objectives 2, 3 and 5; this Chapter 3 gives recommendations for improvements (objectives 1 and 4) for the drainage system, both from a technical and a managerial standpoint, for Georgetown and the low-lying coastal areas.

The key issue overarching all topics is perhaps that the present approach in Guyana is largely *reactive*. Action is generally only taken once a problem has occurred and plans are made basically on a project-by-project scale and crises-driven. This seems to have worked rather well under the given circumstances. An example is the placement of extra mobile pumps after the discharge capacity under gravity turned out to be insufficient. Other examples are the recent removal of solid waste, the excavation of drainage tunnels, or helping each other in case of shortage of equipment.

A *proactive* approach has advantages as it generally lowers flood risks and can avoid dangerous situations which in the future may be less manageable. This will be the case under less favourable conditions, such as combined high precipitation and high tides. Due to a lack of data or statistical analysis, it is yet not possible to determine the probability of occurrence of such extreme combined events, but it is clear to the team that the current flood management system is vulnerable and may collapse dramatically under such unprecedented conditions.

In the next Sections, concrete suggestions are given for ongoing support, aiming to make the Guyana approach towards water management more *proactive*. Considering the economic situation of Guyana and the relatively mild character of the flooding events under normal conditions, it is not recommended to consider new large scale, expensive infrastructure. Instead, it is advised to take a large number of small steps over a period of several years (short and medium term) that will increase the knowledge and the collective ownership of the drainage infrastructure among local experts, Guyanese governments, and the people of Guyana. By increasing trust, cooperation and local expertise Guyana can become a South-American example of effective and efficient water management.

The suggestions cover a wide palette of topics and have been grouped as follows:

- Upgrade Modelling capability (Section 3.2);
- Increase flood resilience of people and business (Section 3.3);
- Upgrade dredging capabilities / improve flow efficiency (Section 3.4);
- Develop long-term plan with investment programme based on risk approach (Section 3.5);
- Develop and test pilot Living with Water (Section 3.6);
- Develop and apply a life cycle approach for the drainage assets (Section 3.7);
- Data management (digitise) (Section 3.8).
- Technical improvement options (section 3.9)

3.2 Upgrade Modelling capability

The current practice of (maintaining and) improving the drainage system is largely projects-based. Decisions on which element of the drainage system needs adjustment (excavating channel X, or increasing the pump capacity at sluice Y) is largely based on field experience of the responsible engineers. Under the conditions and with the means they have, they do a very good job. However, they have no tool available other than the 'model' given in Figure 2.16 to specify the requirements of each part of the drainage system, in such a way that the system as a whole functions most effectively.

A computer (hydraulic) model could be such a tool, so that project proposals can focus on those measures that have maximum contribution to the functioning of the whole drainage system. Costs for setting up and running a computer model are always significantly lower than the benefits that come with better predictions and better design of critical infrastructure. Modelling saves money and will result in considerable improvement of the current drainage.

The advantages of having an "Urban Drainage Model for Georgetown (UDMG)" are:

- It increases the quantitative understanding of the "flow-of-water" through the system of primary, secondary channels, interconnecting culverts, tunnels and sluices / pumps.
- The UDMG can also be used to find the current 'weakest spots', i.e. locations where the discharge capacity of water is reduced (for example bridges, tunnels, or non-streamlined channel bends). The model will show where the bottlenecks are and where overcapacity exists.
- Based on the systems analysis it will be possible to find improvement measures that have the highest cost-benefit ratio. Costs are related to the measure itself (such as widening a channel, or adding additional pump capacity); benefits are reduced damage from inundations. With monetary information on costs and benefits, it is easier to convince decision-makers that any project proposal is a good 'business case' for the city.
- An example of a "new element" in the drainage system that can be analysed with the UDMG, is a City Retention Basin (or a few of them). This is an allocated area inside the catchment area that can be inundated during high rainfall or outside water levels. During dry periods these areas can be used for other purposes as long as it can be flooded without damage during wet periods. Examples are parking places or city parks. How this helps to alleviate the consequences of floods needs to be computed first, for which the UDMG would be an ideal tool.

- The UDMG can also be prescribed for those who want to build something in or close to the drainage system. It can be used by authorities or developers as an impact assessment tool to obtain a No Objection Certificate for carrying out their anticipated works. This has an extra benefit that any reduction in drainage capacity (so potential increase in flood damage) will need to be compensated by the developer.
- If the model is used in forecast mode (i.e. this requires a coupling with rainfall prediction, rainfall-run-off and river and sea water level predictions), then model results can be used to warn people in case of a predicted flood (if people take measures in time, damage can be reduced). Or the model predictions can be used to install extra (mobile) pumps to temporarily increase the discharge capacity.
- The model can also be used for a Stress Test on climate extremes and compute the associated risks. A variety of climate change scenarios for the long term (50, 100 y) can be applied as well as different scenarios for urban development. Such Stress Test Analysis will provide valuable information on required space for water for the future. It may show for example that certain channels may need to be widened in the future under certain climate change scenarios. In that case it is better to keep these areas free from construction so that future generations still have that space for channel widening available. The UDMG in this respect will be an important tool for long-term urban planning as well.

Additional advantages of having a model as is proposed here is that it can be used to reach flood safety levels according to nationally accepted standards. This is important to attract international investors, who want to be sure about the flood safety of their investments.

The model can also be used in interactive sessions with stakeholders or those who intend to interfere with the drainage system (developers, authorities, etc). A special type of modelling is the so-called Maptable: a large computer touchscreen positioned horizontally as a 'table'. Stakeholders with conflicting spatial interests that may have an impact on the drainage system, stand around the 'table' and can easily draw their ideas on the 'map'. With the hydraulic model as the core of such Maptable, it will become 'instantly' clear to all participants what the consequences of any proposed interference would be. This way of co-operating, based on facts and figures, has proven to be very effective in finding solutions or measures that are acceptable to all involved stakeholders (they have "experienced" themselves what the consequences are, while standing around the table).

Developing and running the UDMG, is clearly not a one-time job. On the longer term it will require a dedicated team of modelling and hydraulic experts, for example operating from a "Guyana Hydraulic Modelling Centre". The team believes that Guyana which is so dependent on well-managed flow of water, can benefit greatly from such own Modelling or Knowledge Centre (Section 4.1). This will be attractive too for brilliant hydraulic engineers and give them sufficient scientific and practical challenges.

Clearly, it will take time (years) to reach a situation with a fully validated and daily operational model as described above. To keep it doable, we recommend building a model by:

- Working step by step. Start with a very simplified spreadsheet-type of model that covers the entire drainage system of Georgetown. For this purpose a simple network model will do to start with (UDMG version 1). Focus on understanding and use it as an impact assessment rather than expecting exact quantitative results.

- The total system might be described in several smaller sub models. This will give more interfaces but is easier to understand and can be operated by several persons specialised in their own area of interest.
- When a model or set of models is available that takes into account the relevant principles, start to calibrate the model with measurements under different rainfall conditions. Students can help to do these measurements.
- Make sure that the model is owned by those who use it. Consultants can help setting up the model and training of the people but the model must be implemented within the existing Guyana organisation(s).
- Set up a planning of the development of the model with clear milestones.
- Give feedback on the status and results of the model to the decision makers and other stakeholders. Decision makers must ask for this feedback as well to keep the modelling team focused.
- Make sure the people working in developing the model haven enough recourses and time. Time and resources must be specially allocated otherwise the work will be lost in the day to day business.

In view of the last bullet, we suggest to make a division between operational units and a 'strategic unit' within NDIA, with the latter being responsible for developing and applying the UDMG.

In view of the above, we recommend to:

R1a Make a project plan to gradually develop the hydraulic drainage model for Georgetown, with the design requirements mentioned above.

R1b 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. Use this understanding to support project proposals that have already been made (for example increasing the pumping capacity of the most northern sluice along the Demerara River).

R1c Start selecting two or three engineers with a passion for computers and modelling and train them on the subject of hydraulic modelling.

3.3 Improve the resilience of the population

Flooding will remain an issue in Guyana and in Georgetown. It is important to communicate this to the people. A communication strategy can be developed and implemented to explain the principles of Living with Water.

Most people will be aware of flood threats when it happens and forget about it soon after. This loss of awareness influences their behaviour regarding the existing water management infrastructure (such as neglecting its function). Living with Water is not just about threats and flood damage; it is also joyful and economically extremely valuable (obviously for agriculture, but waterfront assets often are more financially valuable). People who are aware of the benefits of living with water tend to understand better the constraints that space for water puts on them as well.

Flood risk maps are an example of a specific way of communication to the people. It shows the probability of floods and the consequences of floods. This is further worked out in Section 3.5.

The team noticed that many owners of houses anticipate on inundation events. This resilience of people against inundation can be further increased with the following measures:

- Building two-storey houses with the main functions on the second floor, and making this norm mandatory for project developers;
- Flood-proofing sewage infrastructure and prevention of squatting (without sanitation) in flood-prone areas to reduce health risks;
- Assistance for the private companies to flood-proof their businesses;
- A detailed flood risk map for urbanized areas so that people know their situation and also know where they can go in case of a flood.
- Better early warning systems so that people can reduce damages from flooding.

It often helps if flood resiliency is linked to the identity of the people. For Georgetown this could be a shared symbol, for example the Water Lily that is found in many channels.

In view of the above, we recommend to:

R2a Develop a communication plan with the aim to increase the understanding of the people about what it means to live with water (in terms of potentials and challenges) and execute this plan. It has to be clear that the flood risk will never be reduced to zero. Consider to use a shared symbol.

R2b Make an inundation probability map of Georgetown and use it to explain to the people why it is important to build their properties (houses and businesses) flood-proof.

R2c Prepare a simple explanation (for example, a Youtube video) on how the drainage system works, why water needs space, and why it is important to keep the drainage system free from constructions and solid waste.

3.4 Upgrade dredging capabilities

The cross-sectional flow area of many of the drainage channels in Georgetown is reduced as a result of sedimentation. Although the sources of the deposited sediments have not been examined, it is likely that much of the sediments enter the drainage system from the landside (roads, illegal deposits, discharges, construction activities). Water that enters the drainage system through leakages at the sluices or via overtopping of the seawall, may also add sediment into the drainage system, but we estimate this source to be of less importance (because the volume of water with its sediment yield is expected to be small relative to the water volume of the drainage system).

The deposited sediments must be removed regularly in order to maintain the conveyance capacity of the system. (Note that the consequences of not doing so can be easily computed with the UDMG as described in Section 3.2). The standard way to remove the deposited sediments is by excavator that operates from the landside. However, as illustrated in Sections 2.1 to 2.3, this is not possible everywhere due to the presence of buildings or specific human activities.

At low tide the doors of the outfall sluices are raised to release the city water. Along the Demerara river (where gravity is still the main discharge mechanism), we have seen that the outflow is hydraulically reduced due to shallow water in front of the sluices Figure 2.13). Dredging is carried out to maintain a certain depth, but these channels tend to silt up quickly. The standard way to maintain these outfall channels is by excavator placed on a pontoon (sometimes with another excavator to keep the pontoon at its position during excavation). Sometimes these operations are frustrated when other vessels are moored inside the outfall channels.

A good way to maintain the city's drainage channel at locations where excavation from the landside is not possible, would be by floating mini dredgers, such as cutter suction dredgers. In the Netherlands as well as in many other countries these mini dredgers are often used to dredge channels in highly urbanised areas or in situations where (nearly fluid) mud needs to be removed. Sometimes, a floating pipeline is used to pump the dredged sediments/water mixture to a location where it can be further processed (Figure 3.1).

If such mini dredgers become available these may also be used to maintain the outfall channels. This would require the mini dredgers to be easily transportable, especially across the streets. An alternative would be that the NDIA exploits its own cutter suction dredger for the maintenance of the outfall channels as well as the river and river mouth sections. In that case the mini-dredgers only need to operate within the city limits.

Figure 3.1 Left: Excavator; right: Dedicated floating mini-dredgers

Before a mini-dredger (or two) is purchased, it first needs to be determined if such an investment is worth the money. This assessment starts with the computation of the potential benefits of dredging channels that currently cannot be maintained. For this, the UDMG (Section 3.2) can be used, or if not yet available it can be estimated based on experience and information from previous flood events. The benefits of dredging are the expected reduction in flood damages, for which different flood scenarios, each with their own percentage of occurrence, need to be considered.

The expectation is that dredging results in a lowering of the flood risk (in terms of $/y). This benefit should be compared with the costs for purchasing, maintaining and operating the mini-dredgers (capex and opex, resulting in $/y). Based on these data, a business case can be developed and a sound decision can be made on required dredging capacity. The type of equipment follows from operational considerations (depths, types of sediment to be dredged, necessity for floating discharge pipes, etc). In many cases dedicated equipment is developed that serves the requirements best. Dutch manufacturers have ample experience with the design and delivery of such dedicated equipment.

In view of the above, we recommend to:

R3a Specify the requirements for small scale floating dredgers for the city of Georgetown and develop the afore-mentioned business case. Decide on whether it should be a public or a private entity to run the city dredging operations. Prepare a Request for proposal (RfP) to purchase dedicated equipment

R3b Purchase the equipment and start operations. Evaluate the performance on a regular basis.

3.5 Develop long-term plan with investment programme based on risk approach

Without drainage systems, flood damage will occur multiple times per year. The avoidance of this damage is the monetary benefit (GYD/y) of the drainage system. These benefits are not only monetary, but also refer to health and safety issues. Under extreme flood events, resulting in rapidly rising water or strong flow velocities, casualties may fall due to drowning. And, during inundations, water from the sewerage system may get mixed with the surface drainage water, causing serious health threats (diseases). Having an adequate and well-functioning drainage system thus avoids economic damage and reduces the number of casualties.

Improving and maintaining the drainage system is a rational and in fact 'smart' investment if the associated costs are lower than the reduction in flood risks. Since available budgets are always limited, it is important to select those (improvement or maintenance) measures that lower the flood risk most. Today's practice in Guyana in proposing improvement measures seems to be primarily projects-based, without an assessment of the whole drainage system. This implies that the chosen measures may in the end not have the largest reduction of the flood risks.

An approach that has been developed and applied in the Netherlands to prioritise improvement measures, is called the Rational Risk Approach. It is a consistent (probabilistic) method that analyses all elements of the flood defense system, it computes failure probabilities of each element under a wide variety of extreme conditions (each with their own probability of occurrence), it computes the (monetary and non-monetary) consequences of any such failure, and it multiplies the probability of floods with all potential consequences. By doing so, valuable information is gained on the weakest parts of the defence system.

In a risk approach one considers not only the events that have occurred in the recent past (which in fact is only useful to gain experience), but in essence all conditions that may theoretically occur. More extreme conditions, for example, may be more important to prepare for than the small scale frequent events that people perhaps have learned to live with. A once-per-hundred years condition for instance (10^{-2}/y) with a computed damage of say '1000', results in a flood risk of '10'. A once-per-year event (10^{0}/y) with 'annoying damage 1', gives a flood risk contribution of only '1', which is ten times smaller. This example shows that it is important to look at more extreme events as well, which can only be done with data, computer models and statistical analysis.

A Rational Risk Approach differs from a more traditional (responsive) approach because it multiplies flood probabilities with flood consequences. By doing so, it becomes obvious that risks can be lowered either by lowering the probability of floods (improving the drainage system), or lowering the consequences of floods (spatial planning), or a combination of both. Either way, it has proven to be an effective method to steer spatial developments and to prioritise measures that have the largest contribution to flood risk reduction.

Reference is made to the Flood Risk document (FLORIS) prepared by the Dutch government on how a Rational Risk Approach has been developed and applied on all water defences in The Netherlands (copies of which can be made available on request through the Dutch Embassy). It shows in particular to be a good instrument to prioritise measures and to prove that the investment was financially sound. It also gave valuable insight to the decision-makers on actual flood risks so that a comparison could be made with other types of risks.

First steps towards a Risk Approach

A full Risk Approach at this moment is not possible in Guyana, due to a lack of data and modelling capacities. However, a good first step would be to consider the various elements of the drainage system as interconnected elements of a system, and to look for its weakest elements. It would also be a good step to consider drainage system improvements (concrete projects) as investments that need to be in accordance with the value (monetary, culturally, or whatever) of what is being protected. It makes no sense to invest in protecting an area that has little value. Vice versa, it makes much sense to invest in protecting high-valuable areas.

Another good first step towards a full Risk Approach is to understand that spatial planning and drainage management are connected domains. If, for example, the flood risk in an area is lowered by a factor two, but sometime later, the value of properties in that area has risen tenfold, then the risk still increased by a factor five.

In addition to these more general 'understandings', a first step towards working with a Risk Approach would be to prepare flood hazard maps. These are maps of certain flood prone areas showing what could happen under 1/10, 1/50, or 1/100 years conditions (rainfall, river and sea levels). It will provide information for now and for the future (2030, 2050 and 2100) for a number of climate change scenarios.

Flood hazard maps differ from flood maps such that they are projections for what can be expected under extreme conditions with a specific frequency of occurrence. It is a first step towards a risk approach in decision-making. Flood hazard maps can be used for planning purposes and to compare areas. They can also be used for investment purposes as they show which areas may be more favorable than others.

After Guyana staff has gained experience in working with flood hazard mapping, a next step can be made towards the development of a full Risk Approach for the drainage system of Georgetown and other low-lying coastal areas in Guyana.

Risk Approach applied to the sea defence

In addition to the drainage system, we suggest to apply the basic philosophy of the rational risk approach to the sea defence of (parts of) Guyana. By doing so, it will be possible to justify the investment in upgrading certain stretches of sea defence, including the various drainage outfall structures.

The probability of breaching of the sea defence system can be computed by considering different conditions (water levels, waves, mud bank behavior) with their own expected frequency of occurrences. The next step is to calculate the impact (in terms of economic losses and in terms of expected casualties) of different scenarios of dike breaching. Multiplying the probability of floods with the corresponding consequences of any such flood gives quantitative data on the actual flood risks.

The next step will be to make preliminary designs of measures that lower the calculated flood risks. These can include a variety of works, such as higher seawalls, creating favorable tranquil conditions for mangrove growth, or the upgrade of outfall structures. By doing so, it will become clear which measures lower the flood risk most effectively, therewith justifying their implementation.

The risk based approach suggested here is not merely a technical procedure. Local involvement is important as to understand in detail what are the potential damages and threats of a sea defence or outfall structure failure. Also, local participation in developing improvement measures is important as per today, much of the space that would be required for such improvement works, is being used (occupied) by local people. Including them in the process will make the implementation of selected measures easier at a later stage.

In view of the above, we recommend:

R4a to prepare a first set of flood hazard maps for a region yet to be chosen (for example one isolated catchment area in Georgetown). The experts will need to be trained to develop similar maps for other regions in Guyana as well, without further support from foreign experts.

R4b to set up the framework for analysis for the sea defence risk assessment and elaborate on the assumptions and potential improvement measures. A number of experts from various related Departments can then be trained in the set-up and use of this approach.

3.6 Develop and test pilot Living with Water

The issue of drainage improvement and management is not purely a technical issue but most of all, a managerial or governance issue. Given the urgency, the complexity and the fortunate awareness of some of the important decision-makers on the issues, the team proposes to set up an experiment in one or two pilot locations.

These pilots can bring together some of the previous recommendations: they can generate experience with the application of hydrological models, Guyanese law, the involvement of different governments in the process, and the communication that is needed towards developers, construction companies and households. Different techniques and designs can be tested and evaluated.

The second aim of the proposed pilots is to create a showcase for other areas. The problems have persisted for so long that concrete proof is needed showing that something can be done, also in the Guyanese context. In a pilot the advantages of a new approach can be made clear; for example, when drainage reserves are kept open they have a better visual quality and can serve recreational or other purposes.

The most logical pilot would be a new development that aims to create enough space for water from the beginning and to design attractive recreational spaces around drainage canals. More difficult, but also much needed, would be a pilot in the existing urbanized area of Georgetown. One more or less not-interconnected catchment area may be selected depending on the level of cooperation from the households, governments and companies occupying the land. A collective redesign process could be started in which other desired functions are integrated into the spatial plan (for example, transport over water, or recreational facilities, or a bicycle path).

In both pilots, the principle considerations behind the Rational Risk Approach (section 3.5) will be included in the discussions.

In view of the above, we recommend:

R5a to develop a pilot "Living with Water" in which all elements of an integrated long-term and holistic "Drainage Management" are specified and made applicable to Guyanese situations. One pilot location could be chosen in consultation with GuySuCo (low-lying coastal area with planned or unplanned urban development on formerly rural lands). Involve different governmental agencies to develop structural ways of cooperation;

R5b to develop a similar pilot for an existing highly urbanized catchment area in Georgetown.

3.7 Develop and apply a life cycle approach for the drainage assets

The key elements of the drainage system, i.e. the channels, culverts, sluices (kokers), pumps and outfall channels, are in fact 'built assets'. Asset management has developed different tools and techniques to guarantee a proper and reliable functioning of the assets. Some lessons can be learned from Built Asset Management to be applied and implemented to the management of the drainage systems.

A key approach in built asset management relates to the so-called life cycle approach, which is illustrated in the Figure 3.2 below. It basically comes down to a cyclical approach, which starts for example with data collection (inspection). Data and information is collected in a consistent manner, and used to make decisions on maintenance or improvement operations. Any such operation then needs to be planned, designed and constructed. Then the life cycle continues with inspection of the new (improved) situation, which is input for making new decisions, etc.

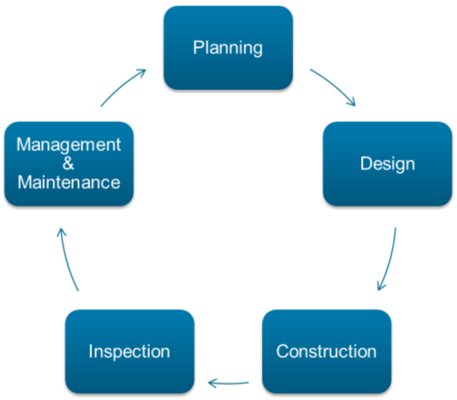

Figure 3.2 Life cycle approach

Looking at the drainage system from an asset management perspective, it becomes evident that managing the drainage system is a continuous process that requires on-going attention in order to keep it functioning (operations, maintenance), to improve it to acceptable levels (Risk Approach based), and to make it future proof (climate change, economic development).

Some recommendations that fall under asset management are listed in Table 3.1 below:

Recommendation	**Example**
Make an inventory of all assets	Map with all structures
Define the function of each asset	Pump must raise the water from level A to level B
Define clear functional requirement of each asset	Pump 5m3/sec
Define the required availability	Pumps must be available 99% of the time that water levels in the channel exceed the outside water level
Define the required reliability	Sluice gate may fail 1 in every 1000 closing operations
Allocate the responsibility for the maintenance of all assets	Sluices in Georgetown for MoPI, Channels in Georgetown for Municipality
Allocate specific resources	Fixed budget per asset per year Maintenance crew
Make a distinction between plannable maintenance and unexpected failures	Plan the plannable Prepare for the possible failures
Keep good statics on the actual performance of the assets	Downtime hours per month with cause and solution
Analyse the resources and performance	Compare cost and availability/reliability of comparable assets

Table 3.1 Built Asset Management actions

In view of the above, we recommend (R6a) to consider the suggestions given in Table 3.1 above. Some of these recommendations also fall under Recommendations such as to develop a Risk Approach, or to map the different elements of the drainage system.

3.8 Data management (digitise)

It has been mentioned before: decisions would ideally be made on facts rather than on ad-hoc decisions or short-term political preferences. During the various interviews it became clear that quite some data is available, for instance long term recordings of rainfall, data from weather stations, tidal data, incident flow measurements in drainage channels, and even a Lidar measurement of the entire coastal zone. These Lidar data could be used to prepare the flood hazard maps mentioned in Section 3.3.

These data are collected by different Departments and Agencies. Coordination on data collection and management (where to store it and how to use it in decision-making processes) seems to be not effective enough. There are different Acts that give detailed descriptions of who is responsible for what, but it would help if ‘what and where’ is mapped (possible showing overlaps). For example, the long-term records on rainfall could be statistically analysed to better understand possible changes in climate conditions, which would be valuable input for both the Risk Approach (Section 3.5) and the Asset Management Approach (Section 3.6).

When considering a pilot on Living with Water (Section 3.6), it is important to have reliable data available on issues such as land use, ownership, dimensions of the various drainage system elements, future plans for urban development, and so on.

Data is also of key importance to set up and run the Hydraulic Model mentioned in Section 3.2 (UDMG). Although maps are available showing the locations of channels, kokers, culverts and sluices (as in Halcrow, 1991), not much data is available on water levels, flow velocities under different rainfall conditions, or hydraulic bottlenecks (bridges, cables, etc).

In view of the above, we recommend to:

R7a Start collecting all digital data on the different elements of the drainage system (Georgetown and elsewhere), apply gap analysis to see what misses and start collecting and digitising these missing data. This includes data on locations of canals , sluices and pumps, their dimensions, capacities, flow velocities, bed composition, embankment composition, etc).

R7b to start collecting all relevant hydro-meteorological data that is required for a risk assessment (of the drainage system as well as the sea defence system), to use a fixed format for such data collection and to store in in a national central data base. Apply gap-analysis to see which data is missing.

R7b Use geo-informatics to collect data on land use, long-term shoreline dynamics (mud banks), and flood events. Store these data in a fixed format in the central database.

R7d Start analysing the data in a consistent manner and contributing to better understanding of the flood risks. Lidar data in combination with land use data can be used to prepare flood hazard maps. Long-term rainfall data (GuySuCo) can be used to determine the frequency of occurrences of extreme rainfall events, which serves as input for the risk assessment.

3.9 Technical improvement options

Technical upgrade of sluices

The table below gives some technical improvement options for the sluices. A distinction is made between the two functions of the sluices; drainage of the hinterland and protecting the hinterland from outside waters (river and sea defence).

	Drainage	High water defence
Construction	- Increase redundancy by construction extra and large enough connections. - Clearing the channels and outfalls by dredging (see recommendation 3)	- Most sluices have stop-log recesses but no stop-logs haven been seen on the site. Stop logs should be available at all sites and placed during extreme conditions. (maintenance and keeping them from being stolen will be difficult.) - Place shutters in the connections between catchment areas so a problem in one area can be confined.
Gates	- Double the lifting gear (winches) so there is redundancy. When one fails the	- For new structures use gates that can be closed in currents. - Replace wooden gates by

	other can be uses.	stronger steel gates so there is less chance of collapse
Pumps	- Keep a quick intervention team (pick up with 2 or 3 people and small equipment) ready at critical moments in order to support in case of problems	n.a.
Operations (human failure)	- Place communication at each outfall in order to check the presence at critical moments (just before opening of the gates). - Keep a quick intervention team (pick up with 2 or 3 people and small equipment) ready at critical moments in order to replace when normal watch is not present or support in case of problems	- Keep available materials and equipment in case of failure. For example truck with small crane and big bags filled with stones that can be dumped in (front of) the sluices.

Table 3.2 possible technical improvements of the outfall sluices

Increase the hydraulic efficiency of the tertiary and secondary drainage system

Sharp corners give hydraulic losses and lead to local sedimentation as can be observed at a few intersections of the channels. Streamlining corners of canals would lead to less sedimentation and increases the conveyance capacity.

In view of the above, we recommend:

R8a to consider the upgrade options listed in Table 3.2;
R8b to consider improving the hydraulic efficiency by streamlining corners of canals if space allows.

4 PROPOSED FOLLOW-UP ACTIVITIES

4.1 Our key messages

National debate

During heavy rainfall parts of Georgetown are inundated because the storage and discharge capacity of the soil and drainage system is less than the inflow of water. Flooding of the city with outside water from the river or the ocean fortunately occurs less frequent, but this could become a real threat under more extreme conditions or on the longer term with accelerated sea level rise. In view of the consequences of flooding, the mission concluded that improvements of both the drainage system, the river and sea defence, as well as the way water is being managed, requires step-by-step improvement. These do not only relate to technical improvements on a systems-scale, but as said also deal with behaviour of public and authorities.

The first question that arises is what level of flood safety would be required. Clearly, if budgets and time were unlimited, then very high safety levels and optimised management could be implemented, but this is obviously not the case. This means a debate is needed in society, led by politicians, on what quantitative norms have to be achieved: for example an acceptable flood of major parts of Georgetown of once per ten years with maximum inundation depths of 1 foot. Discussing acceptable safety levels is not only applicable for Georgetown or other cities, but for the rural countryside as well.

Part of the discussions is who is willing to pay for a higher level of flood safety. Beneficiaries are likely willing to pay, but how much do people want to pay for the flood safety of others (solidarity). It is clear that these are often politically-driven discussions.

The team noted that some of today's drainage improvements are mainly project-based and often initiated after a flood crisis when people start to complain. A shift is needed from (continuous) 'crisis management' to more long term planning, for maintenance as well as for improving the infrastructure. Maybe a program structure could work to organize a debate on priorities with the ten regions. The NDIA Board could lead such a program.

Water management of urbanized areas and agricultural areas should be described as separate problems in water law and water plans. Drainage of urbanized areas is now too much a side issue and no core business for NDIA and GuySuCo, while the Ministry of Communities, local councils / municipalities, and project developers have too little responsibilities and too little knowledge of the water system. This way neither agriculture nor urban areas can be optimized. Maps could be made on who is responsible for which areas; this can make clear where gaps or overlaps exist.

Water management not only requires money, it also requires space for water. In principle, Guyana has enough space, but the idea that water needs space is not accepted yet. Especially the urban population needs more information on how the Guyanese water system works and what variability in water levels can be expected. A communication program might be developed to inform key stakeholders directly, such as companies along the Demerara river, government agencies, project developers, architects and so on. A short Youtube film with infographics can be a way to make this information accessible to the wider public.

The lack of a knowledge infrastructure and institutional memory may well be the largest barrier for improvement of the Guyanese water systems. A lot of knowledge is available in the heads of the people involved but it is not combined, it is not accessible to others and there are no foundations laid for further knowledge development. Maps and graphs with monitoring data, numerical models assessing the potential impact of climate change, digital databases and evaluation reports are needed. This is why the team formulated most of their recommendations about these topics.

Every crisis can be evaluated so that it leads to learning. Such a knowledge base would help to convince funding agencies and tax payers; it would help to decide on efficient and effective spending of funds on infrastructure, and it would help to keep highly educated personnel interested. It would also be the basis for informing the public (flood hazard maps). Perhaps, a Guyana Water Knowledge Institute could be founded, logically linked to the Hydromet office.

The IDRM plan proposes a high quality risk analysis in a 15 step plan but this would take too long to complete; better to start with bringing the available knowledge to the surface in a workshop (and use the result immediately in communication to key stakeholders and the wider public) and then to work on gradually refining the analysis.

Since integrated water management involves all sectors, the water sector needs to be well-connected to all sectors. As described in this report, water problems are connected to a complex set of other problems: spatial planning, the economy, the relation between government and citizens, roads and public transport, to mention just a view. A structural link between water planning and spatial planning is an important gateway to other parts of society. If space can be planned for water, many problems can be solved. Another crucial link is with local government to deal with housing and the building code, to ensure construction of flood-resilient housing.

Key messages

Based on their observations and analysis, the team concludes that improvements of the operation and management of the Drainage System is possible and necessary. Frequent inundation is a threat to the economic development as well as to public health. The frequency of today's flood events in Georgetown is rightfully no longer accepted by the authorities. This implies that the drainage system needs to be upgraded and adequately managed.

As described in this report, drainage control and management is both a technical and a managerial or governance issue. The team gave hands-on technical training, and had many discussions about how water threats are being dealt with. This resulted in the following key messages:

1. Drainage in Guyana is an important aspect of water management in a broader sense and needs long-term and focussed attention and improvement;
2. Living with Water gives both restrictions and pleasure. People should be aware of both, so that decisions are accepted, not frustrated. This requires education, communication and participative decision-making. Flood hazard maps may be helpful to increase the awareness.
3. Improve the predictability of Government on water issues, so that law enforcement becomes less difficult. Clearly, this requires a role model for all responsible authorities (good leadership behaviour).

4. Improve numerical modelling capacity so that drainage and flooding can be looked at from a systems-perspective. The model can be used to decide on maintenance measures as well as improvement projects. And: the model can show the resiliency of the drainage system for unprecedented climate events that may happen one day (stress test).
5. Determine the flood risks associated with poor drainage of flooding from outside (river, sea), and use the data to justify projects based on costs/benefits and highest contribution to lowering flood risks (rational risk approach).
6. Short-term technical improvements can be made to the discharge capacity and reliability of the different elements of the Georgetown drainage system, such as new sluices, more pump capacity, retention basins ("store before discharge"), wider channels, more interconnectedness, and better streamlining.

4.2 Alignment with other projects

Like in most countries, budgets are under pressure in Guyana. With a population of around 800,000 it is difficult to generate the large sums of money needed for new water infrastructure or to follow up all of the short- and long-term recommendations mentioned in this report. The lack of budget can sometimes be alleviated with grants from foreign donors, such as the European Union (EU), who has supported the strengthening of the sea defences for decades.

The World Bank has a programme called the Guyana Flood Risk Management that is focused on the East Demerara Water Conservancy. The conservancies are low level embankments or dams that regulate inland water from rainfall. They serve two purposes, namely, irrigation and flood protection. This project is less relevant for the drainage issues addressed in this DRR - Team mission.

The Caribbean Development Bank is also funding sea defences through a loan (indications are: 8-9 million US$ (2015 – 2017) and may co-finance the purchase of a (larger) dredger for maintaining the rivers.
Japanese and Indian funds are active as well on specific projects, such as the (proposed) replacement of the mobile pump at the northern-most sluice along the Demerara river in Georgetown (JICA).

The EU has provided support to the Sea & River Defence sector since the late Seventies. Whereas previous programmes aimed to rebuild critical sections of sea walls, later programmes also focussed on developing local management capacity for maintenance (Sturm, e.a., 2014). In 2010, the EU allocated a total amount of 17 million Euro for the rehabilitation and reconstruction of the sea defences and included the provision of technical assistance for Capacity Building and Institutional Strengthening of the Sea Defence Sector. This was implemented under project support i.e. contracts were awarded to a contractor to do physical works and a consultant to carry out supervision. The works are completed and consisted of Reconstruction of 1.5 km and Rehabilitation and Maintenance of approximately 18 km of Sea Defences.

The current EU 10th EDF is providing support through a Budget Support Programme (ca 15 million EUR) with timelines for the release of fixed and variable tranches. The Government of Guyana finances these projects largely by themselves, with the EU contribution as a grant. Under Budget Support the government has to implement physical works as well as policy issues. The programme is ongoing and the total targets

(2013 – 2015) are 9 km construction, 5 km rehabilitation and 59 km maintenance works. In addition, the government must have demonstrated that they have committed a total of 5.592 billion GYD (some 25 million EUR) in the sector.

The EU Programme Manager in Guyana (Delegation of the European Union to Guyana) refers to two ongoing contracts:

- Preparation of a Costed Sea and River Defence Sector Policy". The outputs are Costed Sea and River Defence Sector Policy (report by Sturm, e.a., 2014), Memorandum of Understanding between three ministries (completed), Updated Integrated Sea and River Defence Sector Policy (ongoing) and Development of an Integrated Sea and River Defence Sector Strategy (ongoing).
- Production of a Coastal Engineering Design Manual. The outputs are a coastal engineering design manual (ongoing) and training and dissemination workshops.

The upcoming 11th EDF (estimated 34 million EUR) will focus on:

- Continued enhancement of Guyana's protection against sea damage through integrated coastal management, with benefits to the population and economic activity in low-lying parts of the coastal regions and
- Improving Guyana's upper stream catchment areas management, to strengthen flood control and prevention capacities.

The formulation of details of this new programme is under review. The programme will focus on sea defences, mangroves, possibly drainage and irrigation primary infrastructure and flood protection.

In particular the 11th EDF addresses the drainage issues as these have been analysed by the DRR - Team mission. As stated before, the coastal defence is as strong as its weakest links, including the drainage water outfall structures. It therefore is most logical to look for ways to co-finance some of the recommendation given in this report from the available 11^{th} EDF budgets.

4.3 Summary of recommendations

The team is aware of the fact that much needs to be done. It will probably take a long time before Guyana has developed their own model of modern water management, based on key principles like integration over all sectors and governance layers, long-term, finances-secured, knowledge-based, and participative. The objective for the long term would then be to base all water-related decisions on adequate data and information, using open and informative communication to all stakeholders, and to apply financially sound investment strategies with a long-term commitment for financing, clearly embedded in legislation.

The team looked for short term measures which are meant to contribute to such a future situation (no regret and doable). The recommendations given in this report are summarized below. These need to be further specified and detailed before they can be executed. It is also recommended to start internal debates on the topics mentioned in Section 4.1.

1 Upgrade modelling capability

R1a Make a long-term project plan to gradually develop the hydraulic drainage model for Georgetown, with the design requirements mentioned in Section 3.2.

R1b 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. Use this understanding to support project proposals (such as for example increasing the pumping capacity of the most northern outfall sluice along the Demerara River).

R1c Start selecting two or three engineers with a passion for computers and modelling and train them on the subject of hydraulic modelling.

2 Improve flood resiliency of people

R2a Develop a communication plan with the aim to increase the understanding of the people about what it means to live with water (in terms of potentials and challenges) and execute this plan. Consider to use a shared symbol, such as for example the water lily.

R2b Make a flood hazard map of Georgetown and use it to explain to the people why it is important to build their properties (houses and businesses) flood-proof.

R2c Prepare a simple explanation (for example, a Youtube video) on how the drainage system works, why water needs space, and why it is important to keep the drainage system free from constructions and solid waste.

3 Upgrade small-scale floating dredging capabilities

R3a Specify the requirements for small scale floating dredgers for the city of Georgetown and justify the investment based on a cost/benefit calculation. Decide on whether it should be a public or a private entity to run the "City Dredging Operations".

R3b Purchase dedicated equipment and start operations. Evaluate the performance on a regular basis.

4 Develop and apply rational risk approach

R4a Prepare a first set of flood hazard maps for a region yet to be chosen (for example one isolated catchment area in Georgetown). Next steps are to prepare flood hazard maps for other areas as well, including rural areas.

R4b Set up the framework for analysis for the sea defence risk assessment using the Rational Risk Approach briefly described in Section 3.5). The items mentioned under 'national debate' in Section 4.1 should be part of this activity.

5 pilot "Living with Water"

R5a 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. One pilot location could be chosen in consultation with GuySuCo (low-lying coastal area with planned or unplanned spatial pressure on formerly rural lands);

R5b The same as R5a, but now for an existing highly urbanized catchment area in Georgetown.

6 Asset Management

R6a Consider the suggestions given in the Table in Section 3.7 on Asset Management.

7 Data Management

R7a Start collecting all available data on the drainage system (Georgetown and elsewhere), digitise, and apply gap analysis to see what misses. Start collecting and digitising these missing data. This includes data on locations, dimensions, capacities, flow velocities, bed composition, embankment composition, etc).

R7b Start collecting all relevant hydro-meteorological data that is required for a risk assessment (of the drainage system as well as the sea defence system – see Section 3.5). Use a pre-set format for such data collection and store it in a national central data base. Apply gap-analysis to see which data is missing.

R7b Use geo-informatics to collect data on land use, long-term shoreline dynamics (mudbanks), and flood events. Store these data in a fixed format in the central database.

R7d Start analysing the data in a consistent manner and contributing to better understanding of the flood risks. Lidar data in combination with land use data can be used to prepare flood hazard maps. Long-term rainfall data (GuySuco) can be used to determine the frequency of occurrences of extreme rainfall events, which serves as input for the risk assessment.

8 Technical short-term improvements

R8a Consider the technical upgrade options listed in the Table in Section 3.9;

R8b Consider improving the hydraulic efficiency by streamlining corners

The team recommends the Guyana authorities to discuss these different recommendations and to prioritize them. Based on the outcomes of these discussions it can be decided how the different activities can best be funded (e.g. partly in the 11th EDF of the EU) and planned.

The above recommendations can be split up in short-term (months – year), medium-term (year – years) and long-term (years, decades), as follows:

Short-term (in 2016):

- Discuss the DRR-Team's observations with stakeholders and set priorities on follow actions;
- Discuss opportunities of co-funding measures related to recommendations under item #1, #4, #6 and #7 with the EU Representative (EDF);
- Make a plan to upgrade modelling capacity (R1a);
- Make a spreadsheet type of network model for Georgetown (R1b); (note: a team of Dutch students from the Technical University Delft has expressed their keen interest to help – follow up actions are now being taken).
- Select Guyana staff members to be trained in modelling (R1c);
- Improve flood resiliency of people (R2a, R2b and R2c);
- Start collecting all available data and make a plan to collect relevant missing data (R7a, R7b and R7c);

Medium-term (2016-2018):

- Upgrade small scale floating dredging equipment (R3a and R3b);
- Develop rational risk approach and apply to Guyana coastal zone (R4a and R4b)
- Develop a Pilot on Living with Water in a rural location and in a highly urbanized catchment area in Georgetown (R5a and R5b);
- Apply asset management principles to the maintenance cycle of the various infrastructure (R6);
- Analyze the data from the centrally stored database (R7d).

Long-term (>2018):

- Continue upgrading modelling capacity and data gathering (R1, R4, R7);
- Improve legislation based on lessons learned from the Pilots Living with Water and the results from the Risk Assessments.
- Improve risk approach (R4) and base long-term investment programmes on long-term holistic decision-making (all recommendations).

4.4 Structural measures

Specially designed floating mini-dredgers can help to maintain some of the drainage channels which cannot be reached from the land side (Section 3.4). In the Netherlands, specialised companies are very much capable of designing equipment that is optimally suited to work under Guyana conditions.

Other structural measures relate to ICT. Software will need to be licensed, which can be costly in case the software is no freeware. Computers may need to be purchased as well with sufficient power to make the types of model computations as mentioned in Section 3.2.

4.5 Non-structural measures

The leading principle for our suggested follow-up actions is changing the current more *reactive* project-by-project approach into a more upfront *proactive* systems-based approach. Another leading principle is a more integrated long term planning based on systems analysis and cost/benefit risk-based approaches.

This requires some preparatory work of international experts, transfer, installation or execution in Guyana followed by model improvements and capacity building of Guyanese experts. As described in this report, this includes:

- The UDMG model (Section 3.2);
- Early warning system (Section 3.3);
- Risk analysis pilot area (Section 3.5);
- Pilots Living with Water (Section 3.6);
- Streamlining Data management (Section 3.8).

4.6 Planning and Financing

Because all suggested DRR - Team follow-up activities are considered relevant, we haven’t ranked them. Final choices will depend on possible matching funds from other running or expected initiatives (as mentioned in Section 4.2).

To support the decision on how to proceed, below table has been prepared showing ranges of costs and required time for each of the suggested activities. It is noted that the figures only serve to give a first estimate of cost ranges (personnel costs only relates to foreign experts; input from Guyanese experts and entities have not yet been included).

		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

Table 4.1: List of recommendations and associated cost estimates

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ANNEX A – Team members and participants

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Mr. Omadatt Chandan	NDIA	Corporate Secretary
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ANNEX B– wrap-up meeting presentation of findings

Presentation highlights:

Wrap-up meeting notes: discussion and responses 26nov2015

There is a need for integrated planning; and thus, cooperation between agencies

A standard on the reserves is needed; in the future even more space will be required. An intrinsic design of the drainage system should be made and it should not involve any kokers; the kokers and the outfall structures are the weakest links. Not all outfalls are working and because of the mud waves along the coast this is hard to avoid. If the system is more connected on the land it may become more resilient.

Dredging of the outfalls is possible but siltation will still be high; agitation of the channel should be used as an additional method. This of course does require an amount of water. Placing pumps as close to the outfalls as possible is also a good idea. This is already done now: placing pumps close to sluices. Some extra excavators may be used at the beginning of the rainy season.

Water should be integrated in spatial planning. What plans are being prepared at the Housing department for the next two years? Can they be used as pilots in an integrated approach?

Organizational issues will have to be sorted out in Guyana; a map with all the responsibilities may help (or the Maptable). It can also be sorted out further in a pilot project. Also what communication is needed between agencies. All involved agencies can help to make a list of potential pilot projects.

Both the drainage system and the sea defence should be modelled, starting with a simple model. Acquiring modelling capacity by training local people should be a priority. Building up this knowledge base will make it interesting for highly educated people to stay.

Once the model is started it can be decided where to collect empirical data to calibrate the model. There already are data to start with: datasets that have not been used; scattered datasets; and there also will be some data gaps. A recommendation is to make a wish list of data and check what is available.

Water retention should also be considered. It is not always the best solution to get rid of the water fast. Water retention is needed to respond to droughts and buffering water upstream will reduce flooding downstream.

Is it possible to find finances for a training session? This DRR - Team will report on this mission to the governments of Guyana and the Netherlands; and then it has to be decided what follow up is possible.

Immediate responses after the presentation:

Responses: Overall the DRR - Team has proposed doable solutions.

It is an interesting angle to treat water as a friend; so far we mostly try to expel it.

It should not become an academic exercise. The Task Force should be involved in the follow up. At the same time, we need to take the long term into account.

The issue of drainage should also be brought to a wider audience. NDIA has to sit with new developments, and make sure there is enough space for water.

The people in this room should be brought together more often.