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Managing Flood Risk in Guyana

The Conservancy Adaptation Project
2008-2013

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This publication was funded by the
European Union in the framework of the ACP-EU Natural Disaster Risk Reduction Program
managed by the Global Facility for Disaster Reduction and Recovery .

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Aerial view of East Demerara Water Conservancy headquarters at Flagstaff

Contents

Aerial view of coastal agricultural and urban areas

Technical Summary

The East Demerara Water Conservancy (EDWC) and east coast drainage and irrigation systems provide water storage and flood control mechanisms for Guyana's most populous region, including the capital city of Georgetown. In 2005, extreme rainfall caused devastating flooding along these coastal lowlands, with many areas remaining inundated for up to three weeks. The flood highlighted the vulnerability of the EDWC dam to overtopping and potential breaching.

The Conservancy Adaptation Project (CAP) was conceived in the wake of the 2005 flood to help the Government of Guyana adapt to the threats posed by future climate change. The aim was to reduce the likelihood of catastrophic flooding along Guyana's low-lying coastal areas, also threatened by sea level rise.

The aim of the CAP is to reduce the likelihood of catastrophic flooding along Guyana's low-lying coastal areas

The project financed a comprehensive analytical assessment of the EDWC and coastal lowland areas in order to develop a program of strategic interventions and policies aimed at addressing recurrent flooding and the anticipated impacts from sea level rise. An engineering baseline was developed based on: (i) LiDAR (Light Detection And Ranging) laser mapping aerial surveys and high-resolution aerial photography, and (ii) ground-based bathymetric surveys. These enabled the construction of the first high-resolution topographic and land-use map for the EDWC and east coast, suitable for modeling water flow across the low-lying region. (iii) A new hydro-meteorological monitoring system was also installed in and around the EDWC necessary for understanding hydro-dynamic processes and helping to monitor water-levels in the EDWC on a near real-time basis, and (iv) computer models of the EDWC and east coast were set up for understanding how the hydrological system varies under extreme weather scenarios and for testing the impacts of various proposed interventions. The project also financed specific rehabilitation works, geotechnical studies of the EDWC dam to understand its stability, and operational improvements aimed at enhancing the flood control capacity of the EDWC.

CAP Objectives

- *To strengthen understanding of the EDWC and the coastal drainage systems through the development of a hydraulic engineering foundation critical for flood control management*
- *To identify strategic interventions for follow-on investments to reduce flood risk*
- *To implement selected infrastructure investments aimed at increasing the drainage relief capacity of the EDWC*
- *To strengthen institutional capacity to manage water levels in the EDWC*

The project identified key investments totalling over US$ 123 million. These are being used by the Government to update the national master-plan strategy for drainage and irrigation and to plan future investment programs for reducing flood risk.

Key Facts:

- ***Funded by: Global Environment Facility (GEF) Special Climate Change Fund (SCCF) grant of US$ 3.8 million.***
- ***Dates: January 2008 to August 2013.***


Sluice at Ogle

Drainage and Irrigation System

Guyana's low-lying coastal plains along the Atlantic Ocean are highly populated and generally lie below sea level. At least 40% of the Guyanese population of over three-quarters of a million people live in Guyana's Region 4, which includes the capital city Georgetown. Region 4 is bounded by the Demerara River to the west, the Atlantic Ocean to the north and the Mahaica River to the east. Here, the coastal plains are situated between a water storage basin called the East Demerara Water Conservancy (EDWC) and a protective seawall complex. A dense system of drainage and irrigation canals allows for bi-annual harvests of rice and sugar, which account for over 25% of GDP.

The drainage & irrigation system is gravity-based, augmented by pumps.

The drainage and irrigation system originated during the Dutch colonial period (late 1600s) and has been expanded over time. The EDWC itself originates from the 1880s and stores water during the dry season for irrigation and household use, and acts as a flood-control mechanism in the wet season, when a network of sluices and canals helps to drain away excess water. Drainage mostly functions by gravity, supplemented by pumps.

Due to its age and to climatic pressures, this system is now under increasing stress.

Due to its age and to climatic pressures, this system is now under increasing stress. Sea level rise, for example, poses a significant threat leading to a reduction in the amount of water that can be drained by gravity alone.

In January 2005, extreme rainfall caused devastating flooding on the coastal lowlands, with many areas remaining inundated for up to 3 weeks and water levels reaching chest height in many homes. Due to the inability of the system to drain away the excess water quickly enough, water levels in the EDWC were significantly above safe operating levels, weakening the dam and leaving it more vulnerable to overtopping and potential breaching. Fortunately the dam did not breach but the 2005 flood and other floods since then have highlighted the vulnerability of the system to catastrophic failure.

Sea Level Rise

- *Sea level globally is rising at a rate of about 2-4 mm/year.*
- *Tide-gauge records for Guyana from 1951-1979 show that, in Guyana, sea level is rising at about 10 mm/year, much more than the global average.*

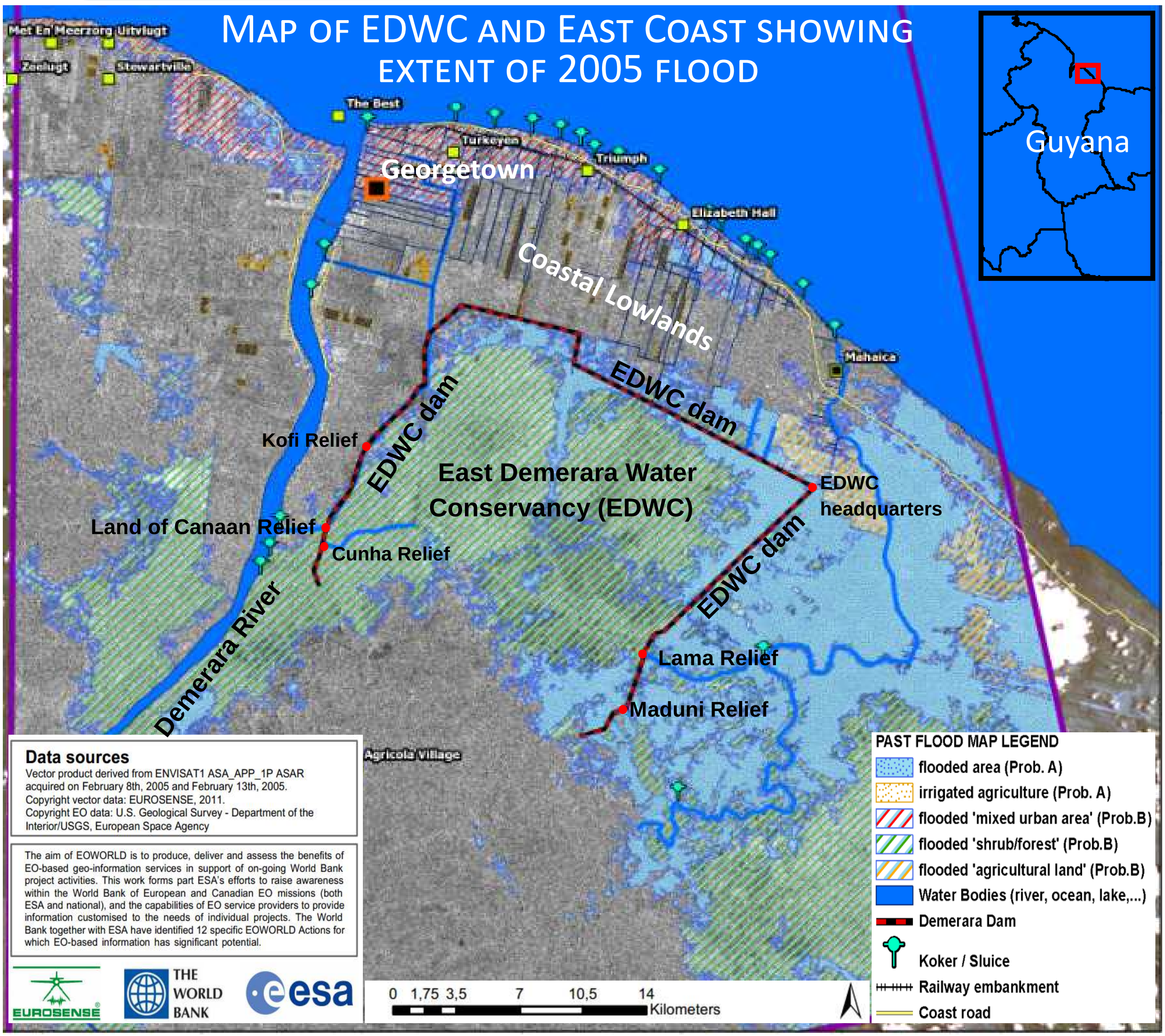
A seawall prevents flooding along the coastal plain

East Demerara Water Conservancy (EDWC)

- *The EDWC was constructed around 1880 from several existing drainage systems to form a more efficient water storage and distribution system and to act as a flood control reservoir.*
- *It is bounded on 3 sides by a dam embankment (67 km length) made of clay, earth and organic pegasse (peat) and has 5 main drainage relief canals.*
- *It covers an area 571 km^2 (an area 3.5 times bigger than Washington, DC) and stores approximately 250 million m^3 of water at the maximum safe-operating level.*

January 2005 Flood

- *Over 1 m of rain fell in January 2005, nearly 5 times the normal amount, with 65 cm in just 5 days (an estimated return period of 1000 years).*
- *The extreme rainfall caused widespread flooding which affected almost half of Guyana's population.*
- *Total damages from the disaster are estimated to have been US$ 465 million or 59% of Guyana's GDP for 2004.*



Detail of sluice at Kofi

1. Conservancy Adaptation Project

The Conservancy Adaptation Project (CAP) was designed to help Guyana adapt to climate change by reducing the vulnerability of the low-lying coastal areas to catastrophic flooding. The CAP, a Global Environment Facility grant of US$ 3.8 million, is a flagship project for Guyana and the Caribbean in applying modern technology to support a long term strategy to reduce flood risk. The project was subdivided into 3 components.

1 *Pre-investment studies for engineering works*

This component aimed to strengthen the Government's understanding of the EDWC and coastal plain drainage systems and identify key areas for follow-on intervention.

A hydrological engineering foundation was created using a combination of state of the art aerial surveys and *in-situ* monitoring techniques. (1) Detailed aerial surveys of the area using LiDAR technology and ortho-photography have been used to produce a high-resolution topographic map suitable for understanding water flow over the relatively flat terrain. These aerial surveys have been accompanied by extensive ground-based surveys to establish channel profiles and water depths. (2) A new hydro-meteorological monitoring system has been installed in and around the EDWC, and flow measurements have been carried out to help understand the hydrological behaviour of the EDWC system. (3) Computer models of the EDWC system and east coast drainage areas have been set up to help understand how the hydrological system varies under extreme weather scenarios and for testing the impact of various proposed interventions.

The CAP modeling studies have pin-pointed strategic key areas where interventions would provide maximum improvements

The CAP modeling studies have pin-pointed strategic key areas where interventions would provide maximum improvements to the EDWC discharge capacity and east coast drainage systems, critical for flood zone management. Pre-engineering designs have been completed for a set of prioritised investments aimed at significantly reducing the vulnerability of the system to sea level rise and extreme rainfall.

2 *Investments in specific adaptation measures*

The CAP has funded specific infrastructure investments aimed at helping the Government manage water levels in the EDWC and helping to increase drainage capacity. In particular the two sluices at Lama, on the eastern side of the conservancy, were rehabilitated helping to lower water levels in times of need, and a pontoon and hydraulic excavator were purchased under the project, to make it easier and faster to reach areas of the dam in need of repair.

3 *Institutional strengthening*

Government agencies have received training in hydro-meteorological monitoring, use and application of LiDAR datasets, data management and computer-based hydrological modeling. Furthermore, a series of workshops have brought together various government agencies involved in the management of the complex drainage system, as well as stakeholders, donors, practitioners and others, to ensure broader consensus and coordination on future action.

The CAP has led to the identification of several short- to medium-term strategic investments totalling over US$ 123 million

The CAP has led to the identification of several short- to medium-term strategic investments totalling over US$ 123 million, including rehabilitation of key drainage relief channels and improved conveyance within the EDWC, strengthening of the EDWC dam and various investments in the east coast drainage systems.

Follow-up investments will lead to increased capacity to manage water levels in the EDWC and lessen the high vulnerability of the area to extreme climate events. The methodologies employed in the CAP can be used as a template for identifying key areas for follow-on interventions in other similar regions.

1.1 Hydrological Data Collection

Hydrometric Network: To thoroughly understand the hydrological behaviour of the drainage system (see **Figure A**), an extensive network of automatic hydro-meteorological instrumentation has been installed at several locations in and around the EDWC. Instrumentation is programmed to send data regularly to an online central database using a telemetry system, making it easier and more efficient to manage water levels in the conservancy on a near real-time basis. Text message warnings can also be sent to mobile phones when the water levels are too high. The instrumentation is composed of raingauges, water-level sensors and a current profiler.

Tipping-bucket raingauges (see **Figure B**) record the amount and the intensity of rainfall. They work by funnelling rain into one of two small 'buckets' of known capacity (e.g. 0.2 mm), which pivot like a see-saw when full. Each bucket-tip triggers a switch enabling a logger to record how much rain has fallen and when.

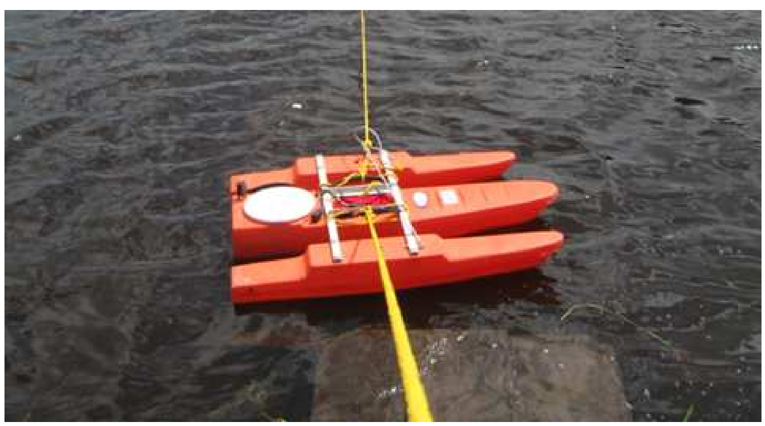
Water-level sensors (see **Figure C**) measure water depth automatically, in this case at 15 minute intervals. The sensors are actually pressure transducers and work by measuring the pressure exerted by a column of water above the sensor and converting this to depth (making adjustments for air pressure).

Discharge (the volume of water flowing in a channel during a given time interval) can be measured using a boat-mounted Acoustic Doppler Current Profiler (ACDP) (see **Figure D**), which is manually pulled across the width of the river to collect channel profiles and to measure discharge. The ADCP transducer works by emitting 'pings' of sound at constant frequency into the water, which bounce off suspended particles or the riverbed back to the device. The travelling time of the sound and the change of pitch (variable due to the Doppler effect) gives an estimate of distance from which velocity, and hence discharge can be calculated. By collecting discharge measurements at a particular location, at low, medium and high water levels, a relationship can be developed so that discharge can be calculated for any river level.

The instrumentation was installed in January and February 2012 and complements the existing national network of hydro-meteorological instrumentation.

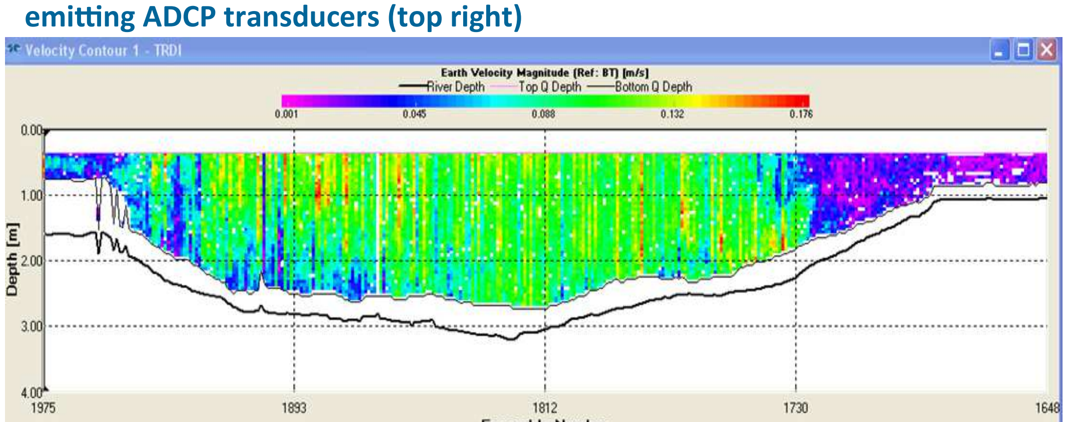
A baseline knowledge of the hydrological system is vital for contemplating rational investments aimed at increasing the current discharge capacity of the flood control system.

Acoustic Doppler Current Profiler (ADCP)



D

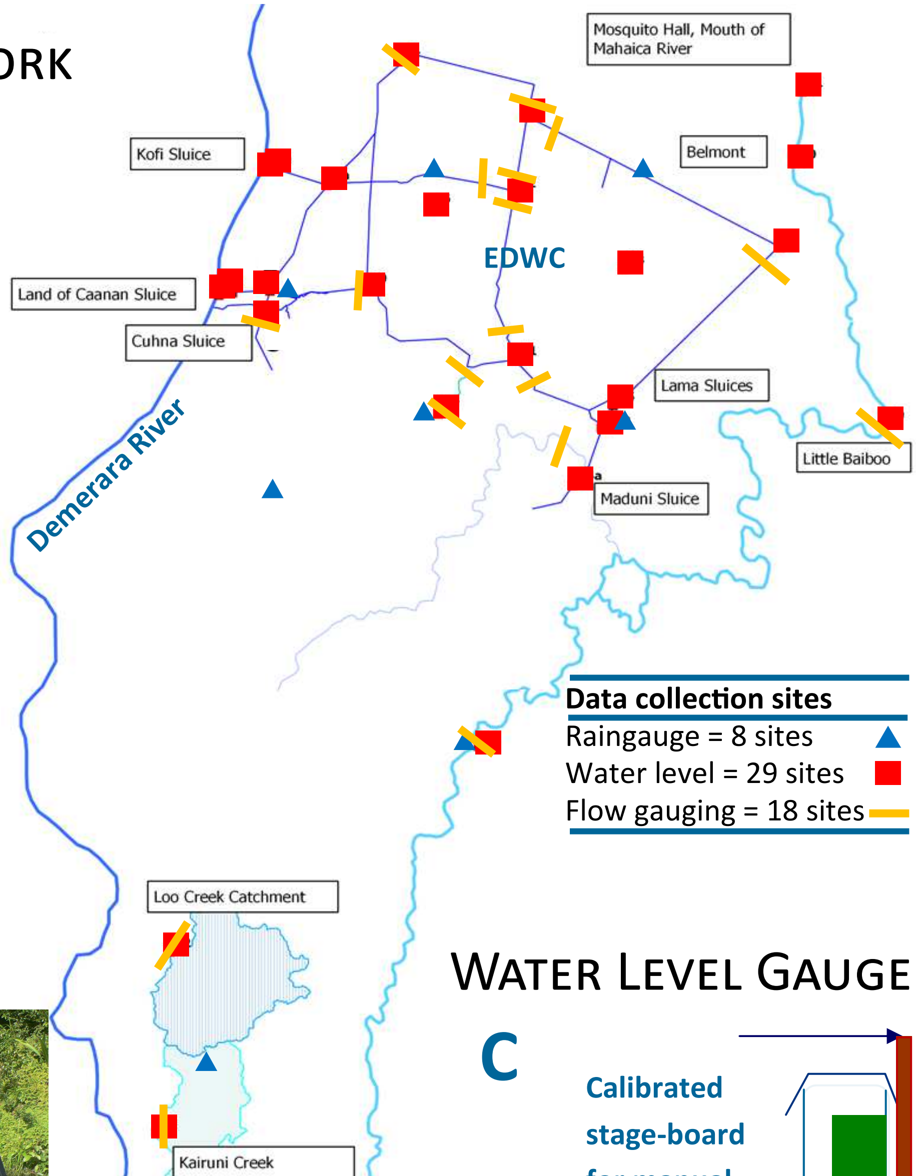
ADCP (above), example river velocity profile (below) and the sound-emitting ADCP transducers (top right)



Hydrometric Network

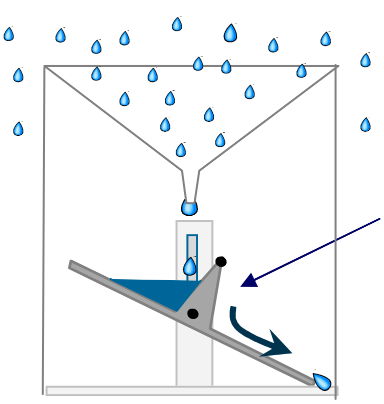
A

Instrumentation	
30	SDI-12 water level sensors
38	FROG loggers for logging data (with inbuilt telemetry)
8	0.2 mm Tipping-bucket raingauges
2	Handheld Archer-pad field computers
1	Timeview data management system for web-access



Raingauge

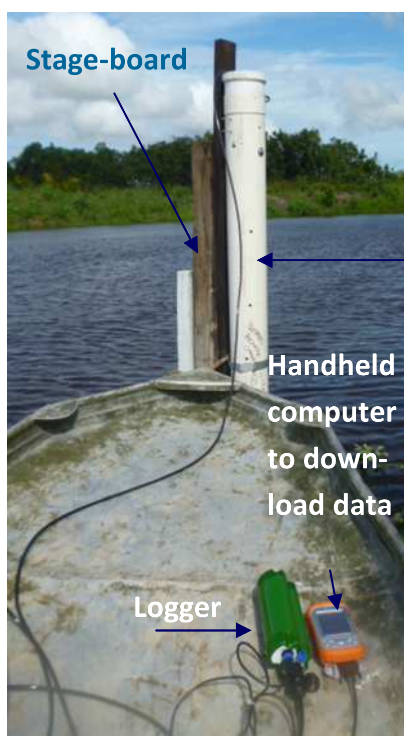
Tipping-bucket raingauges involve a

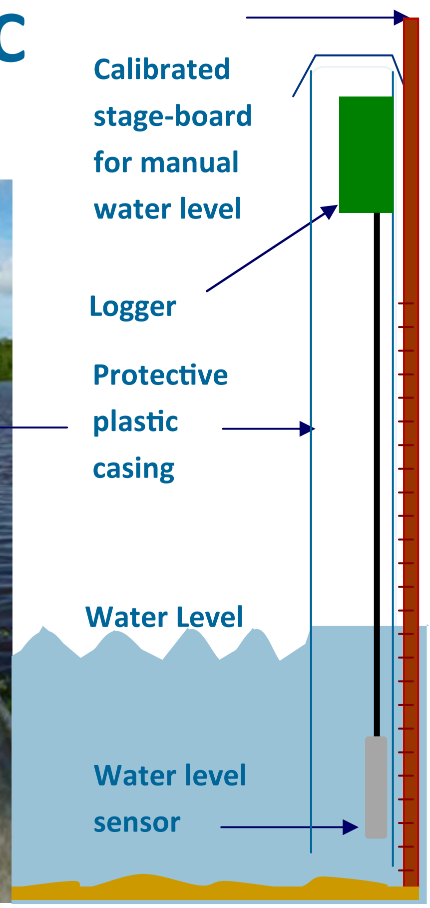


bucket of known size which fills with water and tips when full. Each tip is recorded.

Water Level Gauge

C





1.2. LiDAR & Bathymetric Surveys

Detailed topographic and land-use maps are needed in addition to hydro-meteorological data for understanding water flow over the low-lying coastal plains. In the CAP, these were obtained using a combination of LiDAR, bathymetry and aerial photography.

LiDAR (Light Detection And Ranging) is an airborne laser mapping and altimetry system which produces accurate and spatially geo-referenced land elevation data. It works by sending a laser light signal to the ground and measuring how long the pulse takes to return. Data collection usually involves an aircraft-mounted Global Positioning System (GPS) receiver (for keeping track of the aircraft location), an Inertial Measurement Unit (INS) (for keeping track of aircraft rotation) and a laser range-finder (which includes the laser source and detector, the scanning mechanism and the timing and processing system).

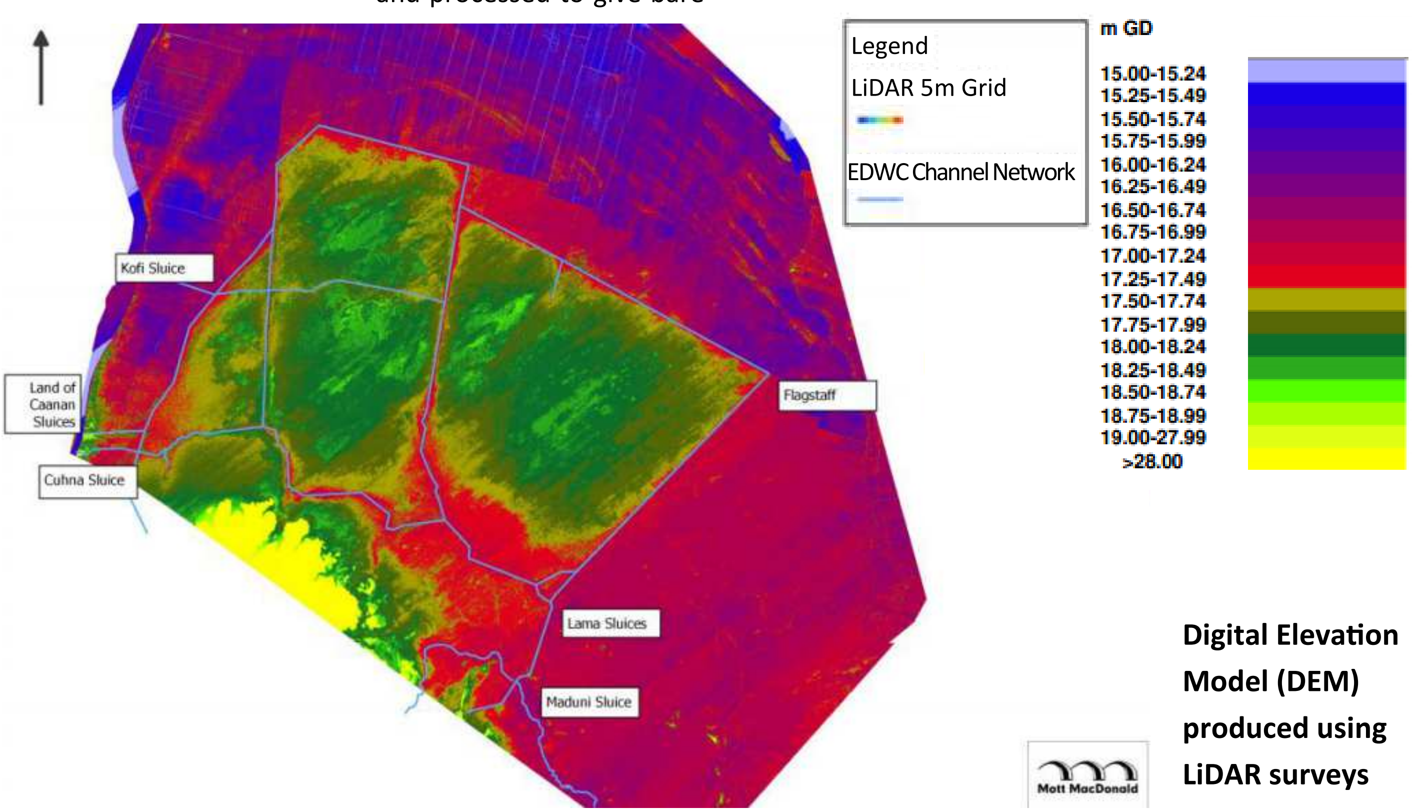
For the CAP, LiDAR data was collected during the dry-season (April 19 and 25, 2011) when water levels and clouds were at their minimum. LiDAR was flown over the EDWC, east coast and Georgetown area, covering 1100 km^2.

The data was filtered and reduced to a 30 cm grid, and processed to give bare-earth elevations. A vertical accuracy of <± 9 cm at the 95% confidence limit was achieved.

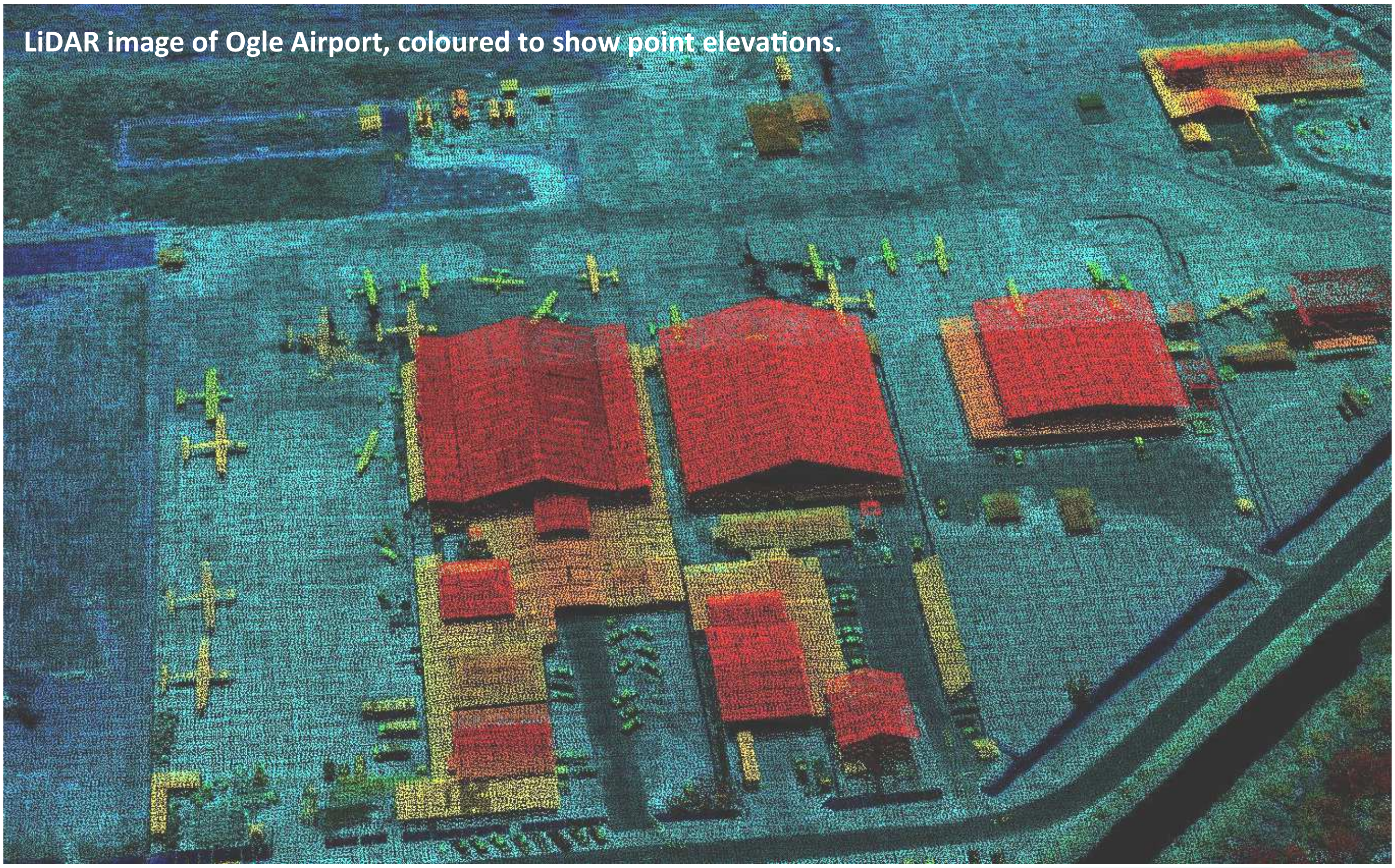
Bathymetric surveys: The LiDAR beam does not penetrate water surfaces, so the LiDAR data was supplemented with extensive bathymetric surveys. Bathymetry is the measurement of underwater relief (depth). In the CAP, depths of areas of standing water were measured manually from a boat, using range-poles, along a 500 m grid across the whole of the conservancy. In the EDWC channels, data was collected with a portable echo-sounder. GPS measurements were taken at each location.

Digital Elevation Model (DEM): A DEM was produced using the LiDAR data and was supplemented by aerial photography, collected at the same time as the LiDAR data.

Use of datasets: These datasets provide essential baseline information and have many uses, e.g. topographic data is necessary for land-use and drainage planning, preliminary designs for infrastructure projects and flood risk management, and will help decision makers to manage Guyana's water-resources.

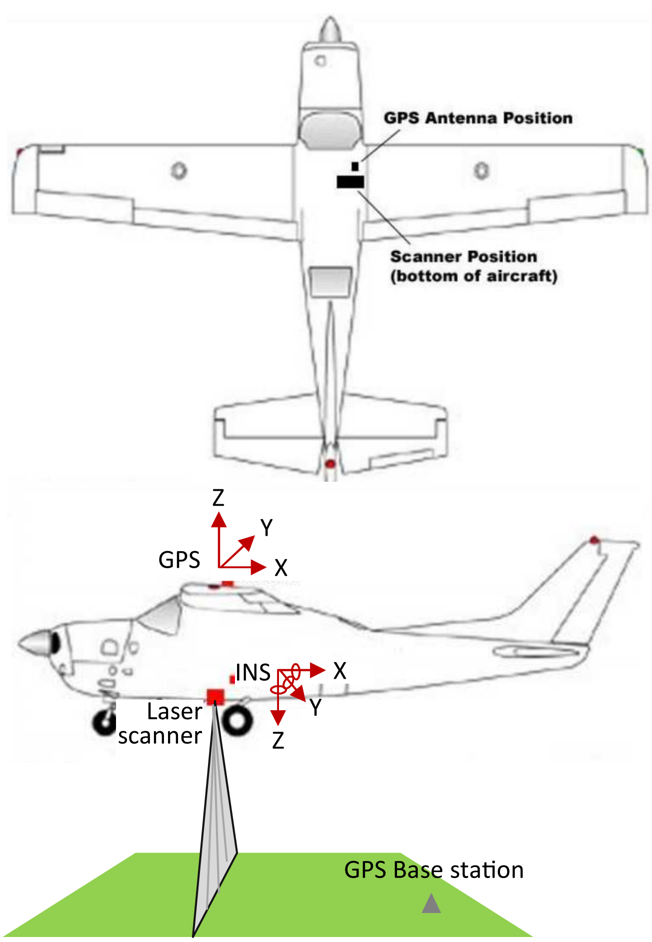


Digital Elevation Model (DEM) produced using LiDAR surveys



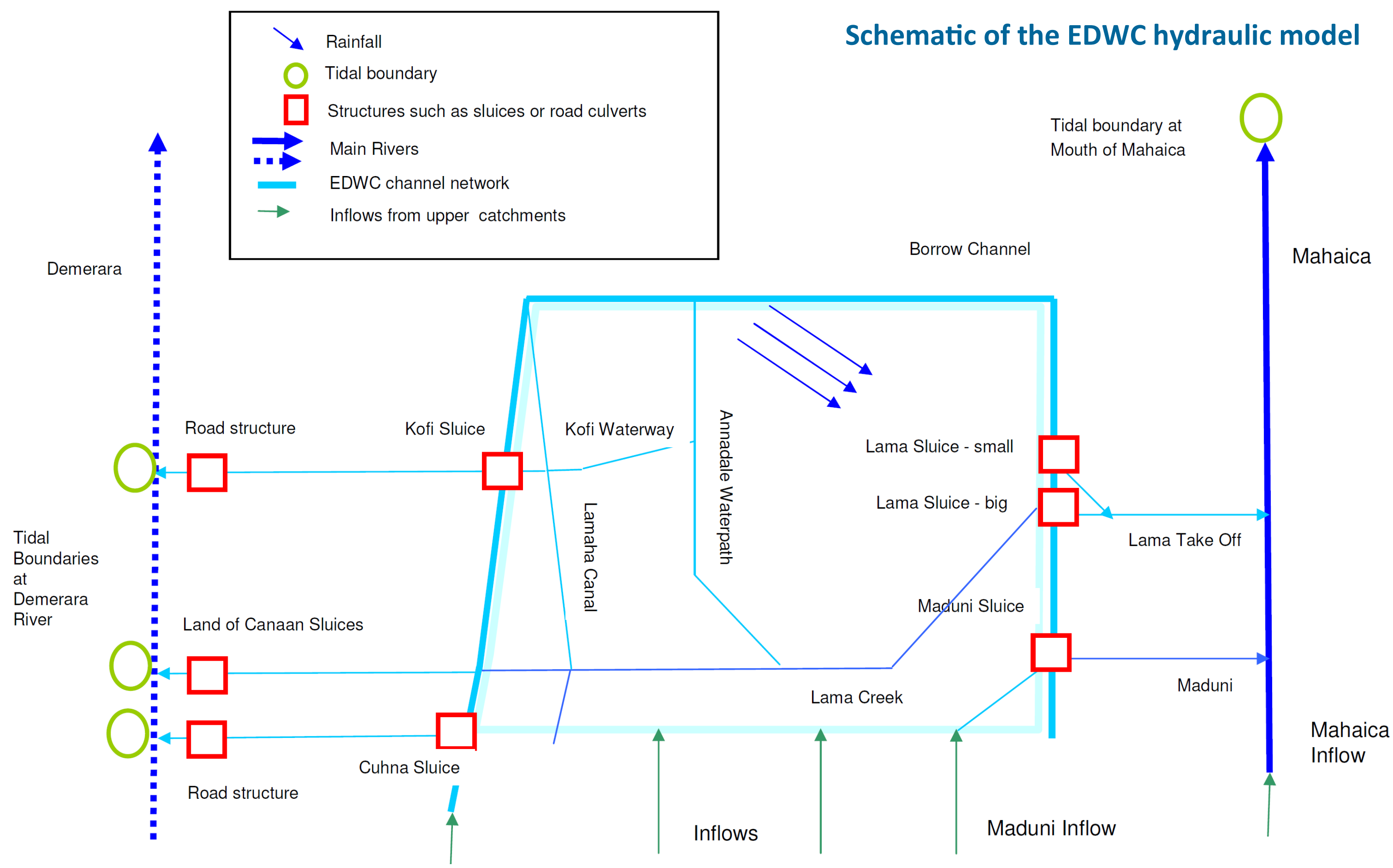
LiDAR image of Ogle Airport, coloured to show point elevations.

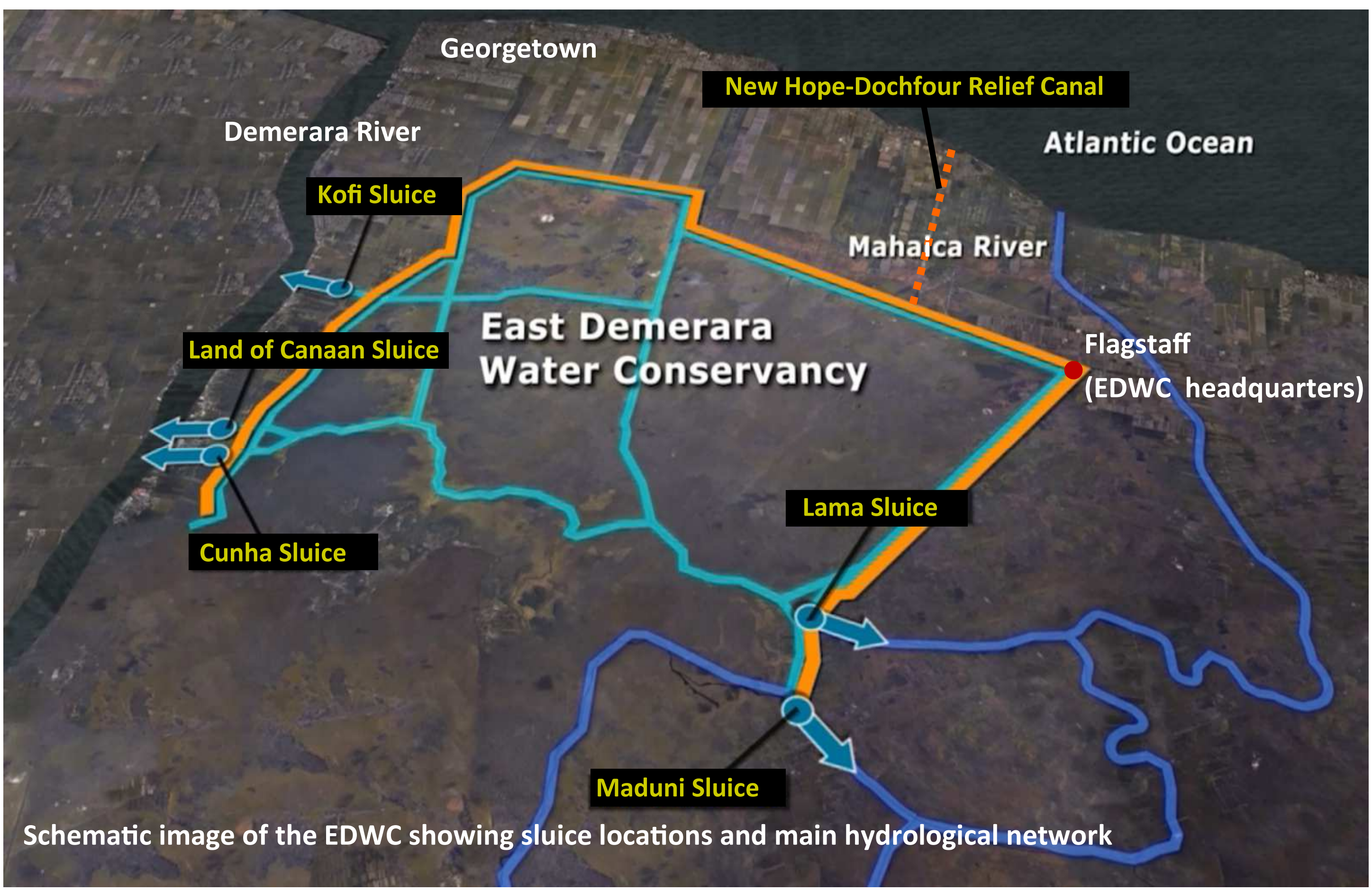
Aircraft-mounted LiDAR system



Definitions:

- ***Bathymetry*** *is the measurement of underwater relief, the equivalent of underwater topography.*
- ***DEM*** *stands for Digital Elevation Model, also known as DTM or Digital Terrain Model. It is a 3 dimensional representation of a terrain.*
- ***Echo-sounder*** *a device for measuring water depth using sound (sonar).*
- ***GPS*** *stands for Global Positioning System. It is a satellite navigation system used to provide ground position and time.*
- ***LiDAR*** *stands for Light Detection and Ranging. It is an airborne laser mapping and altimetry system which produces accurate and spatially geo-referenced land elevation data.*
- ***m GD*** *stands for meters above Georgetown Datum, a local reference point set to 17.07m below mean-sea-level. In these terms, the EDWC dam crest-level is at 18.29 m GD.*





Schematic image of the EDWC showing sluice locations and main hydrological network

1.3.1 Modeling—EDWC

Computer models are an important tool for water-resources management because they can be used to test how the system works under different climate or land-use scenarios. *Hydrological models* focus on water movement and distribution, whereas *hydraulic models* deal more with the mechanics of water flow.

In the CAP, a hydrological model was used to provide the spatial and temporal inputs necessary for running a one-dimensional hydraulic model, linked with a series of storage cells, giving a two-dimensional representation of the conservancy system.

To set up the models, spatial data and technical parameters are required, including topography, land use, soil types and properties, water-ways and infrastructure. In the CAP, these were obtained from LiDAR and other surveys. To run and calibrate the models, all inputs and outputs to the system are required, such as rainfall, climate data, and river flow, which were obtained from the hydro-meteorological monitoring system and existing tidal datasets. The models were run for rainfall return periods of 50, 100, 1000 and 10,000 years, with storm-durations of up to 40 days.

The models were calibrated and validated using historical data collected during the 2005 floods and new data collected during the CAP, including the January to March and May to July 2012 rainy seasons.

The calibrated models were used to test the system: (i) under 2005 conditions, where only the Land of Canaan sluice drained water into the Demerara river; (ii) for current conditions, with the Cunha and Kofi sluices operational; and (iii) under near-future conditions with the new Hope-Dochfour canal operational, draining into the Atlantic Ocean.

The results of the models show that in 2005, even a 50-year rainfall event would have meant that water-levels throughout most of the conservancy would have been above the safe operating level of the dam. However, the improvements made since 2005 have greatly reduced this risk, except along parts of the northern perimeter dam. Furthermore, the models show that the new Hope-Dochfour canal will reduce water levels even further so that water levels around all of the conservancy will remain below safe operating level.

In fact, the new Hope-Dochfour canal, once operational, will significantly improve drainage from the conservancy and the models show that even for an extreme 10,000 year rainfall event (an event much more severe than in 2005), water levels in the EDWC will not reach the top of the dam.

The models were also able to test the impact of potential new interventions aimed at improving drainage capacity in the conservancy. The models show that water levels in the conservancy are generally shallowest in the vicinity of Land of Canaan. Increasing the conveyance of internal channels combined with increasing the discharge capacity to the Demerara river will therefore help lower water levels in the rest of the conservancy even further.

Further modeling studies have also been made to investigate options to improve flood management and water storage demands in the EDWC. The recommendations made will help the Government revise the operational management of the EDWC.

Land of Canaan 5-door sluice

1.3.2 Modeling-East Coast

Hydraulic modeling of the coastal lowlands of Region 4, also known as the east-coast Demerara, was carried out to assess the drainage capacity and to test options for improving the system.

Several drainage areas along the east coast were identified as being vulnerable to flooding following a series of site visits and stakeholder discussions. To select priority areas for detailed modeling, a multi-criterion analysis was used which considered frequency of flooding, rate of dissipation, population, affected agricultural areas and key areas of infrastructure and agricultural significance. Following the analysis, 6 broad drainage areas were identified.

Conceptually, the coastal drainage system, particularly in urban areas, can be considered to comprise a number of discrete drainage compartments, bounded by roads and other embankments that are connected through a series of drains to the primary drainage network. The modeling therefore prioritised the modeling of the main drainage network above the secondary and tertiary drainage systems.

Walkover surveys and LiDAR surveys were used to identify the complex network of drains, inter-linkages, flow directions and other characteristics of the drainage regime needed for building the models. Six models were set-up, one for each drainage area, however as canal water levels have not been recorded or monitored, the models are necessarily uncalibrated.

The models were used to test a number of interventions which would improve drainage and reduce the area prone to flooding. An analysis of the costs and benefits of the interventions was carried out by comparing the costs of the proposed intervention with the area of land which would benefit from the proposed intervention (worked out by comparing the area of land which currently becomes inundated during a 50-year rainfall event against the area of land which would remain dry following the proposed works).

Ogle pumping station

The models were used to test a number of interventions which would improve drainage and reduce the area prone to flooding

Options considered for interventions include increased pump capacities, increased culvert widths, adding water storage areas, channel improvements and separating urban and agricultural drainage systems.

It became evident during the modeling that many of the key components of existing drainage facilities were designed for agricultural drainage and not for the mixed urban and agricultural land uses that now exists in many areas. The Liliendaal regime for example, no longer holds agricultural lands at all.

The results of the cost-benefit analysis shows therefore, that in most cases, separation of urban and agricultural drainage areas, providing different levels of service to both, would be most beneficial. Other recommendations include additional pumping capacity in many areas, and resizing of outlet systems and culverts.

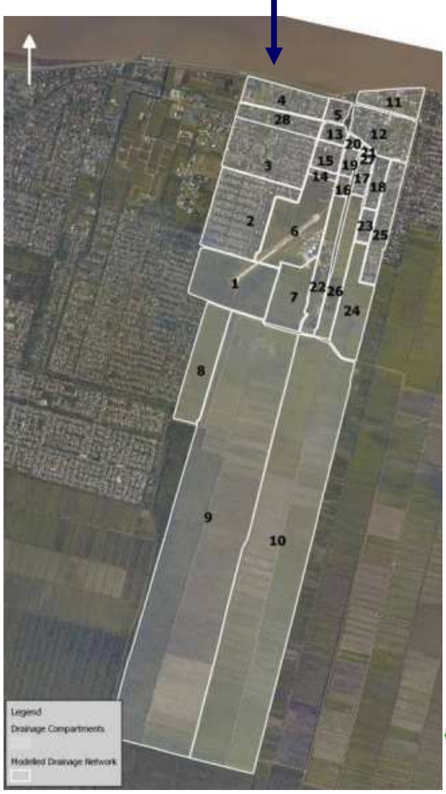

Drainage canal at Ogle

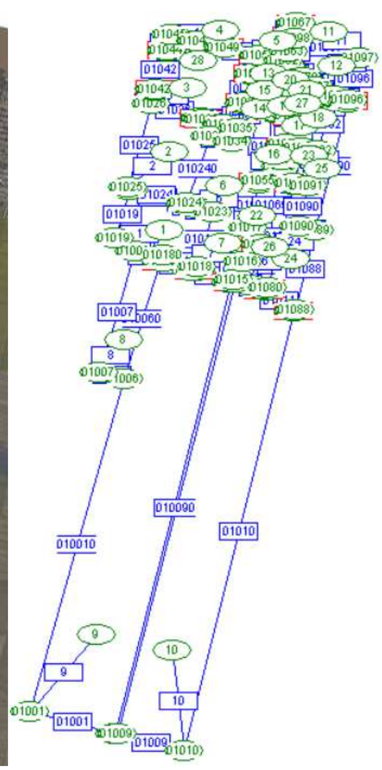
Map of East Coast Demerara highlighting selected drainage areas

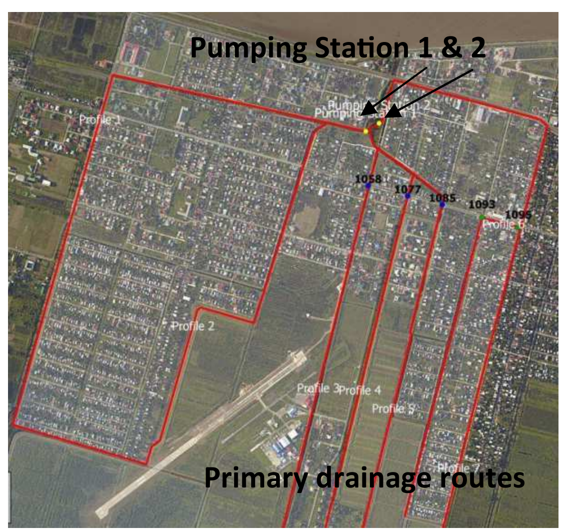
Modeled Drainage Regimes

1. *Liliendaal*
2. *Ogle*
3. *Montrose & Sparendaam*
4. *Mon Repos & Annandale*
5. *Enterprise, Strathspey & Paradise*
6. *Beehive and Clonbrook*

Mott MacDonald

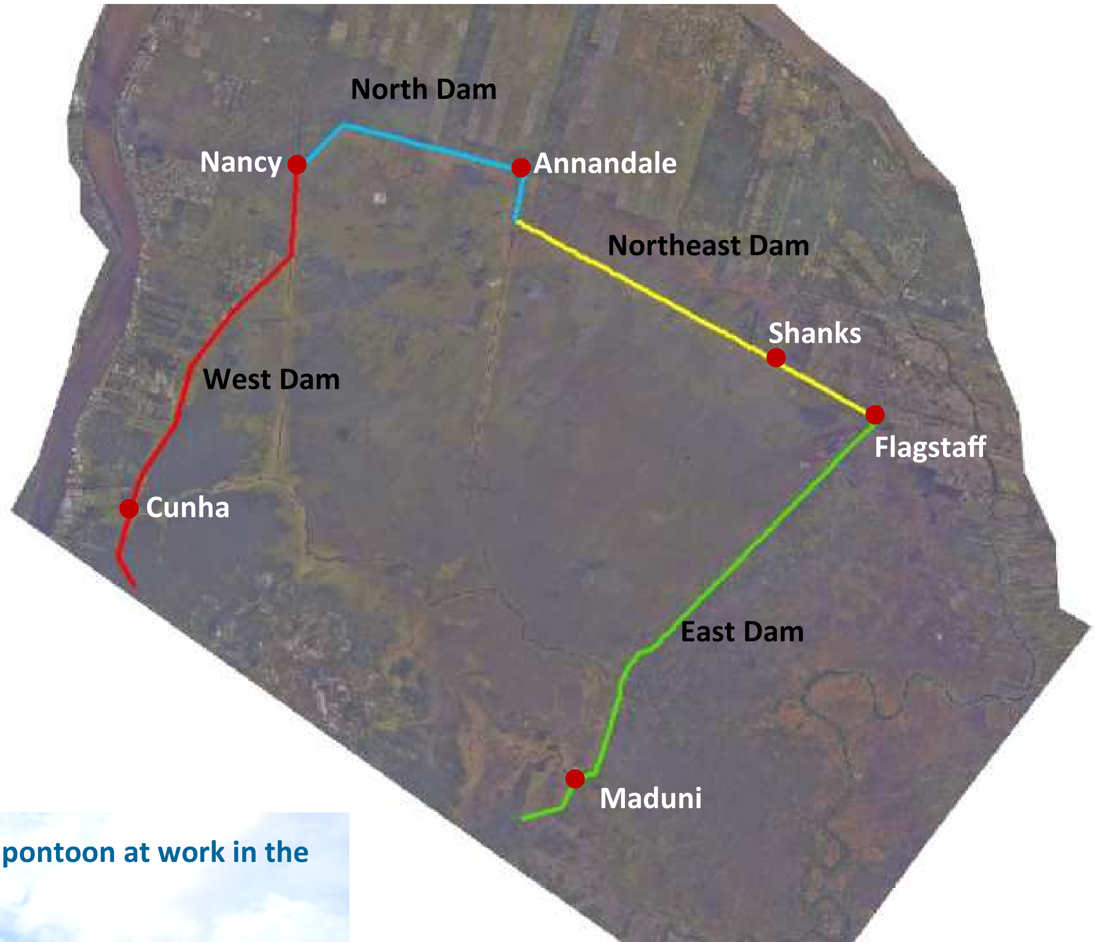






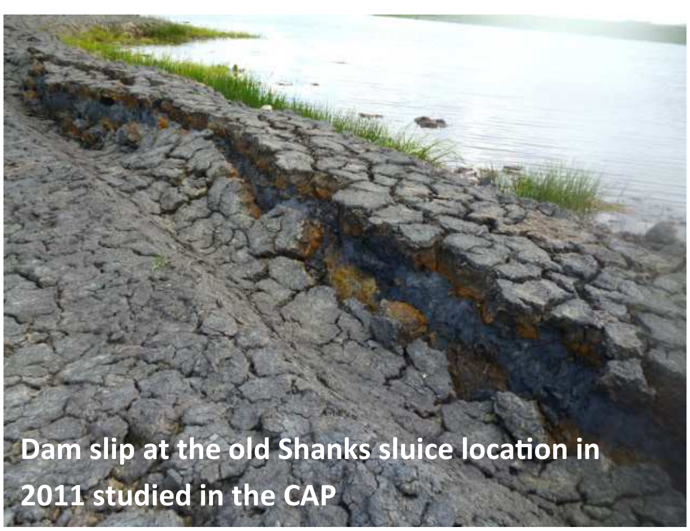
Schematic of Ogle drainage system model (lower centre), drainage compartments (lower left) and primary and secondary drains with their associated catchment areas (lower right) .

Nomenclature of the EDWC dam for the purposes of the CAP



The new excavator and pontoon at work in the conservancy

Historical EDWC dam breach



Dam slip at the old Shanks sluice location in 2011 studied in the CAP

1.4 Dam Stability

The existing EDWC dam is over 130 years old. Due to its age, it has had many minor slope failures, which have generally been repaired without consequences. However, these failures indicate the fragile nature of the dam.

As part of the CAP, a geotechnical stability analysis has been carried out on the dam. For most of the dam, the study supports the historical evidence which suggests that earthwork stability is reasonable, but falls marginally short of international standards.

Under certain conditions, however, the stability of the dam becomes marginal, as evidenced by the historical incidence of localised instability. One such instability occurred at the old Shanks sluice location in 2011. Although the failure did not result in a breach, it provided an opportunity to study and understand slope stability parameters.

The results of the study show that the north east dam, between Annandale and Flagstaff Mahaica, is the most fragile part of the dam and in need of rehabilitation. It is founded on pegasse (peat) to a depth of up to 4m, and is constructed of very soft clays with a high pegasse content. The north dam, between Nancy and Annandale, and the east dam between Flagstaff Mahaica and the Maduni Creek, have also been found to have marginal stability. The west dam, from Nancy to the Cunha Canal on the east bank is built on and constructed of better clays, however the side slopes are very steep, the crest is very narrow and it is overgrown. It therefore does not meet international standards, but it is still considered stable.

Possible designs for the rehabilitation of the dams have been drawn up with the recommendation that the rehabilitation of the north east dam be carried out first.

2.CAP Investments

In addition to the non-structural flood risk reduction measures (i.e. data collection, engineering studies, drainage modeling, dam designs etc.), the CAP has funded the complete rehabilitation and upgrade of the two sluices at Lama on the eastern side of the Conservancy. A long-boom excavator was also purchased and a floating punt and pontoon were designed and constructed under the project. This has improved drainage and helped to rapidly mobilize equipment to areas of the dam in need of repair and respond to dam breaches, thereby improving dam safety. The purchase and installation of the hydrological instrumentation has also helped manage the conservancy water levels on a near real-time basis, and contributed to the national weather-forecasting system.

Finally, other essential surveying equipment, office supplies and computing equipment were also purchased under the project.

3. Institutional Strengthening

In order to ensure the sustainability of the CAP results, training has been given to various government agencies in the use and maintenance of hydro-meteorological instrumentation, the analysis and potential uses of the LiDAR and other remote sensing datasets, data management, dam safety and hydrological modeling. This will help strengthen the management of the drainage and irrigation system.

Other Government Initiatives

Since 2005, the government has been carrying out several improvements to the drainage system in parallel with the CAP. For instance, the EDWC dam has been reinforced in several places, maintenance and repairs have been carried out and several sluices, relief-structures and channels have been rehabilitated, including those at Cunha and Kofi. Also, a new channel was excavated from the northern borrow channel near Flagstaff to the Kofi waterway to improve conveyance within the conservancy. The modeling results show that these improvements have increased outflow capacity of the EDWC by 25% during 50 and 100-year flood scenarios.

...these improvements have increased outflow capacity of the EDWC by 25% during 50 and 100-year flood scenarios

Additionally, and importantly, a new relief canal is being built at Hope Dochfour to help relieve discharge pressure on the eastern side of the EDWC during times of flood. The construction includes a new intake regulator, a bridge over the public road and a sluice at the Atlantic Ocean. The CAP modeling results show that this relief channel, once operational, will lead to a significant reduction in water levels in the EDWC, particularly in the north-eastern corner of the EDWC.

Looking Forward

As previously indicated, the CAP generated a portfolio of recommended discrete and strategic investments totalling approximately US$ 123 million, to include interventions such as excavations within the EDWC and optimization of drainage towards the Demerara River, reconstruction of all sides of the EDWC dam, various interventions along the east coast including additional pump capacities, channel and culvert widening and separation of urban and agricultural drainage, and safety improvements to existing water control structures.

the CAP generated a portfolio of recommended discrete and strategic investments

The results and investments identified under the CAP have contributed to and have been incorporated within the Government's drainage and irrigation master-plan for Region 4 (part of the national plan).

The CAP technical foundation and pre-engineering studies will help policy-makers plan targeted flood-reduction measures and interventions for Region 4. However, the CAP also serves as a demonstration for the development of adaptation interventions that can be implemented in similar contexts in Guyana, other countries in the Caribbean and elsewhere.

The CAP technical foundation and pre-engineering studies will help policy-makers plan targeted flood-reduction measures

Further Information

For further information related to the CAP, or for access to any of its datasets, please contact:

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ACP-EU Natural Disaster Risk Reduction Program

An initiative of the African, Caribbean and Pacific Group, funded by the European Union and managed by GFDRR