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LDA LAND DRAINAGE AUTHORITY

ADAPT ACTION | A PROGRAM AFD GROUPE

Integrated Management of Flood Risks and land Drainage Master Plan (LDMP), Mauritius

D5.2 – Elaboration of the integrated Land Drainage Masterplan - Volume 2

2022.05.05

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Deliverable: D5.2 – Land drainage Master plan – Second Part

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OVERVIEW

The Land Drainage Masterplan was commissioned by the Agence Francaise de Development (AFD) for the Government of Mauritius with the main purpose of reducing vulnerability of the population and various activities to heavy rain and flood events in the context of climate change.

Its aim is to provide technical assistance to LDA in the form of vulnerability and feasibility studies, drafting of national policy, good governance and action plans as well as capacity building. It is also intended to support the LDA in their effort to provide guidelines and principles of stormwater management to designers in order to mitigate the impacts caused by their projects.

The Second part of the Land Drainage Masterplan (LDMP) comprises four chapters, namely: -

Chapter 1 : Introduction

2 : Existing situation description including hazard maps for different return period, asset exposed, primary and secondary drainage infrastructure and natural area with drainage function

3 : Action plans to improve drainage infrastructures implementation for short term and middle term and Recovery measures

4 : Operation and control for drainage system and monitoring

A. INTRODUCTION

The long term annual rainfall over the island is 2010 mm with a notable variance between precipitation on the central plateau which is of the order of 3600 mm and that on the coastal region which experiences some 1500 mm per annum.

The island's hydrography is such that the south and east part of the island abounds with rivers contrary to the northern part, commonly known as the Northern Plain, which has little run-off due to its geological formation made up of mild undulating and younger lava flows, basaltic intrusions and high permeability soil. 25 major rivers and a multitude of rivulets and drainage axes constitute the main drainage infrastructure of the island.

The existing drainage infrastructure does not have sufficient capacity to drain stormwater during heavy rainy spells and lack of preventive maintenance exacerbates the flooding problem. With increasing population and per capita income and rapid infrastructure development, there is a high pressure for forested and agricultural land to be cleared in favour of urbanisation, leading to increased surface runoff and ever increasing challenges for an efficient land drainage system.

Some sixty sites had been declared as being critical and prone to flooding by the National Disaster Risk Reduction and Management Centre (NDRRMC).

The study and the preparation of this Land Drainage Masterplan was conducted by a consortium comprising SUEZ, Mega Design Consulting Engineers, Acterra, DAY Marine and Scene-Ries Consult and monitored by a technical and committee chaired by the Land Drainage Authority.

The Masterplan comprises the following components:

- An inventory and mapping of all the existing natural and manmade drainage infrastructures;
- An identification of vulnerable areas, including the impact of future developments on potential flood prone areas;
- The definition of a reference hydrology at the scale of each rainfall sub-catchment, based on new IDF curves,
- The elaboration of flood mapping and associated vulnerability assessment;
- The proposal for national rules in order to account for land drainage issues in territorial development with the objective of flood risk reduction, taking into account water quality and biodiversity preservation to improve the resilience of the country in the context of climate change;
- The definition of broad protection objectives at the scale of the most vulnerable catchments, based on detailed studies conducted at a more localised level.

B. Existing situation description including hazard maps for different return periods, asset exposure, primary and secondary drainage infrastructure and natural area with drainage functions

This Chapter deals with the following topics:

i. Hazard maps by modelling

Within the framework of the Land Drainage Master Plan, one of the first steps on the priority and complementary sectors consists in establishing hazard maps for different return periods. Thus, the flood hazard maps (flood heights and velocities) have been established by hydraulic modelling on the 5 + 11 sectors retained in the framework of the Master Plan.

In relation to hydraulic modelling, the choice of the type of modelling to be implemented is dependent on the topography of certain parts of the territory. Thus, the territory has been modelled as follows:

- **a coupled 1D/2D modelling is generally**[1] sufficient (by injection of peak flows at calculation nodes determined upstream of the issues),
- **a distributed modelling in full 2D** for coastal, low-lying catchments such as those in the north of the island and those whose topography is conducive to bifurcations and flood transfers from one catchment to another.

A map to identify the recommended model types is provided in this framework.

ii. Asset Exposed

As part of Activity 1, all the data relating to the issues being investigated were collected and updated. These are:

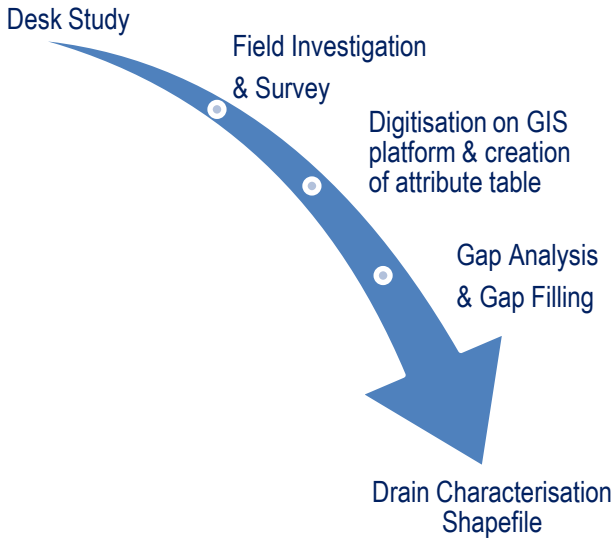
- Urban areas:
  - Buildings
  - Infrastructure:
    - Road
    - Metro line
  - Population:
    - Population potentially impacted
    - Population density at risk
  - Activities:
    - Economic activities
    - Sensitive equipment
  - Future urbanisation :
    - growth zones including smart cities (VRS, PDS, NHDC, Master plan)
    - Morcellement projects

These assets have been integrated into the Land use platform (current and future) and are considered in the vulnerability and cost benefit analyses of the action plan.

[1] Locally, especially in areas with high diffuse runoff, where it is necessary to complete the analyses with a distributed full 2D model

iii. Main primary and Secondary Drainage infrastructure

This activity comprises the identification and characterization of primary and secondary drains as defined by LDA. It was undertaken in the sequence shown below:



An approximate length of 600km of main drains were thus inventorised within the 5 municipalities and at those sites classified as most vulnerable to flooding. Attributes thus recorded on a GIS environment include drain types (roadside drain, urban drain, irrigation canal or river), drain material, drain class (primary secondary or tertiary), the precise coordinates of the drains and their sizing.

iv. Natural Area with functional drainage attributes

Natural areas having a drainage function include:

- Lowland areas
- Areas with natural open spaces providing land drainage and water cycle functions, such as:
  - Coastal marshlands
  - Upland marshlands
  - Lakes and reservoirs
  - Rivers and streams
  - Mangroves
  - Intertidal mudflats
  - Sand beach and dunes
- Ecosystems involved in drainage system (storage, filtration): These areas correspond to ESAs with a specific role in water storage and filtration.
  - Coastal marshlands
  - Upland marshlands
  - Lakes and reservoirs

Synthesis maps have been established in the framework of the LDMP.

C. Action plans to improve drainage infrastructure implementation for short term and middle term

i. Guide to the gradual implementation of better risk management: implementation of non-structural, recovery and structural measures

The objectives of the Land Drainage Master Plan are to promote the emergence of work programmes dealing in a balanced and coherent way with all the components of the flood prevention policy, i.e., non-structural measures (planning documents linked to building permits) and structural measures (actual works)

The aim is to promote integrated flood risk management, at the scale of the territory, regarding flood hazards and the assets put in place to respond to these hazards.

In this context, the following scheme summarises the flood risk reduction policy to be put in place.

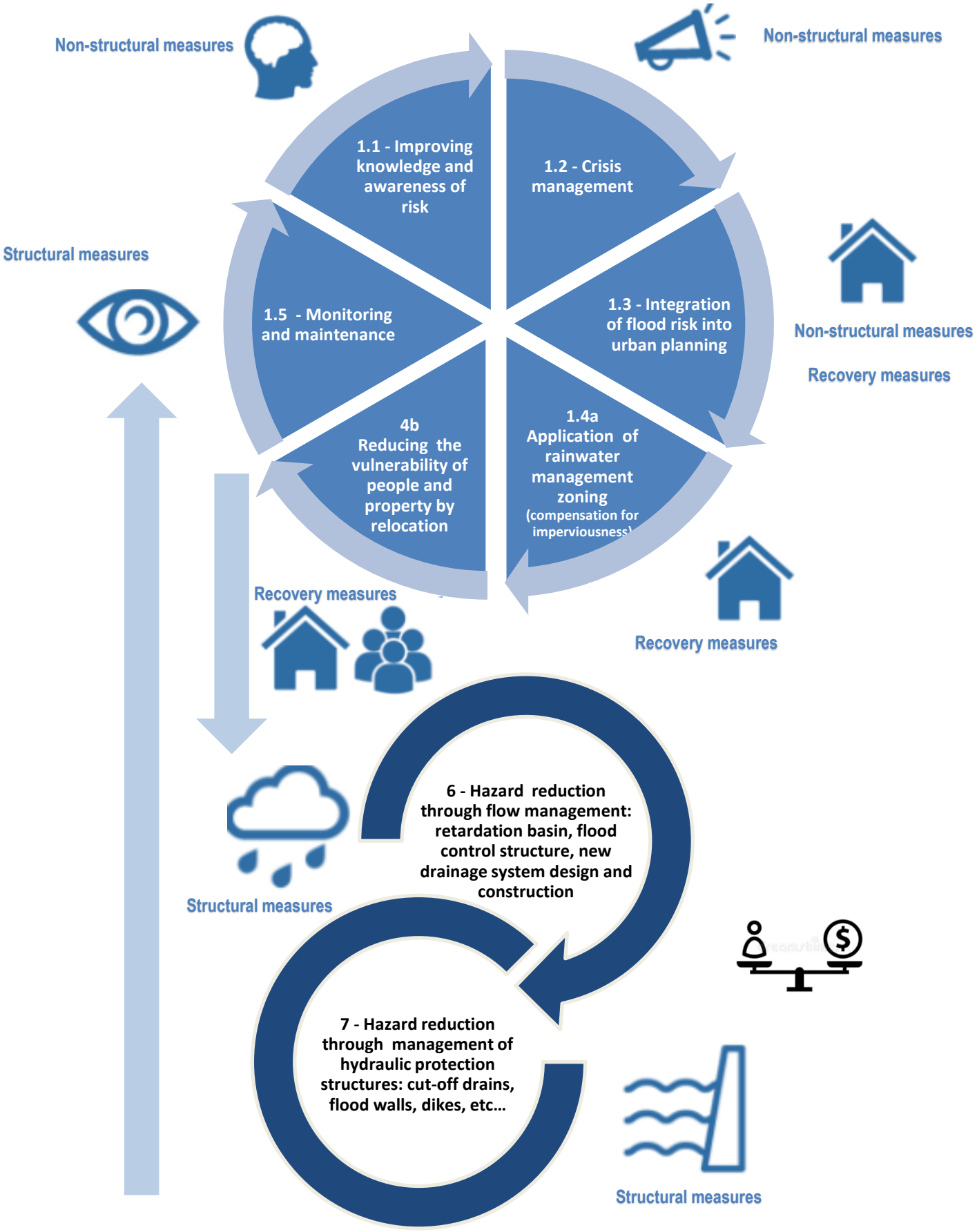


Figure 1 : Flow chart for designing a flood risk reduction programme

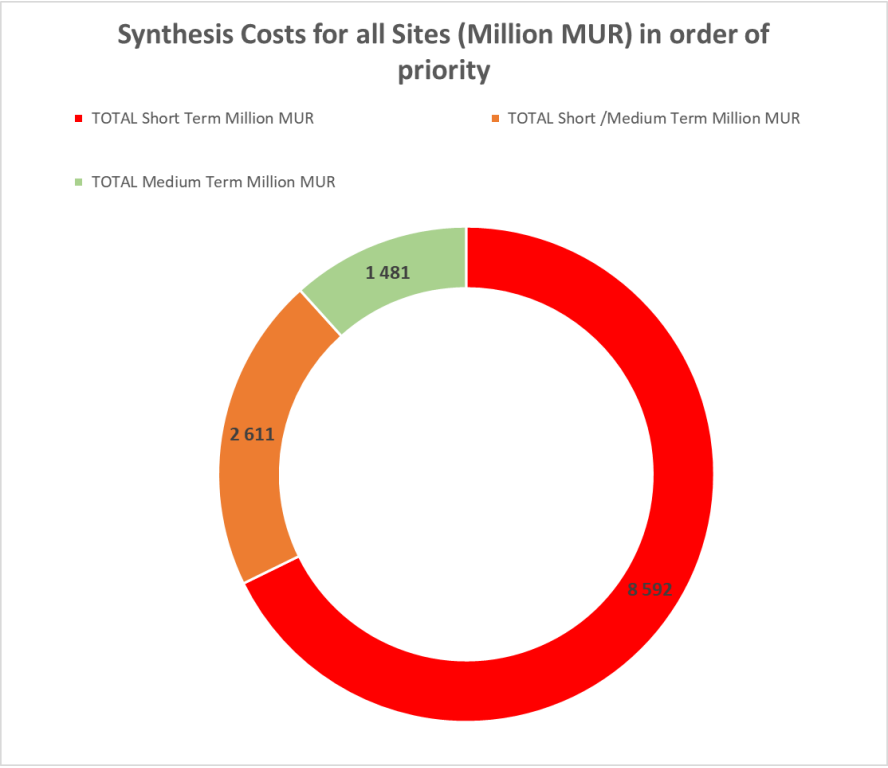
ii. Protection level, costs and schedule forecast

Within the framework of the studies of the design functions and the optimisation phases, the level of protection was defined based on:

- The logic of the development principle described in the preceding chapter, namely:
  - Initially, identification of structures which would help to reduce runoff and limit peak flows by lengthening their concentration time and by dynamic slowing down of the runoff (retardation basin, flood expansion zone);
  - Complementary research on the protection of densely populated areas through the creation of structural works such as new drains, cut off drains, flood walls and dikes.
- The feasibility of the works in the local context, particularly in relation to the topography and density of urbanised areas
- The overall effectiveness of the structures. This effectiveness is evaluated on the basis of cost-benefit analyses for events of various occurrences (T=10, 25, 50 and 100 years).

The financial cost estimates for the actions include the cost of construction, provision for wayleave and Land Acquisition, provision for relocation of houses, contingencies and Project Management cost.

iii. Actions plan synthesis



	Id	Sectors	Cost Million MUR	Priority	Scheduling proposal
PS	S73	LATANIERS RIVER AND CANAL DES ANGLAIS	188	1	Short term
	S75 - S74	POUCE RIVER, POUDRIERE STREAM, RUISSEAU CREOLE AND CUT-OFF DRAIN - Including La Paix (for CBA)	2 135	1	Short term
	S77	CANAL DAYOT AND URBAN DRAINS	205	2	Short/Medium term
	S65	FLIC-EN-FLAC	372	2	Short/Medium term
	S32	BEL OMBRE	22	1	Short term
	S47	NOUVELLE FRANCE	561	3	Medium term
	S6&5	GRAND BAIE / PEREYBERE	356	2	Short/Medium term
CS	S01	SECTOR 01 - MAPOU PITON COTTAGE	802	1	Short term
	S25&102	SECTORS 25 AND 102 - CLEMENCIA BEL AIR OLIVIA PONT LARDIER	469	3	Medium Term
	S43	SECTOR 43 - FLACQ	1 649	1	Short term
	S59	SECTOR 59 - COTEAU RAFFIN	155	3	Medium Term
	S72	SECTOR 72 - TERRE ROUGE	1 120	1	Short term
	S74	SECTOR 74 - PORT LOUIS LA PAIX	*Included with S75*	1	Short term
	S78	SECTOR 78 - POINTE AUX SABLES	650	1	Short term
	S82	SECTOR 82 - HENRIETTA MALAKOFF	307	1	Short term
	S85	SECTOR 85 - VACOAS QUATRE BORNES	795	2	Short/Medium term
	S86	SECTOR 86 - CUREPIPE AVAL	360	2	Short/Medium term
	GRAND TOTAL Million MUR		**10 147**		
	Provision for uncertainties due to external factors (MUR devaluation, oil and other commodity prices, global sanitary and geopolitical context)		**25%**		
	GRAND TOTAL Million MUR with uncertainties		**12 684**		
	TOTAL Short Term Million MUR		**8 592**		
	TOTAL Short /Medium Term Million MUR		**2 611**		
	TOTAL Medium Term Million MUR		**1 481**		

The measures proposed in this LDMP master plan for 16 vulnerable sites can be adapted to all the catchment areas of the territory, while respecting the solution-finding philosophy as described in volume 2 of the Land Drainage Master Plan (see chapter 3).

Of course, each measure will have to be adapted to the local context of the catchment areas and sub-catchment areas to be considered.

D. Operation and control of drainage system and monitoring

Hydraulic structures represent an important asset for the managing authorities because they are essential for the continuity and/or protection of people and properties. The lack of maintenance of structures not only leads to adverse consequences for the safety of people and properties and the responsibility of the representatives of the communities, but also to heavy financial consequences in the event of significant deterioration or even collapse of the structure.

A thorough knowledge of their condition and the implementation of preventive maintenance are likely to prevent their deterioration and the resulting incidents. In addition, the operating conditions and the quality of their maintenance significantly extend their lifetime.

These monitoring and maintenance activities involve various measures at various scales:

- At national scale : Governance measure

- At guideline scale: Stormwater Management Facility Performance Monitoring, in particular for pond monitoring
    - Definition of a significant rainfall event"
    - Check list of points requiring attention

- At infrastructure scale: Establishment of a monitoring and maintenance scheme / operation and maintenance (O&M) plan or manual
    - Conventional operations including:
        - Preventive maintenance
        - Corrective maintenance
        - Responsibility for maintenance
    - General maintenance activities including:
        - Inspections
        - Maintenance description and frequency for manmade drain and for green infrastructure

1 INTRODUCTION

1.1 Background

Mauritius is a volcanic island in the Indian Ocean with a surface of about 1865 km^2, situated about 900 km to the east of Madagascar and at latitude 20° South and longitude 58° East in the Indian Ocean. Mauritius has a resident population of 1,266,030 (Statistics Mauritius, 2020) and almost an equal number of tourist arrivals per year. The Gross Domestic Product (GDP) for the year 2019 was MUR 498 billion (13b USD) (Statistics Mauritius). The economy of Mauritius is a mixed developing economy based on agriculture, exports, financial services, and tourism.

It lies near the edge of the southern tropical belt and has a tropical climate with two distinct seasons: a hot and humid season from November to April and a cold dry season from June to September, with the month of October and May known as the transition months. January and February are the warmest months with average day maximum temperature reaching 29.2 degrees Celsius while July and August are the coolest months with the average night minimum temperatures dropping down to 16.4 degrees Celsius.

The Long term mean annual rainfall (1971-2000) over the Island is 2010 mm. February and March are the wettest months while October is the driest month. Mean summer rainfall (1971-2000) is 1344 mm, which is 67% of the annual amount over the Island. Mean winter rainfall (1971-2000) is 666 mm. Although there is no marked rainy season, most of the rainfall occurs during summer months. (MMS,2021). Across the island mean annual rainfall varies between a high of 3600 mm in the central plateau to 800mm on the leeward coastal zone

In 2019, Mauritius received 3,972 million cubic metres (Mm^3) of precipitation (rainfall). Annual evaporation has been estimated at 30% (1,192 Mm^3), surface runoff at 60 % (2,383Mm^3) and the groundwater recharge at 10% (397 Mm^3) (Statistics Mauritius, 2019). Potential annual evapotranspiration amounts to between 1100 mm and 1600 mm with small inter - annual variations. The average relative humidity amounts to 80%.

According to statistics, Mauritius gets directly hit by a cyclone once every 5 years on average, although occurrence has been less frequent in recent years. Still, every year the island is hit by the remnants of 3 to 5 storms, which form on the Tropic of Capricorn where the body of water heats up to 26°C for an extended period of time, bringing in their wake a lot of rainfall.

The island's hydrography is such that the south and east part of the island abounds with rivers contrary to the northern part, commonly known as the Northern Plain, which has little run-off due to its geological formation made up of mild undulating and younger lava flows, basaltic intrusions and high permeability soil. 25 major rivers and a multitude of rivulets and drainage axes constitute the main drainage infrastructure of the island.

The existing drainage infrastructure does not have sufficient capacity to drain stormwater during heavy rainy spells and lack of preventive maintenance exacerbates the flooding problem. With increasing population and per capita income and rapid infrastructure development, there is a high pressure for forested and agricultural land to be cleared in favour of urbanisation, leading to increased surface runoff and ever increasing challenges for an efficient land drainage system.

Floods resulting from overflowing watercourses and drains inundate properties and public utilities, causing not only damage to infrastructure but also degradation of water quality, leading to serious health hazards and adverse impacts on the economy. Increased urbanization with the associated compaction and sealing of the ground surface further increases the risk of flooding. In February/March/April 2019, heavy rainfall hit the country, flooding several districts and reminding the population of the painful memory of the 2013 floods that killed 11 persons.

The adverse impacts of climate change in terms of temperature rise and increase in rainfall intensities have been experienced over the last 10 years, during which period, a number of flash floods had occurred which had inundated many localities including Port Louis, Fond du Sac, Cottage, Vacoas, Nouvelle France, Riviere des Creoles, Bamboux Virieux and Flacq.

Some sixty sites had been declared as being critical and prone to flooding by the National Disaster Risk Reduction and Management Centre (NDRRMC).

1.2 Land Drainage Authority (LDA)

The LDA has been set-up as an independent authority charged with the coordination, policy development and implementation of measures related to land drainage and watershed management, including soft and hard measures which could allow for co-benefits in climate risks alleviation.

The LDA's mandate is to ensure synergy and coherent actions on Mauritius Island and to focus on the improvement of flood risk characterisation, flood risk understanding and flood risk management considering its impacts on the mainland of Mauritius in the context of climate change (additional risks and associated uncertainty).

The main objectives of the LDA are:

- the development and implementation of a land drainage master plan;
- coordinating the construction of drainage infrastructure by the local authorities, the NDU, the RDA and any other relevant stakeholders; and
- ensuring that there is a routine and periodic upgrading and maintenance of the drainage infrastructure.

As detailed in section 5 of the LDA Act (2017), LDA's mandate shall be to:

- carry out an inventory and mapping of all the existing natural and manmade drainage infrastructure;
- undertake a study based on a hydro-meteorological and hydrographic survey and produce and keep under review a flood risk map and a Land Drainage Plan;
- conduct and coordinate research and development on land drainage and watershed management and share all available information with relevant stakeholders;
- identify, in collaboration with the local authorities, the National Development Unit (NDU), the Road Department Authority (RDA), the National Disaster Risk Reduction Management Centre (NDRRMC) and any other relevant stakeholders flood risk areas;
- cause any work related to land drainage to be carried out by the local authorities, the National Development Unit, the Road Development Authority and any other stakeholders;
- cause to be carried out the upgrading and maintenance of the drainage infrastructure to be carried out by the local authorities, the NDU, the RDA and any other relevant stakeholders;
- prepare and implement land drainage schemes;
- advise the Minister on the formulation and implementation of land drainage policies and strategies;
- advise and update the Minister on any matter relating to land drainage; and
- take any other action deemed necessary in line with the provisions of the Act.

1.3 Enhancing Resilience to Climate Change (ER2C)

In the wake of COP21 and the Paris Climate Agreement, the Parties drew up "Nationally Determined Contributions" (NDCs)—voluntary commitments to fight climate change and adapt to its effects.

Following the Paris Climate Agreement, the Agence Française de Development (AFD) has launched Adapt'Action to support countries seeking technical assistance for the institutional, methodological and operational implementation of their commitments to fight the effects of climate change in the form of vulnerability and feasibility studies, guidance in drafting national policy and action plans, as well as capacity-building actions

Higher temperatures, increasingly variable rainfall, and more pronounced droughts are all effects of climate change

Although their contribution to greenhouse gas emissions is negligible, the Indian Ocean States are on the front line of climate change. Their environments, economies, and societies are suffering from significant and potentially irreversible damage from its effects. Island States are moreover highly exposed to extreme climate events (cyclones, floods, etc.) and to coastal erosion and marine flooding.

The ER2C project consists the integration of climate change adaptation and risks in the government's public policies and sectors such as coastal zone land planning, disaster risk management, and drainage and the main objectives were as follows:

- Assess climate change vulnerability for five high-priority sites.
- Draft preparatory studies and terms of reference for the Land Drainage Master Plan.
- Provide technical assistance, training, and institutional development support to the Land Drainage Authority staff.
- Formulate the national disaster risk reduction policy and action plan for mainland Mauritius and its outer islands.
- Assessed the functionality of current drainage infrastructure and designed a rehabilitation programme.

1.4 The Land Drainage Master Plan (LDMP)

The main objective of the assignment is the elaboration of the Integrated Land Drainage Master Plan as a basis to the strategy, to be implemented by the Authorities and all stakeholders to reduce vulnerability of the population and various activities to heavy rain and flood events, in the context of climate change and uncertainty.

The Master Plan will include:

- An inventory and mapping of all the existing natural and manmade drainage infrastructures;
- An identification of vulnerable areas, including the impact of future developments on potential flood prone areas;
- The definition of a reference hydrology at the scale of each rainfall sub-catchment, based on new IDF curves,
- The elaboration of flood mapping and associated vulnerability assessment;
- The proposal for national rules in order to account for land drainage issues in territorial development with the objective of flood risk reduction, taking into account water quality and biodiversity preservation to improve the resilience of the country in the context of climate change.
- The definition of broad protection objectives at the scale of the most vulnerable catchments, based on detailed studies conducted at a more localised level;
- And finally, an action plan on the short and middle term.

1.5 Project Team

The Land Drainage Master Plan was carried out by a multi-disciplinary team comprising SUEZ of France as the main consultant in association with Mega Design Consulting Engineers of Mauritius. Sub-consultants included Acterra of France, and DAY Marine and Scene-Ries of Mauritius.

The Project Team comprised in the main:

- Arnaud Bonnafe - Team Leader
- Dharmanand Sooredoo - Deputy Team Leader
- Mathieu Ropert - Senior Hydraulic Engineer
- Aurelien Deconnick - Hydraulic Engineer
- Gopal Chand Khushiram - Civil Engineer
- Blandine L'hévéder - Climate Change Expert
- Vassen Kauppaymuthoo - Environmental expert

1.6 Workplan

The project started contractually in January 2020 and was scheduled to be completed within 15 months by end March 2021. Due to various delays, the most significant being the lockdown due to Covid19 both in Mauritius and in France, the Workplan had to be revised with completion of the study rescheduled for end 2021.

1.7 Structure of the LDMP report

Following the different activities constituting the assignment, various interim reports have been prepared and compiled into the main Land Drainage Masterplan Report, viz

Report	Description
D1	Report on the existing situation including land drainage issues and vulnerability assessment
D2	Hydrology study report, including new IDF curves, hydrological methodology for different return periods and risk and vulnerability due to climate change.
D3	Report on Existing Drainage Capacity including topographical survey and Flood maps on 5 priority sites and 11 most vulnerable sectors
D4	Feasibility Assessment Report

The LDMP report D5 comprises two parts; namely

- Report D5.1- Land Drainage Master Plan-First Part, comprising, inter-alia, hydrology framework, zoning and rules on territorial development and sizing of drainage infrastructure.
- Report D5.2-Land Drainage Master Plan-Second Part, comprising detailed hydraulic study reports on the priority sites and the most vulnerable sectors.

This document constitutes Report D5.2 and addresses the Terms of Reference:

- Executive Summary
- Chapter 1 : Introduction

- Chapter 2: Existing situation description including hazard maps for different return period, asset exposed, primary and secondary drainage infrastructure and natural area with drainage function
- Chapter 3: Action plans to improve drainage infrastructures implementation for short term and middle term and recovery measures
- Chapter 4: Operation and control for drainage system and monitoring,

List of Acronyms, Conventions and Abbreviations

AFD	Agence Française de Développement
BRIO	Building Resilience in Indian Ocean
CC	Climate Change
CCVA	Climate Change Vulnerability Assessment
CGDD	Commission Générale pour le Developpement Durable
CORDEX	Coordinated Regional Climate Downscaling Experiment
C1	Component 1
C2	Component 2
C3	Component 3
CCVRA	Climate Change Vulnerability and Risk Assessments
CWP	Center for Watershed Protection
DEM	Digital Elevation Model
DRR	Disaster Risk Reduction
DTM	Digital Terrain Model
D1	Deliverable 1
EIA	Environmental Impact Assessment
ER2C	Enhancing Resilience to Climate Change
ESA	Environmentally Sensitive Areas
GIS	Geographic Information System
ICZM	Integrated Coastal Zone Management
IDF	Intensity Duration Frequency
IOC	Indian Ocean Commission
IUCN	International Union for Conservation of Nature
IWRM	Integrated Water Resources Management
LDMP	Land Drainage Master Plan
LIDAR	Light Detection And Ranging
MAIFS	Ministry of Agro Industry & Food Security
MBEMRFS	Ministry of Blue Economy, Marine Resources, Fisheries and Shipping
MEPU	Ministry of Energy and Public Utilities
MESWMCC	Ministry of Environment, Solid Waste Management and Climate Change
MoH & LUP	Ministry of Housing and Land Use Planning
MMS	Mauritius Meteorological Services
MOI	Mauritius Oceanographic Institute
NbS	Nature Based Solution
NDC	Nationally Determined Contribution
NDRRMC	National Disaster Risk Reduction and Management Centre
NDU	National Development Unit
NHDC	National Housing Development Company
ROM	Republic of Mauritius
PDS	Property Development Scheme
SCS - (NRCS)	Soil Conservation Service renamed Natural Resources Conservation Service)
SLR	Sea Level Rise
TA	Technical Assistance
TSS	Total Suspended Solids
VAT	Value Added Tax
VRA	Vulnerability Risk Assessment
WMA	Wastewater Management Authority
WRCP	World Climate Research Programme
WRU	Water Resources Unit
RDA	Road Development Authority
SuDS	Sustainable Drainage Systems
ToR	Terms of Reference
USDA	United States Department of Agriculture
VRS	Voluntary Retirement Scheme
WIO	Western Indian Ocean (WIO):
1D/2D	1 Dimensional / 2 Dimensional

2 EXISTING SITUATION DESCRIPTION INCLUDING HAZARD MAPS FOR DIFFERENT RETURN PERIODS, ASSET EXPOSURE, PRIMARY AND SECONDARY DRAINAGE INFRASTRUCTURE AND NATURAL AREA WITH DRAINAGE FUNCTIONS

2.1 Hazard Maps

The flood zone maps for different return periods (10, 25, 50 and 100 years) are provided in **Annex 2 (Priority sites) and 3 (Complementary sites)** for all the sectors that have been modelled, i.e., the following sectors:

- **Priority sites :**
  - Port Louis:
    - Sector 73- Rivière Lataniers and Canal Anglais;
    - Sector 75 - Rivière du Pouce, La Poudrière Stream, Ruisseau des Créoles and Cut-off drain; and
    - Sector 77 - Canal Dayot and drains within its urbanised zone.
  - Sector 65 - Flic-en-Flac;
  - Sector 32 - Bel Ombre;
  - Sector 47 - Nouvelle France;
  - Sector 5&6 - Grand Baie / Pereybere.

- **Others sites (complementary sites) :**
  - Sector 1 - Mapou Piton Cottage;
  - Sectors 25 and 102 - Clemencia Bel Air Olivia Pont Lardier;
  - Sector 43 - Flacq;
  - Sector 59 - Coteau Raffin;
  - Sector 72 - Terre Rouge;
  - Sector 74 - Port Louis La Paix;
  - Sector 78 - Pointe aux Sables;
  - Sector 82 - Henrietta Malakoff;
  - Sector 85 - Vacoas Quatre Bornes;
  - Sector 86 - Curepipe aval.

The map below shows the location of all the catchment areas and surfaces modelled in the LDMP.

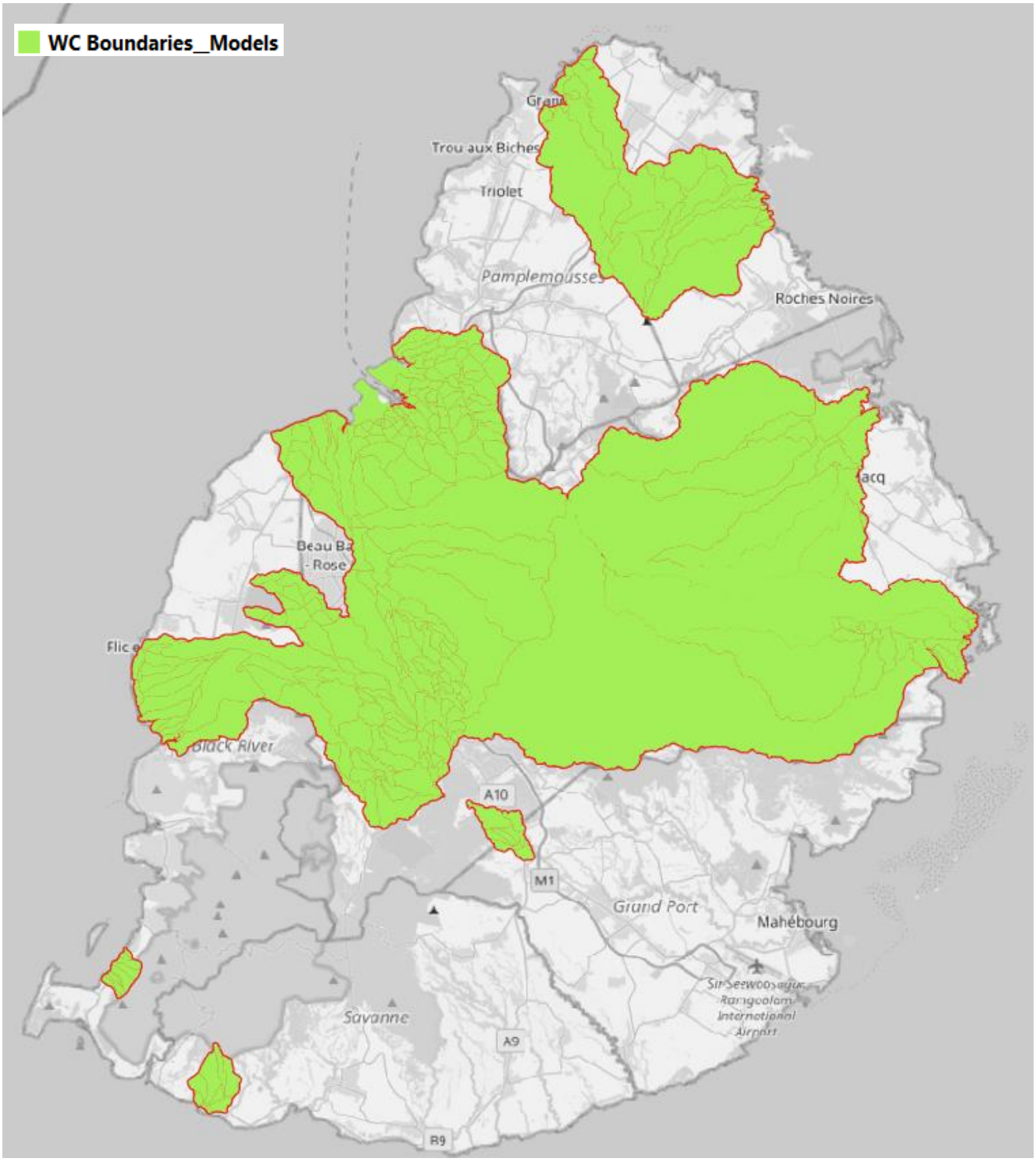


Figure 2 : Land Drainage Master Plan modelled areas priority and complementary sites - Catchment areas modelled (5+11 areas)

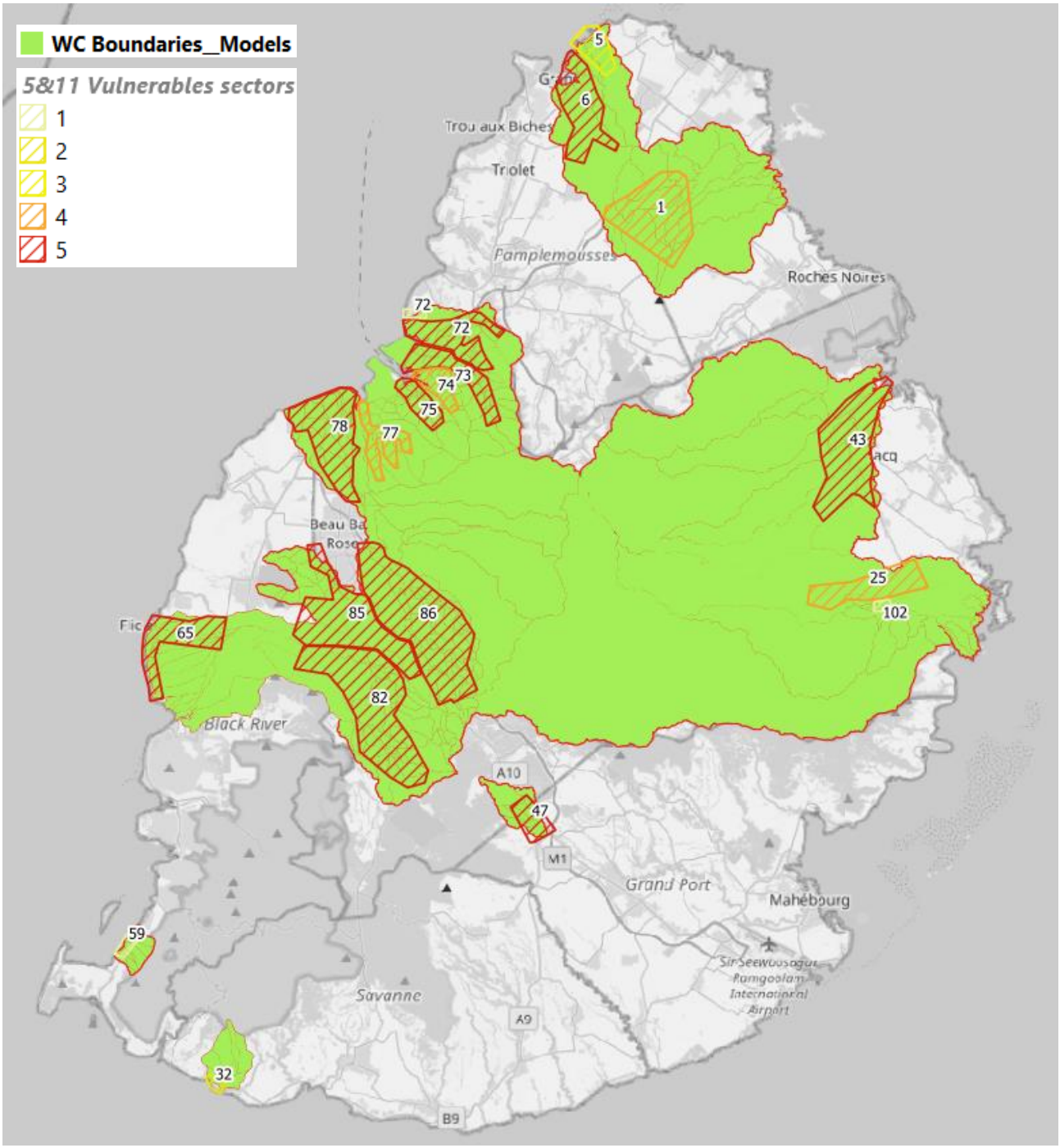


Figure 3 : Land Drainage Master Plan modelled areas priority and complementary sites - Catchment areas modelled and boundaries of vulnerable sectors (5+11 areas)

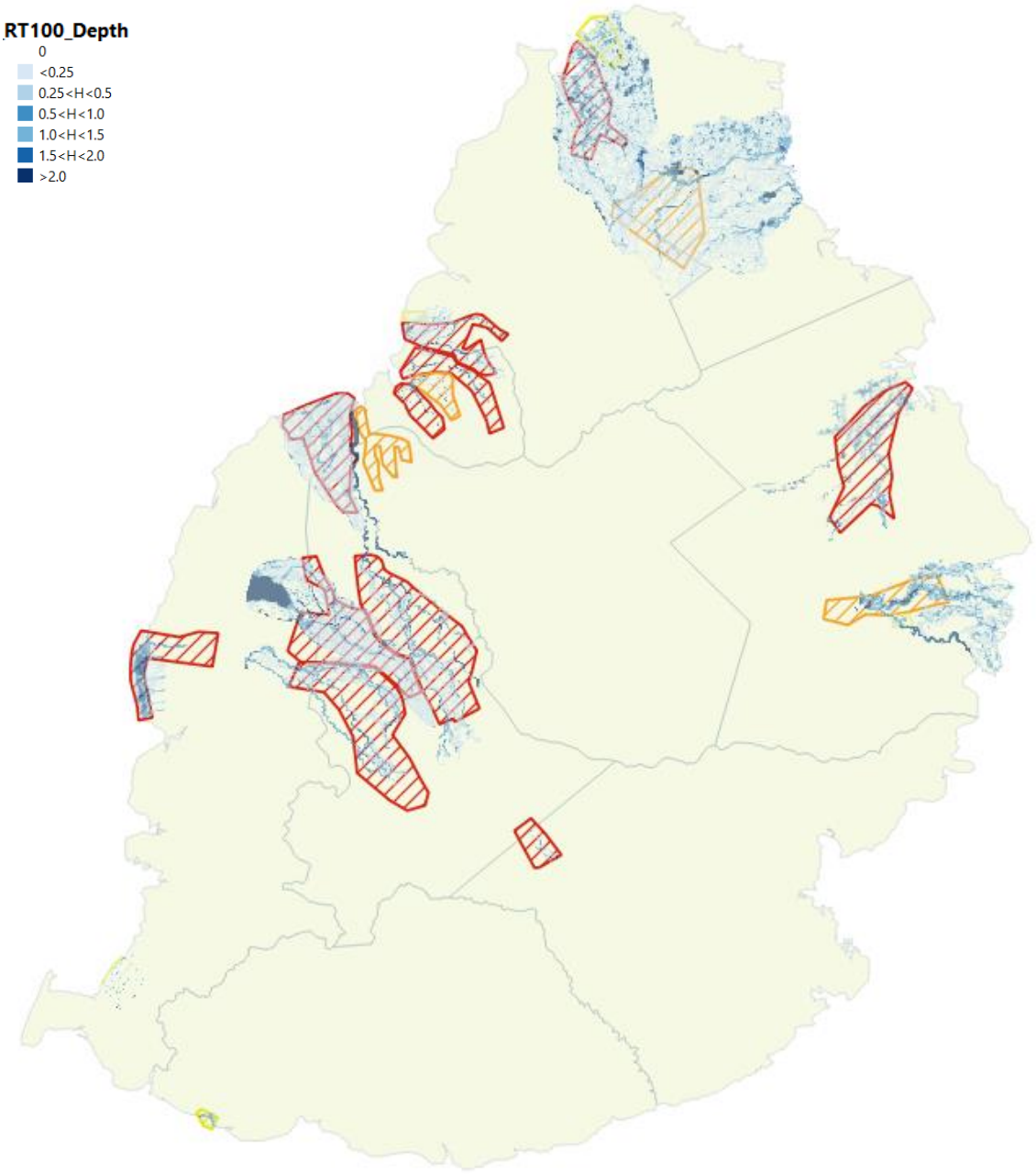


Figure 4 : Land Drainage Master Plan modelled areas priority and complementary sites - T100y hazard Modelling (5+11 areas)

This is completed by an understanding of the hazard, at the scale of the whole island, by:

- Information on past floods (known to date, i.e., April 2022):
  - **flood marks** (224)
  - **flood prone area** (332[2])

- Potential flood zone information by **hydrogeomorphological analysis** (EXZECO)
  The **hydrogeomorphological** method is essentially used for the diagnosis of flood-prone areas. It is now one of the tools recommended by different ministries all over the world (nearest example in Reunion Island) responsible for flood prevention. This method is a favourite tool for mapping flood-prone areas, as it perfectly matches the requirements of this type of study. It provides information on the natural unfurling of floods over large linear areas.

  The following figure synthesises these hydrogeomorphological units.

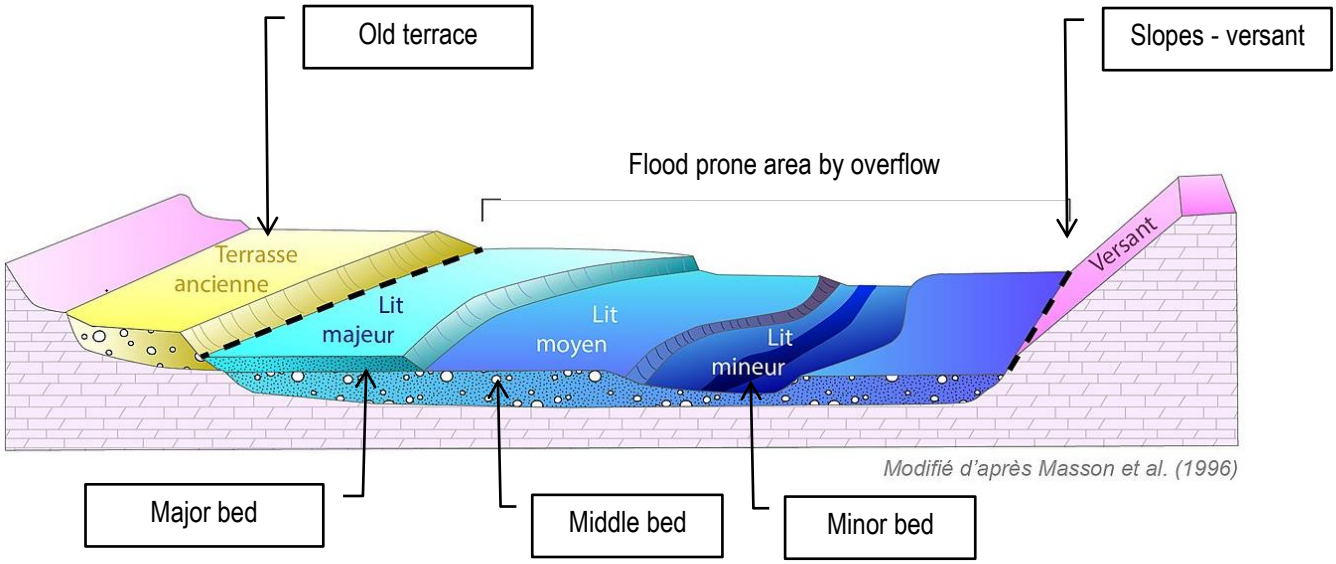


Figure 5: Hydrogeomorphological units (source Masson and al. 1996)

For a global analysis at the scale of the whole island, the characterisation of potentially flood areas was carried out by the ExZEco method.

This method is based on topographic analysis which highlights flow accumulation areas using a random effect on the DEM[3]. This method is equivalent to filling thalwegs with an enforced height of water.

The hydrogeomorphological coverage, by definition, representing the complete topographical framework of the area, gives an envelope which is globally superior in coverage than those resulting from urban runoff by modelling, taking into account the open drains and the flow in networks.

[2] Included 27 additional FPAs provided by LDA (2 May 2022)
[3] reference: https://www.asprs.org/wp-content/uploads/pers/1988journal/nov/1988_nov_1593-1600.pdf - K. Jenson and]. O. Domingue - 1988

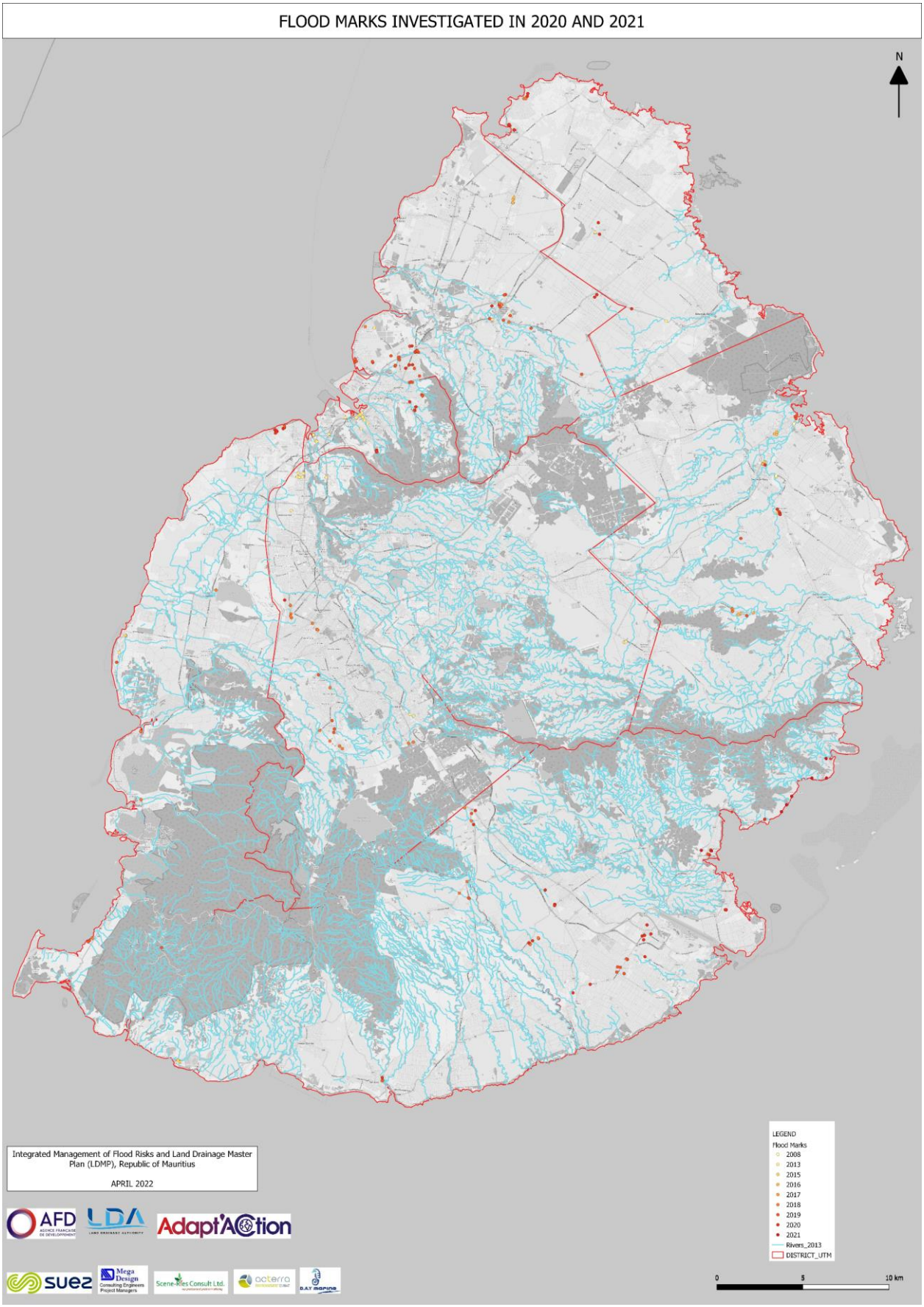


Figure 6 : Flood marks investigated (224) in 2020 and 2021 – classification by date of events

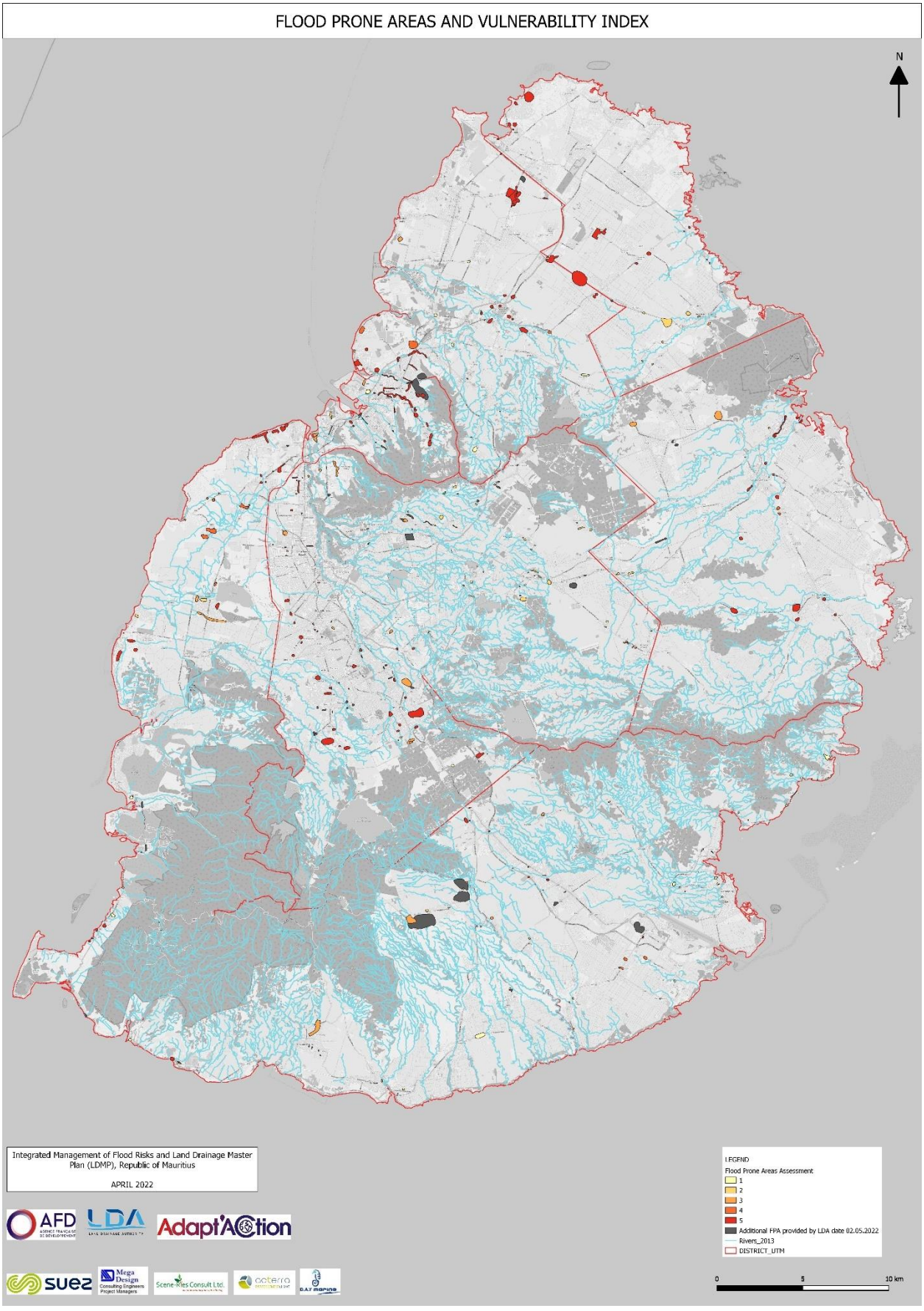


Figure 7 : Flood Prone Area and vulnerability (332) – status April 2022

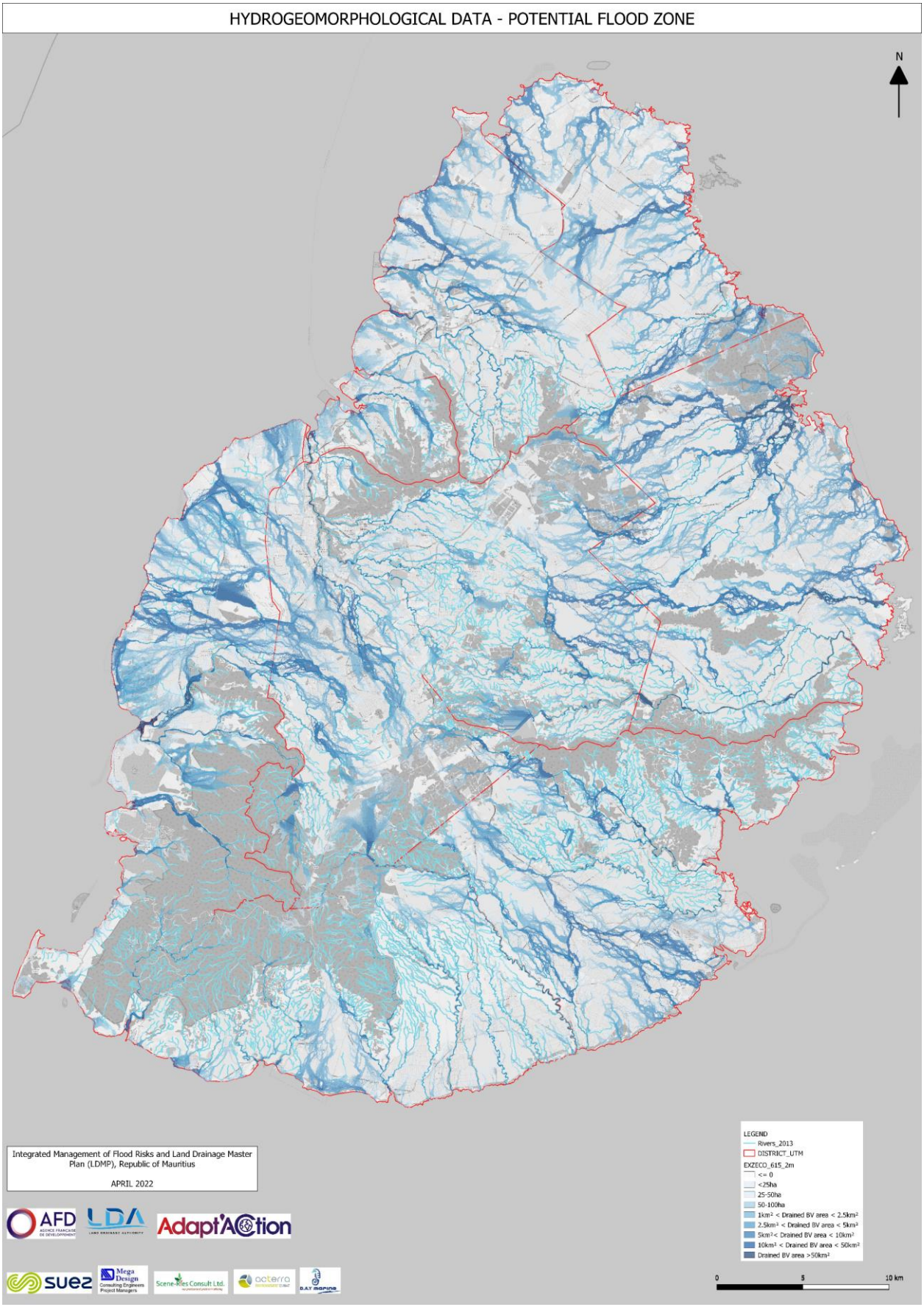


Figure 8 : Hydrogeomorphological data – Potential flood zone

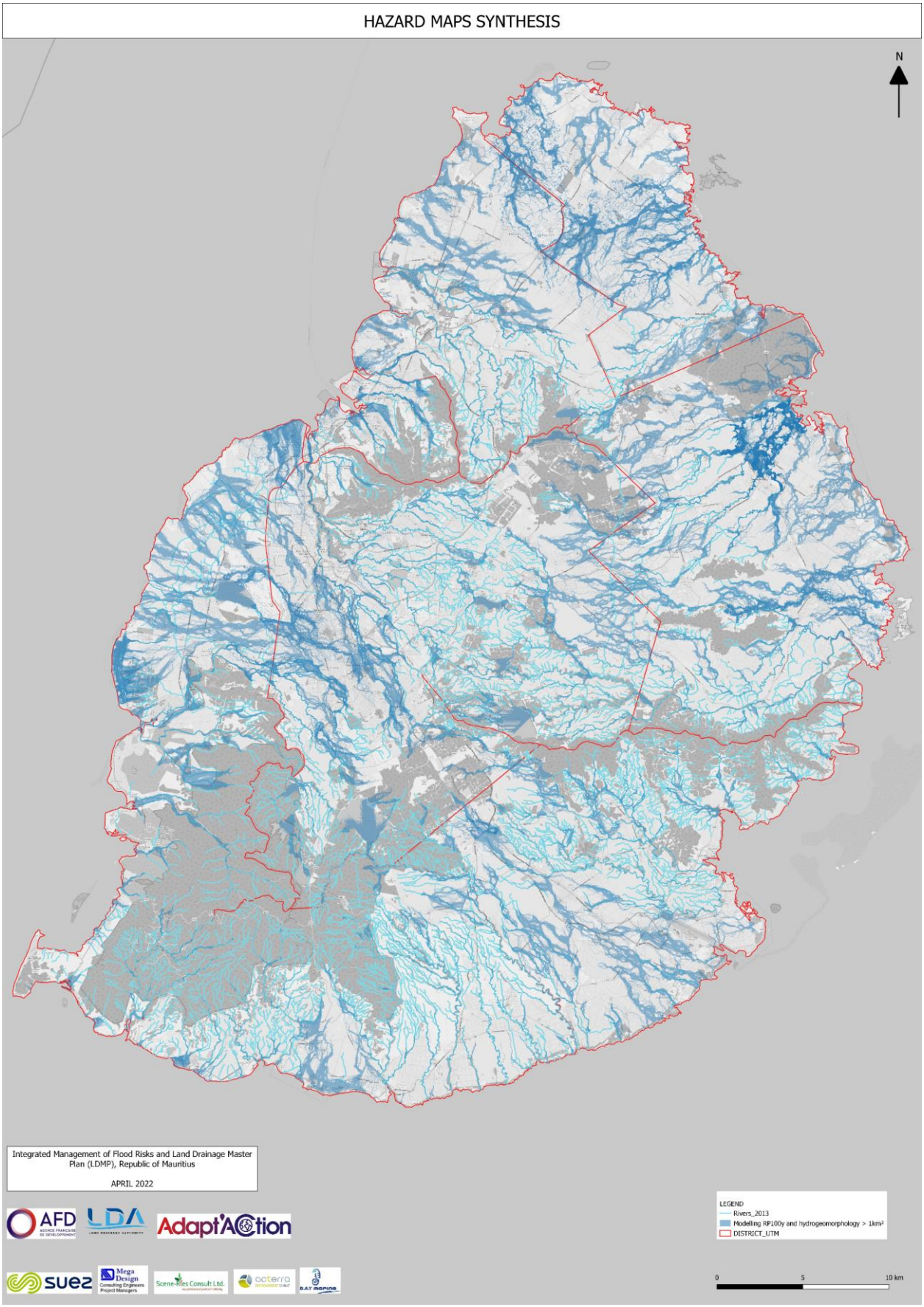


Figure 9 : Hazard map synthesis – Modelling RT 100 y and hydrogeomorphological data

2.2 Asset exposure

The synthesis of assets exposed to flood risks is shown in the following maps:

It involves identifying, at the scale of the whole territory, the flooded and potentially flooded areas of the following main assets:

- Human **assets**: urban areas and buildings
- Economic assets:
  - Activities
  - Road infrastructure
- Future development - areas with no outlet in present situation

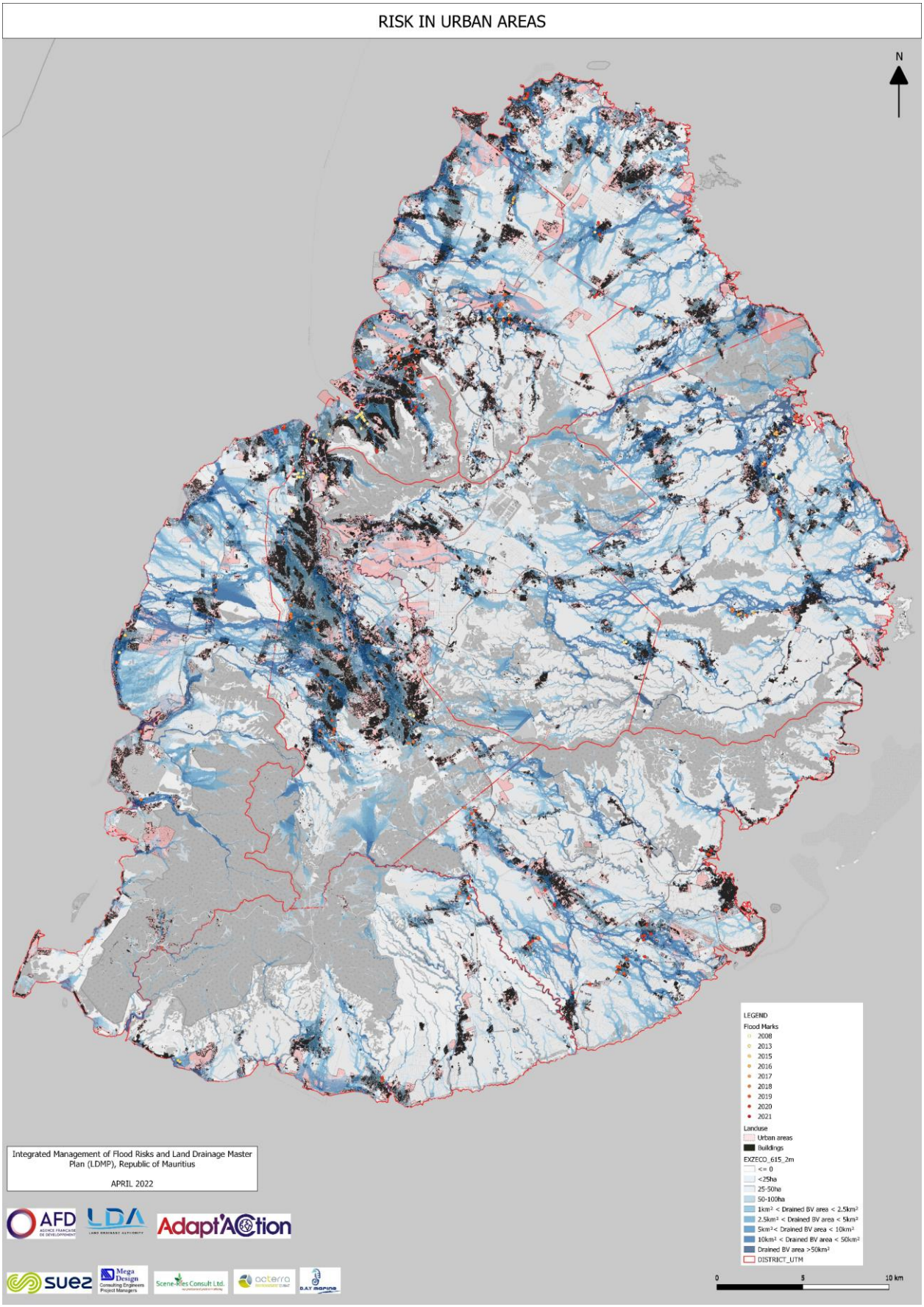


Figure 10: Built up areas, flood marks and potentially flood areas

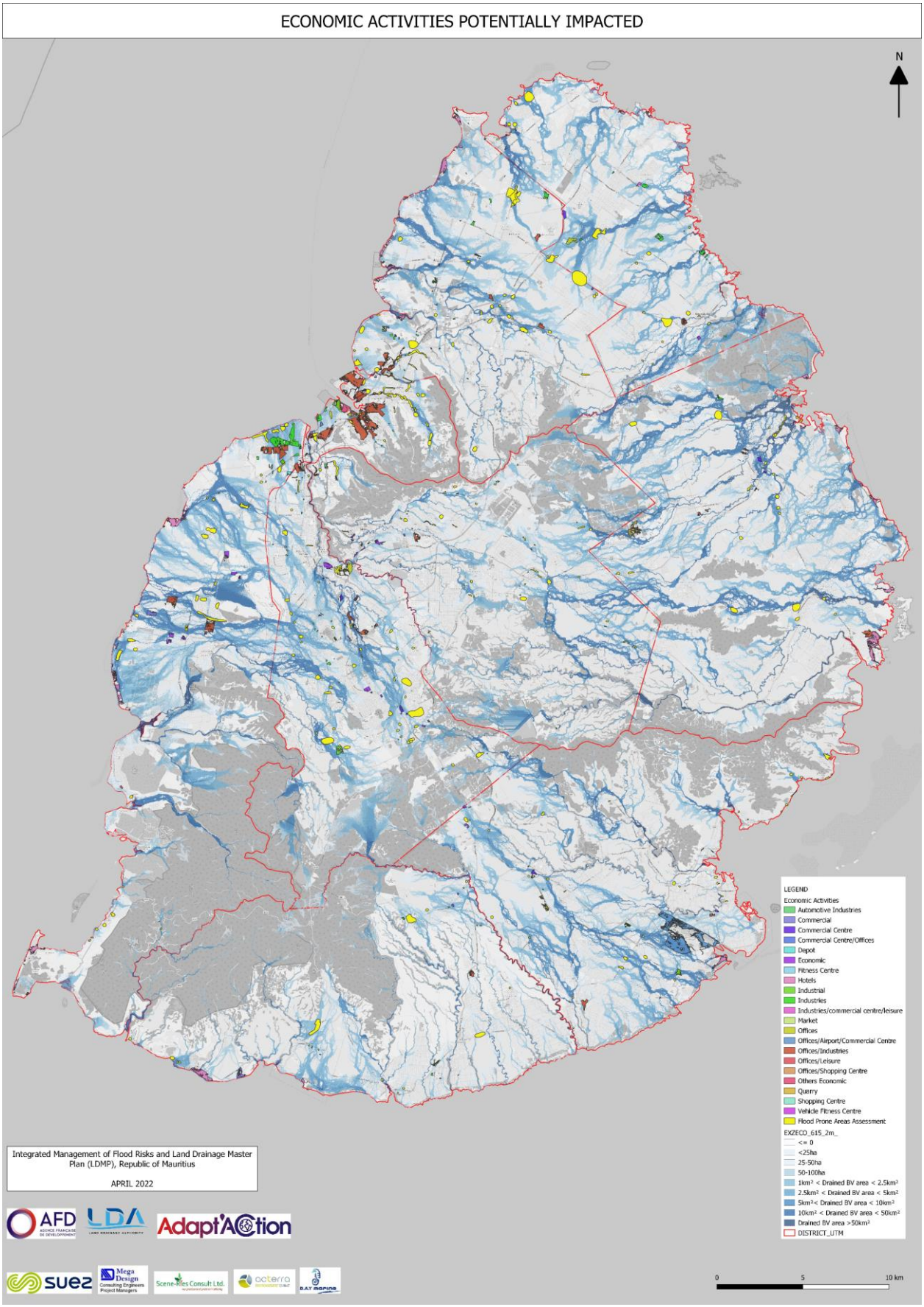


Figure 11: Economic Activities potentially impacted

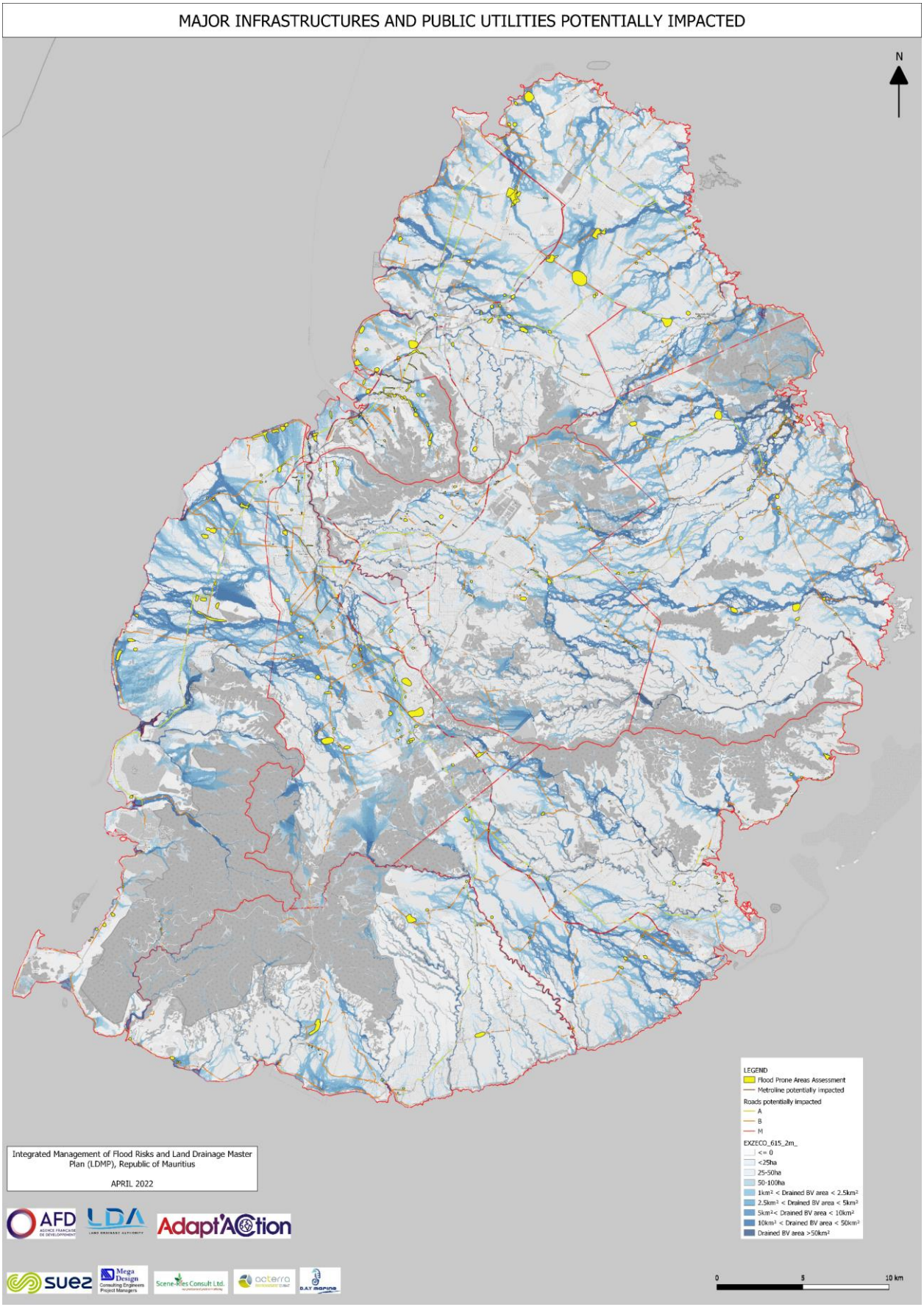


Figure 12: Major infrastructures potentially impacted

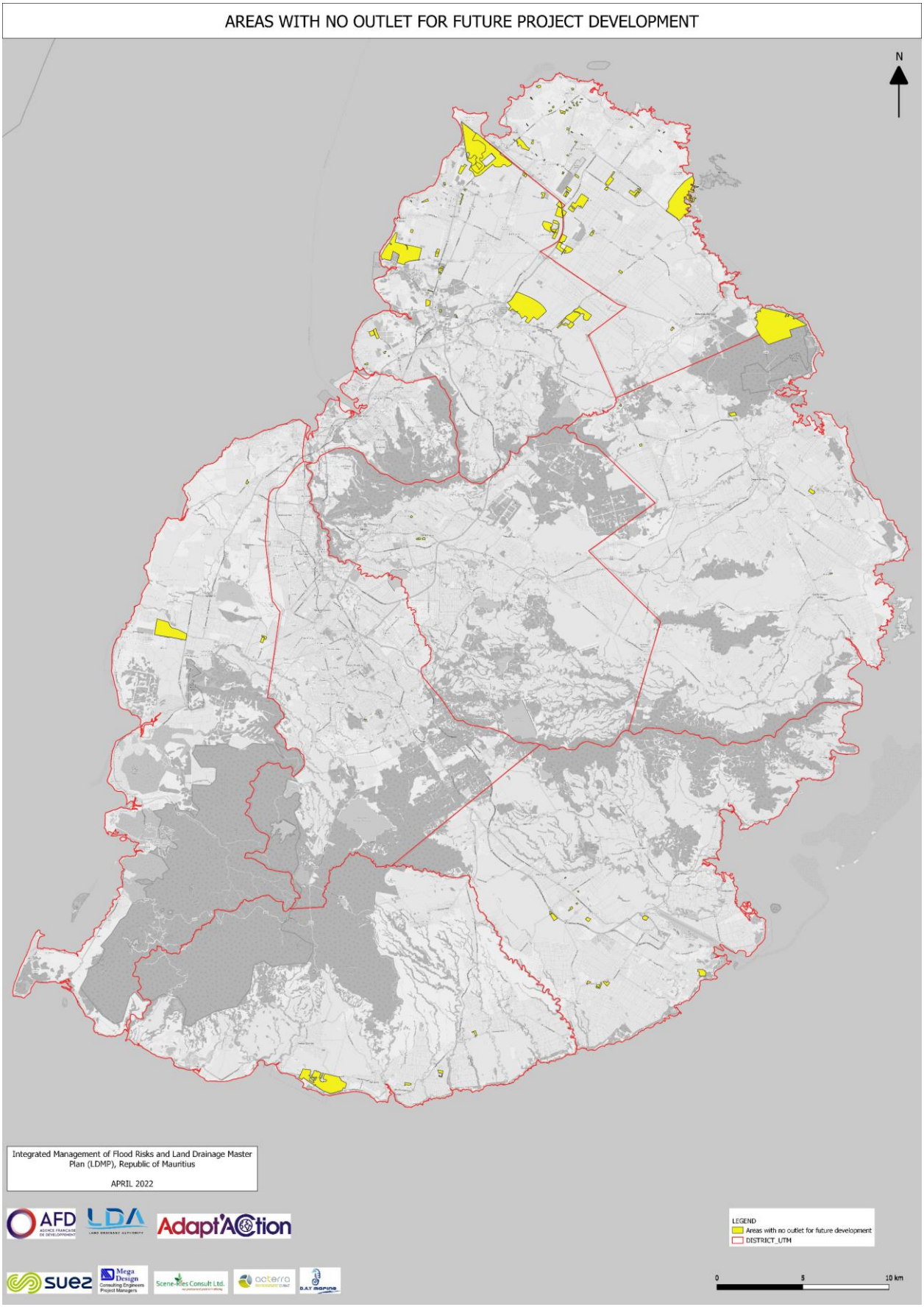
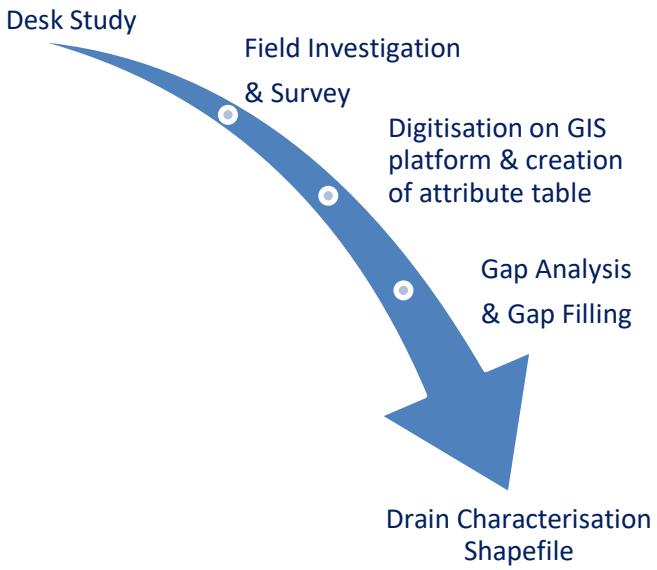


Figure 13: Areas with no Outlets earmarked for future development

2.3 Characterisation of main Primary and Secondary Drainage infrastructure

This activity comprises the identification and characterization of main primary and secondary drains as defined by LDA. It was undertaken in the sequence shown below:



2.3.1 Desk study

Desk study comprised the collection of all available data pertaining to drain networks including data extracted from NDU's design and as constructed reports.

2.3.2 Field Survey

Field survey was undertaken on a zone wise basis by teams of two to three persons alternating between field and desk work monitored by one supervisory personnel. As a trial run in the region of Quatre Bornes, all drains (Primary, Secondary and Tertiary) were inventoried, irrespective of their classification and including irrigation canals (La Ferme canal and Trianon Grosses Roches) which form an integral part of the land drainage system.

Following discussions and an ensuing decision by LDA, only Primary and Secondary drains were inventoried.

2.3.3 Drain Mapping on GIS

The surveyed data were digitized in batches on a GIS platform and entered into an attribute table listing different fields described below:

Field	Description
Authority	Municipal Council, District Council, RDA, etc.
Name	Name/ location of the drain
DrainType1	Roadside drain, urban drain, irrigation canal or river
DrainType2	Material and type of drain (e.g. covered RC U-drain, open stone masonry Drain)
Class	Primary, Secondary or Tertiary Drain
EntryX_Coo	The WGS 84 UTM Zone 40S X coordinates at the upstream section of a particular drain
ExitX_Coo	The WGS 84 UTM Zone 40S X coordinates at the downstream section of a particular drain
Botwidth_mm	The bottom width of a particular drain section
Topwidth_mm	The top width of a particular drain section
Depthup_mm	The upstream depth of a particular drain section
Depthdw_mm	The downstream depth of a particular section of the drain
Diameter_mm	Diameter of drain, where applicable (e.g. conduits)
EntryY_Coo	The WGS 84 UTM Zone 40S Y coordinates at the upstream section of a particular drain
ExitY_Coo	The WGS 84 UTM Zone 40S Y coordinates at the downstream section of a particular drain
Length_m	The length of a particular drain section
Remarks	Remarks on the drain section
Source	Mega Design or Day Marine

Separate polylines were drawn on the GIS environment to demarcate different drain classes, types, widths and changes in direction. To visualise the flow direction from the shape file, the drain line type should be selected as 'Arrow Right Middle'.

2.3.4 Extent of Drain Characterised

The extent of drain surveyed for the different regions across the island is as follows:

Region		Length of Drains Characterised (km)
1	Baie du Cap	0.16
2	Baie du Tombeau	0.99
3	Bel Air Riviere Seche	4.43
4	Bel Ombre	5.89
5	Bramsthan	1.74
6	Cascavelle	2.24
7	Centre de Flacq	0.52
8	Clemencia	12.56
9	Cottage	1.82
10	Esperence Trebuchet	0.23
11	Flic en Flac	4.01
12	Fond du Sac	2.58
13	Grand Bay	1.72
14	Grand Gaube	0.17
15	La Gaulette	1.32
16	Le Hochet	2.99
17	Mapou	2.36
18	Moka	8.51
19	Municipal Council of Beau Bassin Rose Hill	63.63
20	Municipal Council of Port Louis	146.89
21	Municipal Council of Quatre Bornes	53.40
22	Municipal Council of Vacoas Phoenix	150.12
23	Municipal Council of Curepipe	123.28
24	Nouvelle France	4.54
25	Piton	2.16
26	Poste de Flacq	0.61
27	Petite Riviere	0.11
28	Queen Victoria	1.34
29	Richelieu	2.02
30	Seizieme Mille	0.39
	Total Length of Drains Characterised	**602.34**

2.4 Natural Area with functional drainage attributes

Natural areas with drainage attributes include:

- **Lowland areas**

- **Areas with natural spaces providing in land drainage and the water cycle services.**
  These areas correspond to the ESA giving services in land drainage and water cycle:

Type of natural areas	Main water cycle Functions
Coastal marshlands	Retention, filtration, infiltration
Upland marshlands	Retention, filtration, infiltration
Lakes and reservoirs	Retention, filtration
Rivers and streams	Drainage, infiltration
Mangroves	Filtration - coastal erosion mitigation
Intertidal mudflats	Filtration - coastal erosion mitigation
Sand beach and dunes	Filtration - coastal erosion mitigation

- **Ecosystems involved in drainage system (storage, filtration)**
  These areas correspond to ESAs with a specific role in water storage and filtration.

Type of natural areas	Main water cycle Functions
Coastal marshlands	Retention, filtration, infiltration
Upland marshlands	Retention, filtration, infiltration
Lakes and reservoirs	Retention, filtration

The following maps summarise these attributes:

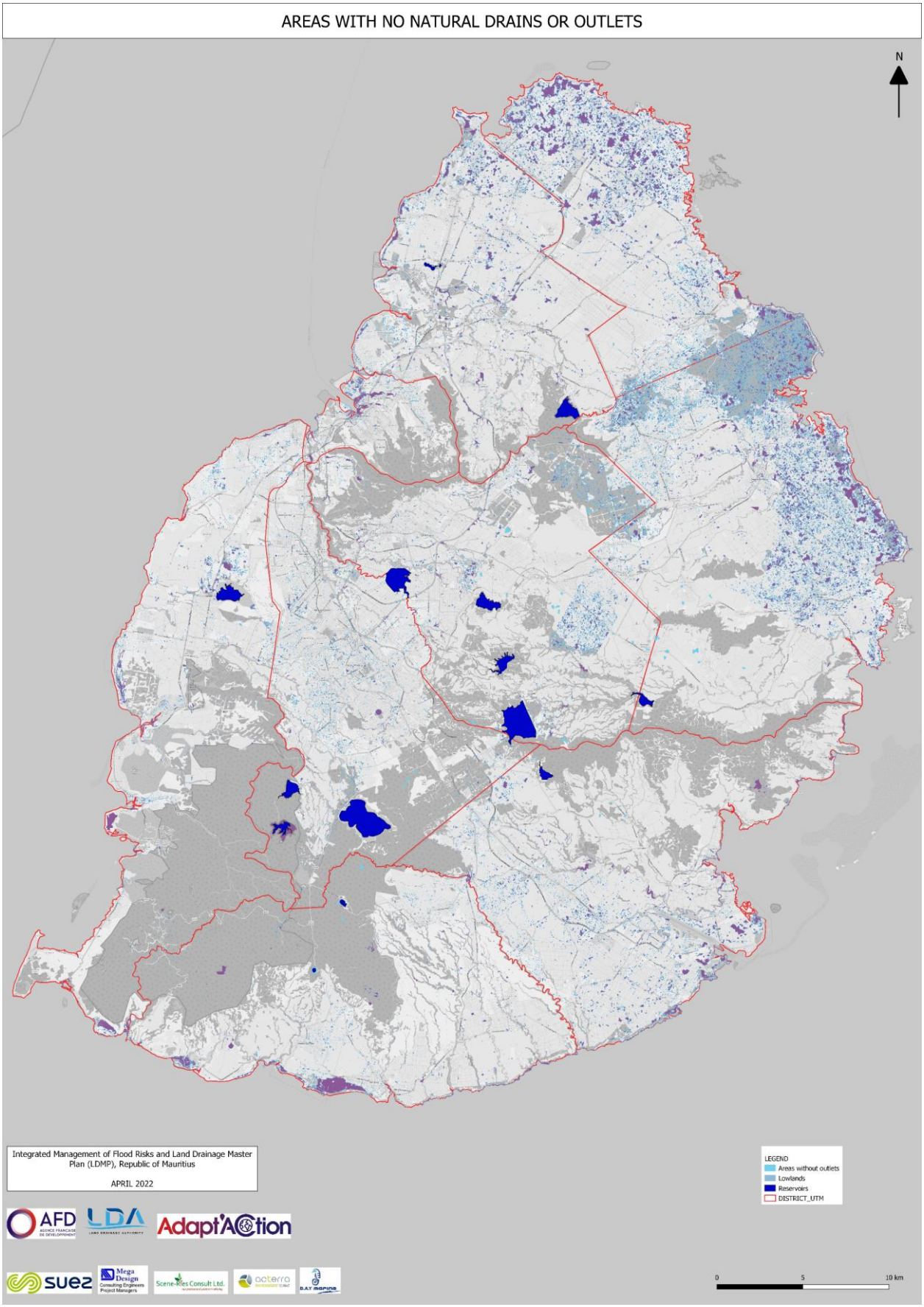


Figure 14: Areas with no outlets and lowlands

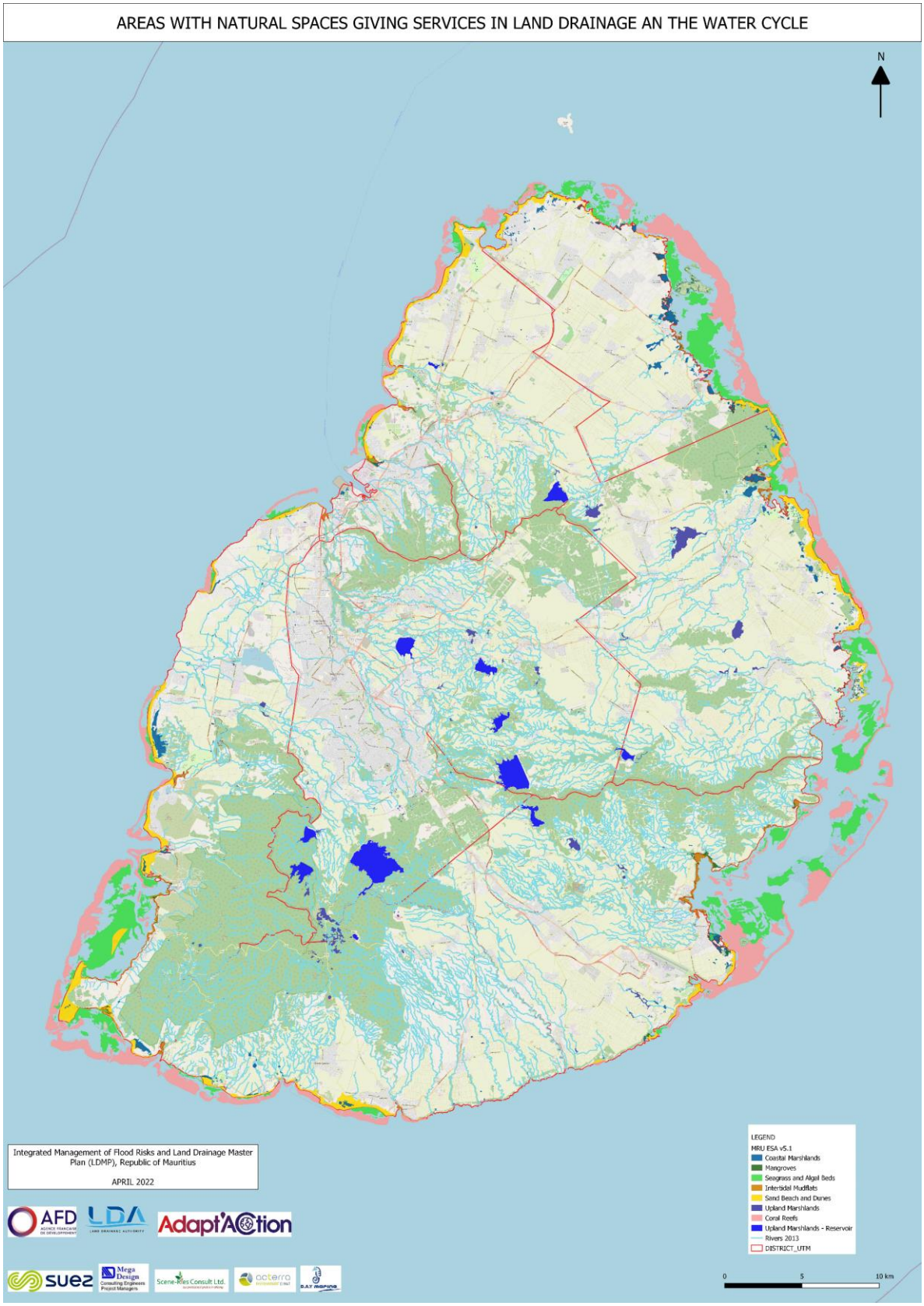


Figure 15: Areas with natural spaces providing land drainage and the water cycle services

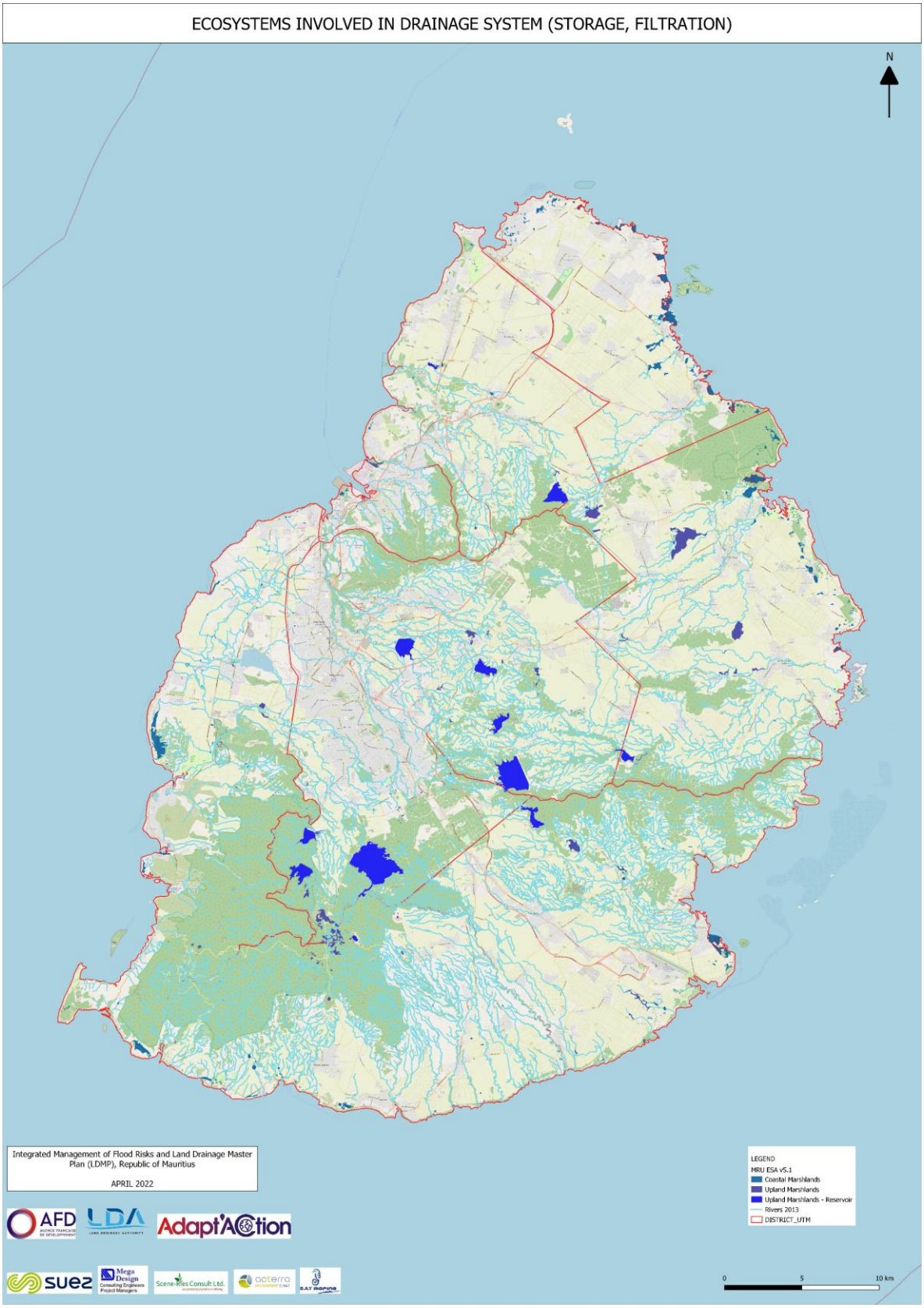


Figure 16: Ecosystems involved in drainage system (storage, filtration)

3 ACTION PLANS TO IMPROVE DRAINAGE INFRASTRUCTURE IMPLEMENTATION FOR SHORT TERM AND MIDDLE TERM AND RECOVERY MEASURE

3.1 Background: guide to the gradual implementation of better risk management: implementation of non-structural, recovery and structural measures

3.1.1 Introduction

The objectives of the Land Drainage Master Plan are to promote the emergence of work programmes dealing in a balanced and coherent way with all the components of the flood prevention policy, i.e. non-structural measures (planning documents linked to building permits) and structural measures (actual works)

The aim is to promote integrated flood risk management, at the scale of the territory with regard to flood hazards and the assets put in place to respond to these hazards.

To this aim, the LDMP should mobilise a set of flood risk management activities articulated around **non-structural measures, recovery measures** and **structural measures:**

- Improving knowledge and risk perception (non-structural measures);
- Monitoring and maintenance (structural measures);
- Crisis management (non-structural measures);
- Consideration of flood risk in urban planning (non-structural measures);
- Reducing the vulnerability of people and properties by relocation (recovery measure);
- Management of flows: retention basin, flood control structure, (structural measures); and
- Management of hydraulic protection works: creation of new drains including cut-off drains, flood walls, dykes, etc. (structural measures).

3.1.2 Non-structural and mitigation measures

3.1.2.1 Improving knowledge and awareness of risk

Non-structural measures

This improvement measure concerns two types of actions to assist local authorities in raising awareness among the general public and to prepare measures to reduce the vulnerability of people and properties.

On the one hand, improving risk awareness with:

- the development of awareness-raising actions accompanied by incentive messages to really involve all categories of stakeholders (elected representatives, school children, economic actors, etc.) and prepare them to deal with a major risk;
- the production and updating of municipal information data sheets on major risks
- an information meeting held every two years at municipalities and district councils on natural risks

- the installation of flood indicators (marker) based on identified flood markers (especially in sectors mostly frequented by the public). A communication campaign for the general public can be carried out to supplement and enhance the value and importance of the flood indicator marker installations.

On the other hand, improvement on the knowledge of flood risks will be necessary when gaps concerning the hazards, or the assets are identified. The flood hazard mapping studies carried out within the framework of the LDMP by modelling and hydrogeomorphological areas could be completed for the rest of the country with regard to the modelling of the reference event (T100 years.

Within the framework of modelling, the choice of the type of modelling to be implemented is important with respect to the topography of certain parts of the country. In this respect, the following map indicates the catchment areas for which:

- **a coupled 1D/2D modelling is generally**[4] sufficient (by injection of peak flows at calculation nodes determined upstream of the point of issue),

- **a distributed modelling in full 2D** (distributed model - the rain falls directly on the topographic meshes of the 2D domain of the whole catchment) (WC: AB, CD, DE, EF, FG, GH, H, HI, I, IJ, JK, K, KL, L, LM, M, MN, NP, PQ, QR, RS, TU, U, UV, V, VW, YZ, ZA)

[4] Locally, especially in areas with highly diffused runoff, it will be necessary to complete these models with a distributed full 2D model

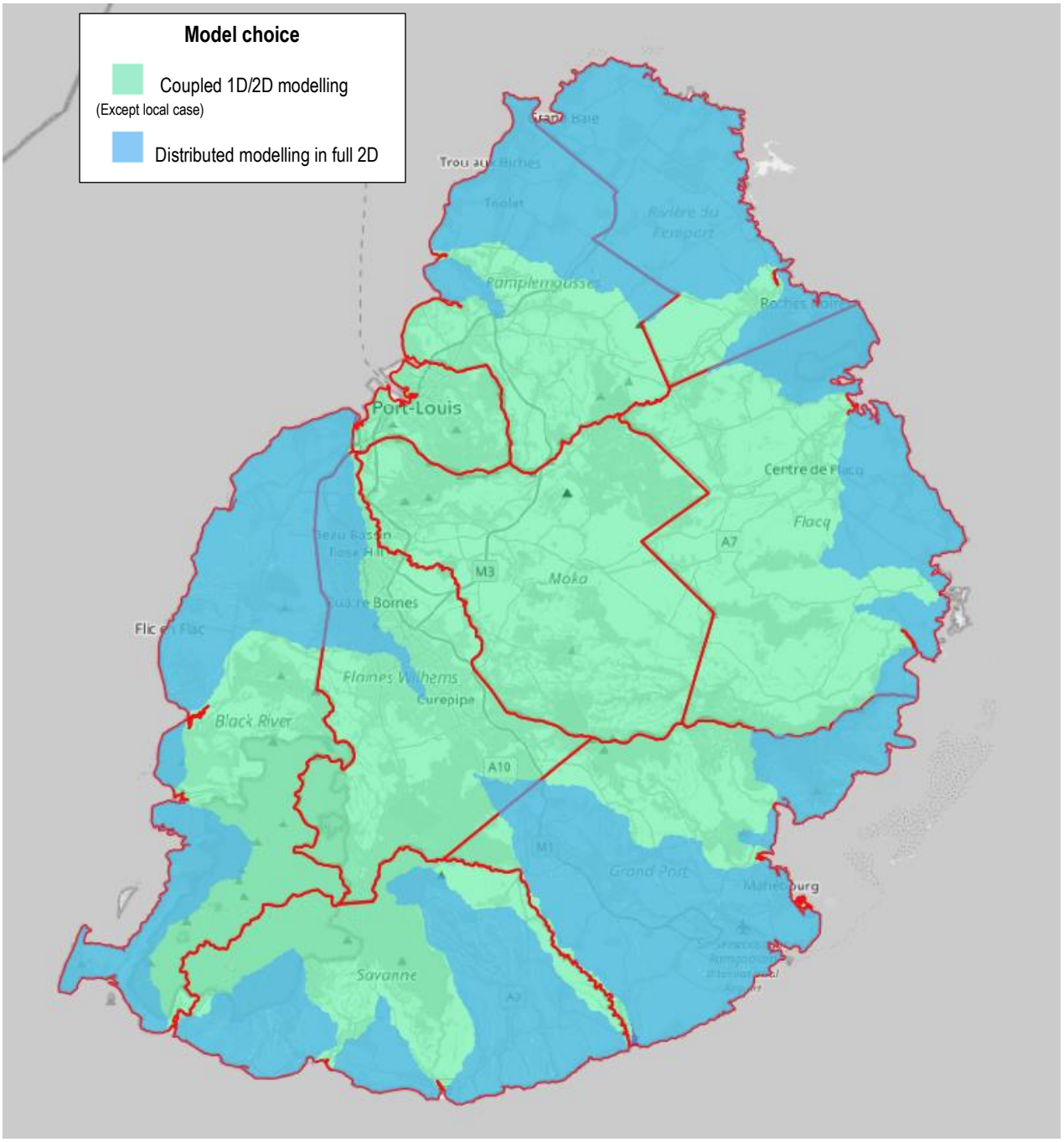


Figure 17: Modeling 1D/2D and full 2D recommended to improve knowledge flood risk

3.1.2.2 Crisis management

Non-structural measures

With regard to crisis management, reference is made to the work on the Enhancing Resilience to Climate Change (ER2C) in the Republic of Mauritius study[5] :

"The most relevant way is to mobilise local resources for local responses, and as the issues at stake go beyond the local level, mobilise district and then national and then international scales. People on the spot will be the best to know the situation, to be involved in the implementation for better resilience for them, their family, their community, their company, their villages. NDRRMC already has a local network, including a representative for each District Council and a thorough knowledge of local conditions. The formulation of local DRR plans by local authorities with support from NDRRMC would strengthen and complement the national framework, whilst ensuring greater ownership and understanding issues at stake/ assets at risk at the local level."

These measures should be extended at the level of the inter-municipality or a coordination of local organisations and should be encouraged in urban areas to optimise the organisation of the emergency services and to mutualise the means.

Moreover, it is essential that the authorities responsible for risk management have a thorough knowledge of the flood hazards likely to be encountered in the country (refer to the hazard maps presented in the LDMP).

Lastly, municipalities are strongly encouraged to schedule crisis management exercises based on this knowledge of the flood hazards. The development and continuous improvement of various crisis management plans such as business continuity plans for companies, special safety plans for educational establishments, family safety plans and special requirements for tourist areas are also recommended.

3.1.2.3 Integration of flood risk into urban planning and the application of rainwater management zoning (compensation for imperviousness).

3.1.2.3.1 Integration of flood risk into urban planning

Non-structural measures - Recovery measures

The integration of natural risk issues in land use and urban planning policies has been given priority in the LDMP approach. This integration is part of sharing competences between the different stakeholders (Ministry of Environment, LDA, NDRRMC, MoH & LUP...) and is based on several types of actions:

- The State must be responsible for establishing No Go Zones and No Expansion Zones, the implementation of which is a key objective of its policy in the sectors under consideration.
- National and local authorities must consider flood risks in planning documents and annex the No Go Zone and No Expansion Zone to planning maps. An analysis proportionates to the assets, of how flood risk is addressed in these planning documents is necessary.

  Approaches to limit the effects of soil imperviousness are applied (see following chapter).

With regard to planning, reference is made to the work carried out by the Enhancing Resilience to Climate Change (ER2C) study in the Republic of Mauritius[6]:

[5] Source ER2C: C1D2c

*"Producing risk mapping leads to **planning the future of the development on the land while avoiding building on risk-prone zones** and implementing adaption **measures to prevent/protect/adapt** existing buildings located in identified risky zones. This part refers to the MHL through the OPS at national scale and with local authorities at local scale. Risk mapping must be part of the OPS (annexed) and local planning (annexed) in order to inform new project operator on the type and level on risk on the land. Depending on the level of risk, some areas may be forbidden to build on and some may be authorized with restriction or with technical specification to ensure protection for people and goods (in order not to increase vulnerability."*

Lastly, within the framework of this activity, it is recommended to carry out actions in collaboration with the MoH & LUP and the Ministry of the Environment in order to:

- Anticipate land use/management of land reserves (flood expansion zones, areas for the effective functioning of watercourses, etc.)
- Carry out assistance dialogue with the MoH & LUP for the integration of flood risks in urban planning documents

(Refer to D5.1 First Part LDMP for further details)

[6] Source ER2C : C1D2c

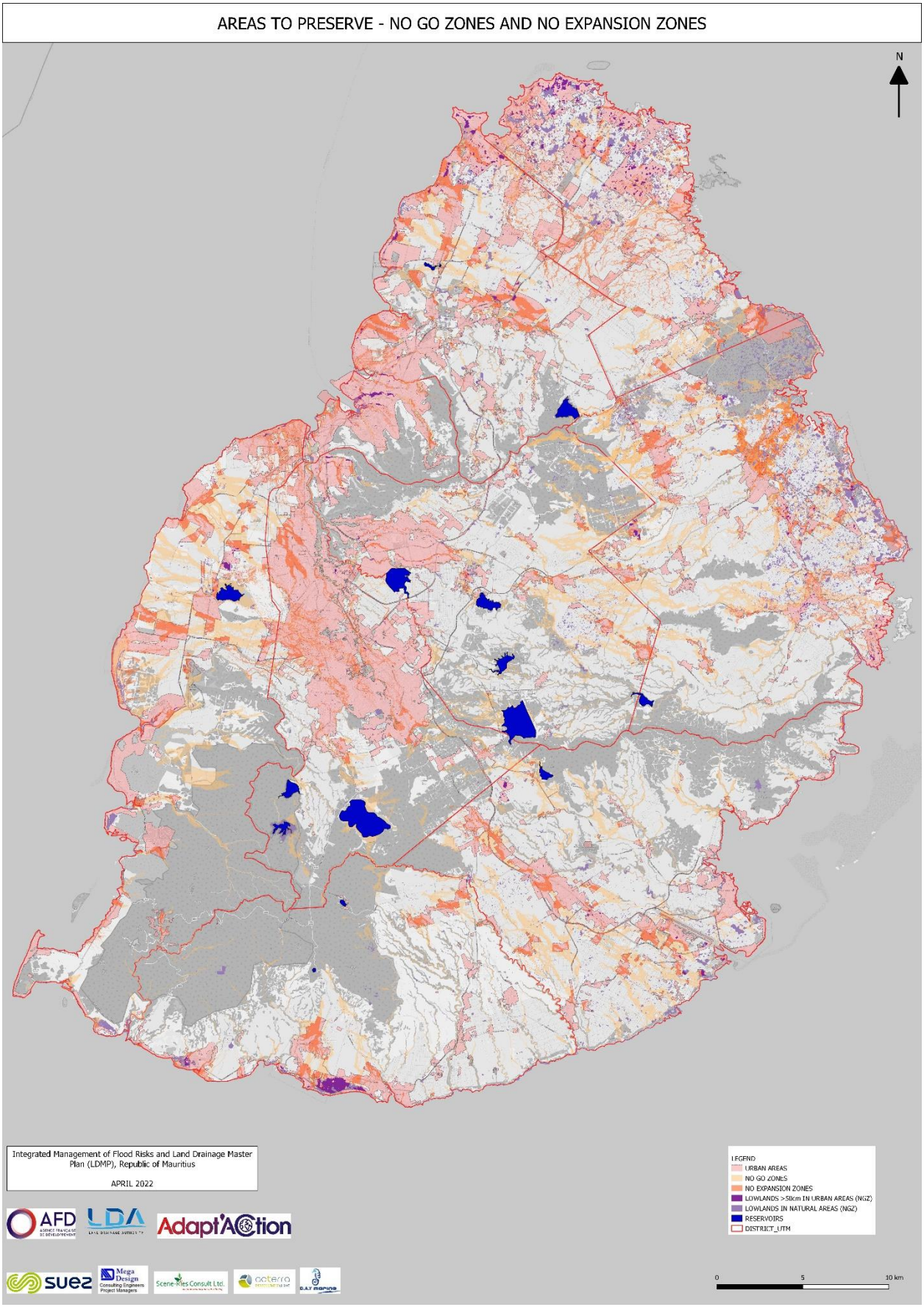


Figure 18: No Go Zone and No Expansion zone (refer to D5.1 First Part LDMP for further details)

3.1.2.3.2 Application of rainwater management zoning (compensation for imperviousness)

Recovery measures

(refer to D5.1 First Part LDMP for further details)

The development of new urbanised areas can only be carried out beyond the ambit of planning rules (No Go Zone, No Expansion Zone and buffer from watercourses, rivulets, feeders and natural paths - ref. previous point), in respect of hydraulic compensation for the newly impervious surfaces.

For this reason, strict control at the planning permission stage and compliance with the regulations must be effected to enforce the stormwater zoning rules presented in the first part of the Land drainage master plan.

3.1.2.3.2.1 Development project situation

Compensation volume per active surface area intercepted (including new created active surface areas):

V in m^3/ha of active surface area intercepted.

These unit volumes depend directly on:

- **Newly urbanized active surfaces:** the higher the recourse to controlling imperviousness (green areas, porous materials, etc) the lesser will be the useful retention volume.

  Note: The use of porous materials will allow developers to reduce the adverse impact from their project and also to limit the need (volume and therefore space) for retardation basins imposed by the stormwater zoning management.

- **Selection of the return period of rainfall.** Depending on the stakes of the catchment area, and the existing situation pertaining to the risk posed by runoff flow, the following conservative return periods will be retained for the compensation volume:
  - **Zone 1 – Z1:** catchment areas with low to moderate risk (Level 1). The compensation is equal to the volumes generated by a 10-years rainfall – retention of 69 to 113 mm depending on location (local Rainfall intensity).
  - **Zone 2 – Z2:** catchment areas with moderate risk (level 2). The compensation is equal to the volumes generated by a 25-years rainfall - retention of 84 to 144 mm depending on location (local Rainfall intensity).
  - **Zone 3 – Z3:** catchment areas with moderate to high risk (level 3). The compensation is equal to the volumes generated by a 50-years rainfall - retention of 96 to 173 mm depending on location (local Rainfall intensity).
  - **Zone 4 – Z4:** catchment areas with high risk to very high risk (levels 4 and 5). The compensation is equal to the volumes generated by a 100-years rainfall; - retention of 107 to 203 mm depending on location (local Rainfall intensity).

- **Location of the project** and the corresponding reference rainfall. Projects located upstream of urbanized areas, within catchments in the central plateau and receiving most rainfall, will sustain higher needs for compensatory actions.

The following table summarises **the rainfall – stormwater zoning**, making it possible to define the ratio of controlled discharge and compensation volume by zone and by spatial location (Region II, average for the whole island and region I without spatial correction).

These values define the minimum and maximum volumes and means of compensation to be put in place. They include the effects of climate change based on the Clavius-Clapeyron law and approach.

Table 1: Summary of data of zonal compensation

Rainfall zones		Minimum value: Rainfall Region RII	Average value for the territory (Rainfall region RI with spatial correction)	Maximum value : Rainfall Region RI without spatial correction
Zones	QI = Maximum unit controlled discharge rate (l/s/ha of intercepted catchment area)	V = Unit Compensation Volume (m^3/ ha of intercepted active surface area)		
Zone 1	65	830	1 110	1 360
Zone 2		1010	1 370	1 730
Zone 3		1 150	1 630	2 080
Zone 4		1 290	1 910	2 440
N.B :Basic Sizing	*Natural controlled discharge flow with a 10-year return period for a natural catchment*	*Zone 1: compensation is equal to the volumes generated by a 10-year rainfall* *Zone 2: compensation is equal to the volumes generated by a 25-year rainfall* *Zone 3: compensation is equal to the volumes generated by a 50-year rainfall* *Zone 4: compensation is equal to the volumes generated by a 100-year rainfall*		
		Taking into account climate change on the basis of a global warming of 2.6 °C (For scenario RCP8.5) over the period and application of Clavius-Clapeyron Law only i.e., + 18.2% on the accumulated precipitation - + 30 % average on unit volumes (ref 4.1)		

For these dimensions, the retention time varies from 2 to 8 hours depending on the return period of protection, the configuration of the works (discharge device) and the rate of soil imperviousness. This time remains compatible in the local context, subject to ensuring good maintenance of the infiltration structures.

3.1.2.3.2.2 Devices for single-family houses

A single-family house is defined as any development with a plot size of less than 1000 m².

The following table presents the type of system to be implemented, valid for the whole island.

Table 2: Compensation - single value for single-family houses

Application single value for single-family houses Unit value for whole island			
Zones	**QI = Maximum unit-controlled discharge rate (l/s/ha of intercepted catchment area)**	**V = Unit Compensation Volume (m³/ ha of intercepted active surface area)**	**Orifice diameter in mm**
For whole island	**130**	**280**	**80**
N.B :Basic Sizing		*Compensation is equal to the volumes generated by a 10-year rainfall*	*Calculation established for a hole under 1 metre of hydraulic head*
		Calculation Without climate change factor	

Example of application:

Table 3: Compensation - single-family houses – application example

Plot size in m²	**500**		**750**		**1 000**	
Floor area (m²) of the house and the concrete covered area	150	250	200	300	300	400
% of waterproofing	0.30	0.50	0.27	0.40	0.30	0.40
Retardation volume in m³	4.2	7.0	5.6	8.4	8.4	11.2

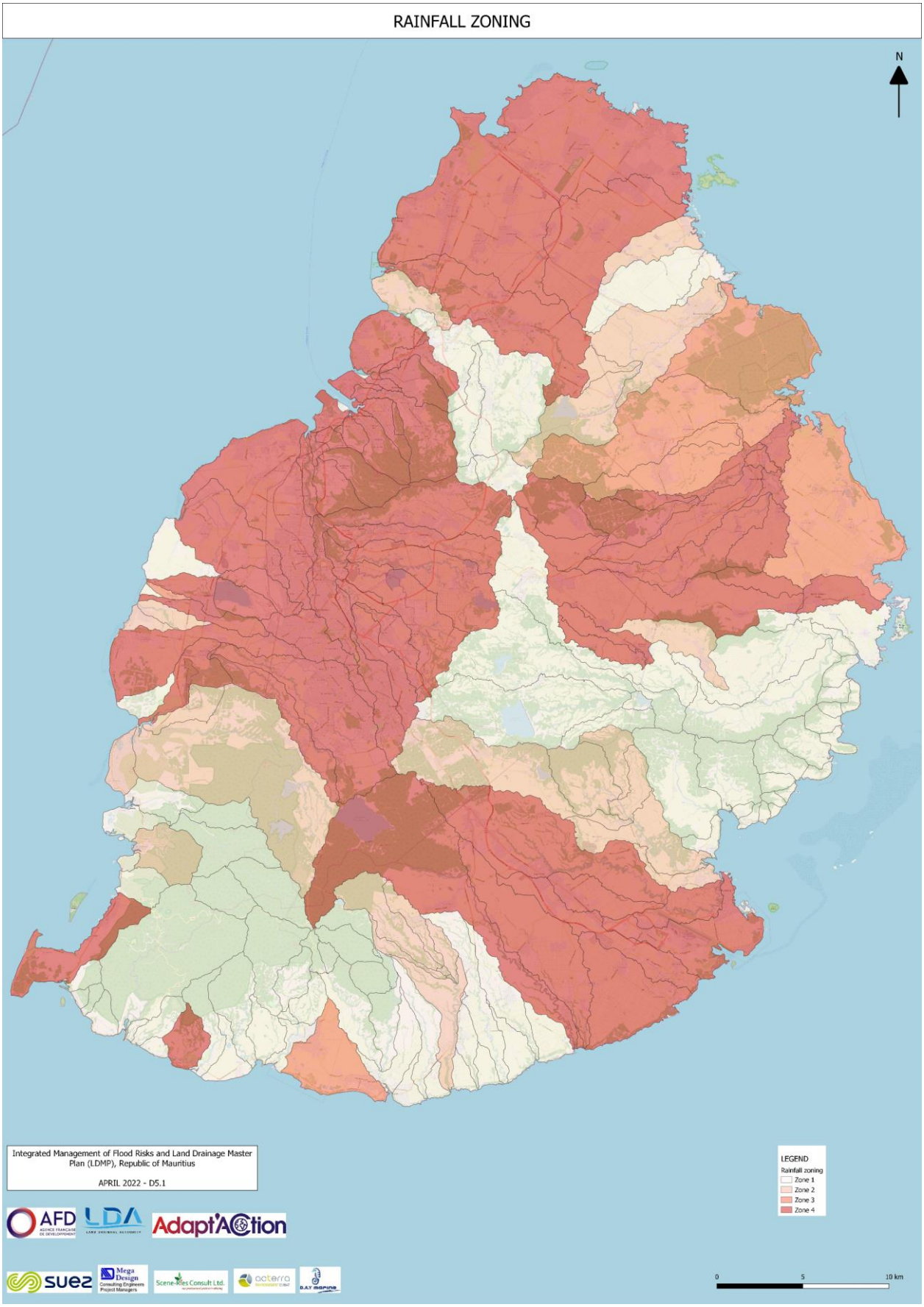


Figure 19: Rainwater management zoning (Ref D5.1 First Part LDMP for further details)

3.1.2.4 Reducing vulnerability of people and properties by relocation

Recovery measures

Vulnerability reduction measures are complemented or a possible alternative to protection works or dynamic slowing down of runoff (following actions).

It is recommended that priority be given to global operations on at least one neighbourhood (e.g. in the case of urban renovation) with an operator who leads and monitors its implementation. Linkages with existing housing improvement tools should be favoured to promote the coherence of public policies and their effectiveness. The mobilisation of network operators must be encouraged.

The acquisition of properties in risk zones, as well as the necessary measures to limit access and prevent occupation, must be planned for the predicted risk of torrential rain or rapidly rising floods, or of marine submersion that seriously threatens human life.

Note on the components related to relocation (D5.1 first part):

Relocation of buildings can be made applicable in the following instances:

- Where there are **serious risks to human life**. The notion of risk will be assessed particularly in regard to the probability of its occurrence and the warning time for the advent of the natural event, which time is necessary to alert and evacuate the population, etc,
- In the event of significant degradation of ESAs which play a significant role in the water cycle within the catchment.

With regard to the risks to human life the buildings subject to relocation will be:

- Buildings located within natural flow axes without any possibility to open up any right of way for buffers and setbacks to divert the drain. The risks in this instance are linked to the runoff velocity and the effects of obstructing the free flow of stormwater.

- Buildings located within low-lying areas with no possibility of stormwater disposal by gravity, and with water retention depths exceeding 1 m from the habitable floor level. Removal of such buildings would enable the creation of retention ponds (e.g rain gardens), allowing a reduction in flood depths for neighbouring buildings, and

- Groups of buildings located in low-lying areas with no possibility for gravity outlet, and for which in the event of frequent rainfall (less than 10 years return period), inundation of the living floor is greater than 50 cm, in which case a cost-benefit analysis will be carried out for comparison with the cost of protection measures if they are feasible.

In the case of buildings located within ESAs, relocation should be mandatory, regardless of the degree of risk, the objective being to restore the wetlands to their natural functional state.

3.1.3 Structural measures

3.1.3.1 Introduction

The measures listed in the following chapters are to be considered sequentially and in order of priority.

Indeed, good flood risk management requires the regular monitoring and maintenance of existing networks in the first place: rivers, streams and man-made drains.

Secondly, flood risk management must involve relocation actions for the areas most at risk from flooding.

Once these two preliminary actions have been implemented, only then will it be possible to build "curative" structural measures to reduce the flood risk, in the following order:

- In the first stage, by flow management: construction of retardation basins and flood control structures,
- In a second phase, by implementing hydraulic structures: new drainage channels including cut-off channels, flood walls, dikes, etc.

3.1.3.2 Monitoring and maintenance

Structural measures

Chapter 4 details the provisions to be implemented to achieve a sufficient level of monitoring and maintenance of water systems.

Only the main points are summarised hereunder:

- Governance measures:
  - Stormwater management facility inspection & maintenance requirements and schedule & frequency of maintenance activities to ensure that the facilities will continue to operate as designed,
  - Maintenance activities such as cleaning of streets, storm drains and streams, garbage collection, cleaning of infiltration sumps
- Stormwater Management Facility Performance Monitoring – focus on Control stormwater peak discharge
- Monitoring and maintenance scheme:
  - Preventive maintenance
  - Curative maintenance
- Inspections

In order to facilitate maintenance operations at the entrances to the drainage networks but also at sensitive points such as bridges and other crossing structures, the need is also emphasized for the inclusion of trash rails (Peignes à Embacles) type structures across the island.

Trash rails are structures placed at the entrance of bridges or culverts to trap the majority of large debris while smaller floating objects get deflected and are guided through the openings. They are usually V-shaped with the crest pointing upstream to divert floating objects towards the banks. The reverse configuration is also used.

Trash rails should be provided with an access ramp for maintenance of the structure. Any major obstruction to flow will lead to a rise in the water stage upstream and failure of the rails may cause damage downstream.

3.1.3.3 Hazard reduction through flow management: retardation, basin, flood control structure, new drain system design and construction

Structural measures

The LDA and other stakeholders involved in flood risk management and more specifically in the design of protection works (NDU for example) must consider solutions integrating a **dynamic flood slowing strategy**. This is an extension of the work to be carried out at the level of the plot or urban development projects within the framework of the mitigation measures linked to the compensation of imperviousness (ref 3.1.2.3.2).

Methods contributing to the **slowing down of runoff** are varied and can be combined (coupled with protection measures described in the following chapter):

- **retention of stormwater upstream,**
- **restoration of flood expansion fields,**
- **development of overflooding areas,**

3.1.3.4 Hazard reduction through management of hydraulic protection structures: cut-off drains, flood walls, dikes, etc…

Structural measures

These are measures which could be implemented as a last resort when all other possibilities for management of stormwater have been exhausted. These measures aim to reduce flood hazards by means of structural works to:

- **Develop rainwater drainage**: construction of new man-made drains

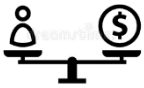
- **Improving the capacity of the existing stormwater drainage system**: widening of drains, improvement of hydraulic crossing structures: culverts, bridges

- **Reduce the hazard zones** by overflow and runoff in densely populated areas by:
    - The creation of new cut-off drains, but in compliance with an upstream-downstream logic and non-incidence for the residents located downstream
    - The creation of protective structures in built-up areas:
        - Dikes
        - Flood walls

Dikes and flood walls are structural elements which may present a higher risk in the event of failure through overflow or collapse. Their use should therefore be limited to areas where no alternative solution is technically possible.

3.1.4 Economic evaluation by cost benefit approach

Measures covered by these analyses are **structural measures**, i.e. works, **structures or developments that modify the hazard**, as well as measures that change the level of protection.



3.1.4.1.1 Comparative mapping

In order to compare the situations before and after implementation of the project, the most effective visualisation tool consists in calculating the differences in water level for a specific flood subject to these two situations.

Thus, the maximum flood levels in the projected situation (P) for a flood frequency Ty (from T10 to T100) are compared to the maximum level at the current existing situation (A) for the same frequency Ty.

The map thus obtained presents the following scenario, identifying those zones freed of inundation as a result of the implementation of the project.

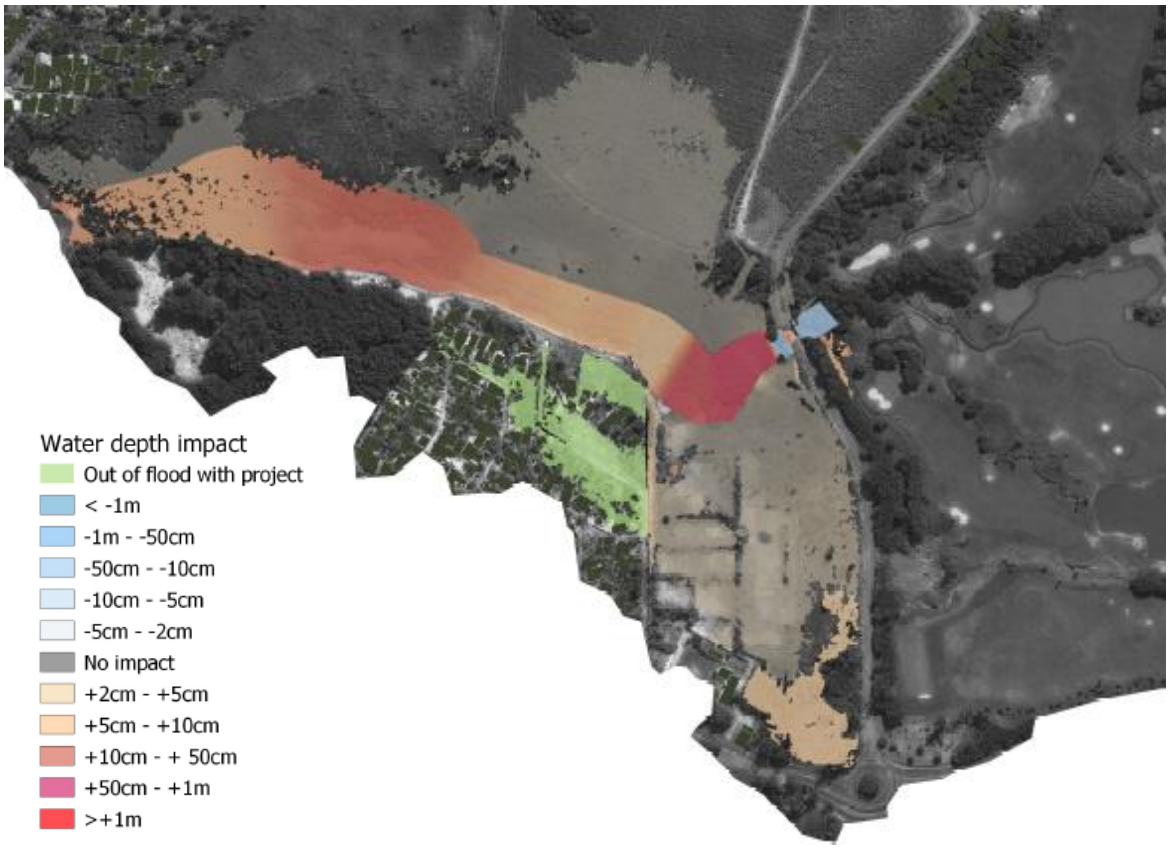


Figure 20: Comparative flood mapping – typical example

3.1.4.1.2 Analysis of the impacts of the solutions - Cost Benefit Analysis (CBA) and multicriteria analysis

3.1.4.1.2.1 Introduction - CBA

The benefits derived from a project are measured through the extent of damage avoided through its implementation. The indicators are thus calculated before and after implementation of the project for a single flood scenario corresponding to the level of protection chosen for the project.

Flood CBA assesses the costs and benefits of a project. It is based on the concept of "damage avoided": the benefits correspond to the total damage that is avoided by such measures.

The indicators of damage avoided to buildings and those to damage avoided to road networks are then aggregated.

3.1.4.1.2.2 Average costs used to estimate the value of fixed assets

The following average costs have been used to estimate the value of different types of construction:

Table 4: Average costs to estimate the value of different types of constructions

	Average cost (inflation adjusted 2018)
Buildings (MUR/m²)	
Residential buildings	13 270
Transport facilities (MUR/linear meters)	
Motorways	33 174
Major roads	27 645
Municipal Roads	22 116
Agricultural tracks and roads	8 846

*Source: ER2C – C1D2a+b - DRR report (*Republic of Mauritius, Ministry of environment and sustainable Development, DRR Strategic Framework and Action Plan, Final Report, August 2012), *inflation adjusted using the input cost index for construction 2012-2018 (source: Statistics Mauritius).*

The damage cost calculations allow sensitivity tests to be carried out for different scenarios according to the depth of flooding (less than 50 cm, greater than 50 cm). An average cost is presented above, irrespective of the flood depth. Different costs benefit figures for different scenarios are given in the annex.

3.1.4.1.2.3 Damage calculation

Once damage costs are plotted against flood frequency the overall cost over the entire country can be calculated for different flood events.

The construction of the annual average damage curve consists in drawing the relationship between the cost of the damage and the frequency of the floods studied (between 0 and 1). A typical example is provided below. The annual average damage and the annual average avoided damage are derived therefrom.

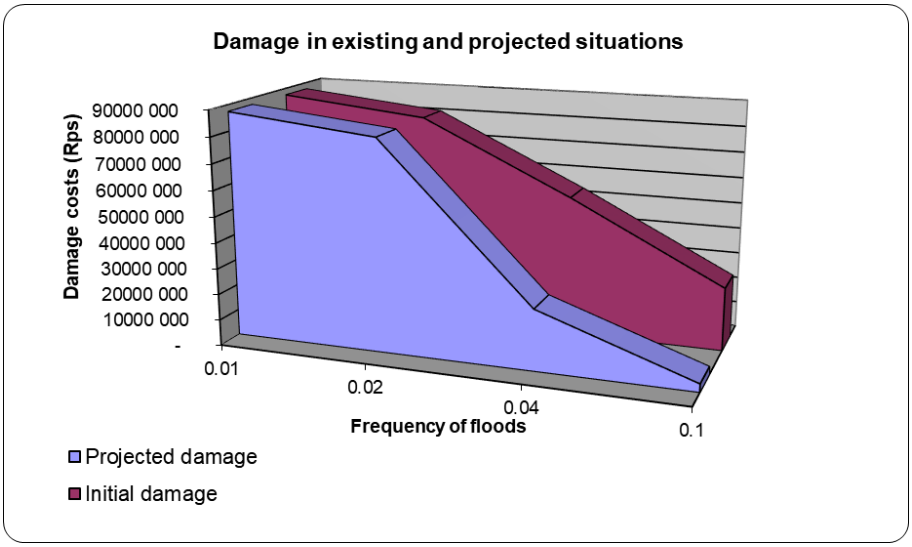


Figure 21: Typical damage curves (initial and projected situations) – Bel Ombre

3.1.4.1.2.4 Net Present Value (NPV) [7]

The Net Present Value (NPV) can be interpreted as the amount of damage avoided, representing a saving by the organisation, less the costs, as a result of the implemented investments.

The computation of the Net Present Value (NPV) consists in comparing the total **cost** of the project (investment and operating costs during its lifetime), calculated using the average estimated unit cost, with the average annual damage avoided- the **benefits**. The year at which break even occurs (when the costs equal the discounted benefits) is noted as the time after which the benefits outweigh the costs and the project is considered profitable.

The NPV is normally calculated by adding the present value of future benefits and the residual value at the ruling interest rate for any particular year, and subtracting therefrom the investment costs and the discounted operational costs and future expenses. The NPV depends on the discounted rate used to calculate these values.

NPV is calculated using the following formula:

$$NPV = -C0 + \sum_{i=0}^{n} \frac{1}{(1+ri)} \times (AAAD - Ci)$$

Where :

- C0 is the sum of the initial costs of the works,
- Ci is the sum of the maintenance costs in year i,
- AAAD is the average annual avoided damage,
- n is the time horizon for the profitability of the works, and
- ri is the discounted rate for any particular year i

L'ACB (analyse coût/bénéfice) : une aide à la décision au service de la gestion des inondations – Centre Européen de Prévention du Risque inondation - 2011

The following parameters have been included in the cost benefit analysis:

- **Maintenance cost: 1% per year**
- **n: The time horizon for which profitability is required: 50 years**
- ri: Discount rate = 4% for the first 30 years, decreasing asymptotically to 2.5% at 100 years and 2% at infinity

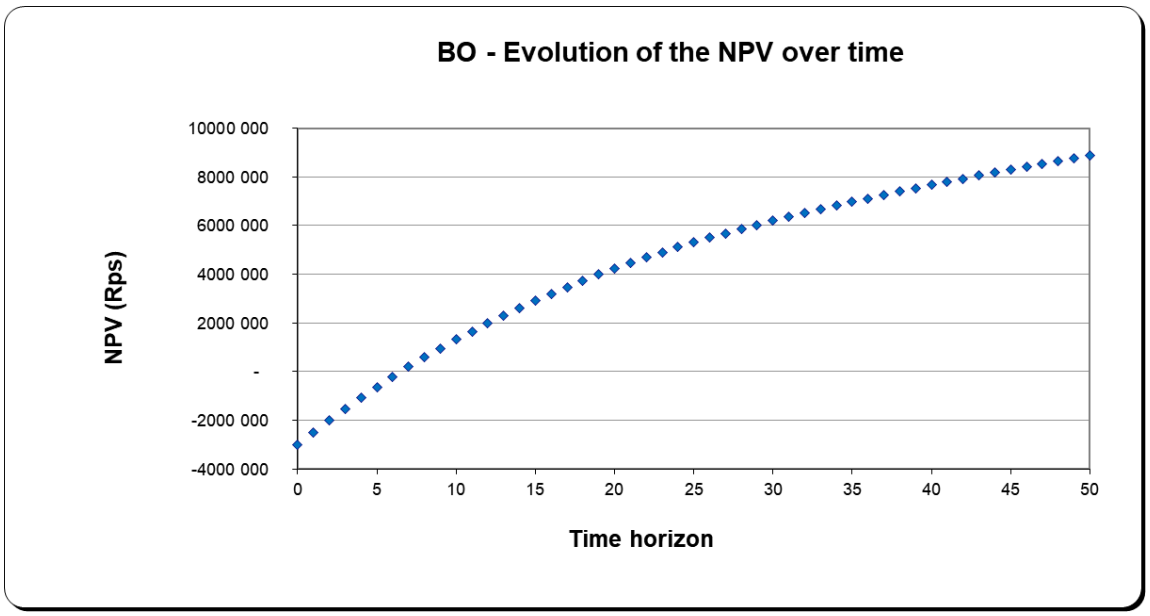


Figure 22 : Typical example of the evolution of an NPV

The net present value (NPV) allows the costs to be deducted from the benefits (avoided damage) derived from the projected measures.

If the NPV is positive, the measure studied, on the basis of the geographical perimeter selected and according to the issues and damage taken into account, is relevant from an economic point of view.

3.1.5 Conclusion

In conclusion, the measures described above have guided the LDMP throughout its preparation in the search for short and medium-term solutions and are summarised in the following chapter and annexes for the 5+11 priority and complementary sites.

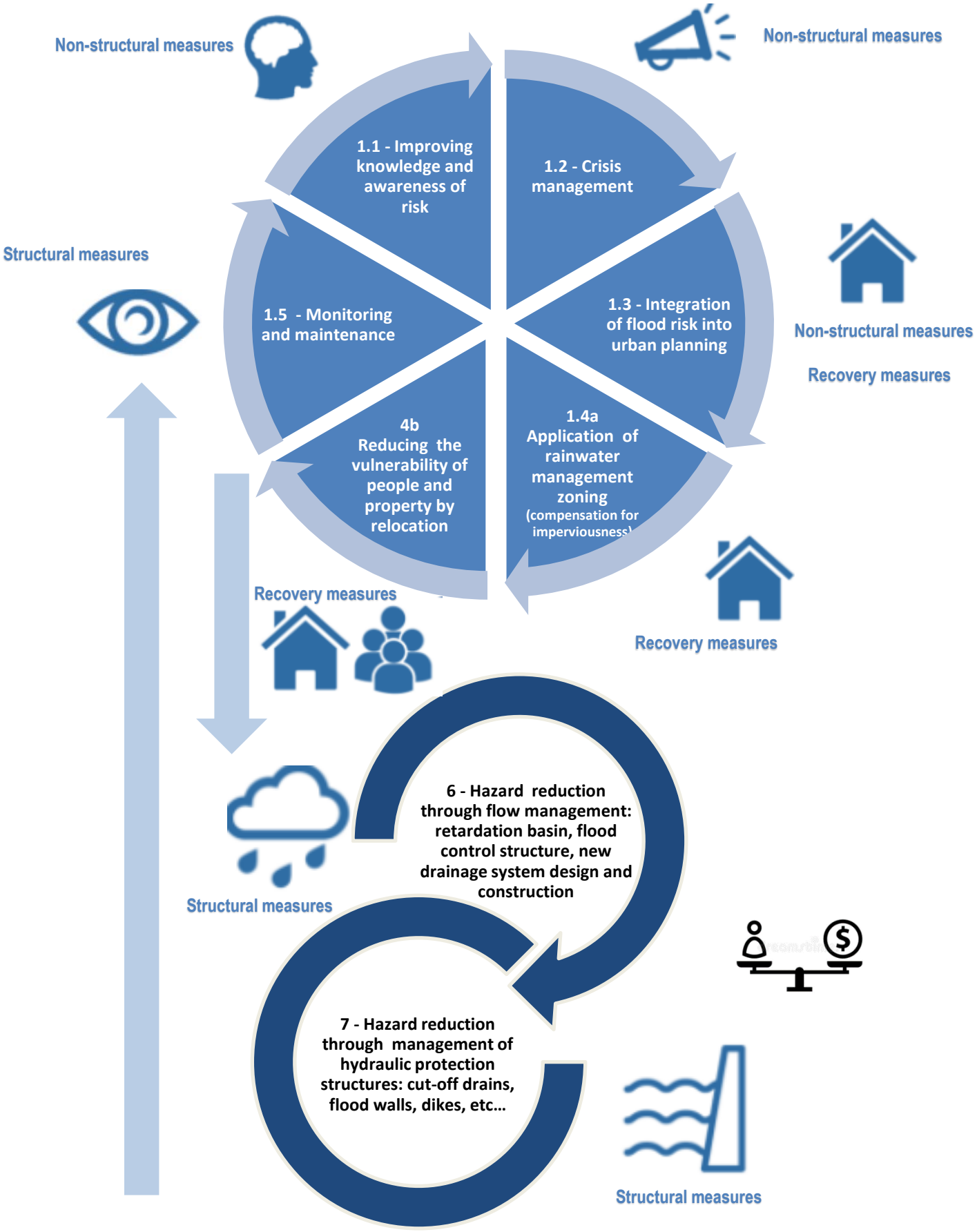


Figure 23 : Flow chart for designing a flood risk reduction programme

3.1.6 Protection level, costs and schedule forecast

3.1.6.1 Methodology and protection level

Within the framework of the design definitions and the optimisation phases, the level of protection has been formulated based on an analysis of:

- The logic of the development principle described in the previous chapter, namely:
  - Initially, identification of structures that would help reduce runoff and limit peak flows by lengthening their time of concentration by dynamically slowing them down (retardation basin, flood expansion zone);
  - Complementary research on the protection of densely populated areas through the creation of structural works such as new drains, cut off drains, flood walls and dikes.
- The feasibility of the works in the local context, particularly in relation to the topography and density of urbanised areas.
- The overall effectiveness of the structures. This effectiveness is evaluated based on cost-benefit analyses for events of various occurrences (T=10, 25, 50 and 100 years).

This level of protection is therefore not fixed and unique; it must be analysed taking into consideration all flood events. In this respect, the following table shows the annual probability of occurrence of flood events of 10 to 100 years. The notion of Return Period is often misunderstood; it is interesting to calculate the failure rate of a structure. For example, a dyke, during a certain number of years (according to the protection it provides, expressed in probability or Return Period) that the protection value is not exceeded. The following table provides such results which are independent of any probability law; it is assumed that the events are exclusive, i.e. independent from one year to the next.

Table 5: Protection level and annual probability of exceedance

Flood protection (in years) - level of protection	10	25	50	100
Annual probability of non-exceedance	90%	96%	98%	99%
Failure in X years				
1 y	10%	4%	2%	1%
2 y	19%	8%	4%	2%
10 y	**65%**	34%	18%	**10%**
20 y	88%	56%	33%	18%
25 y	**93%**	64%	40%	**22%**
50 y	**99%**	87%	64%	**39%**
100 y	100%	98%	87%	63%

As illustration, consider two hydrological events with return periods of 10 years and 100 years. Over durations of 10, 25 and 50 years, they have respectively 65, 93 and 99% of occurrence for T = 10 years and 10, 22 and 39% for T = 100 years. For a centennial event, which the population may consider that it will not occur in their lifetime, the probability of occurrence appears high.

3.1.6.2 Costs estimates

The financial cost estimates for the different measures include:

- The costs of construction work determined on the basis of unit prices;
- Provision for wayleave and Land Acquisition;
- If required, provisions for relocation of houses;
- Contingencies 15%
- Project Management – 5 to 10% depending on the value of the project

3.1.6.3 Priority and scheduling proposal

Priorities are established on the basis of a multi-criteria analysis considering the frequency of flooding events according to modelling (for 10, 25, 50 and 100 year) based on:

- **The vulnerability analysis provided for each site in Annex 2 and 3, including details of**:
  - Total flooded area
    - Total flooded area with water depth exceeding 0.5m
    - Total flooded area with water depth less than 0.5m
  - Flooded built area
  - Number and surface of buildings in flooded area:
    - Number of buildings in flooded area with water depth more than 0.5m
    - Number of buildings in flooded area with water depth less 0.5m
    - Buildings area in flooded area with water depth more than 0.5m
    - Buildings area in flooded area with water depth less than 0.5m
  - Flooded roads:
    - Flooded Motorways
    - Flooded Major roads
    - Flooded Municipal roads
- **The Cost Benefit Analysis**,
- **The need to focus on the most densely urbanised sectors** where people are most exposed to the risk of flooding when they are commuting (sectors of economic and tourist activity, etc.).

The priorities are then ranked from 1 to 3, (1 is the most urgent) and the intervention schedule distributed between:

1	Short term
2	Short/Medium term
3	Medium term

- **Short term (1-2 years),**
- **Short to Medium term (2 to 3 years),**
- **Medium term (3 to 5 years).**

Recommendations relating to social impact, procedures and funding are given in annex 1.1 and 1.2

3.2 Action plan

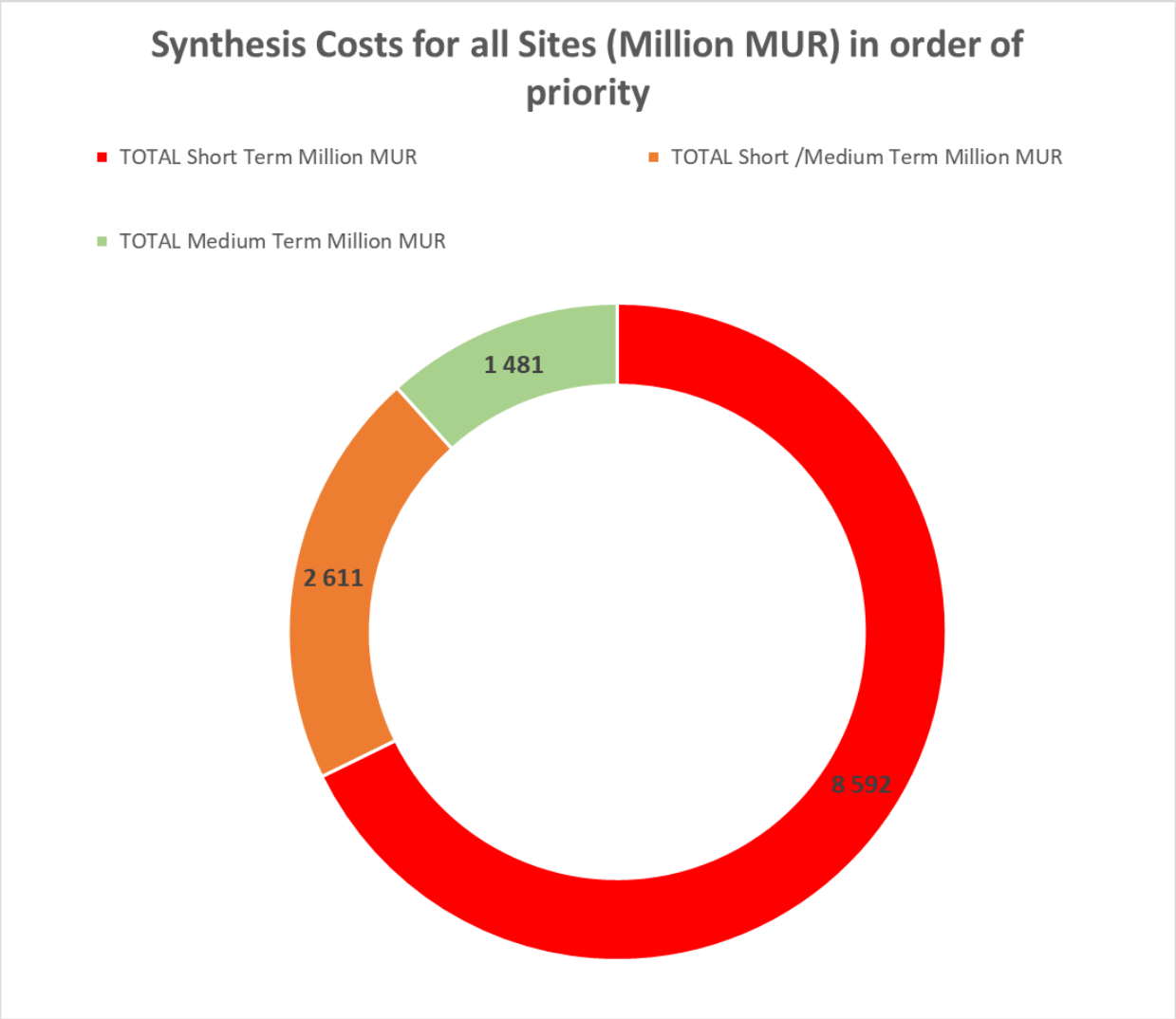
3.2.1 Synthesis – Costs and schedule

The following tables and figures summarise the costs and priorities of actions for each site, including provision for uncertainties due to external factors.

Table 6: Costs, priority and scheduling for individual sites

	Id	Sectors	Cost Million MUR	Priority	Scheduling proposal
PS	S73	LATANIERS RIVER AND CANAL DES ANGLAIS	188	1	Short term
	S75 - S74	POUCE RIVER, POUDRIERE STREAM, RUISSEAU CREOLE AND CUT-OFF DRAIN - Including La Paix (for CBA)	2 135	1	Short term
	S77	CANAL DAYOT AND URBAN DRAINS	205	2	Short/Medium term
	S65	FLIC-EN-FLAC	372	2	Short/Medium term
	S32	BEL OMBRE	22	1	Short term
	S47	NOUVELLE FRANCE	561	3	Medium term
	S6&5	GRAND BAIE / PEREYBERE	356	2	Short/Medium term
CS	S01	SECTOR 01 - MAPOU PITON COTTAGE	802	1	Short term
	S25&102	SECTORS 25 AND 102 - CLEMENCIA BEL AIR OLIVIA PONT LARDIER	469	3	Medium Term
	S43	SECTOR 43 - FLACQ	1 649	1	Short term
	S59	SECTOR 59 - COTEAU RAFFIN	155	3	Medium Term
	S72	SECTOR 72 - TERRE ROUGE	1 120	1	Short term
	S74	SECTOR 74 - PORT LOUIS LA PAIX	*Included with S75*	1	Short term
	S78	SECTOR 78 - POINTE AUX SABLES	650	1	Short term
	S82	SECTOR 82 - HENRIETTA MALAKOFF	307	1	Short term
	S85	SECTOR 85 - VACOAS QUATRE BORNES	795	2	Short/Medium term
	S86	SECTOR 86 - CUREPIPE AVAL	360	2	Short/Medium term
	GRAND TOTAL Million MUR		**10 147**		
	Provision for uncertainties due to external factors (MUR devaluation, oil and other commodity prices, global sanitary and geopolitical context)		**25%**		
	GRAND TOTAL Million MUR with uncertainties		**12 684**		
	TOTAL Short Term Million MUR		**8 592**		
	TOTAL Short /Medium Term Million MUR		**2 611**		
	TOTAL Medium Term Million MUR		**1 481**		

Figure 24 : Projected costs in order of priority



3.2.2 Action plan for priority sites

3.2.2.1 Action plan

The actions for priority sites are detailed in **Annex 2.**

3.2.2.2 Synthesis for priority sites – Costs and schedule

The following tables and figures summarise the costs and priorities of actions for each site.

Table 7: Costs, priority and scheduling for priority sites

Id	Sectors	Cost Million MUR	Net Present Value (NPV) Million Rps	Priority	Scheduling proposal
S73	LATANIERS RIVER AND CANAL DES ANGLAIS	188	65.78	1	Short term
S75 - S74	POUCE RIVER, POUDRIERE STREAM, RUISSEAU CREOLE AND CUT-OFF DRAIN - Including La Paix (for CBA)	2 135	- 19.31	1	Short term
S77	CANAL DAYOT AND URBAN DRAINS	205	- 76.02	2	Short/Medium term
S65	FLIC-EN-FLAC	372	- 145.26	2	Short/Medium term
S32	BEL OMBRE	22	67.58	1	Short term
S47	NOUVELLE FRANCE	561	- 554.86	3	Medium term
S6&5	GRAND BAIE / PEREYBERE	356	- 261.36	2	Short/Medium term
GRAND TOTAL Million MUR		**3 840**			
TOTAL Short Term Million MUR		**2 346**			
TOTAL Short /Medium Term Million MUR		**933**			
TOTAL Medium Term Million MUR		**561**			

Lifetime of the design	50	years
Maintenance annuel cost	1%	%/year

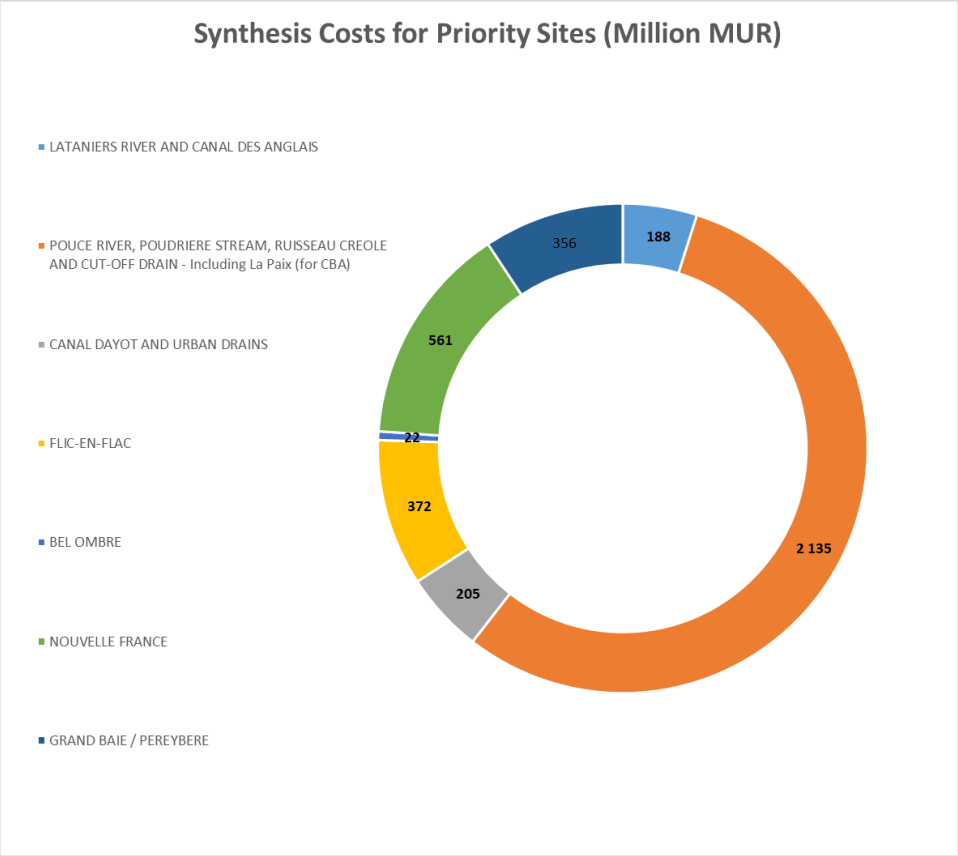


Figure 25 : Costs for priority sites

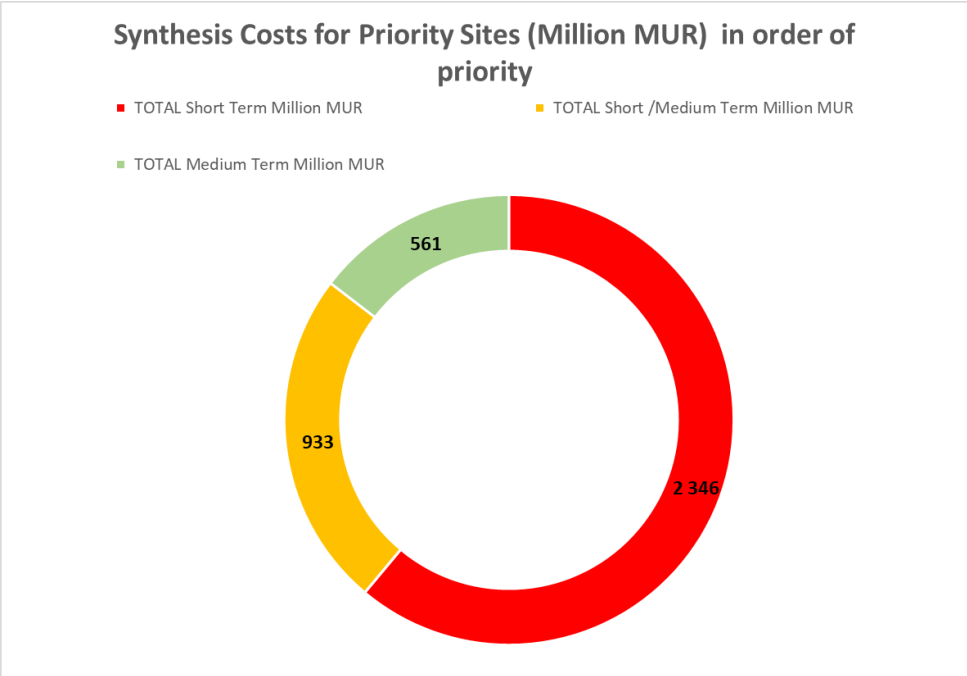


Figure 26 : Projected costs for priority sites in order of priority

3.2.3 Action plan for complementary sites

3.2.3.1 Action plan

The actions for complementary sites are detailed in **Annex 3.**

3.2.3.2 Synthesis for complementary sites

The following tables and figures summarise the costs and priorities of actions for each site.

Table 8: Costs, priority and scheduling for complementary sites

Id	Sectors	Cost Million MUR	Net Present Value (NPV) Million MUR	Priority	Scheduling proposal
S01	SECTOR 01 - MAPOU PITON COTTAGE	802	- 353	1	Short term
S25&102	SECTORS 25 AND 102 - CLEMENCIA BEL AIR OLIVIA PONT LARDIER	469	305	3	Medium Term
S43	SECTOR 43 - FLACQ (All diversions included for costing, CBA based without additional diversions)	1 649	- 281	1	Short term
S59	SECTOR 59 - COTEAU RAFFIN	155	- 45	3	Medium Term
S72	SECTOR 72 - TERRE ROUGE	1 120	683	1	Short term
S74	SECTOR 74 - PORT LOUIS LA PAIX	*Included with S75*		1	Short term
S78	SECTOR 78 - POINTE AUX SABLES	650	1 025	1	Short term
S82	SECTOR 82 - HENRIETTA MALAKOFF	307	84	1	Short term
S85	SECTOR 85 - VACOAS QUATRE BORNES	795	- 241	2	Short/Medium term
S86	SECTOR 86 - CUREPIPE AVAL	360	319	2	Short/Medium term
GRAND TOTAL Million MUR		**6 308**			
TOTAL Short Term Million MUR		**4 528**			
TOTAL Short /Medium Term Million MUR		**1 156**			
TOTAL Medium Term Million MUR		**624**			

Lifetime of the design	50	years
Maintenance annuel cost	1%	%/year

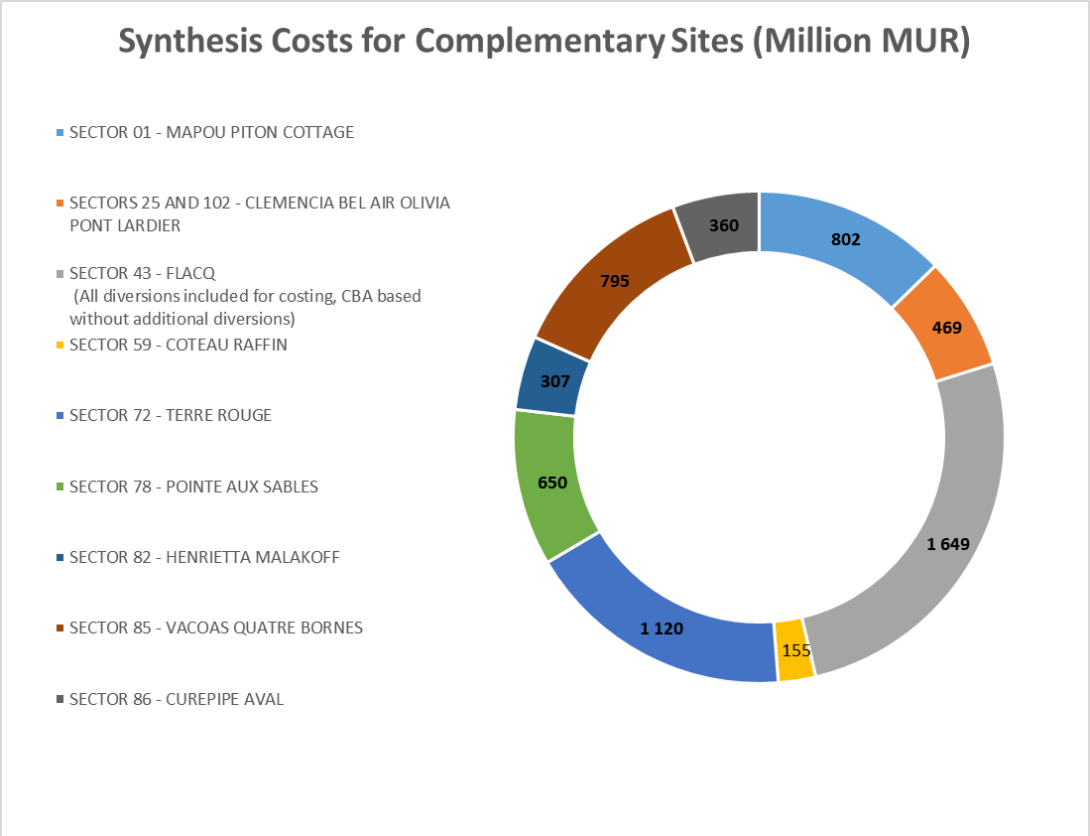


Figure 27 : Costs for complementary sites

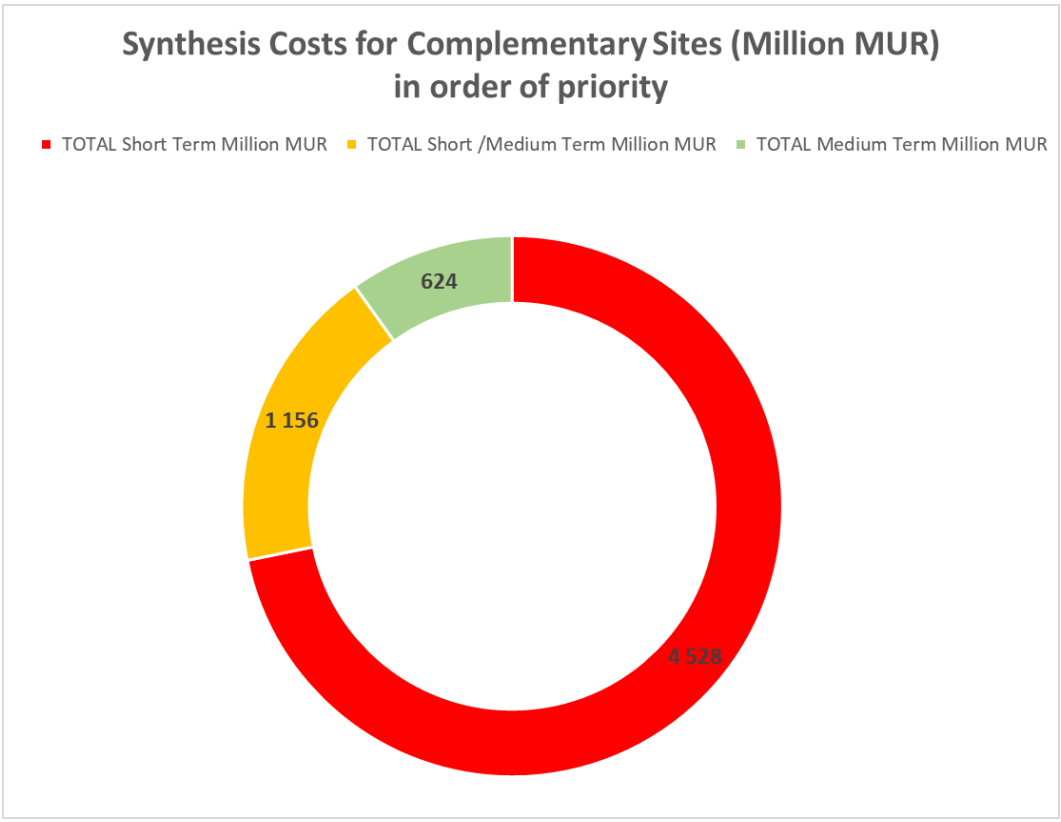


Figure 28 : Projected Costs for complementary sites in order of priority

4 OPERATION AND CONTROL FOR DRAINAGE SYSTEM, MONITORING AND MAINTENANCE

Ref D5.1

Hydraulic structures represent an important asset for the managing authorities because they are essential for the sustainability and/or protection of people and property. The lack of maintenance of structures has detrimental consequences not only for the safety of people and properties and for representatives of the community, but can also carry heavy financial consequences in the event of significant deterioration or even collapse of the structure.

A good knowledge of their condition and the implementation of preventive maintenance are likely to prevent their deterioration leading to incidents. In addition, their operating conditions and the quality of their maintenance significantly extend their lifetime.

4.1 Governance measure

In relation to the operation and control of land drainage, good governance measures include but are not limited to:

- Adoption of good operation and maintenance practices by municipal workers and the public for the storage, handling and transport of materials liable to be washed into the stormwater system.

- Monitoring of construction activities through the submission of documents to describe the specific planning and management of activities aimed at reducing the construction impacts on the quantity and quality of stormwater by such measures as control of erosion, disposal of sediments, control of wastewater from the site, storage and maintenance of plant, storage of construction materials and control over the illicit dumping of waste.

- Standard procedures for submission of stormwater management plans in support of site subdivision and development applications at conceptual/preliminary design stage, including stormwater management targets and objectives, pre-development conditions, post development conditions, storm drainage system design, facility design and water quality control for industrial development.

- Standard procedures for comparison of pre-development, unmitigated post development and mitigated post-development water balance volumes and infiltration volumes.

- Stormwater management facility inspection & maintenance requirements and schedule & frequency of maintenance activities to ensure that the facilities will continue to operate as designed,

- Maintenance activities such as cleaning of streets, storm drains and streams, garbage collection, cleaning of infiltration sumps

4.2 Stormwater Management Facility Performance Monitoring – focus on control stormwater peak discharge

4.2.1 Control stormwater peak discharge: Methods

Different methods are used to control stormwater peak discharge and volume at source or upstream of a catchment area, including but not limited to:

- Detention systems which delay the release and control stormwater flows, but do not reduce the volume.
- Retention systems which alter the volume of stormwater runoff by retaining a portion of the flow for a secondary use.
- Infiltration systems which reduce both the volume and flow rate by absorbing a portion of the flows into the ground.

Variations of detention systems are:

- Dry ponds,
- Wet ponds,
- Constructed wetlands, and
- Bioretention basins

Flood expansion zones can also be created along water courses to retard peak flows.

4.2.2 "Significant rainfall event" and SWM pond monitoring

The purpose of the monitoring program is to confirm to the satisfaction of the LDA that the SWM facilities have been constructed and are functioning in accordance with the design specifications.

Performance monitoring of the SWM facilities shall commence after 90% of the development have been constructed, within the facility's catchment area. The facilities shall be monitored until two (2) years with the occurrence of four (4) significant rainfall events as defined below.

A "significant rainfall event" is defined as an event where greater than 40 mm of rain has fallen in 4 hours.

A list of deficiencies, if any, and related data with respect to the SWM facilities will be required following each year of monitoring. **The Owner is required to perform any remedial works identified by the monitoring program.**

For all these structures, the following monitoring procedures must be carried out:

- The purpose of the monitoring programme for the SWM pond is to confirm to the satisfaction of the LDA that the pond has been constructed and is functioning in accordance with the design specifications.
- The owner shall remove the sediments from the forebay on an annual basis or when the accumulated sediment volume is greater than 25% of the forebay permanent pool volume.
- The volume of sediments shall be estimated using at least 5 uniformly distributed measurements of sediment taken within the forebay.
- The Owner shall carry out a second topographic survey after all the sediment has been removed and submit it to LDA together with a comparative analysis to demonstrate the extent of sediments removed.
- Water quality samplers, if specifically required, shall be installed at the inlet and outlet of the SWM Pond to characterize the facility's removal efficiency for TSS.
- Flow measurement equipment, if specifically required, shall be installed at all inlets and outlets together with a water level sensor for the SWM Pond.

4.3 Monitoring and maintenance scheme

4.3.1 Introduction – importance of maintenance

Before project implementation, an operation and maintenance (O&M) plan or manual should be developed which would identify inspection and maintenance requirements for the proposed project.

In view to facilitating maintenance and follow-up, it is recommended to prepare a **maintenance report**. The report should in principle provide the following information:

- Observations during inspection:
  - Hydraulic operation of the structure (residence time, evidence of overflow)
  - Condition of vegetation in and around the structure
  - Obstructions to the inlet and outlet
  - Evidence of contamination
  - Accumulation of debris
- Measured sediment depths (where relevant)
- Results of monitoring, if flow or quality measurements have been made
- Operation and maintenance activities completed
- Recommendations for the following year's inspection programme.

4.3.2 Maintenance and conventional operations

Most components in a drainage system can be prone to erosion, blockage or subsidence. Minimal maintenance is required to preserve the expected hydraulic capacity within the system. Activities can be categorised either as preventive or remedial.

4.3.2.1 Preventive maintenance

Preventive maintenance includes periodic inspection of the system, monitoring, regular maintenance and analysis of data on reported complaints and problems.

Regular inspection activities should normally include the following

- Street cleaning
- Removal of debris and sediment from catch basins
- Supervision of connections
- Cleaning of outfalls and culverts
- Inspection of physical conditions of pipes and manholes (visually or by camera if necessary)
- Repair or replacement of damaged pipes,
- manholes, catch basins and other components

The implementation and follow-up of a maintenance register is essential to keep records of maintenance activities. Data for each component of the system should be kept up to date, ideally including:

- Date of construction of the systems (possibly including the name of the designer and contractor)
- Type, size and shape of pipes
- Area served and land use
- Manholes and catch basins (location, type and invert (for manholes)

- Inspections (date, methods, location and results)
- Complaints reported (location, nature, date, time, rainfall characteristics leading to complaints)
- Repairs and replacements made.

Several options for managing this information are possible, ranging from codified access to printed plans or a computerised management system to complete geographic information systems (GIS) that integrate system data and spatial representation of this information. A GIS can typically include several other types of data (sanitary sewer system, water supply, roads, etc.) and is the most advanced and effective approach. **We recommend integrating the use of GIS systems to track informations and maintenance.**

4.3.2.2 Corrective maintenance

Corrective maintenance is not usually predictable and becomes necessary in emergency situations. These are actions that require immediate attention, such as a broken pipe or blocked culvert inlets. These actions must be taken to reduce the potential for flooding and limit damage, to prevent injury or to protect receiving environments.

Some risk factors can however be identified and minimised. For example, in the case of blocked culverts, there are physical factors that increase the risk of a culvert being blocked by debris jams during a high flood: banks in a more or less advanced state of erosion, presence of shrubs and trees in a precarious position, debris and objects littering the floodplain and likely to be moved during a flood.

4.3.2.3 Responsibility for maintenance

It is essential to ensure that the responsibilities for operation and maintenance are clearly defined by the various stakeholders. For structures serving a sector, maintenance remains the responsibility of the developer during the construction period until the structures are transferred to the municipality or district council, which will then assume this responsibility. The agreement on sharing of responsibilities for maintenance and keeping the facilities in good condition is of key importance.

4.3.2.4 General maintenance activities

Several factors influence sediment accumulation rates and maintenance requirements: the type of structure, land use in tributary areas, upstream development and wildlife. The table below describes the general maintenance activities associated with the different types of structures.

Table 9: Activities for the maintenance of stormwater management facilities

		Wet retardation basins	Marshes	Dry retardation basin	Infiltration and retardation swale and basin	Trench infiltration	Vegetated Filtering Strips	Pipe oversized	Infiltration Wells or Absorption Trenches	Bioretention swale	Frequency
1	Inspection	Required	Required	Required	Required	Required	Required	Required	Required	Required	For at least the first two years of a system's operation, after each major rainfall event to ensure that operation is adequate. Then on average 4 to 5 inspections per year.
2	Grass cutting	Possibly Required	Possibly Required								Grass cutting is an activity that is in fact simply carried out to enhance the esthetics of the site. The frequency therefore depends on the surrounding land use
3	Weed control			Possibly Required		Possibly Required	Possibly Required			Possibly Required	This type of inspection is usually carried out 2-3 times a year.
4	Planting outside riparian areas	Possibly Required	Possibly Required	Possibly Required	Possibly Required	Possibly Required	Possibly Required				Once or twice a year
5	Specific planting (riparian areas and aquatic plants)	Possibly Required	Possibly Required								Once or twice a year
6	Sediment removal	Required	Required	Required	Required	Required	Required	Required	Required	Required	The need for subsequent interventions will be assessed on a case-by-case basis during inspections.
7	Removal of debris	Required	Required	Required	Required	Required	Required	Required	Required	Required	The need for subsequent interventions will be assessed on a case-by-case basis during inspections.

4.3.3 Inspections

For at least the first two years of operation of a system, inspections should normally be carried out after each major rainfall event to ensure that the system is functioning properly (on average 4 to 5 inspections per year).

After this initial period, when the operating conditions of the system have been validated and confirmed, annual inspections may be sufficient, except in the case of major events which the system and the authority did not experience since the facilities were installed.

More inspections may be required if the structure is designed poorly or if other external causes, such as upstream development give rise to operational or maintenance problems.

The table below lists the basic issues that should be considered during routine inspections.

Table 10: Potential issues during regular inspections

		Regular inspection
1	Wet retardation basins	1. Is there standing water in the pond more than 24 hours after a rain event? (or other assumed retention time?) (This would indicate a blockage of the outlet by debris or sediment - visually inspect the outlet structure). 2. Is the pond always dry, or relatively dry within 24 hours of a rainfall event? (or other assumed retention time?) (This would indicate a blockage of the inlet by debris or sediment or a structure at the outlet with too much discharge capacity - visually inspect the inlet structure or check the design of the outlet structure if necessary). 3. Is the vegetation around the pond healthy or dying? (This could indicate poor planting choices. If this situation is chronic, an analysis should be conducted to identify the cause). Is there any vegetation left in the water? Are there areas around the pond that are easily accessible? (This may indicate a need to replant appropriate vegetation). 4. Is there a visible accumulation of sediment in the bottom or around the high water mark of the pond? (This would indicate a need for sediment removal).
2	Dry retardation basin	1. Is there standing water in the pond more than 24 hours after a rain event? (or other assumed retention time?) (This would indicate a blockage of the outlet by debris or sediment - visually inspect the outlet structure). 2. Is the pond always dry, or relatively dry within 24 hours of a rainfall event? (or other assumed retention time?) (This would indicate a blockage of the inlet by debris or sediment or a structure at the outlet with too much discharge capacity - visually inspect the inlet structure or check the design of the outlet structure if necessary). 3. Is the vegetation around the pond healthy or dying? (This could indicate poor planting choices. If this situation is chronic, an analysis should be conducted to identify the cause). Is there any vegetation left in the water? Are there areas around the pond that are easily accessible? (This may indicate a need to replant appropriate vegetation). 4. Is there a visible accumulation of sediment in the bottom or around the high water mark of the pond? (This would indicate a need for sediment removal).
3	Infiltration basin	1. Is there standing water in the pond more than 24 hours after a rain event? (This would indicate a decrease in soil permeability and, depending on the depth of water in the pond after 24 hours, the need for maintenance action - removal of sediment and reworking of soils. If there is more than one third of the design depth in the pond 48 hours after the rain event, the pond should be cleaned and maintained. 2. Is the pond still dry, or relatively dry within 24 hours of a rainfall event? (or other assumed retention time?) (This would indicate a blockage of the inlet by debris or sediment - visually inspect the inlet structure or check the design of the outlet structure if necessary). 3. Is there a visible accumulation of sediment in the bottom or around the high-water mark of the pond? (This would indicate the need for sediment removal). 4. Are the top layers of soil discoloured? (This may indicate the need for soil remediation).
4	Trench, Swale infiltration	1. Is the trench draining? (Inspect the depth of water in the observation well. If the trench has not drained in 24 hours, the inlet and pre-treatment unit should be cleaned (oil/sediment separator, sumps or grassed ditch). If the trench has not drained within 48 hours, the trench may need to be partially or completely rebuilt to recover its infiltration capacity. 2. Is the trench still dry, or relatively dry within 24 h after a rainfall event? (or other assumed retention time?) (This would indicate a blockage of the inlet by debris or sediment - visually inspect the inlet structure or check the design of the outlet structure if necessary).
5	Vegetated Filtering Strips	1. Are there any areas of vegetation in poor condition or dying downstream of the flow divider (this would indicate the need for new planting for the filter strip). 2. Is there evidence of erosion downstream of the flow divider? (This would indicate the need for new planting for the filter strip. Erosion may be caused by non-uniform distribution of flows in the flow divider or non-uniform height of the flow divider control weir. The weir should be inspected for repairs). 3. Is the weir of the flow divider eroded? (The weir should be rebuilt in areas where its height is not uniform). 4. Is there standing water upstream of the flow divider weir? (This would indicate that the divider is blocked; it should be checked for debris and sediment build-up; the blockage should be removed, and the weir rebuilt if deemed necessary).
6	Bioretention swale	1. Is there standing water in the grassed ditch? (This would indicate a blockage in a weir or a decrease in the permeability of the ditch. Weirs should be inspected for blockages with debris/sediment). 2. Does the vegetation appear unhealthy or dying? (This may require re-turfing). 3. Is there erosion downstream of the ditch? (This could indicate frequent overflowing of the ditch, which means potential blockage of the weir or reduced permeability of the ditch. Weirs should be inspected, and erosion corrected with grassing if necessary. It may be necessary to provide additional erosion protection.

4.3.4 Maintenance descriptions and frequency

4.3.4.1 Catch Basin Inserts

Typical maintenance of catch basins includes trash removal through the use of a screening devices or other debris capturing devices and removal of sediment using a vactor truck. Operators need to be properly trained in catch basin maintenance. Maintenance should include keeping a log of the amount of sediment collected and the date of removal.

It is recommended to integrate the use of GIS systems to track sediment collection and optimise future catch basin cleaning efforts.

4.3.4.2 Green Infrastructure Maintenance

Maintenance of green infrastructure generally requires more labor and less heavy equipment than maintenance of grey infrastructure.

Table 11: Summary of Green Infrastructure OF&M Requirements

	Weeding, Mowing, & Watering	Trash & Debris Removal	Sediment Removal, Draining, & Flushing	Re-grading & Erosion Control	Plan & Component Replacement	Monitoring & Inspection
Bioretention Cells/Rain Gardens	Necessary on a regular basis; more frequent for manicured cells, in urban areas, or near roads/walkways	Necessary on a regular basis, particularly in urban settings	a regular basis, particularly in urban settings As needed, if water is standing for long periods of time	As needed for prevention of channel formation or to repair erosion damage	Plant replacement as necessary; regular mulching to minimize weed growth	Regular monitoring and inspection to ensure adequate infiltration rate
Wetlands	Seasonal mowing of emergent areas; maintain adequate water levels for habitat; regular removal of weeds/ woody growth	Regular trash and debris removal; debris should be prevented from creating areas of pooled water	Sediment removal at a predetermine d depth of sediment accumulated (6-12"); flushing of inflow/ outflow mechanisms when blocked	As needed for prevention of channel formation	As needed; Plant replacement as necessary to maintain 85% vegetation cover of emergent land	Several inspections/y r and following major rain events; Every 2-3 weeks during establishment
Swales	Necessary on an occasional basis for vegetated swales	Removed as quickly as possible to prevent channel blockage	Not necessary unless swale is damaged	Regularly during establishment as needed subsequently to prevent channel blockage	Plant replacement as necessary if the channel is damaged by erosion	Inspect regularly to ensure water is not pooling and channel is not eroded or damaged
Shoreline Restoration - Vegetated Filtering Strips	Seasonal mowing; water as necessary during first 3-5 years and dry periods; mulch at tree bases; weeds kept under ~12	Trash should be removed; natural debris can be allowed to accumulate	Prevention of channel formation, as necessary	Prevention of channel formation, as necessary; replanting if erosion destabilizes stream banks	Plant replacement as necessary to maintain vegetation cover of about 85% of emergent land	Several inspections/y rand following major rain events; every 2-3 weeks during establishment
Infiltration Basins	Mowing and weeding should be conducted on average once per month	As needed	Necessary any time water is not infiltrating within 24 hours	As needed basis if damage is Incurred during a high-volume event	May be necessary after basin has been in use for several years	Monitor to ensure water infiltrates within 24 hours. Inspect 1-2x yr for contaminant build-up
Rain Barrels/ Cisterns	N/A	Mesh screen can filter out debris	Water should be removed 7-10 days after a rain event	Water should drain onto stable, noneroding soil	As necessary	Periodically ensure water is not running into house foundations or erodible area
Pervious Pavement	Controlled herbicide as necessary so as not to disturb pavement	Necessary on a regular basis	Vacuuming at a min. of 1- 2x/yr and, where present, flushing of drainage system	Sediment should be prevented from eroding directly onto pavement	Damaged pavers replaced with spares; small areas can also be repaired with traditional pavement. Infill, can be replaced with a broom	1-2x a year; no standing water should be on surface after a rain event
Green Roofs	Irrigation and fertilization regularly during establishment; weeding on a regular basis subsequently	Necessary on a regular basis. Critical if debris or dead vegetation creates a fire hazard	Drains should be inspected regularly	N/A	As needed; frequency will depend on vegetation type and roof design	Regular inspections; ensure compliance with local guidelines and/or building codes

ANNEX 1.1

SOCIAL IMPACTS AND PROCEDURAL RECOMMENDATIONS

- **Relocation**

In certain cases, relocation is the last resort to be applied to save lives or to build large infrastructures "in public interest". This procedure is often used in Mauritius for the construction of major roads or for the light railway system. However, the Government generally avoids compulsory acquisition of private residential properties both out of social consideration (public outcry) and the high costs linked to compensation. As a matter of fact, the construction of the light railway required the relocation of a few residential properties at La Butte, Montagne des Signaux. This generated into public outcry and court cases. A similar situation occured at Mare Chicose as described hereinafter.

This section describes the legal and social contexts inherent to compulsory purchase and relocation in the public interest.

1. Legal Context

The laws of the Republic of Mauritius, and more particularly the Constitution of Mauritius which is the supreme law of the country, provides for the protection of privacy and property as mentioned in section 3 which is reproduced hereafter:

> **3. Fundamental rights and freedoms of individual**
>
> It is hereby recognised and declared that in Mauritius there have existed and shall continue to exist without discrimination by reason of race, place of origin, political opinions, colour, creed or sex, but subject to respect for the rights and freedoms of others and for the public interest, each and all of the following human rights and fundamental freedoms—
>
> (a) the right of the individual to life, liberty, security of the person and the protection of the law;
>
> (b) freedom of conscience, of expression, of assembly and association and freedom to establish schools; and
>
> (c) the right of the individual to protection for the privacy of his home and other property and from deprivation of property without compensation,
>
> and the provisions of this Chapter shall have effect for the purpose of affording protection to those rights and freedoms subject to such limitations of that protection as are contained in those provisions, being limitations designed to ensure that the enjoyment of those rights and freedoms by any individual does not prejudice the rights and freedoms of others or the public interest.

It is clear therefrom that no person in Mauritius can be deprived of his property without compensation, and therefore the Government of Mauritius **may expropriate with compensation in the public interest**.

This procedure has been used extensively in Mauritius for the construction of roads or other public infrastructures, and land drainage infrastructure may therefore be construed as public infrastructure and subject to expropriation with compensation. However, the Government generally avoids expropriating residential properties considered as the principal place of abode.

The Constitution of Mauritius is supplemented by the Land Acquisition Act as amended in 2013 which lays down the procedures for such acquisitions and the right of appeal to be made to the Supreme Court as mentioned in section 10 of the said act.

In addition, various laws and regulations providing for the protection of Environmentally Sensitive Areas such as the Outline Planning Schemes, the provisions of the Forests and Reserves Act and other legislations provide that the owners of portions of land, although having the ultimate property right guaranteed by the Constitution of Mauritius for privately owned lands, are still subject to limitations of the said property rights based on the provisions of the said regulations. These restrictions include the prohibition from development or the removal of illegal structures in river reserves, natural drains or wetlands.

Section 6 of the Land Drainage Authority Act which is reproduced hereafter specifically describes the intent of the legislator to provide the necessary powers to the Land Drainage Authority in this matter.

6. Powers of Authority

The Authority shall have such powers as may be necessary to discharge its functions most effectively and shall—

(a) with a view to preventing unauthorised activities and developments on drains, canals and other watercourses, or the illegal dumping and discharge of effluents in drains, canals and other watercourses, issue guidelines to relevant stakeholders;

(b) where drainage infrastructure is not upgraded or maintained, direct the relevant stakeholder to upgrade or maintain that infrastructure.

Another piece of legislation which is of essence in the context of construction of land drainage structures is the Code Civil. In fact, article 640 of the Code Civil hereunder provides that:

“640. Les fonds inférieurs sont assujettis envers ceux qui sont plus élevés à recevoir les eaux qui en découlent naturellement sans que la main de l'homme y ait contribué. Le propriétaire inférieur ne peut point élever de digue qui empêche cet écoulement. Le propriétaire supérieur ne peut rien faire qui aggrave la servitude du fonds inférieur.”

(Downstream properties are subject to the natural flow of water from upstream properties. The owner of the downstream property shall not erect any dyke which interferes with the flow. The owner of the upstream property shall not interfere with the right of way of the downstream property)

Social Acceptance

The social acceptance of expropriation from one's house is very low in Mauritius. We can recall the public outcry linked to the relocation of the inhabitants of the village of Mare Chicose following the implementation of the landfill site or more recently the public outcry linked to the pulling down of houses along the alignment of the Metro Express.

Expropriation at Mare Chicose

It is to be noted that expropriation should be a last resort where there is no other alternative for cases of residential buildings or residential properties and this with adequate compensation. However, expropriation of agricultural lands is more acceptable provided that adequate compensation is paid to the land owners.

As mentioned above, the legal framework in Mauritius provides for a safeguard in case of expropriation through appeals to be made at the Supreme Court of Mauritius based on the provisions of the Constitution of Mauritius and section 10 of the Land Acquisition Act as amended in 2013. However, this procedure carries a financial burden and is time consuming: it does not provide for any interruption in the procedure pending the decision of the Supreme Court and few appeals have been made accordingly, leaving many appellants desperate.

It is therefore necessary to set up a clear administrative multi-sectoral consultative procedure to ensure that all technical and administrative remedies including realignment and downsizing of the infrastructure and allowing such infrastructure to be built on private property with the agreement of the land owner and with compensation. It is equally clear that land drainage infrastructure will have to be adapted to the local context and existing residential properties, and not the opposite and that all works will have to clearly demonstrate public interest. The principle of: "eviter, reduire et compenser" (avoid, downsize and compensate) should accordingly be used.

Nevertheless, adequate measures should be taken to cater for illegitimate and illegal construction obstructing natural flow. Provisions have accordingly been introduced in the Building Act to allow for the demolition of illegal infrastructure.

Beside the legal context, the way the works should therefore be implemented needs to be adapted to the local context, taking into consideration the environmental, social and economic factors, including the location and extent of ESAs, the existence or absence of infrastructure, the historical rights (easements or rights of use or of way) and other cultural, religious or social considerations.

Alternative Approach 1: Avoid

In certain cases, alternative land drainage infrastructure can be proposed to avoid existing residential areas. This solution has been adopted for road infrastructure, including at Quatre Bornes (Avenue des Tulipes) and at La Source where one-way roads have been proposed instead of two-way traffic requiring the relocation of residential buildings. This first approach should be preferred above all to avoid public hardship and outcry and to reduce the adverse financial implications for the Government. This approach requires a thorough investigation of technical alternatives and widespread consultation with the people concerned.

Alternative Approach 2: Reduce

There are cases where avoidance is not possible. In this situation, alternative solutions with lower impacts should be explored, including downsizing or a different alignment, while undertaking public consultation. The concept of reduction in an unavoidable case should be subject to a thorough public consultation in order to explain the necessity and the efforts made by the authorities to reduce public hardship.

Alternative Approach 3: Compensate

If aformentioned alternatives do not produced any positive result, the only fall back position is compensation. However, this alternative can take two forms: (1) compensation for the hardship caused with the passage of water on the property or (2) compensation for the expropriation of the land owner. In the first scenario, if the property is used for agricultural purposes or if the residential property is large enough to allow for the free flow of water, the owner may be made aware of the risk and accept that his property is used for the passage of water in return for a certain form of monetary or other type of compensation. However, the public consultation is a critical part of this process and the risks need to be legally acknowledged, if they are not life or property threatening. As a final resort, extensive public consultation has to be made to explain to certain land owners that despite all efforts, no technical alternative or reduction of impacts is possible, and that due to the risks involved to life and property and the necessity to apply the principle of public interest, that person will have to be relocated. The land owner will therefore be subject to the provision of the Compulsory Acquisition Act. However, this should be considered as a last resort.

The Zoning Approach

This three-tiered approach depends on the specificities of the area which is subject to land drainage works, and more specifically to the land zoning and land use which is applicable to the area concerned. In Mauritius, portions of land are located within residential, industrial, agricultural, forest or mountain reserves or conservation zones, each having its own specificities. Moreover, land is either owned by individuals or the State (State Lands formerly known as Crown Lands).

Land drainage projects should therefore be carried out as far as practicable in the following order of priority:

a) Along existing water courses or natural drains located within forest or river reserves

b) On portions of land which are used as forest or or for agricultural purposes and which can be purchased compulsorily at lower costs without causing much hardship to the land owners

c) On portions of land which are industrial in nature

d) On portions of land which are residential in nature.

The practical application of inundation zones can equally be made through the information and acknowledgement of agricultural land owners that the zone may be inundated in the future and that compensation may be paid or made available through other means as agreed between the Government and the land owner to cater for the loss in production of crops. However, this option is limited to portions of land devoid of infrastructure and used solely for agricultural purposes. The types of crop cultivated on such portions of land should be resilient to flooding and sugar cane will be preferred to vegetables in such cases.

Specific conditions are applicable to portions of State Land which are subject to leases containing clauses allowing the State to resume possession without compensation.

Grading the Risk

The issue of risk to life and property is a cross-cutting consideration which needs to be taken into consideration in all cases. All projects should therefore be subject to a risk assessment in order to clearly quantify the level of risk, and mitigating measures if any proposed. The level of decision concerning avoidance, reduction or compensation will depend on the defined level of risk to life or property.

In fact, when the level of risk posed is life threatening, the alternatives to compensation and relocation are limited. The aggrieved persons should be made aware of the said risks, duly substantiated by the findings of the risk assessment report. They should equally be made aware of the lack of alternatives or mitigating measures, and adequate compensation and relocation opportunities should be proposed accordingly. As a matter of fact, in law, making someone aware of the risks and then exposing the person to the said risks does not discharge the State of its criminal liability in case the person accepts to bear the said risks.

]**Mapping and Informing of the Risk Country Wide**

The delimitation of the flood risk areas has already been carried out in the context of this project and the coloured risk graded mapping produced should be made public in order to promulgate cognisance of the risks and measures to be taken to safeguard life and property.

In the case of Chitrakoot and deux Freres, the Government has taken legal steps to prevent the further issue of Building and Land Use Permits due to the high risk of landslides. The same situation applies to La Butte. However, existing dwellings can remain occupied.

The issue of access to information and public consultation is critical at this stage, requiring teams of professional interviewers in order to capture the perception of the people while a group of specialists would be mandated with the task of informing and explaining the situation to all the persons who are at risk.

However, in the case of Riviere des Galets, the Government had proposed relocation to the inhabitants of the coastal strip who live under life threatening conditions and whose properties are at risk of destruction due to exposure to swells. Nevertheless, they have persitently refused to be relocated or to be compensated despite being fully aware of the risks. The Government had no alternative than to have a coastal rock revetment to protect them. This case illustrates the difficulty encountered to relocate persons who are at risk.

The case of illegal and incomplete constructions

Proponents of Illegal constructions did not go through the process of seeking permits to ascertain whether their proposed development is in line with planning, environmental and other standards and guidelines applicable for a specific area at a specific moment.

The issue and validation of the Land Drainage Master Plan for the Republic of Mauritius will provide solid scientific and technical data about the associated risks and mitigating measures which need to be taken accordingly.

This information should form an integral part of the permit securing process in order to protect life and property. However, illegal or incomplete infrastructure will obviously fall outside the ambit of the plan, requiring additional enforcement and legal indemnification processes to safeguard the interests of the State.

Illegal constructions should be subject to the new provisions of the Building Act and the Land Drainage Act related to the pulling down without any compromise of such infrastructure which may be linked to downstream or upstream flooding hazards.

In the case of Bel Air Riviere Seche, the Government should provide no other leeway to the illegal occupiers than to be relocated due to the high risks to life and property in this flood prone area.

The case of wetlands

Wetlands are defined as Environmentally Sensitive Areas (ESA) and they are protected under the Ramsar Convention. Wetlands are often located on lowlands and they are subject to flooding during heavy rainfall events as evidenced by the events at Pereybere, Grand Baie or Flic en Flac.

A detailed ESA mapping has been carried out in order to locate precisely wetlands and it has been concluded that the declaration of such environmentally sensitive areas as “no-go” zones would be the best solution to preserve them while preserving their functions as nature-based solutions to prevent or mitigate flooding in the context of climate change.

Such areas which are sometimes subject to pressure from developers could therefore be transformed into eco-tourism parks in order to generate revenue while preserving their biodiversity and functions.

The onus of the Land Drainage Authority

In all the aforementioned cases, the onus of proof of threat to life and property and lack of alternatives should be on the Land Drainage Authority. The social impacts of such onus should not be downplayed, in as much as the pulling down of residential infrastructure or the forced relocation of part of the population are painful and often cause of public outcry.

The Land Drainage Authority should therefore set up a specific enforcement and information branch/unit in order to deal with such situations which will be common with the implementation of the recommendations contained in the Land Drainage Master Plan.

The team should be mobilised to villages in order to sensitise residents and educate them on the risks posed by illegal constructions and obstructions to free passage of water.

Practical Application of the Recommendations of the Land Drainage Master Plan

The Land Drainage Master Plan makes provision for 320 square kilometres of flood prone areas in Mauritius constituting more than 16% of the total area of the island. The prioritisation on declaration of these areas as No-Go or No-Expansion zones will have to be carried out based on their size.

In fact, zones covering less than 1 square kilometre can be dealt with locally while larger zones need to form part of the prioritisation process of the Land Drainage Authority based on criteria of level of danger to life and property and financial implications.

The Civil Code of Mauritius makes provision for the free passage of water “du front superieur vers le front inferieur” (from upland to lowland). The said piece of legislation equally addresses the issue of “servitudes” which may include

such easements for the free passage of water. Such easements should however be properly defined and formalised in a Registered Deed.

Financing the Application of the Recommendations of the Land Drainage Master Plan

The measures contained in the Land Drainage Master Plan will have an adverse impact on the budget of the Government and alternative financing mechanisms will have to be found in order to ensure that the application of the measures is financially sustainable (Green Climate Fund).

In addition to the funds which have been elaborated in annex 1.2, a new fund could be created to cater for the large costs linked to the construction of land drainage infrastructure. This new fund could be generated from specific taxes to be levied on fuel and other greenhouse gas emission sources which are the main cause of climate change and flooding. These taxes could be balanced by subsidies for clean technologies using renewable energy to encourage the transition in line with the objectives of the Government to reach 80% renewable energy production by 2030.

The monies collected and credited to the fund should be used exclusively for the construction of land drainage infrastructure in a transparent manner, through a non-profit SPV managed by an independent board of directors which would publish accounts accessible to the public.

Insurers could equally play an important role in the process by providing coverage for flooding events guaranteed by the aforementioned fund, a specific solidarity fund or the Government . This system would provide a solution for compensation and public outcry linked to flooding events. Specific low-cost premiums should be made available to low income families.

Flooding, Sustainable Development and Climate Change

The Climate Change Vulnerability Assessment and Adaptation Report financed by the Agence Francaise de Developpement in the context of the project Adapt'Action provides a true and clear assessment of the risks linked to the impacts of climate change in Mauritius as well as the adaptation measures to be adopted.

Most of these measures are nature-based solutions which need to be integrated in the developmental patterns of the Republic of Mauritius. In fact, the concept of Smart Cities should in principle incorporate flood attenuation basins and rain gardens in order to ensure that much of the runoff from the project area is disposed of locally without exerting additional pressure on downstream drainage infrastructure, water courses or natural drains. The use of green spaces and the reduction in the use of concrete are essential in this context. We understand that The Medine Group has used such concepts upstream of Flic en Flac in the Cascavelle Smart City project.

These nature-based climate change adaptation measures should be combined with climate change mitigation measures such as the creation of bicycle tracks along all roads in Mauritius and additional incentives for electric vehicles and renewable energy systems (solar panels for electrivity generation and solar water heaters).

ANNEX 1.2

IDENTIFICATION AND CHARACTERISATION OF FUNDING SOURCES / CONTRIBUTION TO THE PLAN ON SUSTAINABLE DEVELOPMENT ISSUES

All financial data are sourced from the Ministry of Finance website - EDB Economic Development Board - 2021 (https://budgetmof.govmu.org/Documents/2021_22PSIP.pdf)

In order to fulfil Mauritius' national environmental goals and needs, as well as commitments ratified at the international level, significant investments will be required. This is especially relevant in a post-COVID 19 context, where significant resources have had to be placed to support the economy of Mauritius.

In 2018, and prior to the COVID 19 pandemic and its impacts on society, the National Environment Commission (NEC) had recognised the need to allocate substantial financial resources to address environment-related priority issues as a matter of urgency. This has culminated into the revamping and consolidation of the National Environment Fund (NEF), which was recapitalised with Rs 2 Billion for the financial years 2018-2020 and an additional Rs 2 Billion in 2020-2021. However, for implementing the mitigation and adaptation measures under the Paris Agreement alone are estimated at Rs 190 Billion.

To fill this financial gap, enhancing efficiency in investments and resource mobilisation from local, regional and international sources as well as from multilateral funding mechanisms (Multilateral Environmental Agreements) and furthering the use of economic instruments are the priority approaches.

Mauritius forms part of the COMESA, SADC, IORA, AU and it is a beneficiary of preferential trade agreements. However, due to its recent economic development, Mauritius has reached the medium income group of countries and it does not therefore generally form part of the countries which may benefit from direct funding from international organisations

However, despite this situation, Mauritius has recently been a beneficiary of direct funding from the UNDP studies while the World Bank and AFD may provide financial support in the form of soft loans or technical support from consultants. The two major avenues for financing large land drainage projects therefore remain the Adaptation Fund and the Green Climate Fund.

Adaptation Fund

Since 2010, the Adaptation Fund has committed US$ 850 million to projects and programmes to date, including 123 concrete projects. This spans nearly 100 countries, including 19 small island developing states and 33 least developed countries, serving about 28 million total beneficiaries. It also pioneered Direct Access, empowering countries to access funding and develop projects directly through accredited national implementing entities.

Climate change is predicted to greatly affect the poorest people in the world, who are often hardest hit by weather catastrophes, desertification, and rising sea levels, but who have contributed the least to the problem of global warming. In some parts of the world, climate change has already contributed to worsening food security, reduced the predictable availability of fresh water, and exacerbated the spread of disease and other threats to human health.

Helping the most vulnerable countries and communities is an increasing challenge and imperative for the international community, especially because climate adaptation requires significant resources beyond what is already needed to achieve international development objectives.

The Fund is financed largely by government and private donors, and also from a two percent share of proceeds of Certified Emission Reductions (CERs) issued under the Protocol's Clean Development Mechanism projects.

The project has contributed USD 9,119,240 for Climate Change Adaptation Programme in the Coastal Zone of Mauritius. The project has now been completed but the fund may be used for the financing of land drainage projects.

Green Climate Fund

The major avenue for the funding of sustainable development/climate change adaptation measures therefore remains the Green Climate Fund. The Green Climate Fund (GCF) – a critical element of the historic Paris Agreement - is the world's largest climate fund, mandated to support developing countries raise and realize their Nationally Determined Contributions (NDC) ambitions towards low-emissions, climate-resilient pathways.

The GCF achieves its goal by investing across four transitions – built environment; energy & industry; human security, livelihoods and wellbeing; and land-use, forests and ecosystems – and employing a four-pronged approach:

1. Transformational planning and programming: by promoting integrated strategies, planning and policymaking to maximise the co-benefits between mitigation, adaptation and sustainable development.

2. Catalysing climate innovation: by investing in new technologies, business models, and practices to establish a proof of concept.

3. De-risking investment to mobilize finance at scale: by using scarce public resources to improve the risk-reward profile of low emission climate resilient investment and crowd-in private finance, notably for adaptation, nature-based solutions, least developed countries (LDCs) and small island developing states (SIDS).

4. Mainstreaming climate risks and opportunities into investment decision-making to align finance with sustainable development: by promoting methodologies, standards and practices that foster new norms and values.

This process, however, is very heavy administratively and in terms of timeframe, but Mauritius has benefited from funding at the level of USD 79.3 million from the GCF for five projects, including two adaptation projects, two mitigation projects and a cross-cutting project. Four of these projects cover multiple countries in the region, while one specific project is specific for Mauritius, addressing the acceleration of the transformational shift to a low carbon economy in the Republic of Mauritius.

Other Extra Budgetary Funds

A number of special and extra budgetary funds have been created by the Government of Mauritius, some of them being relevant to the financing of the land drainage infrastructure, namely: the Public Sector Investment Programme (Consolidated Fund), the COVID-19 Projects Development Fund, the National Environment and Climate Change Fund, the National Resilience Fund, the Lotto Fund and the COVID-19 Solidarity Fund. The COVID-19 Projects Development Fund accounts for 80% of total Special Funds' contribution, while the National Environment and Climate Change Fund, National Resilience Fund, Lotto Fund and COVID-19 Solidarity Fund account for the remaining 20%. Overall, the COVID-19 Projects Development Fund represents 16% of total PSIP.

Public Sector Investment Programme

The Public Sector Investment Programme (PSIP) is a rolling strategic investment plan for the public sector over the next five years (2021/22 – 2025/26). It covers capital projects executed by Ministries and Departments, Local Authorities, Statutory Bodies, State Owned Enterprises/Public Entities (SOEs) and Rodrigues Regional Assembly.

With the aim of providing greater visibility to investors, the PSIP –

1. captures projects where construction has already started and will be completed during the next five years as well as new projects where construction is planned to start during the coming year/s;
2. provides a list of project proposals that are at early stages of their project life cycle, for which funds are earmarked for preparation only; and
3. includes a list of public projects which are proposed to be implemented with the participation of the private sector.

The PSIP comprises projects funded through the Consolidated Fund, Special Funds and SOEs. Estimates of the PSIP for 2021/2022 amount to MUR 50.1 billion.

Sums have been earmarked for the construction of drains in the consolidated fund for 2021/2022, as described in the following PSIP Codes:

- H0394 Construction of drains in primary schools (MUR 1 million)
- H0393 Construction of drains in secondary schools (MUR 4 million)
- C083902 TMRSU Road Safety Programme Footpaths, walkways, drains and handrails (MUR 20 million)
- D0043, D0130, D0131, E0016, E0029, E0112, E0149 and E0174 NDU operationalisation of the Land Drainage Authority (MUR 485.5 million)

The total funds allocated for drainage issues in the Consolidated Fund for 2021/22 amounts to MUR 1.570 billion.

COVID-19 Projects Development Fund

The COVID-19 Projects Development Fund (PDF) has been set up on 28 April 2020 in the context of the implementation of an investment programme following the negative impact of the COVID-19 pandemic on the economy. The PDF contributes to the financing of projects specified in the Public Sector Investment Programme, such other projects, or such schemes or programmes, as the Minister may approve and consultancy, preparatory or advisory services in relation to projects, schemes and programmes referred to previously.

The PDF also finances projects under the Economic Recovery Programme (ERP), as approved by Government on 23 October 2020, and **drains projects under the National Flood Management Programme**. The ERP comprises a package of measures aimed at boosting GDP, protecting jobs and creating new ones, reducing dependence on imports and improving the wellbeing of the population.

The value of the PDF fund in 2021/2022 amounts to MUR 11.692 billion.

Sums have been earmarked for the construction of bridges in the consolidated fund for 2021/2022, as described in the following PSIP Codes:

C0624, C0625, C0716, C0713 (MUR 120 million) and National Flood Management Programme (MUR 3.6 billion).

National Environment and Climate Change Fund

The National Environment and Climate Change Fund (NECCF) was created under an Act of Parliament in 2002 to finance environment-related projects. The main objectives of the NECCF are, among others, to carry out programmes aimed at reducing pollution, to encourage education and research in the field of environment, to provide support to NGOs which are engaged in environment protection, to encourage local environmental initiatives, to promote activities relating to environment protection and management and to compensate victims in situations of environmental emergency and spills.

The NECCF covers projects, programmes and schemes in the following main areas: rehabilitation, protection and management of beaches, lagoons and coral reefs; management of solid waste, disaster risk reduction, cleaning and embellishment works and landslide management, green economy and environment protection. Land drainage may fall into these categories.

The total value of the NECCF in 2021/2022 amounts to MUR 2.222 billion.

Sums have been earmarked for the construction of drains in the consolidated fund for 2021/2022, as described in the following PSIP Codes:

- A0398, D0043, E0151, D0173, D0184 Flood Management Programme (MUR 982.91 million in 2020/2021 and MUR 46 million in 2021/2022)
- A0399 and D0173 Clean up Mauritius and Embellishment Programme (MUR 57 million).

National Resilience Fund

The National Resilience Fund (NRF) was created in January 2012 to strengthen the resilience of the domestic economy.

The objects of the Fund are, among others, to support enterprises that show concrete efforts at building permanent resilience, act as a contingency fund to **shore up public finances if required**, strengthen the resilience of the economy, finance specific programmes, projects and schemes (to empower vulnerable persons and provide job opportunities for young people, in support of SMEs and enterprises in general, to foster and support their long- term restructuring and deleveraging while providing short term breathing space, especially on cash flow problems and financing requirements, to enable SMEs and enterprises in general to innovate and acquire technology that enables them to grow and become more productive and globally competitive to enable SMEs to have access to industrial space at affordable rates), support restructuring of SME service-providing institutions to allow them to provide better and more effective service, finance promotional campaigns in support of enterprises to consolidate traditional markets and enter into regional as well as new fast growing emerging markets and support the creation of new financing instruments and the development of new economic sectors.

The total value of the NRF in 2021/2022 amounts to MUR 1.402 billion.

Lotto Fund

The Lotto Fund was created in October 2016 to contribute to the financing of projects, schemes and events in relation to sports, culture, leisure, heritage or art development, preservation and rehabilitation of historical and cultural heritage sites and structures, community development, education, health, innovation initiatives, protection of environment; and **support to victims of natural calamities**.

The total value of the Lotto Fund in 2021/2022 amounts to MUR 131 million.

COVID-19 Solidarity Fund

The COVID-19 Solidarity Fund was created by way of regulation following the outbreak of the COVID-19 pandemic across the world and the severe damage that it caused to economies, public health care systems and to the people.

The objectives of this Fund are to contribute to the financing of projects, programmes and schemes related to the COVID- 19 virus and other related public health issues, provide financial support to persons residing in Mauritius and organisations being affected by the COVID-19 virus and provide assistance in such other circumstances related to the COVID-19 virus.

The total value of the COVID-19 Solidarity Fund in 2021/2022 amounts to MUR 50 million.

ANNEX 2

FEASIBILITY ASSESMENT REPORT FOR PRIORITY SITES (D4.1)

ANNEX 3

FEASIBILITY ASSESMENT REPORT FOR COMPLEMENTARY SITES (D4.2A AND D4.2B)

ANNEX 4

STANDARD AND ILLUSTRATIVE DETAILS

List of Drawings

A. Standard Details

Standard Details 1	*Road kerbs*
Standard Details 2	*Open V-drains*
Standard Details 3	*Open U-drains*
Standard Details 4	*Typical Drains Sections*
Standard Details 5	*Drains within Narrow Roads*
Standard Details 6	*Culvert Details*
Standard Details 7	*Culverts within built-up Areas, Drains along Steep Slopes & Drain Outlet*
Standard Details 8	*Upgrading of Hydraulic Capacity of Bridges*
Standard Details 9	*Drains & Floodwalls*
Standard Details 10	*River Bank Erosion Control*
Standard Details 11	*NDU Standard Details*

B. Illustrative Details

Illustrative Details 1	*Restoration of major Beds of Rivers*
Illustrative Details 2	*Detention Basins*
Illustrative Details 3	*Swales*
Illustrative Details 4	*Rain Gardens*
Illustrative Details 5	*Energy Breakers*
Illustrative Details 6	*Flap Valves & Pumps*