MINISTRY OF ENVIRONMENT AND ENERGY
REPUBLIC OF SEYCHELLES

THE STUDY FOR COASTAL EROSION AND FLOOD CONTROL MANAGEMENT IN THE REPUBLIC OF SEYCHELLES

FINAL REPORT SUMMARY

MARCH 2014

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

CENTRAL CONSULTANT INC.
CTI ENGINEERING INTERNATIONAL CO., LTD.

GE
JR
10-070

MINISTRY OF ENVIRONMENT AND ENERGY
REPUBLIC OF SEYCHELLES

THE STUDY FOR COASTAL EROSION AND FLOOD CONTROL MANAGEMENT IN THE REPUBLIC OF SEYCHELLES

FINAL REPORT SUMMARY

MARCH 2014

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

CENTRAL CONSULTANT INC.
CTI ENGINEERING INTERNATIONAL CO., LTD.

Exchange Rate

US$ 1 = SCR 11.381 = JPY 102.19

February 2014

Table of Contents

Abbreviations and acronyms

AfDB	African Development Bank
CAAID	Climate Affaires, Adaptation and Information Division
CAMS	Coastal Adaptation and Management Section
CESD	Climate and Environment Service Division
CFTC	Commonwealth Found for Technical Cooperation
COP2	Second Conference of the Parties
CRU	Climate Research Unit, United Kingdom
DA	District Administrator
DOE	Department of Environment
DOT	Department of Transport
DMP	Disaster Management Plan
DRDM	Divisions of Risk and Disaster Management
DRR	Disaster Risk Reduction
EEWS	Environment Engineering and Wetland Section
EIA	Environmental Impact Assessment
EMPS	Environment Management Plan in Seychelles
GCM	Global Climate Model
GDP	Gross Domestic Product
GEF	Global Environment Facility
GIS	Geographical Information System
GOJ	Government of Japan
GOS	Government of the Republic of Seychelles
GPS	Global Positioning System
GUI	Graphical User Interface
HEC-RAS	Hydrologic Engineering Centers-River Analysis System
IOC(UNESCO)	International Oceanographic Commission
IPCC	International Panel on Climate Change
ISDR	International Strategy for Disaster Reduction
JICA	Japan International Cooperation Agency
MCDY	Ministry of Community Development and Youth
MEE	Ministry of Environment and Energy
MHAETE	Ministry of Home Affairs, Environment, Transport and Energy
MLUH	Ministry of Land Use and Housing
MND	Ministry of National Development
MSLD	Mean Sea Level Datum
NBS	National Bureau of Statistics
NDC	National Disaster Committee

NGO	Non-Governmental Organization
NMS	National Meteorological Services
NOAA	National Oceanic and Atmospheric Administration
NTB	National Tender Board
OJT	On the Job Training
POU	Procurement Oversight Unit
PUC	Public Utilities Corporation
QGIS	Quantum Geographical Information System
RECOMAP	Regional Coastal Management Programme
SCR/SR	Seychellois Rupee
SEA	Strategic Environmental Assessment
SSDS	Seychelles Sustainable Development Strategy
SST	Sea Surface Temperature
TCPA	Town and Country Planning Act
TSZ	Tidal Staff Zero
UNESCO	United Nations Educational, Economical, Scientific and Cultural Organization
UNFCC	United Nations Framework Convention on Climate Change
UNDP	United Nations Development Programme

Chapter 1 Introduction

1-1 Background

The Republic of the Seychelles consists of over 115 islands scattered in the Western Indian Ocean and has a total land area of 452 km^2. The population was estimated at 87,000 in 2011 with over 90% concentrated in the narrow coastal strips around the three main islands of Mahe, Praslin and La Digue. The country depends on its coastal zones for most of its economic activities such as tourism and fishing. About 200,000 tourists visit the Seychelles annually.

The coastal zones have been affected by several disasters in recent years, such as the coastal erosion of Anse Kerlan on Praslin since 1986, disasters caused by the Indian Ocean Tsunami in 2004, three days of inundation in Victoria in 2004, and tidal flooding in the north of Mahe in 2007. Because of the rising sea level and increased rainfall intensity caused by climate change, the risk of natural disasters is increasing, alongside tourism and housing development in the coastal zones.

The Government of the Republic of the Seychelles (hereinafter referred to as GOS) prioritised the issues of coastal erosion and flooding in the 10-year Environmental Management Plan from 2000. However, coastal conservation and flood management have not been effectively implemented in recent years.

Therefore, GOS requested the Study on Coastal Erosion and Flood Control Management in the Republic of the Seychelles (hereinafter referred to as the Study). The Study was conducted from February 2011 to March 2014 through the Detailed Planning Survey by the Japan International Cooperation Agency (hereinafter JICA).

1-2 Objectives and Study Area

The objectives of the Study are as follows:

1) To formulate a coastal conservation plan with regard to disasters to enhance coastal management;
2) To formulate a flood management plan to reduce flood risks;
3) To implement pilot projects in coastal conservation and flood management in order to confirm the effectiveness of the measures to be taken and to enhance the capacity of the relevant personnel engaged in coastal conservation and flood control management;
4) To undertake technology transfer to the relevant personnel through the joint activities of the Study as well as trainings and workshops.

The Study area is located on the islands of Mahe, Praslin and La Digue where damage from coastal erosion and flooding has been caused.

1-3 Study Components and Methods

The implemented Study was divided into four components, namely: basic study, formulation of plans, implementation of pilot projects and technology transfer.

(1) Component 1: Basic Study

The basic study consists of the collection of existing data related to disasters in the coastal zones and the study of the causes of coastal erosion and flooding. Surveys, monitoring and observation of rainfall and water levels, analysis of waves, coastal erosion, and probability of rainfall and flooding were conducted.

(2) Component 2: Formulation of Plans for Coastal Conservation and Flood Management

With regard to coastal conservation, the coastal characteristics and the damage caused by coastal erosion were investigated. The direction of countermeasures was studied and the coasts were classified. The damaged coasts were selected as priority areas and coastal conservation plans were formulated in the detailed study.

The plan for flood management was divided into the plan for Victoria Town and the plan for other flood risk areas. The plan for Victoria Town was formulated after studying the direction of the plan. For the other flood risk areas, the plan was formulated for several priority areas which were selected according to local characteristics and severity of damage. The flood management plan was formulated for the priority areas in the detailed study.

(3) Component 3: Pilot Projects

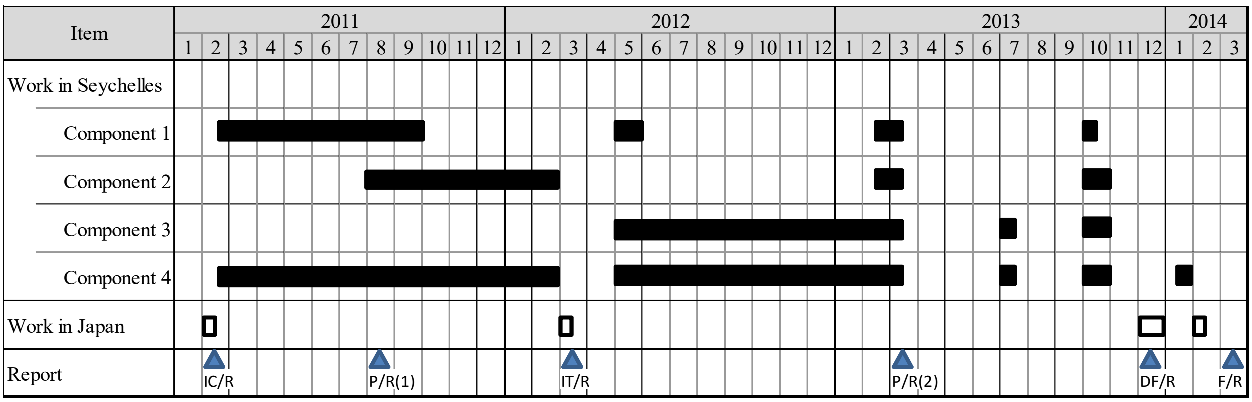
The pilot projects were selected from the coastal conservation plan and flood management plan in view of urgency and the whole or part of the plan was executed. The projects were executed with consideration given to EIA procedures, procurement procedures and the participation of local people.

(4) Component 4: Technical Transfer

The technology in coastal conservation and flood management was transferred to the members of all the related government organisations. The capacity development of the local private sector (NGOs, construction companies and consultants) was also considered from the perspective of fairness. Technology transfer was conducted by OJT (on-the-job training), workshops, seminars and training in Japan in the fields of observation and analysis, planning, execution of pilot projects and management of plans.

The schedule of the Study is shown in Table 1-3-1.

Table 1-3-1: Study Schedule



Note: IC/R: Inception Report, P/R: Progress Report, IT/R: Interim Report, DF/R: Draft Final Report, F/R: Final Report

1-4 Execution of the Study

The Study was carried out by the Study Team and counterpart officials from the Climate Affairs, Adaptation and Information Division, Department of Environment, Ministry of Environment and Energy, under the steering committee and technical committee composed of officials from related ministries.

Chapter 2 Basic Study

2-1 Natural Conditions

2-1-1 Geography

The land areas of the three islands which are the object of the study are Mahe 155km^2, Praslin 38km^2 and La Digue 10km^2. The islands consist of steep granite mountains surrounded by narrow plains and coral reefs. The coasts are classified into three types: rocky granite cliffs, flat sandy beaches and reclaimed artificial coasts. The plains are characterised by coral reefs and sandy beaches with occasional wetlands behind. The reclaimed land is protected by revetments with a height of 2m to 4m above mean sea level. The plains are relatively small covering 5% of the total area of Mahe and Praslin and 16% of La Digue.

2-1-2 Climate

The climate of the Seychelles is classified into two types: northwest monsoons from December to March and southeast trade winds from May to October. In Mahe as shown in Table 2-1-1, the temperature and the humidity are high. The mean temperature is 26.9ºC and the mean humidity is 80%. The mean annual rainfall is 3,500mm in the mountain areas and 1,500mm along the coasts and during December to February the islands receive the most rain.

Table 2-1-1: Climate Conditions

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	402.6	283.2	194.9	186.7	151.6	105.1	76.6	119.3	154.0	189.7	206.3	302.8
Temperature (ºC)	26.9	27.4	27.8	28.1	27.8	26.7	26.0	26.0	26.5	26.9	26.9	26.9
Humidity (%)	82	80	80	80	79	79	80	80	79	79	80	82
Wind Direction	NW	NW	NW	SW-NW	SE	SE	SE	SE	SE	SE	SW-NW	NW
Wind Speed (knots)	6.3	6.3	5.2	4.9	7.8	10.4	11.4	12.1	11.3	7.9	5.4	5.4

(http://www.seychelles.com/en/about_seychelles/climate.php)

In the southwest Indian Ocean, cyclones are generated from October to May and Mahe and the other islands are located outside of the cyclone routes. However, in 1953 and 2006 cyclones caused a great deal of damage. Cyclone Bond became the first cyclone to hit the Seychelles territory.

Figure 2-1-1 Yearly cumulative rainfall map for Mahe Island

(Source: Seychelles Meteorological service, http://www.pps.gov.sc/meteo/Climate.htm)

The mean annual rainfall on Mahe is 2,000mm in the north, 2,200mm to 2,600mm in Victoria and 3,000mm in the mountain range running from northwest to southeast. The rainfall increases at high altitudes.

2-1-3 Oceanic Conditions

The tidal range is a mean high water spring of 1.63m and mean low water spring of 1.11m and 0.45m at the international airport. The waves are as shown in Figure 2-1-1, with a mean significant height of about 1m high in January and 2m in July. Most waves come from the southeast or south and change direction according to the season. The maximum significant wave height with 1/100 probability is estimated at 6.5m. The tsunami generated by the Indian Ocean Earthquake in 2004 reached Mahe Island, attaining 4.4m above mean sea level at maximum.

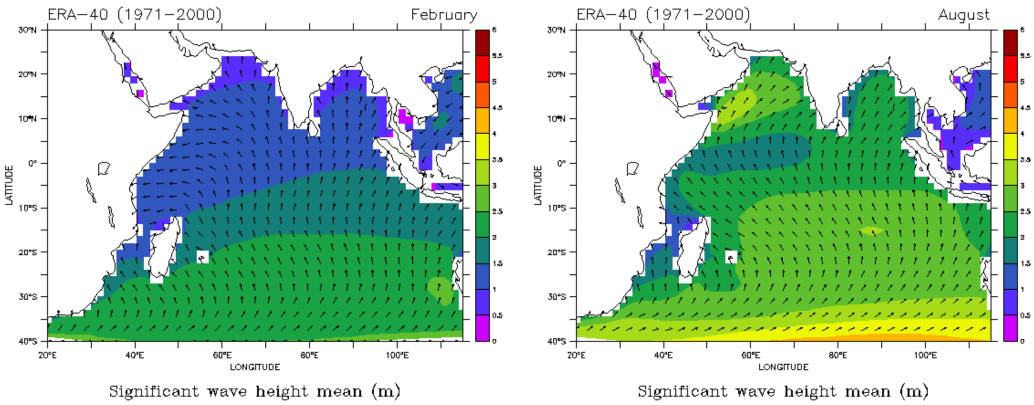


Figure 2-1-1: Monthly Mean Significant Wave Height (m): February and August

2-2 Socio-economic Conditions

2-2-1 Population

The total population of the Seychelles was about 90,000 in 2011 with 86% living on Mahe as shown in Table 2-1-1. The average family size is five members and 20% of the population is under the age of 15. The life expectancy at birth is 73.3 years for both sexes; 70 years for men and 77 years for women (Seychelles in Figures, 2012 ed., NBS).

Table 2-2-1: Population and GDP

Item	2006	2007	2008	2009	2010	2011
Total Population (thousand)	84.6	85.0	87.0	87.3	89.7	87.4
Male	42.9	43.2	45.0	45.0	45.9	43.1
Female	41.7	41.8	42.0	42.3	43.8	44.3
Gross Domestic Product						
GDP (million rupees)	5,600	6,962	9,100	11,450	11,621	13.119
Per capita GDP (thousand rupees)	66.2	81.9	104.7	131.2	129.5	150.0

(Seychelles in Figures, 2012 ed., NBS)

2-2-2 Economic Activity

GDP was 13.1 million rupees as shown in Table 2-2-1 and government expenditure was 5.1 million rupees in 2011. The main industries are tourism and fishing and tourists account for 90% of visitors, numbering about 200,000 in 2012 as shown in Table 2-2-2. Tourism is the major source of 70% of foreign exchange and employs 30% of the workforce.

Table 2-2-2: Trends in Visitor Arrivals

Item	2006	2007	2008	2009	2010	2011
Total Visitor Arrivals (*1,000)	140.6	161.3	159.0	157.5	174.5	194.5

(Seychelles in Figures, 2012 edition, NBS)

2-2-3 Land Use

In Mahe almost 75% of the land is forest and protected areas, with residential areas accounting for 20% and increasing with urban development as shown in Table 2-2-3. (Zoran Vuksanovic (2008): Ile Perseverance, a new town in the Seychelles has an innovative way of avoiding urban sprawl, 44th ISOCARP Congress).

Table 2-2-3: Land Use on Mahe

Land Use	Area km^2	%	Land Use	Area km^2	%
Residential Areas	32	20.1	Built-up non-residential	12	7.7
Protected Areas	16	10.0	Forest area	59	38.6
Agriculture	26	16.7	Total	155	100

(Zoran Vuksanovic (2008): Ile Perseverance, a new town in the Seychelles has an innovative way of avoiding urban sprawl, 44th ISOCARP Congress: Included unknown $10km^2$ and 6.5%)

2-3 Policy, Legal Framework and Organisations

2-3-1 National Policy

One of the main policies related to coastal conservation and flood management is the Seychelles Sustainable Development Strategy (SSDS 2012-2020) which was revised in 2012 from the former Environment Management Plan of Seychelles (EMPS). In the SSDS, there are 13 thematic goals. The goals contain six sub-goals which are related to the formulation of coastal conservation and flood management plans as follows:

- Development of the necessary structures and policy framework to integrate social development and sustainable use of resources.
- Long-term national development and land use management strategies for sustainable land management.
- An effective and integrated national coastal zone management framework.
- Enhancement of actions on mitigation of climate change.
- Provision of life-long learning experience at all levels of society to adopt environmentally sustainable practices.

- Strengthening of the capacity to effectively manage the environment of the Seychelles and to establish an effective environmental information management system.

Other than SSDS, the Seychelles National Climate Change Strategy (2009) and Seychelles National Disaster Management Policy (2011) for disaster reduction were formulated. These policies cover disasters and action according to the policy is necessary.

2-3-2 Legal Framework

Laws related to coastal conservation and flood management are as follows;

- Town and Country Act, 1975
- Town and Country Planning Act, 1972
- Environment Protection Act, 1994
- Beach Control Act, 1971
- Removal of Sand and Gravel Act, 1991

2-3-3 Organisations

The organisations responsible for coastal conservation and flood management are the Ministry of Environment and Energy (MoEE) and the following of the 13 other Ministries.

- Ministry of Home Affairs and Transport
- Ministry of Land Use & Habitat

In the MoEE, the Climate Affairs, Adaptation and Information Division（CAAID）is responsible for coastal conservation and drainage improvement, the National Meteorological Services（NMS）is responsible for meteorological observation, and the Division of Risk and Disaster Management（DRDM）is responsible for disaster response. The organisation of GIS is also attached. Under the Climate Affairs, Adaptation and Information Division, the Coastal Affairs and Management Section manages the coastal zones, drainage and wetlands with about seven members.

2-4 Coastal Erosion Analysis

2-4-1 Coastal Disasters

Coastal erosion in the past was recorded at Anse Kerlan in Praslin from 1989 and five groynes were constructed. The erosion still continues at present. At La Passe in La Digue the erosion started in 1991 after the construction of breakwaters in the south. A hospital was in danger and rock armouring was constructed. The Indian Ocean Tsunami in 2004 reached 1.6m to 4.4m on the ground and caused the destruction of a bridge. Other than that, at North East Point wave runup caused damage on the coastal road at high tide.

2-4-2 Analysis of Coastal Erosion

Coastal erosion was analysed on the reported coasts of North East Point, Anse Aux Pins, Au Cap and Baie Lazare in Mahe, Anse Kerlan in Praslin and La Passe in La Digue. The data used were 1960 maps, 1998 GIS data and recent Google Earth and aerial photos.

The average long term changes in the coastline from 1960 to 1998 and from 1998 to 2011 are as shown in Figure 2-4-1.

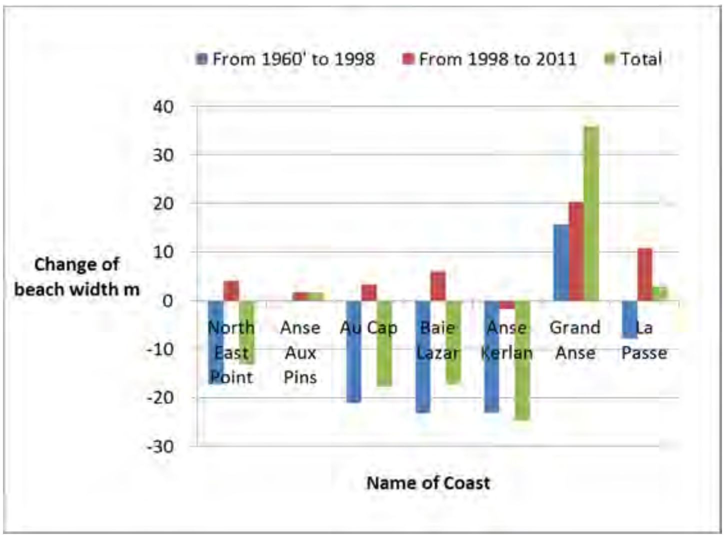


Figure 2-4-1 Changes in Long Term Coastline from 1960 to 2011

From the analysis it was found that about 20m of the coast had been eroded in the 38 years from 1960 to 1998 at North East Point, Au Cap, Baie Lazare and Anse Kerlan. In the 13 years from 1998 to 2011 the erosion was not severe and some coasts accreted. The accuracy of determining the coastline is about 5m on the maps or aerial photos. Therefore, there is some uncertainty. The coast at Grand Anse next to the coast at Anse Kerlan has been accreting continuously. At La Passe, until 1998 the coast was eroded but recently it has accreted. No changes have occurred at Anse Aux Pins. The characteristics and the changes of each coast are explained in the following.

(1) North East Point

The 1.7km long coast is located in the northern part of Mahe and receives moderate waves from north to east in the northwest monsoon period. Because the beach alignment is convex, alongshore sediment movement is predominant. Off the beach there exists a coral reef and beach rock. The beach width varies from 10m to 40m and is about 20m on average. In 2004 the coastal road, bus stop and rehabilitation centre were affected by wave overtopping.

The coastline in the 1960s and in 2011 is shown in Figure 2-4-1 and was eroded in total. The rate is shown in Figure 2-4-1 as about 20m. The coastline changes due to the seasonal changes in wave direction. From October to March the coast is eroded in the north and accreted in the south. From April to September the change is reversed. In the eroded part, waves overtop the road especially at high tide. The reason for the long term erosion is not clear.

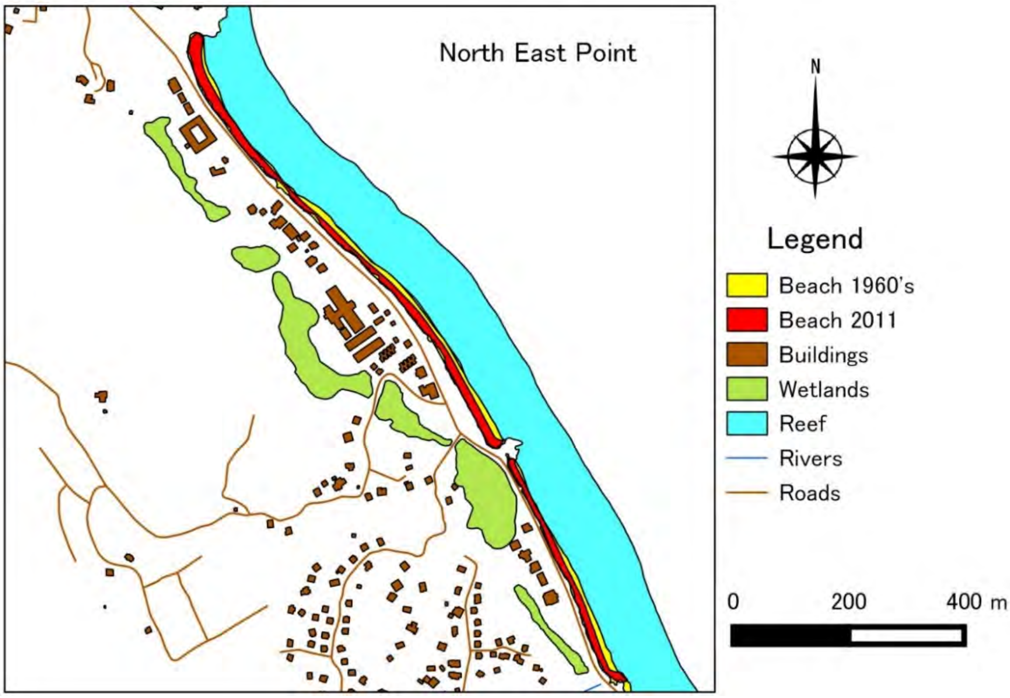


Figure 2-4-1 Beach Changes at North East Point from the 1960s to 2011

(2) Anse Aux Pins

The 1.5km east-facing coast is located south of the international airport. Reclamation off the coast prevents incident waves. It was reported that the coast was eroded and there was a beach scarp. The long-term change is accretion as shown in Figure 2-4-2 from the 1998 GIS data and recent aerial photos of the beach because of the decreasing waves due to reclamation and a breakwater.

The beach scarp was caused by scouring at the foot and lack of recovery because of small waves. The beach in front is becoming shallow and accumulating. The erosion can be prevented by crushed stones at the foot of scarp.

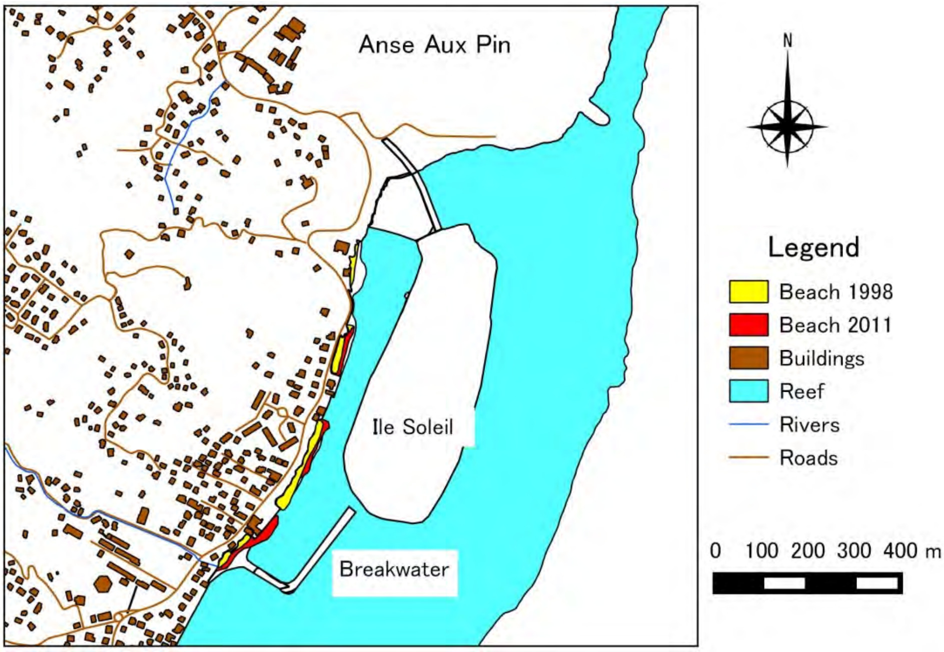


Figure 2-4-2: Beach Changes at Anse Aux Pins from the 1998 to 2011

(3) Au Cap

The east-facing coast is 1km long, made of coral sand and located in the southeast of Mahe, with a 400m-wide coral reef off the beach. The road along the coast is affected by wave overtopping during the southeast trade winds.

The coastline was eroded for about 20m of the whole coast until 1998 as shown in Figure 2-4-3. Several groynes were constructed and the coast in the south accreted because of the southeast trade winds.

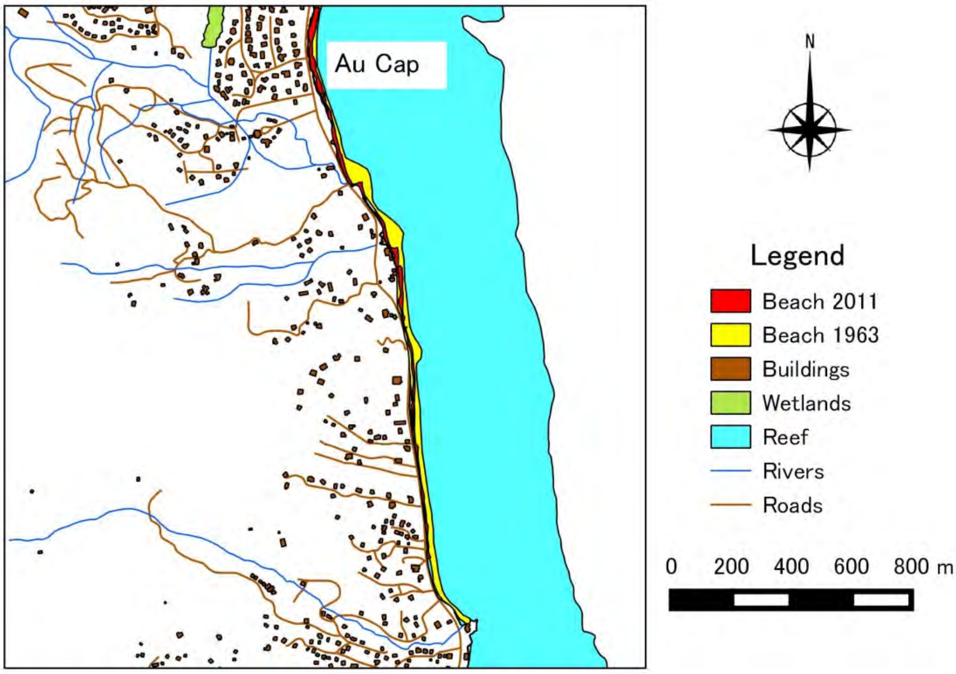


Figure 2-4-3: Beach Changes at Au Cap from the 1963 to 2011

(4) Anse Royale

The 2.5km-long coast is located on the southeast coast of Mahe, with headlands on both sides. It faces the east, with reefs from 500m to 800m wide. The road runs along the coast.

The change in the coastline is shown in Figure 2-4-4 from 1960 to 2011. Erosion was seen in the north and south but was not evident in the middle part. It was said that channel dredging for fishing boats caused the erosion. However, it is not clear. In some parts a coastal revetment that had been constructed was damaged. Recently, rock armouring was constructed for protection.

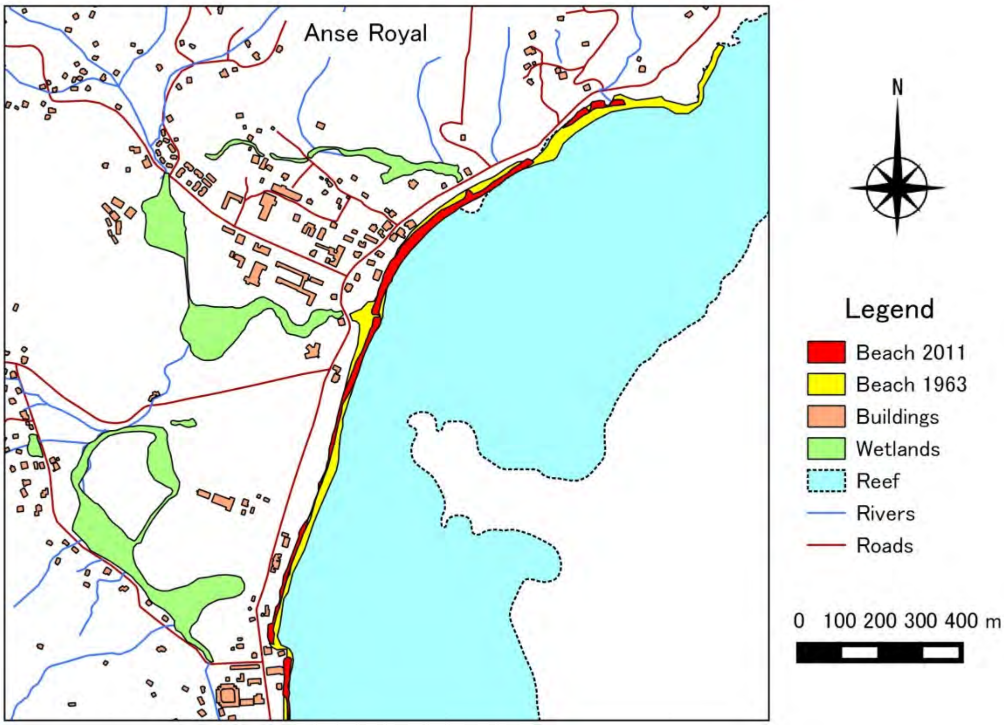


Figure 2-4-4: Beach Changes at Anse Royale from the 1963 to 2011

(5) Baie Lazare

The 2.2km-long coast is located on the west coast of Mahe and receives long waves from the southwest. The Baie Lazare River flows into the sea in the north. No reefs have developed in front of the river mouth. The road runs along the coast and has wave overtopping problems because of the low ground level.

The coastline was clearly eroded for about 20m until 1998 as shown in Figure 2-4-5. The change was caused before 1978 and the reason is not clear. Possibly the sand bar at the river mouth was washed away at a time of flooding and the sediment was lost.

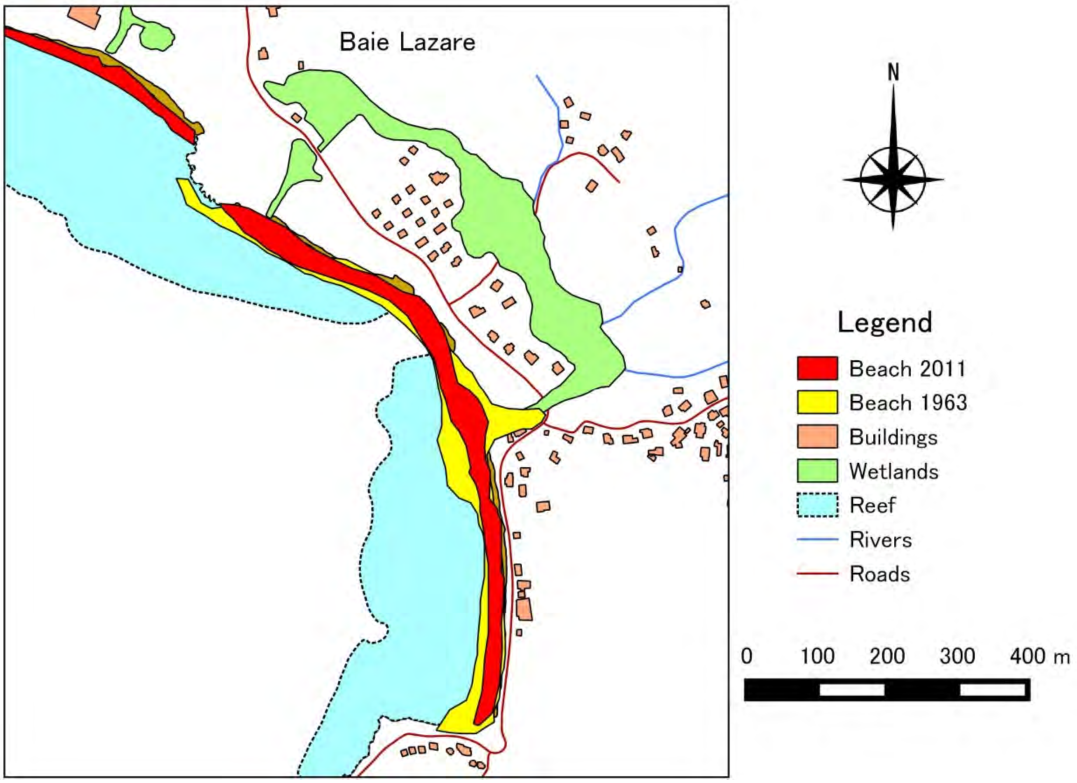


Figure 2-4-5: Beach Changes at Baie Lazare from the 1963 to 2011

(6) Anse a La Mouche

The west-facing coast is about 2.5km long and is located in the southwest of Mahe Island, with a 200m-wide coral reef off the beach. Waves from the west generate longshore sediment transport from the mouth to the back of the bay and the coast at the back was accreted.

The coastline changes from the 1960s to 2011 as shown in Figure 2-4-6 show the overall accretion at the back of the bay. Reclamation and a jetty caused accretion in the west and the coast in the east is stable. On the east side of the jetty, the coast is narrow and has wave overtopping problems.

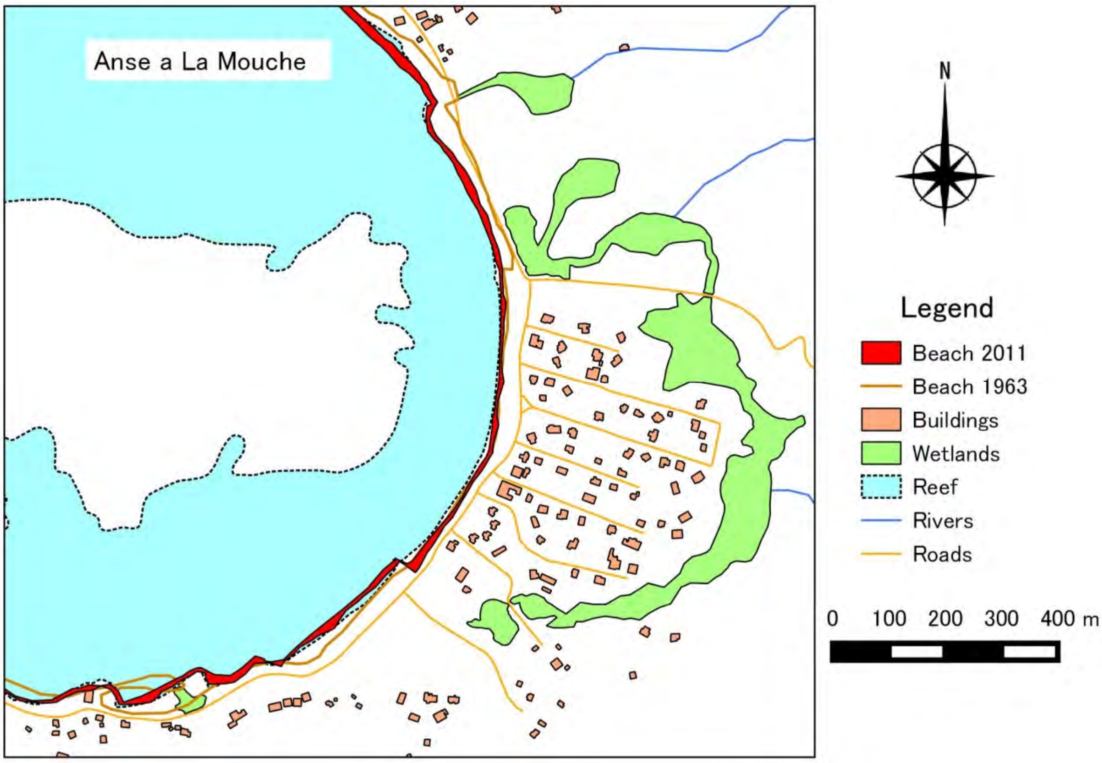


Figure 2-4-6: Beach Changes at Anse a La Mouche from the 1963 to 2011

(7) Anse Kerlan

The coastline at Anse Kerlan located in the north of Praslin consists of 7km-long littoral cells and continues as far as Grand Anse. The coast at Anse Kerlan is convex and faces east with a relatively narrow 500m reef and the coast at Grand Anse faces south with a coastal road and wide reef extending more than 1km.

The coastline changes at Anse Kerlan are shown in Figure 2-4-7. The coast was eroded overall for about 30m. On the other hand, the coast at Grand Anse accreted for 20m as shown in Figure 2-4-8. It is estimated that sediment was gradually transported from Anse Kerlan to Grand Anse. At Grand Anse the wave action is too weak to transport sediment to Anse Kerlan because of the wide reef.

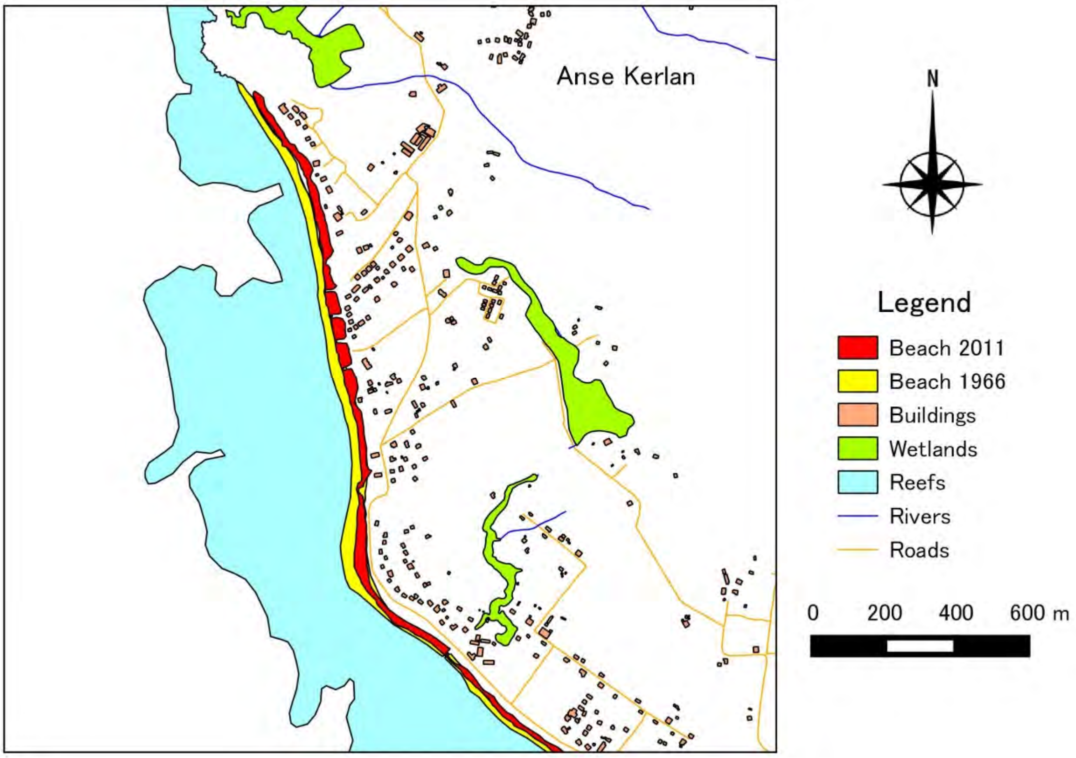


Figure 2-4-7: Beach Changes at Anse Kerlan from the 1966 to 2011

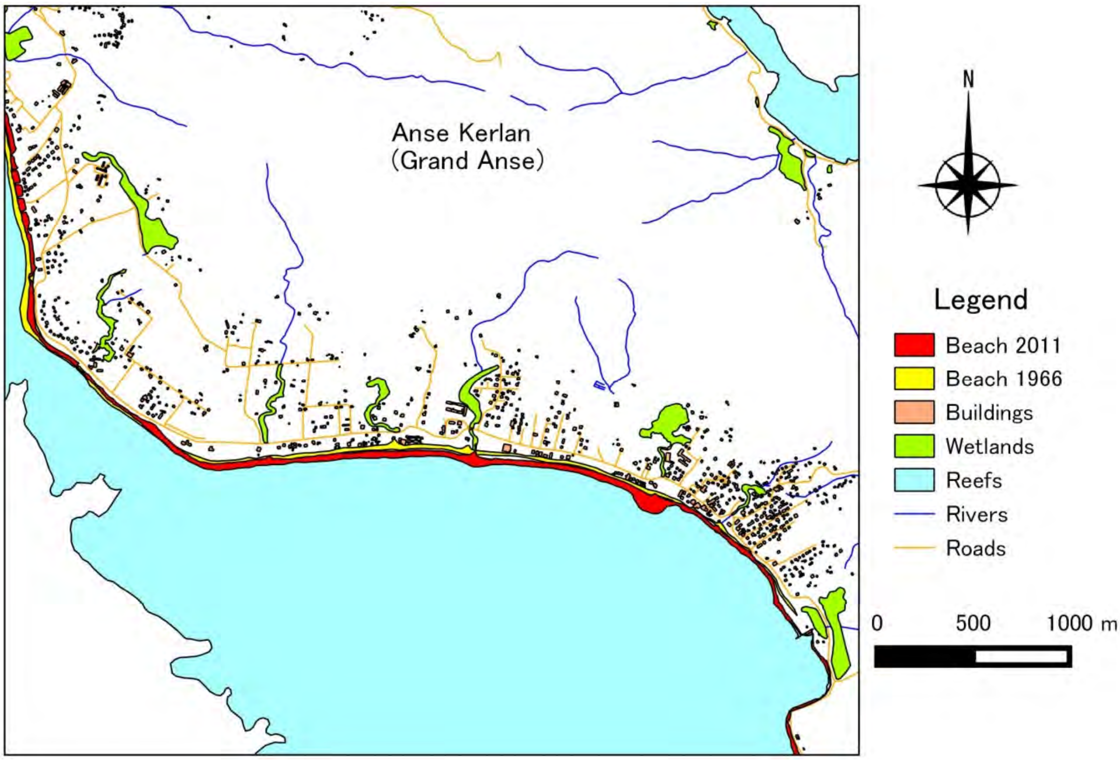


Figure 2-4-8: Beach Changes at Anse Kerlan (Grand Anse) from the 1966 to 2011

(8) La Passe

The coast is located in the western part of La Digue, with a coral reef about 300m wide, and it receives waves from the northwest and southwest because Praslin is located on the west side of the island. The construction of breakwaters for the pier and anchorage caused sediment transport from the south, resulting in accumulation south of the jetty and erosion further south. The process is shown in Figure 2-4-9. The coast is accreting as a whole but is partly eroded.

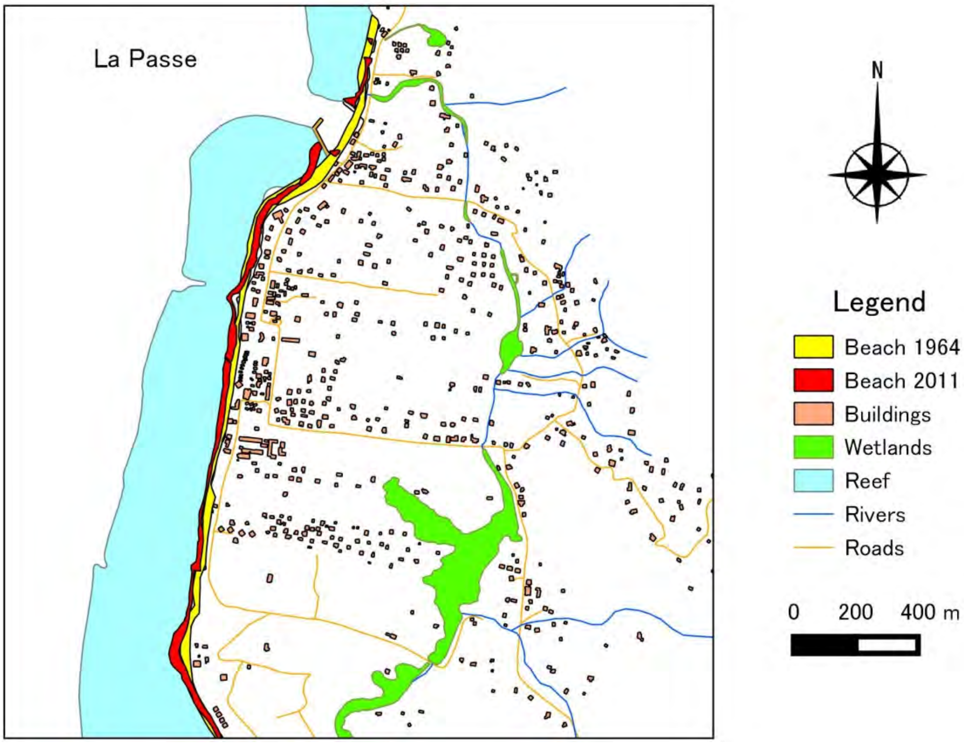


Figure 2-4-9: Beach Changes at La Passe from the 1964 to 2011

2-4-3 Existing Coastal Structures

In the Seychelles, coastal structures have been constructed for coastal protection and harbours. They include revetments, groynes, detached breakwaters and breakwaters.

The revetments are vertical type at Anse Aux Pins and Anse Royal, and rock armouring type at North East Point, Anse Royal, Beau Vallon and reclaimed land. Wooden pile revetments were tried at Baie Lazare and Anse a La Mouche and have stability problems due to wave overtopping.

Groynes have been used at Anse Aux Pins and Anse Kerlan in Praslin and La Passe in La Digue. Detached breakwaters were used at La Passe, but are not very effective because the opening is too narrow. Breakwaters were constructed at fishing ports such as Bel Ombre and La Passe.

2-5 Analysis of Flood Disasters

2-5-1 Past Flood Disasters

In the Seychelles, there is no monitoring system for flood conditions such as inundation depth and inundation duration, therefore past records of flood disasters are limited.

The JICA Study Team browsed through old newspapers to gain a better understanding of the flood situation in the last 25 years. A summary of flood disasters in the last 25 years is shown in Table 2-5-1. According to the newspaper articles, heavy rainfall caused landslides, inundation and flooding which damaged roads, houses and other facilities.

Based on interviews with DRDM, during the recent flood in La Digue, residents were not evacuated during the event. They stayed in their houses and waited until the water level subsided. Moreover, the contingency plans for emergencies had been not approved by the local and national governments.

Table 2-5-1 Summary of Past Flood Disasters in the Last 25 Years

Date	Area	Location	Description
31st July 1989	Mahe	Anse Aux Pins, Pointe Larue	Flooding
28th January 1990	Mahe	Belonie, La Louise, Beau Vallon	Flooding / landslide
18th-19th February 1990	Mahe	Victoria Town, Anse Etoile, Pointe Larue, Mont Fleuri and Bel Eau	Flooding / overflow / damage to houses
18th-22nd May 1990	Mahe	Mont Buxton, Port Glaud, Les Mamelles, Anse Aux Pins	Flooding / landslide/ damage to houses
16th February 1993	Mahe	Victoria, Albert Street	Flooding
18th February 1993	La Digue	La Passe, Anse Reunion	Flooding / mud / damage to drainage and road
10th-13th January 1997	Mahe	Mont Fleuri, Roche Caiman, Foret Noire, Bel Air	Flooding / landslide
9th-12th February 1997	Mahe	Foret Noire, Plaisance. Mont Fleuri	Flooding / landslide
13th-17th August 1997	Mahe La Digue	Victoria Town, Beau Vallon, Pointe Conan, Takamaka	Flooding / overflow / collapsed roads
5th November 1997	Praslin	Grand Anse, Baie Ste Anne	Flooding
29th-30th December 2004	Mahe	Northern regions of Mahe, Victoria Town, Beau Vallon	Flooding / inundated houses / damage to public infrastructure
8th-12th June 2005	Mahe	Grand Anse, Anse Boileau, Port Glaud, Anse Royale, Le Niol	Flooding / landslide / falling of trees
4th-5th January 2006	Mahe	North Mahe, Pointe Conan, Beau Vallon and Mont Buxton	Flooding / landslide / collapsed roads

Source: “Seychelles NATION” Newspaper in Seychelles, Rainfall Data of National Meteorological Services

2-5-2 Flood Analysis

2-5-2-1 General

Flood analysis is conducted in accordance with the following flowchart.

1. Rainfall Analysis

- Collection of Rainfall Data
- Estimation of Probable Rainfall at Each Station
- Consideration of Geographical Distribution of Probable Rainfall
- Equipment Installation for Hydrological Observation

↓

2. Calculation of Design Flood Discharge

- Determination of Return Period for Flood Management Plan
- Setting of Parameters
- Calculation of Design Discharge

↓

3. Flood Model Development and Analysis

- Understanding of Inundation Type and Model Selection
- Setting of Boundary Conditions (Inflow, Tidal Level, Topography)
- Model Verification
- Calculation of Water Level in Accordance with Design Flood Discharge

Figure 2-5-1: Procedures of Flood Analysis

The calculation results and evaluation of the water level for the flood management plan are shown in Chapter 5.

2-5-2-2 Rainfall Analysis

(1) Collection of Rainfall Data

There are 26 rain gauge stations operating at present on Mahe Island and rainfall data for over 20 years are available at 22 locations. Hourly rainfall data are limited to the Seychelles' international airport since the other observatories measure only daily rainfall data, hence the data necessary for analysis of the flood conditions are insufficient. Table 2-5-2 and Figure 2-5-2 show the location of the rain gauge stations.

Table 2-5-2: List of Rain Gauge Stations

NO	Name	Height (m)
1	Seychelles Airport	2
2	Rawinsonde	2
6	Cascade	110
7	La Misere (Fairview)	342
16	Anse Royale PUC	80
17	Anse Royale Police Stn	2
19	Quatre Bornes	85
21	Anse Soleil	8
22	Pointe Au Sel	38
23	Anse Forbans	5
32	Anse Boileau	5
33	Grand Anse Waterworks	2
37	Tea Factory	390
41	Bon Espoir	240
45	La Misere (Mr. Rose)	455
57	Rochon Waterworks	200
58	Hermitage Waterworks	80
61	St Louis	182
74	Le Niol Waterworks	22
76	La Gogue	120
77	Ma Constance(North East)	112
78	Belombre	25

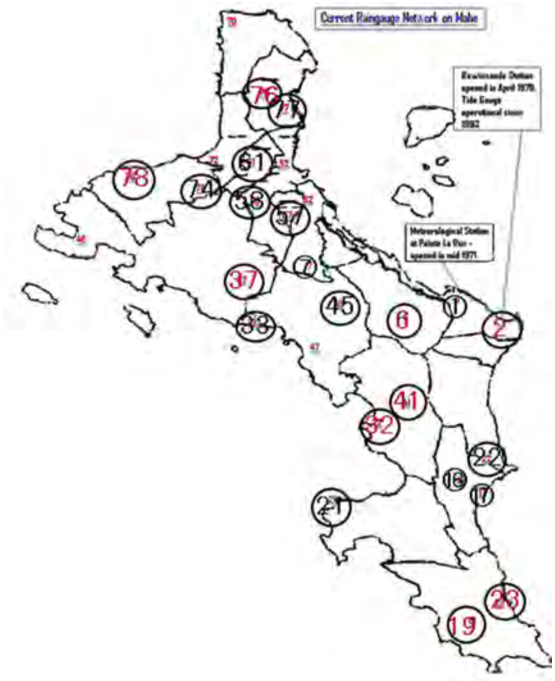


Figure 2-5-2: Location of Rain Gauge Stations

(2) Estimation of Probable Rainfall

Based on the annual maximum daily rainfall at each station, the results of Gumbel's law which is widely used for hydrological statistics are shown in Table 2-5-3.

Table 2-5-3: Probable Annual Maximum Daily Rainfall

St.No	Name/Return Period	100	50	20	10	5	3	2
1	Seychelles Airport	287	262	229	203	177	156	136
2	Rawinsonde	232	208	177	153	128	108	90
6	Cascade	250	225	193	167	141	120	101
7	La Misere (Fairview)	271	245	210	183	155	133	113
16	Anse Royale PUC	288	262	228	201	174	152	132
17	Anse Royale Police Stn	229	209	182	162	140	123	108
19	Quatre Bornes	170	153	132	115	98	84	72
21	Anse Soleil	202	184	159	140	119	103	89
22	Pointe Au Sel	256	234	204	181	157	138	121
23	Anse Forbans	178	163	142	125	109	95	83
32	Anse Boileau	227	204	175	152	128	109	92
33	Grand Anse Waterworks	281	254	216	187	157	133	112
37	Tea Factory	289	260	221	191	159	134	112
41	Bon Espoir	242	219	188	164	139	120	102
45	La Misere (Mr. Rose)	335	299	252	216	178	147	120
57	Rochon Waterworks	287	258	219	189	158	133	110
58	Hermitage Waterworks	349	318	276	243	210	183	158
61	St Louis	313	282	241	210	177	150	127
74	Le Niol Waterworks	291	265	230	203	175	153	133
76	La Gogue	269	241	202	172	141	117	95
77	Ma Constance(North East)	293	263	223	192	160	134	111
78	Belombre	290	260	221	190	158	133	111

(3) Consideration of Geographical Distribution of Probable Rainfall

Since hourly rainfall data are observed only at Seychelles International Airport, the probable rainfall intensity curves only exist there. Therefore, the rainfall intensity curves which have been corrected in accordance with the ratio of the maximum rainfall at each gauge station to that at the international airport station are used.

Considering the height of the mountains and isohyet distribution, the whole area can be divided into 3 parts: the northern, central and southern parts. To compare the maximum rainfall data of each part with that of the airport station where only hourly rainfall data exists, the average rainfall using each higher rank 3 spot (considering the safety of the plan) is calculated.

The probable rainfall at the airport station is approximately the same as that of the central area. The probable rainfall in the northern area is 108% compared to that at the airport station and the probable rainfall in the southern area is 89% compared to that at the airport station.

Consequently, the following coefficient values (shown in Table 2-5-4) are considered according to the target area when applying the Probable Rainfall Intensity Curve in the case of design discharge calculation.

Table 2-5-4: Coefficient Value Applied to Probable Rainfall Intensity Curve

Study Area	Coefficient Value Applied to Probable Rainfall Intensity Curve
Victoria Town	1.1
Pointe Larue	1.0
Anse Aux Pins	0.9
Au Cap	0.9
Anse Royale	0.9

(4) Equipment Installation for Hydrological Observation

(a) Rainfall

The existing rainfall station that measures short-term rainfall is currently located only at Seychelles International Airport. In order to analyse the meteorological impact of torrential rainfall in Victoria City, the distance between the two sites is considered to be too far. Therefore, it is necessary to install new equipment for rainfall measurement in Victoria Town.

In this study, three rainfall gauges were installed near Victoria, two for the mountain area and one for the low land.

The location names are as follows:

1) No.61, St. Louis,
2) No.58, Hermitage,
3) English River Secondary School.

The status of the planned sites for rainfall gauge installation is shown in Table 2-5-5, and the location map is shown in Figure 2-5-3.

Table 2-5-5: Status of Planned Sites for Rainfall Gauge Installation

Location Name	No.61, St. Louis	No.58, Hermitage	English River Secondary School
Location	St. Louis LAT: 4° 37' 7.83" LONG: 55° 26' 22.98"	Hermitage Water Works LAT: 4° 37' 54.28" LONG: 55° 27' 10"	Victoria LAT: 4° 37' 7.84" LONG: 55° 27' 20.53"
Owner of property	Cable & Wireless	PUC	Victoria Town (school)
Status	•Basically agreed on installation of new gauge. (26 April 2011) •Need official letter from PUC to the company	•Discussed with PUC (21 April 2011) •Agreed on installation, no need for further documentation. •Location already fixed •20 June 2011 finished installation	•Basically agreed on installation of RG. (5 May 2011) •Need one more discussion before installation
Photo			
Maintenance	NMS	PUC	NMS
Remarks	Need to prepare an official letter	After arrival of equipment, discuss again with PUC how to install the equipment on the tank	After arrival of equipment, discuss again how to install equipment Require an official letter

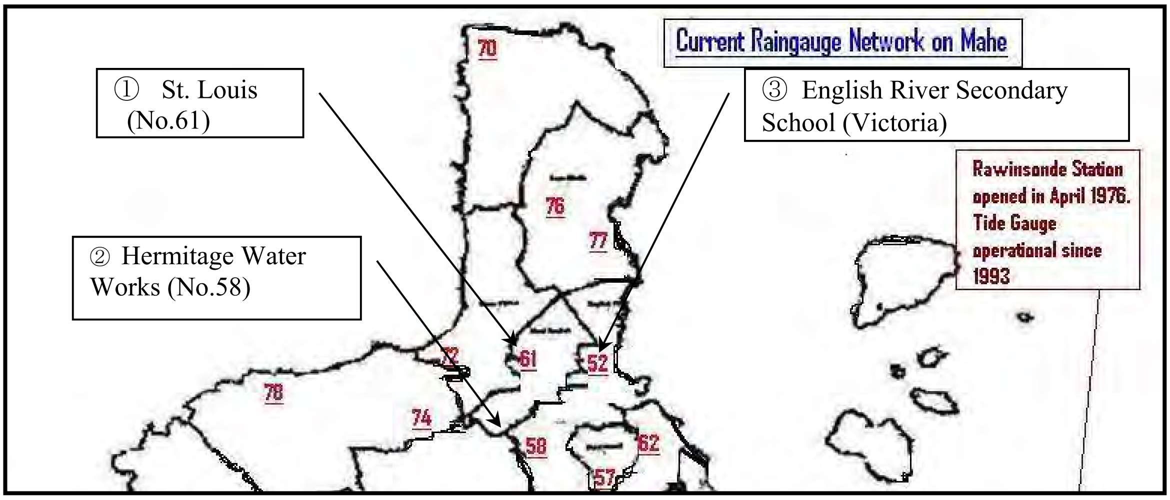


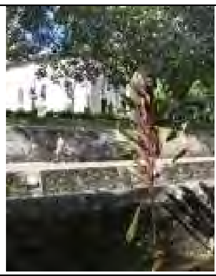
Figure 2-5-3: Location Map of Planned Sites for Rainfall Gauge Installation

It is expected that hourly rainfall data which is required for flood analysis will be obtained continuously in the future.

(b) Water Level (Victoria)

In this study, eight water level gauges were installed in the selected areas. Four gauges were installed permanently in the town of Victoria and the others will be installed at the outlets of rivers or at the inlets and outlets of marsh areas for water movement monitoring. The status of the planned sites for water level gauge installation is shown in Table 2-5-6, and the location map is shown in Figure 2-5-4.

Table 2-5-6: Status of Planned Sites for Water Level Gauge Installation in Victoria

River Name	Anglaise	Moosa	Maintry	St. Louis
Location	Right side downstream of the bridge	Right side next to the Youth Club	Right side upstream of the road	Right side upstream of the road
Owner of property	Private	Private	Private	Private
Status	Installed	Installed	Installed	Installed
Photo				
Remarks	Installation will be after desilting by DOE	Installation will be after desilting by DOE	• Installation will be after the clearing work • DOE will clear the vegetation at the site	• Need to clear the installation site • DOE will clear the vegetation at the site

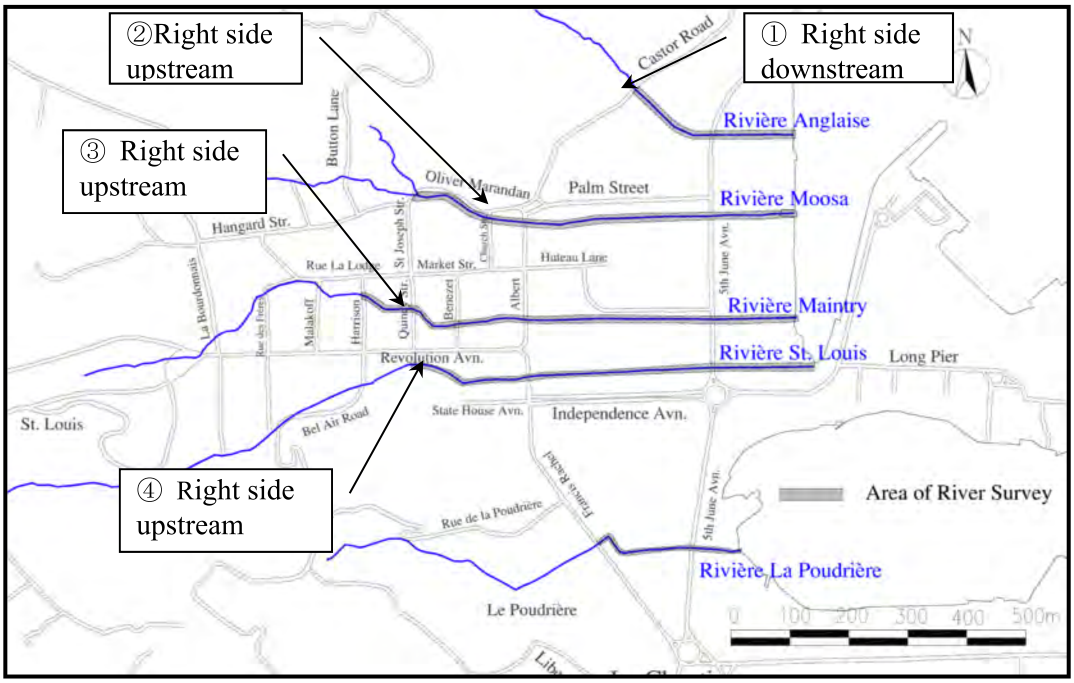


Figure 2-5-4: Location Map of Planned Sites for Water Level Gauge Installation in Victoria

(c) Water Level (Others)

Four gauges in other areas will be installed at the outlets of rivers or at the inlets and outlets of marsh areas for water movement monitoring. Two gauges were installed at each location in Point Laure, Anse Aux Pins, Au Cap, and Anse Royal (one midstream and the other at the river mouth), and observations were implemented. Currently, continuous observations are conducted.

2-5-2-3 Calculation of Design Flood Discharge

(1) General

The *Storm Water Drainage Design Guidelines* were prepared in 1999 by the Commonwealth Fund for Technical Cooperation (CFTC). The document aims to provide a basic reference for MHAETE engineers when planning and designing urban drainage and related structures. Therefore, these guidelines will be adopted for the design and evaluation of the drainage system in this study.

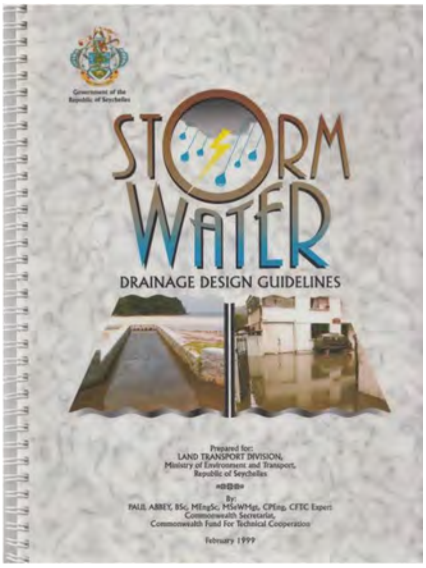


Figure 2-5-5: Cover of Storm Water Drainage Design Guidelines

(2) Determination of Return Period for Flood Management Plan

In this study, the target return periods are set as shown below, consisting of three phases in each area: a Short-Term Plan as the target to be implemented immediately, a Medium-Term Plan as the target for the time being, and a Long-Term Plan as the target for the future taking into consideration factors such as climate change.

Table 2-5-7 Target Return Period

	Short Term	Medium Term	Long Term
Victoria	10	25	100
Others	5	25	100

(3) Catchment Areas

The catchment areas are divided based on a 2m contour line which was incorporated into the existing GIS.

(4) Calculation Formula

The Design Guidelines recommend the Rational Method for estimating the design discharge. The Rational Method is used for drainage areas of 20 km^2 or less. Considering its simplicity and applicability, the Rational Formula is deemed most appropriate and is therefore adopted for calculation of the discharge. The Rational Formula is expressed as

$$Q = \frac{1}{3.6} C_y I_y A$$

where

Q = design discharge, m^3/sec

C_y = runoff coefficient

I_y = rainfall intensity, mm/hr

A = catchment area, km^2

(5) Setting of Parameters

The parameters used in the Rational Formula are set as shown in Table 2-5-8.

Table 2-5-8: Setting of Parameters of Rational Formula (Runoff Coefficient C_y and I_y)

	Victoria City	Other Areas	Remarks
f_i (Coefficient reflecting the land use conditions)	1.0	0.9	"*Storm Water Drainage Design Guidelines*"
C_{10} (Runoff Coefficient applied to 10-year return period)	0.65	0.63	Calculation Formula : $C_{10} = 0.45 + 0.2 f_i$ "*Storm Water Drainage Design Guidelines*"
C_y (Runoff Coefficient applied to target return period)	0.65	0.60	Calculation Formula : $C_y = F_y \times C_{10}$ (F_y is a coefficient relating to return period) "*Storm Water Drainage Design Guidelines*"
I_y (Rainfall Intensity) T_c (Time of Concentration)	Shown in Annex		Coefficients shown in Table 2-5-4 are applied to Probable Rainfall Intensity Formula (Table 2-5-9).

Table 2-5-9: Probable Rainfall Intensity Formula

Coefficient of Formura	Return Period					
	2	5	10	25	50	100
	$r = \frac{a}{t^n + b}$					
n	0.74	0.82	0.91	0.93	0.96	0.98
a	1,401	3,247	7,346	9,847	13,922	17,790
b	8	22	54	68	91	109

*The coefficients of the formula are set according to the curve shown in the "*Storm Water Drainage Design Guidelines*"

(6) Design Discharge

The design discharge planned flow rate which was calculated based on the above conditions is shown in Table 2-5-10.

Table 2-5-10: Design Discharge

	Name	Area (ha)	Return Period 5 Cy	5 Iy	5 Qy	10 Cy	10 Iy	10 Qy	25 Cy	25 Iy	25 Qy	100 Cy	100 Iy	100 Qy
Victoria	Anglaise	57.0	0.62	86.4	8.5	0.65	100.1	10.3	0.69	112.0	12.2	0.79	136.4	17.1
	Moosa	135.0	0.62	80.7	18.8	0.65	94.7	23.1	0.69	106.4	27.6	0.79	130.6	38.7
	Maintry	33.0	0.62	79.2	4.5	0.65	93.3	5.6	0.69	105.0	6.6	0.79	129.1	9.4
	St Louis	118.0	0.62	80.7	16.4	0.65	94.7	20.2	0.69	106.4	24.1	0.79	130.6	33.8
	La Poudrie	38.0	0.62	88.3	5.8	0.65	101.8	7.0	0.69	113.7	8.3	0.79	138.2	11.5
Point Larue	PL-1	59.0	0.60	82.9	8.2	0.63	94.9	9.8	0.67	105.8	11.6	0.76	128.1	16.0
	PL-2	29.0	0.60	75.5	3.7	0.63	88.1	4.5	0.67	98.9	5.3	0.76	121.0	7.4
	PL-3	12.0	0.60	77.8	1.6	0.63	90.3	1.9	0.67	101.0	2.3	0.76	123.3	3.1
	PL-4	28.0	0.60	82.9	3.9	0.63	94.9	4.7	0.67	105.8	5.5	0.76	128.1	7.6
	PL-5	6.0	0.60	82.0	0.8	0.63	94.1	1.0	0.67	104.9	1.2	0.76	127.3	1.6
	PL-6_1～3	86.0	0.60	79.4	11.4	0.63	91.7	13.8	0.67	102.6	16.4	0.76	124.8	22.7
	PL-7	38.0	0.60	66.1	4.2	0.63	79.0	5.3	0.67	89.3	6.3	0.76	110.7	8.9
	PL-8	24.0	0.60	66.1	2.6	0.63	79.0	3.3	0.67	89.3	4.0	0.76	110.7	5.6
Anse Au Pinn	AAP-1	18.0	0.60	74.6	2.2	0.63	85.4	2.7	0.67	95.2	3.2	0.76	115.3	4.4
	AAP-2	34.0	0.60	74.6	4.2	0.63	85.4	5.1	0.67	95.2	6.0	0.76	115.3	8.3
	AAP-3	58.0	0.60	72.2	7.0	0.63	83.3	8.5	0.67	93.0	10.0	0.76	113.1	13.9
	AAP-4	55.0	0.60	70.0	6.4	0.63	81.2	7.8	0.67	90.9	9.3	0.76	110.9	12.9
	AAP-5	101.0	0.60	55.5	9.3	0.63	67.0	11.9	0.67	76.1	14.3	0.76	94.9	20.3
	AAP-6	16.0	0.60	66.6	1.8	0.63	78.1	2.2	0.67	87.7	2.6	0.76	107.5	3.6
	AAP-7	33.0	0.60	52.4	2.9	0.63	63.8	3.7	0.67	72.6	4.5	0.76	91.0	6.3
Aux Cap	AC-1	41.0	0.60	67.3	4.6	0.63	78.7	5.7	0.67	88.3	6.7	0.76	108.2	9.4
	AC-2	95.0	0.60	69.3	11.0	0.63	80.6	13.4	0.67	90.3	16.0	0.76	110.2	22.1
	AC-3	27.0	0.60	63.6	2.9	0.63	75.2	3.6	0.67	84.7	4.3	0.76	104.4	6.0
	AC-4	54.0	0.60	61.5	5.5	0.63	73.1	6.9	0.67	82.5	8.3	0.76	101.9	11.6
	AC-5	58.0	0.60	61.5	5.9	0.63	73.1	7.4	0.67	82.5	8.9	0.76	101.9	12.5
	AC-6	50.0	0.60	61.5	5.1	0.63	73.1	6.4	0.67	82.5	7.7	0.76	101.9	10.8
	AC-7	46.0	0.60	61.5	4.7	0.63	73.1	5.9	0.67	82.5	7.1	0.76	101.9	9.9
	AC-8	31.0	0.60	62.5	3.2	0.63	74.2	4.0	0.67	83.6	4.8	0.76	103.1	6.8
	AC-9	25.0	0.60	66.6	2.8	0.63	78.1	3.4	0.67	87.7	4.1	0.76	107.5	5.7
Anse Royal	AR-1	51.0	0.60	66.0	5.6	0.63	77.5	6.9	0.67	87.1	8.3	0.76	106.9	11.5
	AR-2	162.0	0.60	55.5	15.0	0.63	67.0	19.0	0.67	76.1	23.0	0.76	94.9	32.5
	AR-3	41.0	0.60	61.0	4.2	0.63	72.6	5.2	0.67	82.0	6.3	0.76	101.4	8.8
	AR-4	84.0	0.60	52.1	7.3	0.63	63.4	9.3	0.67	72.2	11.3	0.76	90.5	16.1
	AR-5	49.0	0.60	56.3	4.6	0.63	67.9	5.8	0.67	77.0	7.0	0.76	95.9	9.9
	AR-6	82.0	0.60	59.0	8.1	0.63	70.6	10.1	0.67	79.9	12.2	0.76	99.1	17.2
	AR-7	23.0	0.60	72.2	2.8	0.63	83.3	3.4	0.67	93.0	4.0	0.76	113.1	5.5

2-5-2-4 Flood Model Development and Analysis

(1) Basic Policy

In this study, a one-dimensional analysis model is employed for calculation of the water level and for establishment of the flood management plan.

From the point of view of technology transfer to the counterparts, easily obtainable and user-friendly software is employed. In this study, HEC-RAS, developed by the US Army Corps of Engineers, is used for the analysis. As for the tidal level at the river mouth, the probable tidal level is employed as the boundary condition combined with the upper flood discharge.

(2) Model Verification (2004 Flood)

To prove the reasonability of the model, model calibration is conducted by comparing the calculated water levels and observed water levels. In the study, the 2004 flood is employed as the target flood.

The calculated water level of the Maintry River which is adjacent to the flooded area is shown below. The flooded place in the photo is almost L=450 m upstream from the river mouth and is equivalent to the neighbourhood in dotted lines in the road survey results and the following figure which shows the flood water level and the cross section in Maintry River. As of 2011, river-bed excavation to a depth of approximately 20cm was implemented. Therefore, the cross section profile in 2004 was 20 cm higher than the present state.

Figure 2-5-6 shows the existing cross section and the results contrast with those of 2004. The minimum road height near the photographed site was about 1.6 EL.m, and the calculation result in 2004 was 1.9EL.m, and it is estimated that the flood depth was about 30 cm. The flood water level in the photograph is near the floor of the building, and as for the water depth, the outline agrees with the calculation result.

Though there are some issues such as uncertainty as to whether or not the photograph represents the maximum flood water level and the assumption that the cross section of the river was uniformly excavated to a depth of 20 cm, it is possible to judge that there is no problem with application of the one-dimensional non-uniform flow computation by HEC-RAS.

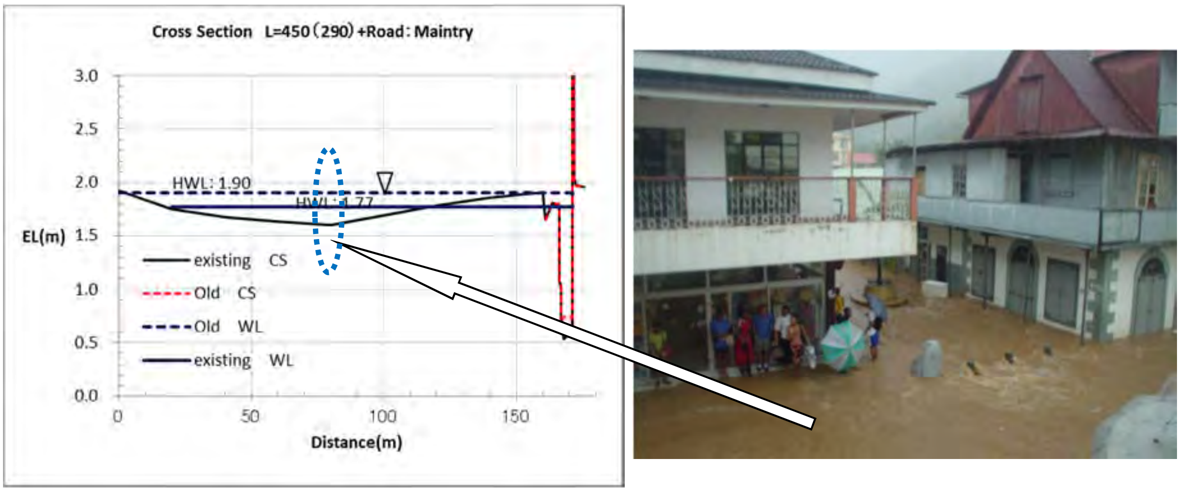


Figure 2-5-6: Photo and Cross Section of Maintry River in the 2004 Flood

2-5-3 Flood Mitigation Measures

2-5-3-1 Past Mitigation Measures in Victoria Town

Since the tsunami in December 2004 was followed by other natural disasters and successive flooding, the President of the Seychelles decided to form a Drainage Task Force in January 2005. The taskforce conducted a preliminary study of the flooding and drainage problems in Victoria.

In the study, 11 projects were proposed and prioritised for action. The status of implementation of each action plan is as listed in Table 2-5-11.

Table 2-5-11: Status of Implementation of Mitigation Measures

No.	Project Location	Project Cost(SR)	Priority	Status
1	Market Street and Church Street	1,890,000	2	Partially Completed
2	Albert Street	684,000	3	Partially Completed
3	State House Avenue	1,234,000	4	Completed
4	Francis Rachel Street	1,382,000	6	Partially Completed
5	Independence Avenue	1,085,000	5	Completed
6	Huteau Lane	485,000	9	Not yet in action
7	St Elizabeth Convent	519,000	1B	Not yet in action
8	English River	988,000	7	Not yet in action
9	Vilaz Trezor	1,000,000	1A	Not yet in action
10	Mont Fleuri	683,000	1C	Not yet in action
11	Mont Buxton	450,000	8	Completed

Source: Preliminary Study of the Flooding Problems in Victoria, June 2005

2-5-3-2 Other Districts

In the study report of October 2004, several projects were prioritised into four action plans (immediate, short-term, medium-term and long-term). Each action plan involved more than 10 projects and some were already implemented within 6 years (2005-2011).

The status of implementation of each action plan is as listed in Table 2-5-12. The total project cost is based on the amount proposed in the study.

Table 2-5-12: Status of Implementation of Mitigation Measures within 6 years

Action Plan	Proposed Projects	Completed Projects	Partially Completed	Total Cost (SCR)		Ratio of Implementation Cost
				Proposed	Implemented	
Immediate Action	12	9	1	1,710,140.0	1,526,030	89.2%
Short-Term Action	14	6	1	3,803,246.0	2,070,596.0	54.4%
Medium-Term Action	17	3	0	5,025,172.0	366,500.0	7.3%
Long-Term Action	17	0	0	10,237,015.0	-	-

The number of proposed and completed projects by district is listed in Table 2-5-13.

Table 2-5-13: Number of Proposed and Completed Projects by District

	Immediate			Short			Medium			Long		Total Cost
District	Plan	Complete	Cost	Plan	Complete	Cost	Plan	Complete	Cost	Plan	Complete	SCR
Baie Lazare	1	1	746,910	3	1	100,900	1	0	0	3	0	847,810
Baie Ste. Anne	5	4	329,030	3	1	77,500	4	0	0	0	0	406,530
Point Larue	2	2	62,220	2	1.5	890,000	2	1	150,000	0	0	1,102,220
Anse Royale	1	1	177,870	3	2	443,400	4	2	216,500	4	0	837,770
La Digue	2	1.5	210,000	2	0.5	177,500	2	0	0	4	0	387,500
Anse Boileau	1	0	0	1	1	381,296	4	0	0	6	0	381,296
Total	12	9.5	1,526,030	14	7	2,070,596	17	3	366,500	17	0	3,963,126

2-6 Analysis of Future Climate Change

2-6-1 General

In order to estimate the impact of future climate change on the coastal erosion and flood management plans, quantitative local information was collected from existing reports and reviewed as much as possible. The information concerns the sea level rise, wave climate, hydrological changes and impact on coral reefs. The impact of climate change on coastal erosion and flooding was studied.

Because of the limited information and the uncertainty of future projections, understanding of the changing climate by monitoring, improved techniques for projection, and adjustment of coastal and flood management to changing future impacts are required.

2-6-2 Sea Level Rise and Wave Climate

The regional sea level in the southwest Indian Ocean is expected to rise between +0.4 to +0.6 m in 2070-2100 as compared with the period from 1960-1990 (Chang-Seng (2007).

The sea level has been monitored since 1993 at Pointe Larue, Mahe. The analysis of 18 years of data (1993-2010) by the Study Team gives a recent mean sea level rise rate of 6.6mm/year. If this rate remains constant this century, the sea level will rise +0.3m by 2050 and +0.6m by 2100 as compared with 2010.

In the Seychelles, offshore waves are mainly dominated by the northwestern monsoon and southeastern trade winds. Therefore, the wave climate will not be altered to a significant extent unless the patterns of the monsoons change. Even if offshore wave conditions do not change, greater wave energy will reach the coastal zones of the Seychelles with the significantly higher sea level losing less energy due to the deeper water depth. It will cause more severe coastal erosion and higher wave run-up than at present. Based on the climatology of the tropical cyclone storm routes from 1972 to 2001, the Seychelles is generally outside the major storm routes.

2-6-3 Hydrological Changes

Although the projection variability is relatively high, the projections by global climate models show smaller annual rainfall changes, 3-5% and 5-6% for 2050 and 2100, respectively.

2-6-4 Coral Reefs

The coral reefs in the Seychelles suffered extensively from coral bleaching resulting from thermal stress caused by the 1998 El Nino phenomenon. The bleaching reduced coral cover to less than 5% on most reefs and the mean coral cover is presently estimated at 11% (Bijoux et al. (2007)). (Source: Jude Bijoux et.al, 2007. *Status of Coral Reefs in the Seychelles Islands*)
As for fringing reefs around Mahe, it is estimated that reef accretion is initially focused offshore, creating a shallow landward lagoon. Fringing reefs will preferentially accrete vertically and prograde laterally if there is no vertical space available. Therefore, the reefs will be able to accrete vertically during the period of sea level rise. Montaggioni (2005) suggested 3.5 (2.3 – 8.8) mm/year as the vertical reef accretion rate for Mahe Island since the last deglaciation. (Source: Montaggioni, L.F., 2005. *History of Indo-Pacific coral reef systems since the last glaciation: Development patterns and controlling factors*)
Observational records show that SSTs have been increasing by 0.1ºC per decade in the oceans where most SIDS are located. In the past 20 years, an SST rise of approximately 1ºC above the normal maximum summer temperature has led to bleaching events. The SST rise will range from 0.38ºC to 2.58ºC around 2100 (Payet et al. (2006)). The impact of climate change on coral reefs will nevertheless be catastrophic. (Source: Rolph Payet and Wills Agricole. 2006. *Climate Change in the Seychelles: Implications for Water and Coral Reefs*, Ambio Vol. 35, No. 4, 182-189)

2-6-5 Impacts on Coastal Erosion and Flooding

Climate change may have the most significant impact on the Seychelles. A possible worse scenario can be assumed when a tropical cyclone/depression passes close by the islands and causes an extremely high tide and flooding simultaneously. Buildings or roads below 2.5m above the present mean sea level are expected to be inundated.
Using existing GIS data, the number of buildings and the length of roads that will be inundated have been estimated. The results show that 2,017 buildings (14%) in Mahe, 1,601 buildings (63%) in Praslin and 321 buildings (48%) in La Digue are expected to be inundated, including 11 hospitals, 15 schools, 21 restaurants and 69 hotels/guesthouses on the three islands. Also, the results show that 67km of roads in Mahe, 43km in Praslin and 7km in La Digue are expected to be inundated. In other words, 42% of the coastal main roads in Mahe, 72% in Praslin and 27% in La Digue are expected to be inundated. The impact will be enormous.

Chapter 3 Formulation of Management Plan

3-1 General

From the basic study, the main issues are as follows:

- Coastal erosion and flood damage in lowland areas are caused by human activities together with natural conditions. The damage is caused by the construction of roads, breakwaters, houses and schools without consideration for the natural characteristics.
- The damage can be minimised by coastal zone management or environmental impact assessments. However, the EIA system and organisation do not function effectively. In particular, manpower and experience are lacking. In addition, legal regulations are not effective either.
- There have been very few past disasters and public interest in disasters is lacking. Also, basic information about natural conditions and damage is lacking and has not been archived.
- The Seychelles Strategy 2017, the Strategy for Climate Change in Seychelles, the Environment Management Plan of Seychelles 2011-2020, and the Seychelles Sustainable Development Strategy 2021-2030 are current development documents. The contents are general and do not fully address the characteristics and limitations of the Seychelles.
- New types of disaster are expected due to further national economic development and climate change in the future in the coastal zones.

Under these conditions, the coastal conservation plan and flood management plan should be included in the long-term proactive management plans for climate change and economic development in coastal areas. The management plan is the overall plan. Based on the plan, the priority coasts and areas were selected and specific coastal conservation and flood management plans were formulated.

3-2 Procedures for Formulation of Plans

The coastal conservation plan and flood management plan were formulated taking into consideration the management cycle as shown in Figure 3-2-1. The planning cycle is issue identification and baseline assessment, management plan preparation and adoption, action plan and project implementation and monitoring and evaluation. Information management and education depend on the cycle.

The problems and risks are identified from the basic data and classified into coastal erosion or flooding and the management plan is formulated to solve the problems. The management plan will be classified into daily management and strategic long-term management. The daily management is the assessment of development of coastal erosion and flooding and the response to the requirements of local people. As for the environmental assessment, past experience was collected and applied to management. The strategic management is intended to respond to future climate change and non-structural measures. The action plan includes the selection of priority areas and planning and execution of pilot projects. Monitoring refers to monitoring the sea level rise, coastal changes, the damage situation and the performance of mitigation measures. The evaluation will be conducted according to the criteria determined in advance. The plan will be revised based on monitoring of economic development, future climate change and similar disasters in other countries because understanding of the actual conditions and estimation are difficult. The revision will be conducted every 10 years. The GIS database can be used as the basic database. The education of local people is important.

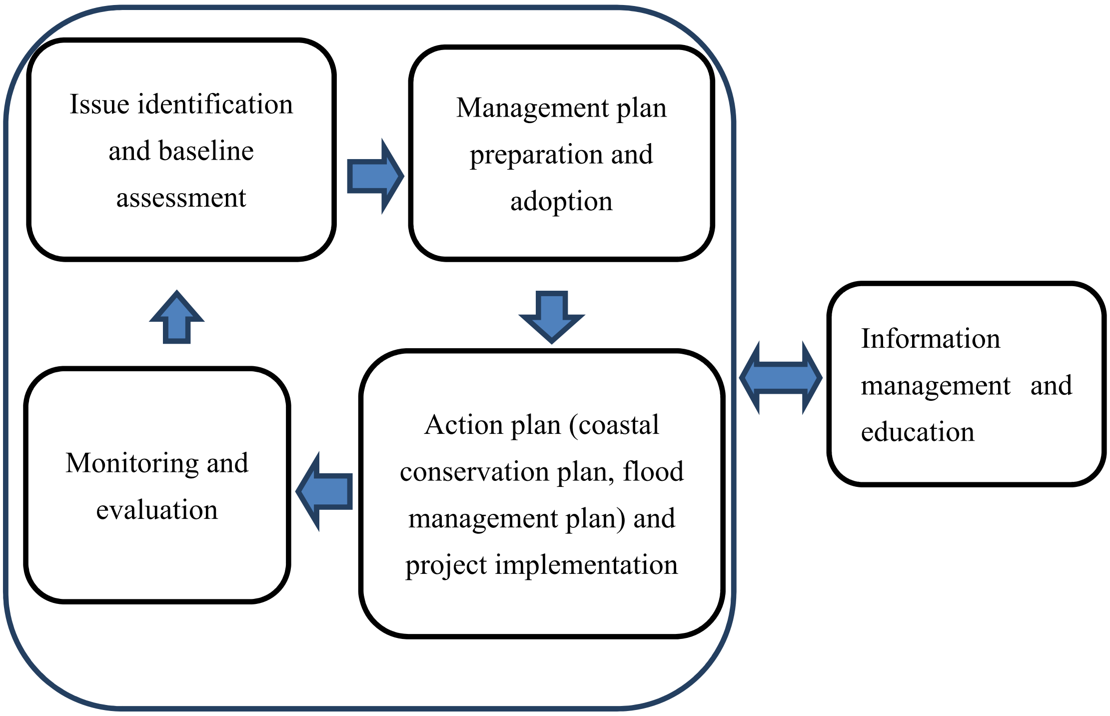


Figure 3-2-1: Planning Cycle

3-3 Objectives

The objectives of the management plan are as follows:

- To mitigate damage to human lives and property by coastal erosion, flooding, tides, waves and tsunamis.
- To harmonise the mitigation measures with nature conservation and the use of coastal areas, wetlands and rivers.
- To contribute to coastal zone development and climate change adaptation for sustainable development in the future.
- To promote awareness and understanding of the value of coasts and rivers and bring together stakeholders.

The objectives are mainly derived from the Seychelles Sustainable Development Strategy (SSDS 2012-2020).

3-4 Basic Conditions of the Plan

The target areas are Mahe, Praslin and La Digue Islands. The target year and design return period were decided according to the importance and scale of the measures as structures as shown in Table 3-4-1.

Table 3-4-1: Target Year and Design Period

	Short Term	Medium Term	Long Term
Target Year	2020	2050	2100
Design Return Period			
Area	**Small Scale**	**Medium Scale**	**Large Scale**
Victoria Town	10 years	25 years	100 years
Others	5 years	25 years	100 years

In the storm water drainage design guidelines in the Seychelles, the recommended return period of drainage facilities is 1/10 for Victoria and 1/5 for other areas, and for the main facilities, which are culverts on main streams, it is 1/25. The design period was decided based on the guidelines. The design condition of tides and waves is as shown in Table 3-4-2. For the waves, only the return period of 1/25 is estimated because the basic data is limited.

Table 3-4-2: Tidal Condition (unit: m above MSL)

Return Period	Target Year		
	2010	2050	2100
1/10	1.33	1.59	1.92
1/25	1.44	1.70	2.03
1/100	1.61	1.87	2.20

Table 3-4-3: Design Wave Condition

Name of Coast	Wave Height (m)	Wave Period (s)	Wave Direction
North East Point (Mahe)	4.0	8.0	ESE
Au Cap (Mahe)	5.0	8.0	SSE
Anse Royale (Mahe)	5.0	8.0	ESE
Baie Lazare (Mahe)	4.0	7.0	SSW
Anse Kerlan (Praslin)	4.0	7.0	SSW
La Passe (La Digue)	4.0	6.0	WSW

3-5 Risk Estimation

The risk was estimated after the investigation and classification of coastal erosion and flood conditions based on certain criteria. For coastal erosion, the classification and risk are shown in Table 3-5-1 and Table 3-5-2, respectively.

Table 3-5-1: Types of Coastal Erosion

Type of Coast	Explanation	Example
(a) Coast with long-term changes	Erosion caused by offshore sediment transport	North East Point
(b) Coast with erosion by changes in waves	The changes in wave height and direction bring coastal changes by on-offshore and longshore transport.	Beau Vallon Beach
(c) Coast with erosion influenced by structures	Coastal structures bring coastal erosion and accretion. Breakwaters, groynes and revetments cause coastal erosion of adjacent beaches.	Anse Kerlan in Praslin La Passe in La Digue
(d) Pocket beach	A pocket beach is protected by the headlands, hence it is stable.	

The risk was estimated based on the ranking of the hazard and the likelihood of hazard occurrence, though available information is limited. The high risk coasts need some kind of measures.

Table 3-5-2: Level of Risk at Present and in Future

Level of Risk	Coast at Present	Coast in Future
High		Anse Kerlan
Moderate	North East Point, Baie Lazare, Anse Kerlan, La Passe	North East Point, Baie Lazare, La Passe
Low	Au Cap, Anse Royal, Anse a La Mouche	Au Cap, Anse Royale, Anse a La Mouche

As for coastal erosion, the classification and risk are shown in Table 3-5-3 and Table 3-5-4, respectively.

Table 3-5-3: Classification of Flood

Type of Flood	Explanation	Example
River flood		
Urban flood	Urban development increases the discharge of water and causes flooding.	Victoria Town
Improper drainage	The design of the drainage channels lacks the necessary capacity.	Pointe Larue
Lowland development	Reclamation near outlet reduces flood capacity. Housing development on low land causes drainage difficulties.	Anse Aux Pins, Au Cap, Anse Royale
River with wetland	Coastal lowland with wetland has some outlet problems because of outlet clogging by sand accumulation.	Au Cap, Anse Royale

The risk was estimated based on the ranking of the hazard and the likelihood of hazard occurrence of flooding. In the analysis, the flood in January 2013 was not considered. Therefore, it is necessary to revise the results.

Table 3-5-4: Level of Risk at Present and in Future

Level of Risk	Area at Present	Area in Future
High	-	-
Moderate	Au Cap, Anse Royale	Victoria, Au Cap, Anse Royale
Low	Victoria, Pointe Larue, Anse Aux Pins	Pointe Larue, Anse Aux Pins

3-6 Alternatives and Management Plan

In the study, the measures will consider future climate change and will be classified into three categories: protection, accommodation and retreat. The applicable measures for coastal conservation and flood management were studied taking into consideration the natural and socio-economic conditions in the Seychelles. The applicable measures are shown in Table 3-6-1.

Table 3-6-1: Applicable Measures in Seychelles

Classification	Coastal Conservation	Flood Management
Protection	Coastal Revetments, Sand Nourishment, Groynes	River Improvement, Drainage Improvement, Ring Dikes, Retaining Ponds, Pump Systems, Water Gates
Accommodation	Land Use Regulations, EIA, Awareness, Risk Maps, Warnings, Emergency Operation	Improvement to Houses, Land Use Regulations, EIA, Awareness, Risk Maps, Warnings, Emergency Operation
Retreat	Setback, Zoning, Relocation	Setback, Zoning, Relocation

The applicability of each measure was investigated from the perspective of function, utilisation, environment, future change, cost, maintenance and applicability to the Seychelles as shown in Table 3-6-2.

Table 3-6-2: Proposed Measures

Classification	Coastal Conservation	Flood Management
Protection	Groynes Nourishment	Drainage Improvement Retaining Ponds
Accommodation	Land Use Regulations, EIA, Risk Maps, Setback	

The management plan for the classified coasts is summarised as shown in Table 3-6-3 and for the classified floods in Table 3-6-4.

Table 3-6-3: Classification of Coastal Erosion and Mitigation Measures

Classification	Problems	Mitigation Measures
Coast with long-term changes	Erosion caused by offshore sediment transport	Nourishment of sediment loss, setback/zoning, relocation
Coast with erosion by changes in waves	The changes in wave height and direction bring coastal changes by on-offshore and longshore transport.	Setback/zoning of changing area, groynes or sand bypass for longshore transport, nourishment for offshore transport, regulations
Coast with erosion influenced by structures	Coastal structures bring coastal erosion and accretion. Breakwaters, groynes and revetments cause coastal erosion of adjacent beaches.	EIA, regulations, structural measures according to the type of impact
Pocket beach	A pocket beach is protected by the headlands, hence it is stable. In future, erosion by economic development and climate change	Do-nothing, monitoring, land use regulations, EIA

Table 3-6-4: Classification of Flood and Mitigation Measures

Classification	Problems	Mitigation Measures
River flood	Rare in Seychelles	River improvement
Urban flood	Urban development increases the discharge of water and causes flooding.	Drainage improvement, regulations, EIA
Improper drainage	The design of the drainage channels lacks the necessary capacity.	Drainage improvement, regulations, EIA
Lowland development	Reclamation near outlet reduces flood capacity. Housing development on low land causes drainage difficulties.	Drainage improvement, EIA, retaining ponds, risk maps, setback/zoning, improvement of houses
River with wetland	Coastal lowland with wetland has some outlet problems because of outlet clogging by sand accumulation.	River improvement, outlet improvement, retaining ponds, regulations, setback/zoning, EIA

The implementation schedule is summarised as shown in Table 3-6-5.

Table 3-6-5: Schedule for Implementation of Management Plan

		Target Period	Short Term (2020)	Middle Term (2050)	Long Term (2100)	Remark
	Activities Items					
1	Structural Measures					
	For Coastal Erosion					
	a	Groynes and Nourishments				Mitigation of erosion
	b	Coastal Zone				Management of coastal zone
	For Flooding					
	a	Drainage System				Improve and enhance drainage system
	b	River System				Improve river system
		i) partial work for river channel and river mouth				
		ii) river improvement work				
	c	River Basin System				Management of river basin
2	Non-Structural Measures					
	a	Regulation for Land Use/Zoning Ordinance				Control regulation of land use and zoning ordinance
	b	Early Warning and Forecasting System				Enhance a communication system
	c	Improvement/Enhancement of Evacuation Center				Improve the evacuation route and relief plan
	d	Awareness Program for Concerned People				Publicities of flooding risk information.

operating periods implementing as needed and continuously

3-6-1 Priority Coasts and Areas

The priority coasts and areas were selected from the problem areas as shown in Table 3-6-6 and Table 3-6-8.

Table 3-6-6: List of Priority Coasts

No.	Name of Coast	Extent of Erosion Problem	Priority Coast
1	North East Point	Long-term erosion and wave overtopping on coastal road Selected as representative coast of this type	◎
2	Anse Aux Pins	Small beach scarp and protected by reclaimed land	
3	Au Cap	Long term erosion and wave overtopping on coastal road with revetment	
4	Anse Royale	Long-term erosion and wave overtopping on coastal road with revetment	
5	Anse Takamaka	Little erosion and protected by coral reef	
6	Baie Lazare	Long-term erosion and wave overtopping on low coastal road with no structures	◎
7	Anse a La Mouche	Accreted coast with pile revetment under RECOMAP project	
8	Anse Boileau	Little erosion with pile revetment under RECOMAP project	
9	Beau Vallon	Stable beach but large variation requires future improvement	
10	Anse Kerlan	Severe erosion caused by longshore transport with groynes	◎
11	Anse Lazio	Beach scarp without reef requires future improvement	
12	La Passe	Erosion and accretion by breakwaters	◎

The ◎ symbol shows the priority coasts. RECOMAP: Regional Programme for the Sustainable Management of the Coastal Zones of the Indian Ocean Countries

Table 3-6-7: List of Priority Areas

No.	Name of Area	Extent of Flooding Problem	Priority Area
1	Victoria Town	Flooding of the boundary area where shops and roads are located between original and reclaimed land because of small flow capacity of drainage.	◎
2	North of Mahe	At foot of mountainous area, lack of proper drains	
3	Pointe Larue	Flooding due to heavy rain on the road and surroundings from Victoria Town to the international airport.	◎
4	Anse Aux Pins	Flooding of lowland around housing development because of improper drainage.	◎
5	Au Cap	Flooding of lowland around schools and housing development because of improper drainage and outlet clogging by sand bar.	◎
6	Anse Royale	Flooding of lowland around schools and housing development because of improper drainage and outlet clogging by sand bar.	◎
7	Baie Lazare	Flooding of lowland area by outlet clogging	
8	Anse Boileau	Flooding of lowland area by improper drainage	
9	Southwest of Praslin	Drainage problem on lowland at housing development sites.	
10	West of La Digue	Drainage difficulty of lowland area because of sand bar along the beach.	

3-7 Monitoring and Evaluation

The management plan should be revised at regular intervals because the conditions and causes of coastal erosion and flooding are uncertain and the impact of economic development and future climate change are not clear. The plan will be improved by the monitoring of beach changes, flooding and inundation and evaluation of the plan. The SSDS is also revised every 10 years. Therefore, the coastal conservation and flood management plan can be revised at the same time.

3-8 Information Management and Education

The maintenance of basic information for coastal zone management is proposed because it is not sufficient. Three rain gauges were installed for continuous measurement of hourly rainfall for climate data. The accumulation of disaster records was proposed to make clear the types, scale and causes of disasters. For coastal erosion, beach profile monitoring was proposed twice a year at eroded coasts in view of seasonal changes with fixed sections.

The monitoring results can be stored in the GIS database and training provided in the use of GIS for daily management.

The education and participation of local people in coastal management were already proposed as an action plan in the SSDS with targets and responsible organisations. The realisation of the plan is expected.

Chapter 4 Coastal Conservation Plan for Priority Coasts

4-1 General

The coastal conservation plan is summarised from the management plan as follows:

- Coastal erosion in the Seychelles is caused by human activities together with natural conditions. The human activities are the construction of coast roads and breakwaters. In future, the impact of climate change will be felt on the coast.
- The coastal conservation measures proposed are nourishment and groynes in the short term and land use regulations, zoning and setback, and reinforcement of EIA of the construction of structures in the long term when considering future climate change.
- Four priority coasts were selected: North East Point, Baie Lazare, Anse Kerlan in Praslin, and La Passe in La Digue.
- Structural measures will be considered to enable application of the proper materials, machinery and construction methods used in the Seychelles. Also, the maintenance requires limited human resources.
- In the long term, structural measures have limitations because of the difficulties of scale and cost. The Government of the Seychelles has to send a clear message as to how it will deal with long-term measures.

The coastal conservation plan for priority coasts is summarised in Tables 4-1-1 to 4-1-4.

Table 4-1-1: North East Point Conservation Plan

Item	Explanation
Coastal Conditions	The 2km-long coast is located in the northeast part of Mahe and is protected by a narrow coral reef and beach rock. Waves come from the northwest from December to March and from the southeast from May to October. A coastal road and houses are located along the coast and the beach is used by local residents for recreation.
Problems	Erosion and wave run-up at high tide on the coastal road affects traffic. The beach was eroded for 20m in width from 1960 to 2011 and the seasonal variation was about 20 m. Possible causes of the long-term erosion are offshore transport.
Evaluation of alternatives	Sand or gravel nourishment was selected to compensate for the loss of sand and to make beach use even the needs of maintenance because revetment causes loss of sand in front of the revetment.
Contents of the plan	Sand nourishment for 20m in width for a 2-km stretch of the beach is proposed with maintenance nourishment.

Table 4-1-2: Baie Lazare Conservation Plan

Item	Explanation
Coastal Conditions	The coast is located on the southwest coast of Mahe and is partly protected by a coral reef. Wetland has formed behind the sand bar where the coastal road and houses are located. The Baie Lazare River flows into the wetland and flushes out the sand bar in times of flooding. This possibly causes loss of sand from the beach.
Problems	Coastal erosion and wave run-up affect the coastal road, shops and houses along the beach. Coastal erosion started two or three years before 2008. Wave run-up and coral debris were reported during high tides in May 2007. Stone and wooden pile revetments were constructed in the past and today broken revetments remain.

Item	Explanation
Evaluation of alternatives	Maintenance of the beach by sand nourishment is better than direct protection by revetment because revetment causes loss of sand from the beach. The prevention of sand loss in times of flooding by a submerged reef in front of the channel is not feasible because of cost. Traffic control at high tide is not reliable and other measures are necessary against the future sea level rise.
Contents of the plan	Sand nourishment for 20m in width for a 400 m-stretch of the beach is proposed with maintenance nourishment. It is necessary to monitor the beach profile for estimation of the causes of erosion and the necessary sand volume for maintenance.

Table 4-1-3: Anse Kerlan Conservation Plan

Item	Explanation
Coastal Conditions	The coast is located in the west part of Praslin and is protected by a coral reef. It receives waves from the northwest in winter and from the south in summer, resulting in seasonal changes in longshore sediment transport. Along the coast, hotels and restaurants are developing for tourism activities. The coast has one of the best beaches in Praslin.
Problems	The erosion causes the loss of property and use of the sandy beach for bathing. This results in deterioration of tourism activities. Originally, at Anse Kerlan the beach sand was transported from the north to the south and deposited at Grand Anse. After the erosion became severe, five groynes were constructed in 1990 and they prevent the return of sediment from the south. The coastal road was shifted inland because of the erosion.
Evaluation of alternatives	In view of the fact that the beach is important for tourism, sand nourishment and groyne construction are appropriate for recovering the beach and reducing longshore transport. A revetment may cause loss of beach sand.
Contents of the plan	Three groynes and sand nourishment for 20m in width for a 1,000 m stretch of the beach are proposed with maintenance nourishment to stabilise the beach.

Table 4-1-4: La Passe Conservation Plan

Item	Explanation
Coastal Conditions	The coast is located in the west part of La Digue and protected by a wide coral reef and Praslin Island to the west. Therefore, waves come from the north and south, and not from the west. A jetty is provided for the ferry to Praslin. The anchorage is protected by three breakwaters.
Problems	The breakwaters at the jetty cause accretion at the anchorage and erosion of the south beach. Erosion causes loss of land and wave overtopping in the hospital grounds. The anchorage is difficult to use and needs dredging.
Evaluation of alternatives	To reduce accumulation of sediment in the sheltered area, a groyne with sand bypass from the anchorage to the eroded beach was proposed. Rearrangement of the breakwaters and groynes is one alternative. However, it would be necessary to conduct a detailed study and that is not within the action plan. The arrangement of the groynes was considered for future development based on the existing proposed plan.
Contents of the plan	One groyne and sand bypass of 1,000 m3 of sand from the anchorage to the south beach are proposed.

4-2 Coastal Conservation Plan

4-2-1 North East Point

(1) Conditions and Problems

The 2km-long coast is located in the northeast part of Mahe and is protected by a narrow coral reef and beach rock. Waves come from the northwest from December to March and from the southeast from May to October. A coastal road and houses are located along the coast and the beach is used by local residents for recreation. The beach has a slope of 1/7 and an average height of 2.5m to 3.0m. The coastal road is 2.5m to 4.0m in height.

The problems are long-term erosion and beach changes due to the changes in wave direction and wave run-up at high tide in spring on the coastal road. The beach was eroded for 30m in width from 1960 to 2011 and the seasonal variation was about 20 m.

The estimated wave run-up height was 3.6m in 2010, with a probability of 1/25 and 4.0m in 2050 because of the sea level rise. When the beach is eroded by seasonal variation, the beach height declines by about 1.5m. Then the waves run up to a height of 4.3m on the road. Sand also runs up with the waves.

The cause of long-term erosion is estimated as offshore sediment transport because of the narrow coral reef as shown in Figure 4-2-1. The beach rock acts as protection for the beach, but possibly makes accumulation of sand difficult.

If no action is taken, the beach will be eroded opposite the road. Maintenance of the beach or the construction of a revetment is required. In the long term, the increased erosion and wave overtopping will cause traffic problems and damage to structures. The road needs countermeasures and maintenance such as raising or repairing of the road.

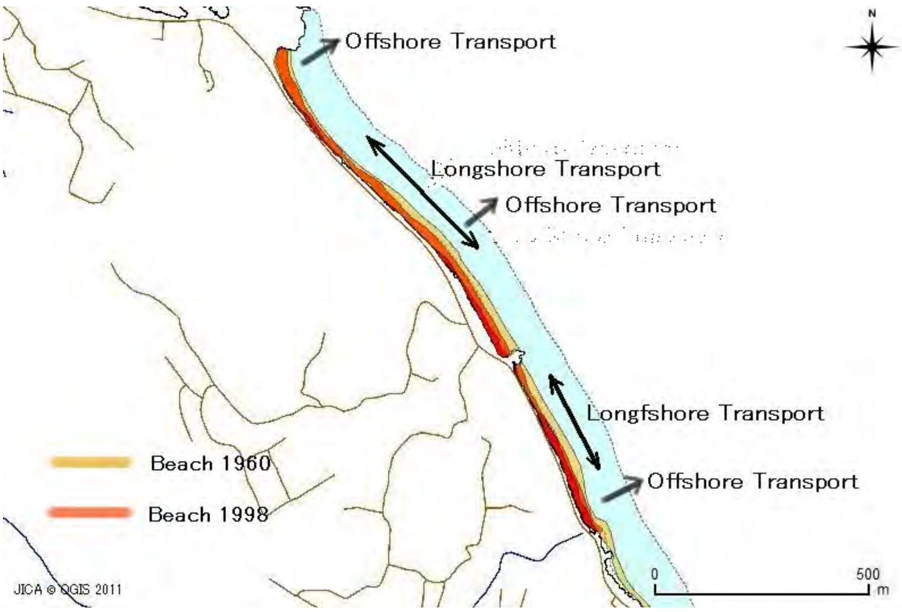


Figure 4-2-1: Estimated Sediment Movements at North East Point

(2) Evaluation of Alternatives

The alternatives for coastal conservation are (1) to raise the road and construct revetments, (2) sand or gravel nourishment, and (3) traffic control and setback as long-term alternatives as accommodation.

The coastal road runs from Victoria to Bea Vallon through Glacis and is important for local transport. It has to be protected from erosion and wave overtopping. The first alternative is the construction of revetments and raising of the road. The necessary height of the revetment would be 4.5m, about 2.0m higher than the present height of 2.5m. Revetments sometimes cause scouring in front and increased run-up height.

Sand or gravel nourishment is one measure to deal with seasonal variations due to changes in wave direction and the interruption of offshore sediment transport. The beach will be kept in its present condition and wave run-up will decrease. The gravel reduces sediment movement by gentle slopes though the conditions will change from the present.

For long-term measures, zoning, setback and traffic control are proposed to counter the sea level rise in future.

The measures were evaluated based on the criteria of function, coastal use, environment, future changes, cost, maintenance and applicability in the Seychelles. Sand or gravel nourishment was selected to compensate for the loss of sand and to make beach use even the needs of maintenance because revetments cause loss of sand in front of the revetment.

(3) Coastal Conservation Plan

Sand nourishment was proposed for 20m in width for about a 2 km stretch of the beach with maintenance nourishment as shown in Figure 4-2-2. At present, because the cause of the erosion is not clear, the effects of nourishment and the causes are analysed by the pilot project.

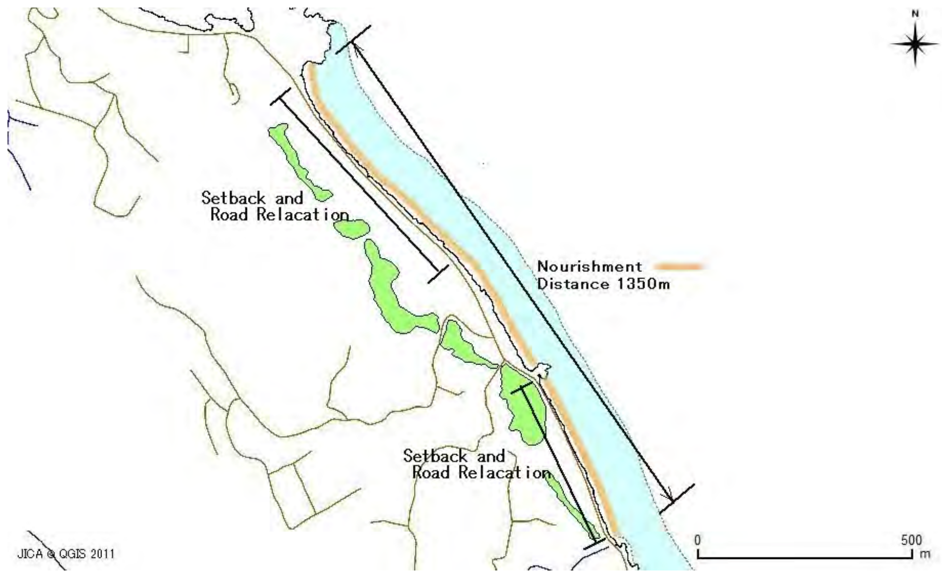


Figure 4-2-2: Measures at North East Point

(4) Environment and Social Considerations

There are several impacts of sand nourishment. One impact is the misdistribution of benefits and damage, and such impact is not clear at present. Therefore, the impact will be monitored after the nourishment. Nourishment sometimes causes outlet clogging from the wetland so the outlet will be improved. Other impacts occur during the construction stage such as air pollution and noise from heavy machines and water pollution. The impacts are limited to only a short time and are slight.
As for the measures for the long term, setback is effective and will be conducted with the understanding of local people after evaluation of the monitoring results.

4-2-2 Baie Lazare

(1) Conditions and Problems

The coast is located on the southwest coast of Mahe and is partly protected by a coral reef. Wetland has formed behind the sand bar where the coastal road and houses are located. The Baie Lazare River flows into the wetland and flushes out the sand bar in times of flooding. This possibly causes loss of sand from the beach as shown in Figure 4-2-3.
The problem here is that the coastal erosion and wave run-up affect the coastal road, shops and houses along the beach. Coastal erosion started two or three years before 2008. Wave run-up and coral debris were reported during high tide in May 2007. Stone and wooden pile revetments were constructed in the past and today broken revetments remain.
If no action is taken, the wave run-up will cause traffic problems and maintenance and repair of the road will be necessary in the short term. For the long term, it will bring improvement or reconstruction of the road.

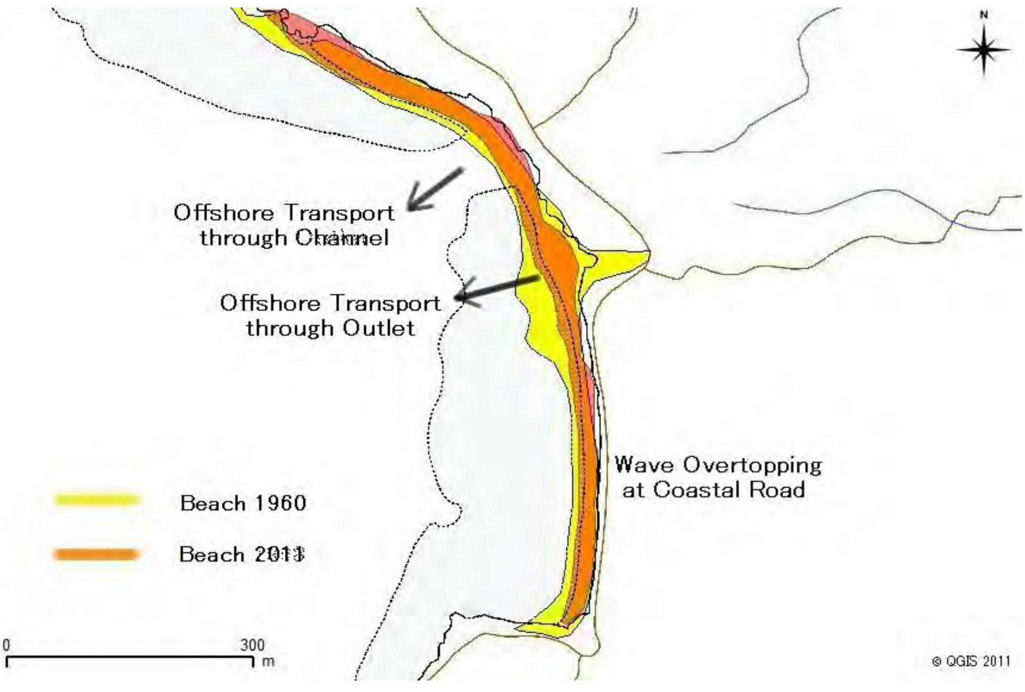


Figure 4-2-3: Estimated Sediment Movements at Baie Lazare

(2) Evaluation of Alternatives

The alternatives for coastal conservation are (1) the construction of revetments, (2) sand nourishment, and (3) traffic control and setback as long-term alternatives as accommodation.

Basically, the coast faces southeast and receives moderate waves. Structural measures are not suitable because the opportunities of high waves are rare.

The construction of submerged structures to prevent offshore loss of sediment during flooding is a possible measure but it is not economical. Traffic control is another measure. In future other measures will be necessary to counter the future rising sea level because of low ground.

(3) Coastal Conservation Plan

Sand nourishment for 20m in width for a 400 m stretch of the beach is proposed with maintenance nourishment as shown in Figure 4-2-4. It is necessary to monitor the beach profile to estimate the causes of erosion and the necessary sand volume for maintenance.

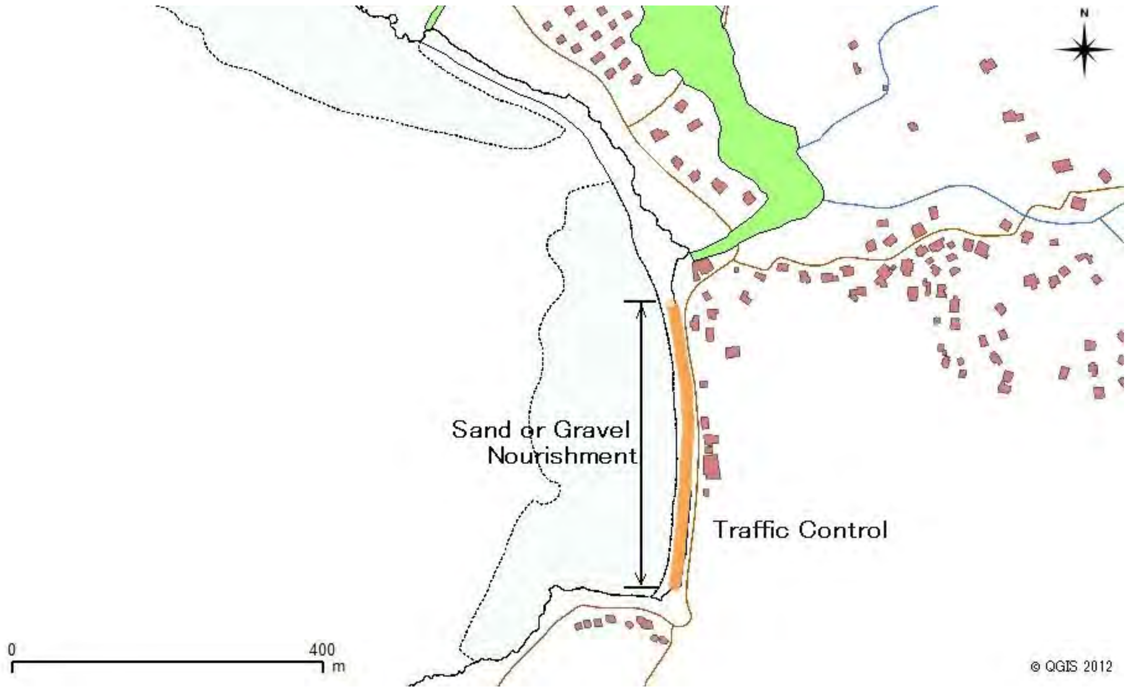


Figure 4-2-4: Measures at Baie Lazare

(4) Environment and Social Considerations

There are several impacts of sand nourishment. One impact is the misdistribution of benefits and damage and such impact is not clear at present. Therefore, the impact will be monitored after the nourishment. Other impacts occur during the construction stage such as air pollution and noise due to heavy machines and water pollution. The impacts are limited to only a short time and are slight. Traffic control is only applied during high waves and has little impact because the chances of occurrence are limited.

4-2-3 Anse Kerlan

(1) Conditions and Problems

The coast is located in the west part of Praslin and is protected by a coral reef. It receives waves from the northwest from December to March and from the south from May to October, causing seasonal changes in longshore sediment transport. Along the coast, hotels and restaurants have developed for tourism activities. The coast has one of the best beaches in Praslin.

The erosion causes the loss of property and the use of the sandy beach for bathing. Also, the erosion deteriorates tourism activities. Originally at Anse Kerlan the beach sand was transported from the north to the south and deposited at Grand Anse. Some of the sand was returned to Anse Kerlan by the waves from the south. After the erosion became severe, five groynes were constructed in 1990 and they prevent the return of sediment. The coastal road was shifted inland due to the erosion.

On the coast, the sand dunes are about 3m high and the ground is 3m to 4m high. The estimated wave run-up is usually 3m in height. After the erosion the beach became steep and the wave run-up is about 3.7m in height. Therefore, the erosion is more severe than the wave run-up.

At present, the owner of the land has constructed rock armouring to counter the erosion. The rock armouring causes scouring in front and increases sediment transport and loss of the beach. This makes it difficult to use the beach and the value for tourists will be lost.

The reason for the problems is that the environmental impact assessment was not adequate when they constructed the groynes and revetments.

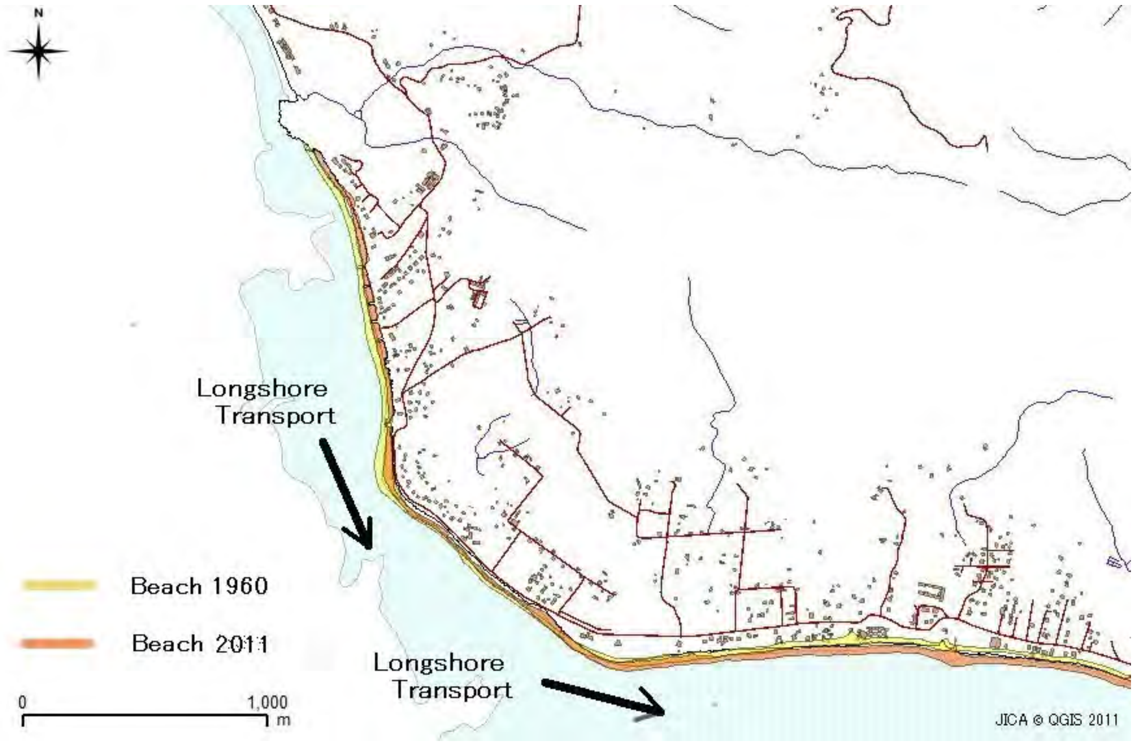


Figure 4-2-5: Estimated Sediment Movements at Anse Kerlan and Grand Anse

(2) Evaluation of Alternatives

The alternatives for coastal conservation are (1) the construction of revetments, (2) the construction of groynes and sand nourishment, (3) the construction of groynes and artificial reefs, and (4) setback and relocation of buildings as accommodation.
Revetments prevent erosion but cause scouring in front. The loss of sand makes it difficult to use the beach and deteriorates the scenery. Therefore, it is not suitable for tourist beaches. Groynes and nourishment are appropriate because they control longshore sediment transport and maintain the sandy beach. For the prevention of offshore sediment loss, artificial reefs are one measure. However, at present it is difficult to conduct proper planning and design of the reefs because suitable information is limited.
In view of the fact that the beach is important for tourism, sand nourishment and groyne construction are appropriate for recovering the beach and reducing longshore transport. Revetments may cause loss of beach sand.

(3) Coastal Conservation Plan

Three groynes and sand nourishment for 20m in width for a 1,000 m stretch of the beach were proposed with maintenance nourishment to stabilise the beach as shown in Figure 4-2-6. The existing groynes and revetments have to be partly removed.

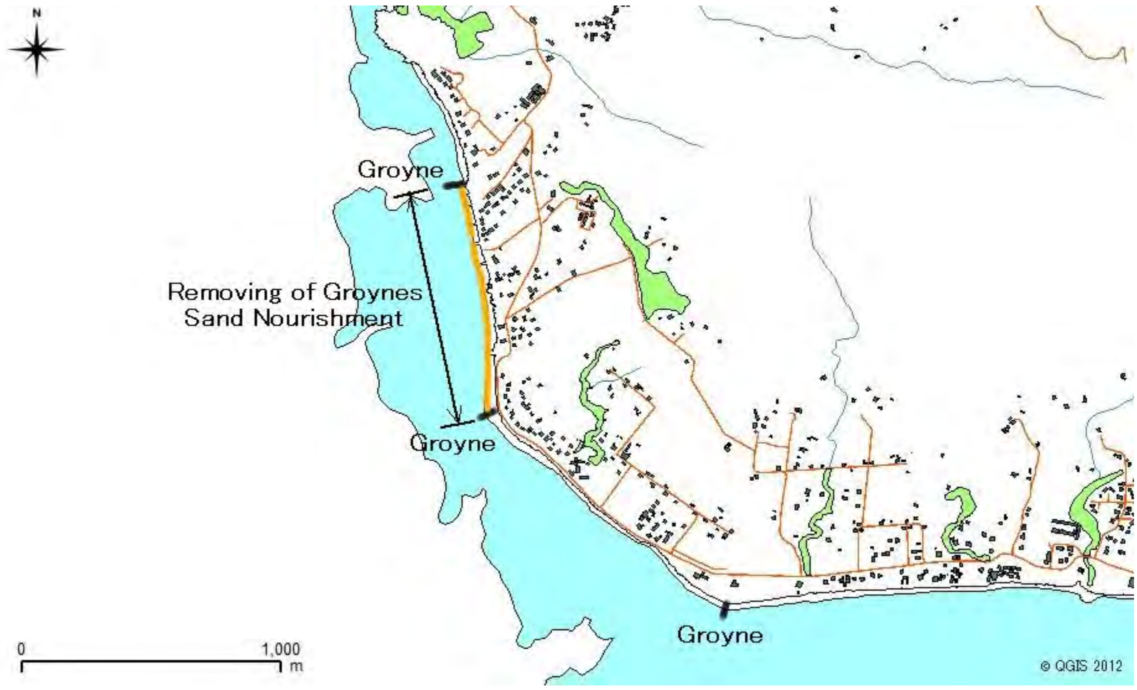


Figure 4-2-6: Measures at North East Point

(4) Environment and Social Considerations

There are several impacts of sand nourishment. One impact is the misdistribution of benefits and damage and such impact is not clear at present. Therefore, the impact will be monitored after the nourishment. The impact of the groynes is limited because several existing groynes have been removed. The impact will be mitigated by sand nourishment to recover the beach.

The scenery will be greatly improved by reducing the groynes and revetments compared to at present. As for the long-term measures, setback is proposed as accommodation. In some cases buildings will have to be relocated. After the monitoring of the proposed plan for the effects of the nourishment and the impact of climate change, this will be executed with the understanding of stakeholders.

4-2-4 La Passe

(1) Conditions and Problems

The coast is located in the west part of La Digue and is protected by a wide coral reef and Praslin Island to the west. Therefore, waves come from the north and south and not from the west. A jetty is provided for the ferry to Praslin. The anchorage is protected by three breakwaters.

The breakwaters at the jetty cause accretion at the anchorage and erosion of the south beach as shown in Figure 4-2-7. Erosion causes loss of land and wave overtopping onto the hospital grounds. The anchorage is difficult to use and needs dredging. These problems are possibly caused by inadequate environmental impact assessment of the construction of breakwaters and groynes. In front of the hospital, rock armouring was constructed.

At present, sediment is transported to the sheltered area by the breakwaters and the anchorage and the south coast are being eroded. The accumulation in the anchorage makes the mooring of boats difficult.

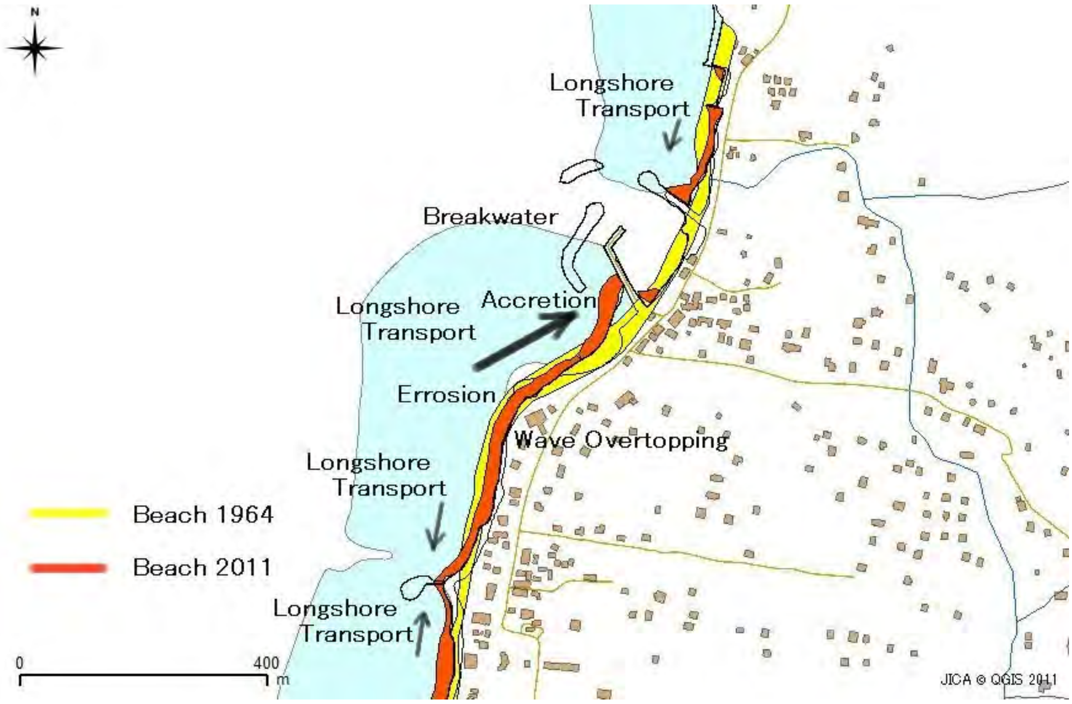


Figure 4-2-7: Estimated Sediment Movements at La Passe

(2) Evaluation of Alternatives

The alternatives for costal conservation are (1) the construction of a groyne and sand bypass, (2) rearrangement of the breakwaters and groynes, and (3) relocation of the hospital and setback. The construction of a groyne and sand bypass would prevent longshore sediment transport from the south to the breakwaters and transport the accumulated sand at the anchorage to south of the groyne. The problems would be solved directly.

The rearrangement of the breakwaters and groynes would reconsider the present conditions and obtain a better solution because the structures were constructed according to the immediate needs at the time. However, the rearrangement has to be studied not only for coastal conservation but also for the development and use of the harbour. This should be a comprehensive and long-term plan.

To reduce the accumulation of sediment in the sheltered area, a groyne with sand bypass from the anchorage to the eroded beach is appropriate. The rearrangement of the breakwater and groynes is one alternative. However, it would be necessary to conduct a detailed study and this is not within the action plan. The arrangement of the groyne was considered for future development based on the existing proposed plan.

(3) Coastal Conservation Plan

One groyne with sand bypass of 1,000 m^3 of sand from the anchorage to the south beach are proposed as shown in Figure 4-2-8.

Figure 4-2-8: Measures at La Passe

(4) Environment and Social Considerations

The impact of construction of a groyne was obstruction of the passage for fishing boats. As mitigation measures, a small channel was dredged near the head of the groyne. The impact on the scenery was mitigated by smooth and harmonious alignment of the structures.

At the construction stage, air pollution, noise and water contamination caused by heavy machinery were expected. However, it was expected that the impact would be limited because the scale was small and the time was short.

4-3 Operation and Maintenance Plan

In the coastal conservation plan, the structures requiring maintenance are sand nourishment, the groynes and the coastal road. The maintenance plan includes not only maintenance but management of the structures.

Basically, the sand is nourished continuously if the beach is eroded to maintain the sediment budget. The volume of sand which is nourished is decided by beach profile monitoring. Generally, the volume of nourishment corresponds to the loss of sediment for 5 to 10 years.

The coastal structures are affected by changes in the beach profile and external forces such as waves. Sometimes they are damaged and lose their functions. It is necessary to repair and maintain the structures. If damage occurs, the situation and causes should be investigated.

On the coastal road, wave overtopping or sand run-up sometimes occurs. To deal with this condition, traffic regulations are one measure according to the tidal and wave conditions. If there is a reef offshore, a warning can be issued based on tide estimation because the impact of the tide is greater than the waves.

4-4 Cost and Benefits

The construction and maintenance costs are estimated as shown in Table 4-4-1 for the priority coasts. The maintenance cost of the groynes is 0.5%/year and maintenance nourishment is estimated from the results of the pilot project at North East Point. The total cost is 113 million Rupees and 3 million Rupees/year until 2050.

Table 4-4-1 Construction and Maintenance Costs for Priority Coasts

Coast	Structure	Length m	Unit Price SCR/m	Construction Cost 1,000*SCR	Ratio of Maintenance %	Maintenance Nourishment m^3/year 1,000*SCR	Maintenance (38 years) 1,000*SCR
North East Point	Nourishment	1,350	17,000	22,950		1,000	21,533
Baie Lazare	Nourishment	400	17,000	6,800		296	6,380
Anse Kerlan	Groyne	3*100=300	11,000	3,300	0.5%		627
	Nourishment	900	35,000	31,500		675	14,963
La Passe	Groyne	50	11,000	550	0.5%		105
	Nourishment	100	35,000	3,500		15	333
Total				68,600			43,940

The cost of each project was estimated. However, the benefits are difficult to assess because of limited reliable information. They will be analysed in future. The damage caused by the January flood was estimated, however the estimate was not reliable.

Chapter 5 Formulation of Flood Management Plan

5-1 General

From the results of the evaluation in Chapter 3, the Flood Management Plan for the Seychelles is summarised in the following:

1. Most of the rivers in the country have the capacity to discharge rainwater. The main countermeasures to be applied in the short term are drainage improvement, O/M and non-structural measures
2. After the completion of the short-term measures, in order to upgrade risk management to a medium-term scale, river improvements are adopted with simultaneous implementation of O/M and non-structural measures.
3. Victoria Town is the only urbanised town in the Seychelles. However, due to rapid development in the country, many locations will be urbanised in the future. An urban drainage improvement plan will be proposed for Victoria Town for the application of short-term measures, while river improvement works will apply medium-term measures.
4. Pointe Larue, Anse Aux Pins, Au Cap and Anse Royale are selected as priority areas for the preparation of the flood management plan.
5. In the above districts, the main drainage is provided along the main road (one side or both sides) and secondary drainage from the residential areas, schools and other facilities is connected to the main drainage. However, the drainage system is not uniform due to the different implementation times, with different agencies' designs and different purposes.
6. For other districts, basically the proposed drainage improvement will apply short-term countermeasures while medium-term measures will be applied for river improvement. However, in some locations drainage and rivers have no clear boundaries, and in these cases, stepwise implementation is proposed.
7. Structural measures for drainage and river improvement works will take into consideration available materials, equipment and common construction methods in the Seychelles. Moreover, less manpower is used by O/M.
8. Structural measures require the proper quality, quantity, safety and schedule control. Moreover, good O/M will contribute to longer structural life and savings in the government budget. In order to achieve/improve skills, training of engineers is of great importance.
9. Moreover, in order to implement river improvement works in the medium term, river basins and river boundaries must be properly maintained by regulations and the Land Use Act. Otherwise, there will be fewer options for countermeasures for flood mitigation in the future, leading to grave questions by the next generation.
10. Even with all the countermeasures, people living on low land will still suffer inundation by rainwater.
11. It should be noted that in the long-term measures, structural measures have limitations because of scale and cost implications. The Government of the Seychelles must start sending clear message and implementing measures based on the SSDS 2012.

The proposed countermeasures in the flood management plan for Victoria Town and other priority districts are listed in Table 5-1-1 and Table 5-1-5 respectively.

Table 5-1-1: Victoria Town Action Plan

Item	Explanation
Conditions	The town has been developed and urbanised in the seaward direction by reclamation. The ground level of the reclaimed land is higher than that of the old town.
Problems	The flow capacity of the drains and rivers is not enough for flood water.
Evaluation of Alternatives	The main cause is lack of drainage capacity. Therefore, the most appropriate measure is to increase the capacity of the drains under the road rather than to make a new drainage system. For medium-term improvement, an increase in the flow capacity of the rivers is preferable.
Short-Term Plan	Improvement of 8 drainage channels totalling 1.3km in length with a 40% capacity increase. The channels are located at Olivier Maradan (88m), Market Street (108m), Huteau Lane (179m), Palm Street (121m), Benezet Street (125m), State House Avenue (96m), Independence Avenue (223m) and Francis Rachel (321m)
Medium-Term Plan	River improvements including 1,080m-long bed excavation, 340m-long channel widening, 780m-long wall construction and a 28 m-long elevated dike. The five rivers are the River Anglaise, River Moosa, River Maintry, River St. Louis and River La Poudriere.

Table 5-1-2: Point Larue Action Plan

Item	Explanation
Conditions	At one time the road ran along the coast and small rivers flowed out to the sea. The Seychelles International Airport and main highway were developed on reclaimed land fronting the old coastal road.
Problems	The reclamation obstructs the river flow and drainage from the road. Flooding on the road makes it difficult to access the airport from Victoria Town. Also, drainage problems are severe at three lowland sites.
Evaluation of Alternatives	As a short-term measure, drainage improvement was proposed. In the medium term, enlargement of the existing culvert was proposed. As the cause is lack of proper drainage, direct improvement or extension is more appropriate than reducing flood discharge by construction of a retarding basin.
Short-Term Plan	Drainage improvement by a culvert (30m) under the road, extension of the drainage channel (40m) to the wetland and widening of the existing channels are proposed.
Medium-Term Plan	Enlargement of the existing 8m-long culvert is proposed.

Table 5-1-3: Anse Aux Pins Action Plan

Item	Explanation
Conditions	Along the coast wetland formed and at one time stored flood water. The lowland around the wetland has been developed for housing or public facilities such as schools.
Problems	The sand deposited at the outlet by the waves causes flooding problems in the residential area on low land. At Chetty Flat the drainage does not work well due to lack of management.
Evaluation of Alternatives	At Chetty Flat the improvement of the existing channel is long and needs land acquisition. The proposed new channel is short and easy to maintain. The improvement of the rivers was considered according to the characteristics of each river and the appropriate improvement selected.
Short-Term Plan	At Chetty Flat the construction of a new 120m-long drainage channel to the sea is proposed.
Medium-Term Plan	Improvement of the river near the mouth is proposed. One measure is 300m-long riverbed excavation and the other is widening of the river for 200 m with construction of a new box culvert.

Table 5-1-4: Au Cap Action Plan

Item	Explanation
Conditions	Along the coast wetland formed and at one time stored flood water. The low land around the wetland has been developed for housing estates and public facilities such as schools.
Problems	The sand deposited at the outlet by the waves causes flooding problems in the residential area on low land. New measures using pipes have been adopted but the flow capacity is not enough.
Evaluation of Alternatives	The flooding is caused by the lack of flow capacity at the mouth. Therefore, increasing the capacity by widening or dredging of the river and maintaining the river mouth is appropriate.
Short-Term Plan	Improvement of the drainage system is proposed.
Medium-Term Plan	Improvement of the river near the mouth is proposed by widening of the river (620m) and two bridges with widening of the river mouth (230m).

Table 5-1-5: Anse Royal Action Plan

Item	Explanation
Conditions	Along the coast wetland formed and at one time stored flood water. The lowland around the wetland has been developed for housing or public facilities such as schools.
Problems	The sand deposited at the outlet by waves causes flooding problems in the residential area on low land.
Evaluation of Alternatives	Flooding is caused by the lack of flow capacity at the mouth. Therefore, increasing the capacity by widening or dredging of the river and maintenance of the river mouth is appropriate.
Short-Term Plan	A 120m-long drainage ditch of is proposed.
Medium-Term Plan	Improvement of two rivers near the mouths is proposed by widening of the rivers (170m), river bed excavation (1400m) and a bridge with widening of the river mouth (130m).

5-2 Flood Management Plan for the Priority Areas

5-2-1 Victoria Town

(1) Profile of Victoria Town

Victoria is the largest settlement on Mahe and also the capital of the Republic of the Seychelles. About one-third of the people in the Seychelles live in Victoria which has a population of 23,300.

In the *Preliminary Study of the Flooding Problem in Victoria* report mentioned above, two zones were identified, the Central Victoria Area and the Greater Victoria Area covering about 1.18 km^2 and 10.05 km^2, respectively.

Review of the results of the *Preliminary Study of the Flooding Problem in Victoria, 2005*, as well as investigation of the existing conditions and discussions with DOE, reveal that the inundation points are concentrated in five catchments, namely the River Anglaise, River Moosa, River Maintry, River St. Louis and River La Poudriere areas. The core area of Mahe Island and the problem of the drainage facilities in this area are of great importance and urgency and quick improvement is needed. Therefore, these five catchments are the target areas for the formulation of the urban flood management plan for Victoria Town.

The study area is as indicated in Figure 5-2-1.

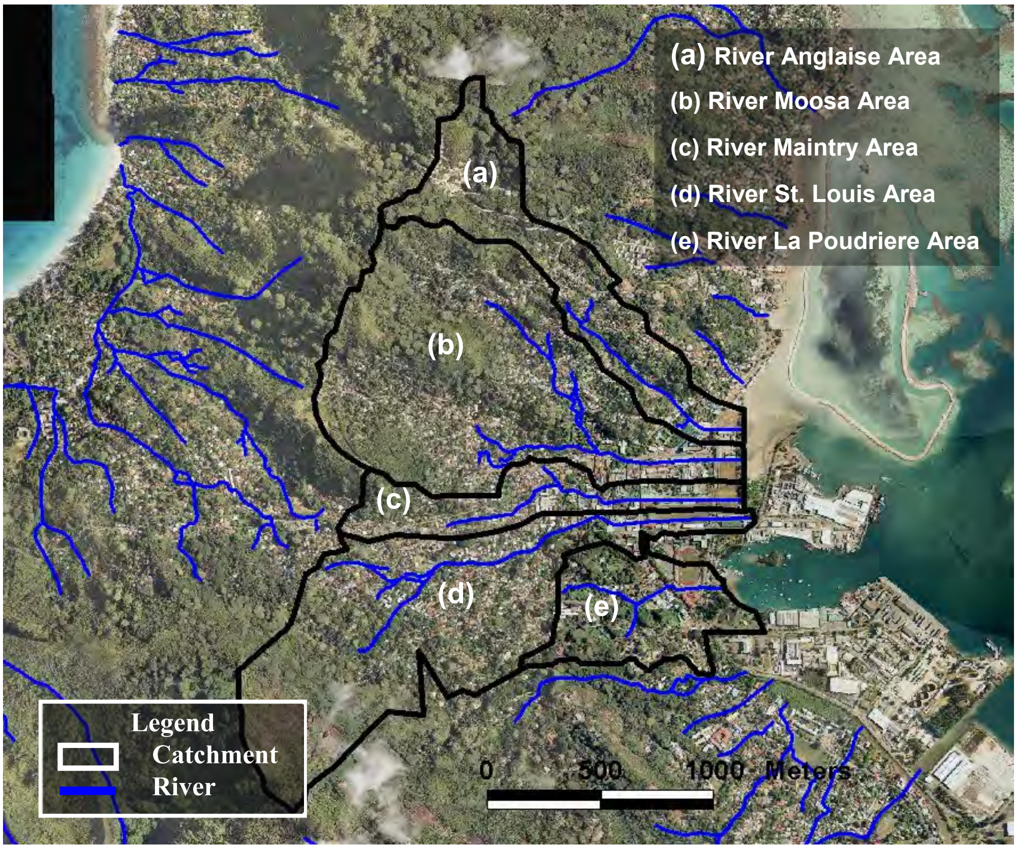


Figure 5-2-1: Study Area

(2) Existing River and Drainage System

As mentioned above, the study area consists of five river catchments. Detailed descriptions of the existing drainage system in each catchment are as described below.

River Name	Catchment Area, km^2	Width, m	Depth, m	Problems at the Site
Anglaise River	0.57	4.1- 5.2	1.3-3.0	Obstructions in river
Moosa River	1.35	3.7-12.3	1.0-3.0	Water overflow at confluence point
Maintry River	0.33	1.7-3.7	0.4-2.3	Sand silting and obstruction by pipes and cables
St. Louis River	1.18	3.5-13.5	0.9-2.6	Obstruction by pipes, cables and concrete structures
La Poudriere River	0.38	2.1-4.4	1.1-2.5	Obstruction by pipes, cables and concrete structures

The five rivers have good flow conditions and are well maintained. However, in some locations, the flow capacity of the original sections has been diminished due to obstacles such as concrete structures, cables and pipes as shown below.

Photo 5-2-1:
Obstacle in River Anglaise

Photo 5-2-2:
Obstacle in River Maintry

Photo 5-2-3:
Obstacle in River La Poudriere

Most of the drains have good flow conditions and are well maintained, but some drains are already settled and are not in proper working condition as shown in Photo 5-2-4. In some locations, obstacles are found in the drains as shown below.

Photo 5-2-4:
Settled side drain at Market Street

Photo 5-2-5: Obstacle near junction of 5th June Ave. and Manglier Rd.

(3) Problem Analysis

A hydraulic analysis was conducted to evaluate the existing drainage network. A 10-year return period was used as recommended in the Drainage Design Guidelines.

The location of the flood prone areas almost matches the location of the inadequate drains. It is obvious that the main cause of flooding in Victoria Town is the insufficient capacity of the drains (undersized and/or improper longitudinal slope, etc.).

(4) Urban Drainage Improvement Plan

A number of the drainage problems were discussed in the previous section, leading to the recommended plan for future drainage improvement. In this sub-section the required infrastructure components are identified. The following discussions outline the drainage improvement plans for each area.

(a) Outline of the Improvement Plans for Each Area

1) River Moosa Area

The calculated discharges based on the foregoing discussions are shown in the appropriate columns in Table 2-5-17. Some drains have inadequate design discharge. The proposed drainage improvement plans are shown in Table 5-2-1. The locations of the proposed drains which are to be improved are shown in

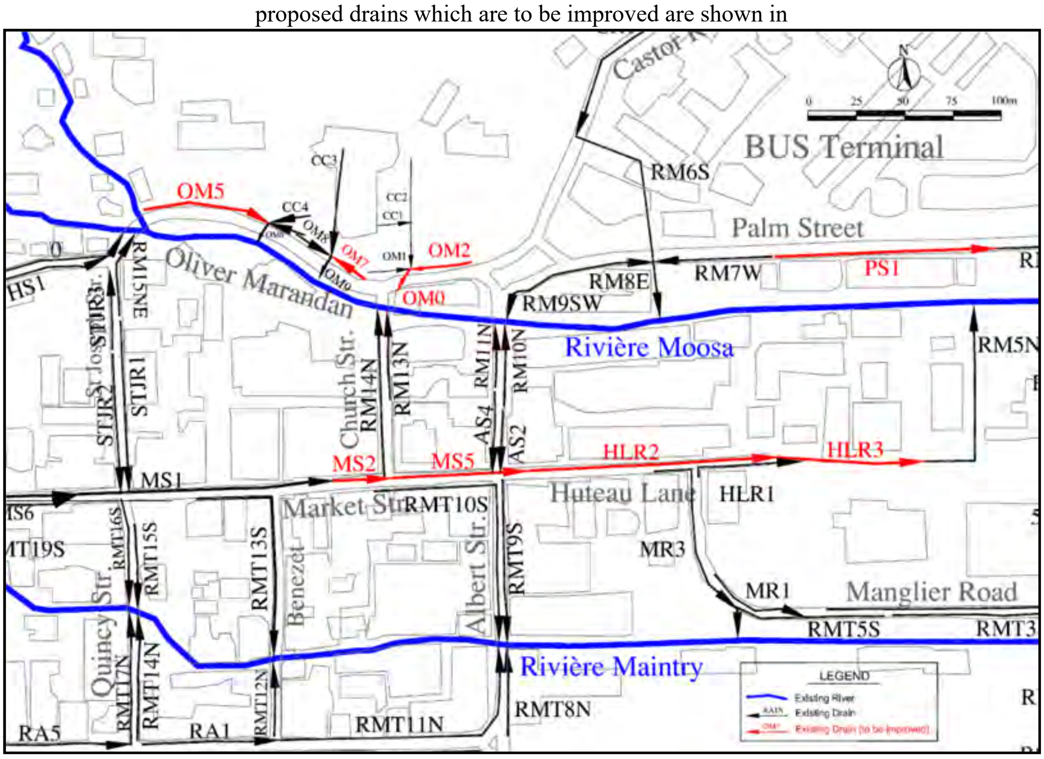


Figure 5-2-2.

Table 5-2-1: Proposed Drainage Improvement Plan for River Moosa Area

Drain Sr. No.	Location	Existing							Proposed							Remark
		Ld	W	H	Beginning Point		End Point		Ld	W	H	Beginning Point		End Point		
		m	m	m	GL	Invert EL	GL	Invert EL	m	m	m	GL	Invert EL	GL	Invert EL	
OM7	Oliver Marandan	20.61	0.37	0.31	2.81	2.50	2.55	2.24	20.61	0.37	**0.40**	2.81	2.41	2.55	2.15	Improvement work -open drain in rock - H 0.31m → 0.40m
OM5	Oliver Marandan	54.63	0.27	0.18~0.80	4.71	4.53	3.50	3.32	54.63	0.27	0.18~0.80	4.71	4.53	3.50	3.32	Rehabilitation work -remove the sediments for open & covered drains Improvement work
OM2	Oliver Marandan	47.79	0.30	0.20	2.83	2.63	2.80	2.60	47.79	0.30	**0.30**	2.83	2.53	2.80	2.45	Improvement work -open drain in rock - H 0.20m → 0.30m
OM0	Oliver Marandan	20.00	0.15	0.15	2.83	2.68	2.80	2.65	20.00	**0.30**	**0.30**	2.80	2.53	2.83	2.40	Improvement work -closed drain under the road - 0.15x0.15m → 0.30x0.30m
MS2	Market Street	34.40	0.50	0.45	2.10	1.65	1.80	1.35	34.40	0.75	0.45	2.10	1.65	1.80	1.35	Improvement work -covered drain under walkway - B 0.50m → 0.75m - provide the new grating or concrete cover
MS5	Market Street	73.70	0.70	0.50	1.80	1.30	1.38	0.88	73.70	**0.80**	0.50	1.80	1.30	1.38	0.88	Improvement work -covered drain under walkway - B 0.70m → 0.80m - provide the new grating or concrete cover
HLR2	Huteau Lane	138.60	0.94	0.60	1.38	0.78	1.34	0.74	138.60	**1.10**	0.70	1.38	0.68	1.34	0.44	Improvement work -covered drain under the road - 0.94x0.60m → 1.10x0.70m - provide the new grating or concrete cover
HLR3	Huteau Lane	40.40	0.60	0.70	1.34	0.64	1.21	0.51	40.40	**1.10**	**0.70**	1.34	0.44	1.55	0.35	Improvement work -covered drain under the road - 0.60x0.70m → 1.10x1.00m - provide the new grating or concrete cover
PS1	Palm Street	121.10	0.50	0.50	2.00	1.50	2.00	1.40	121.10	0.50	**0.70**	2.00	1.50	2.00	1.30	Improvement work -covered drain under walkway - H 0.50m → 0.70m

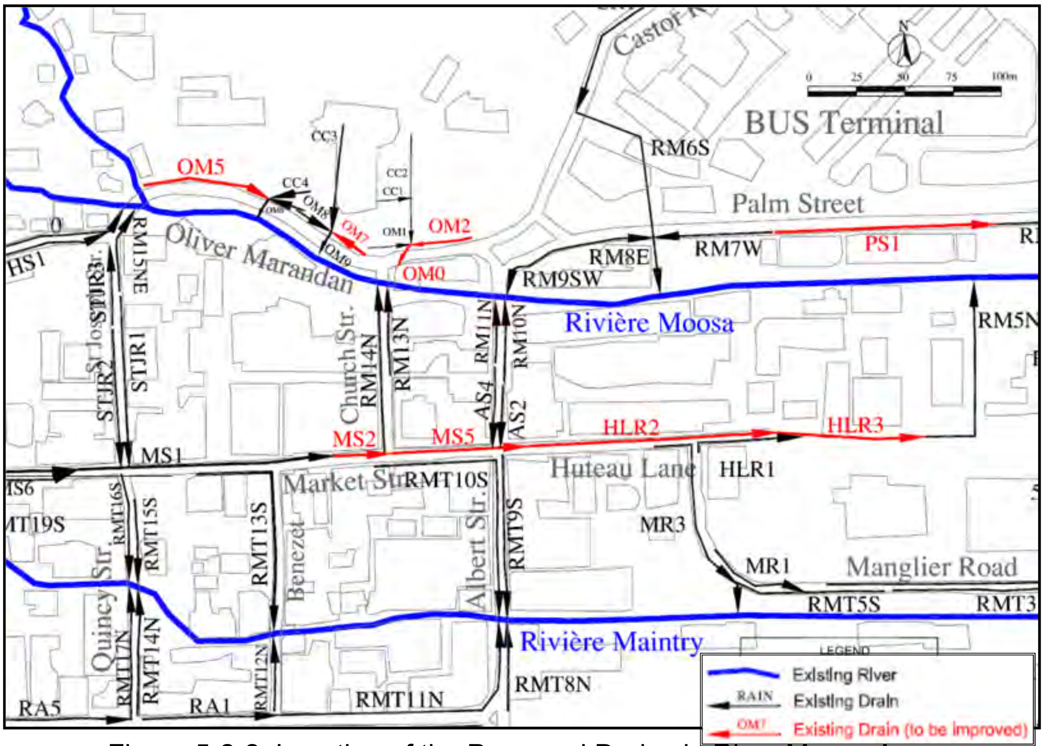


Figure 5-2-2: Location of the Proposed Drains in River Moosa Area

2) River Maintry Area

The calculated discharges based on the foregoing discussions are shown in the appropriate columns in Table 5-2-2. Some drains have inadequate design discharge. The proposed drainage improvement plans are shown in Table 5-2-2. The locations of the proposed drains which are to be improved are shown in

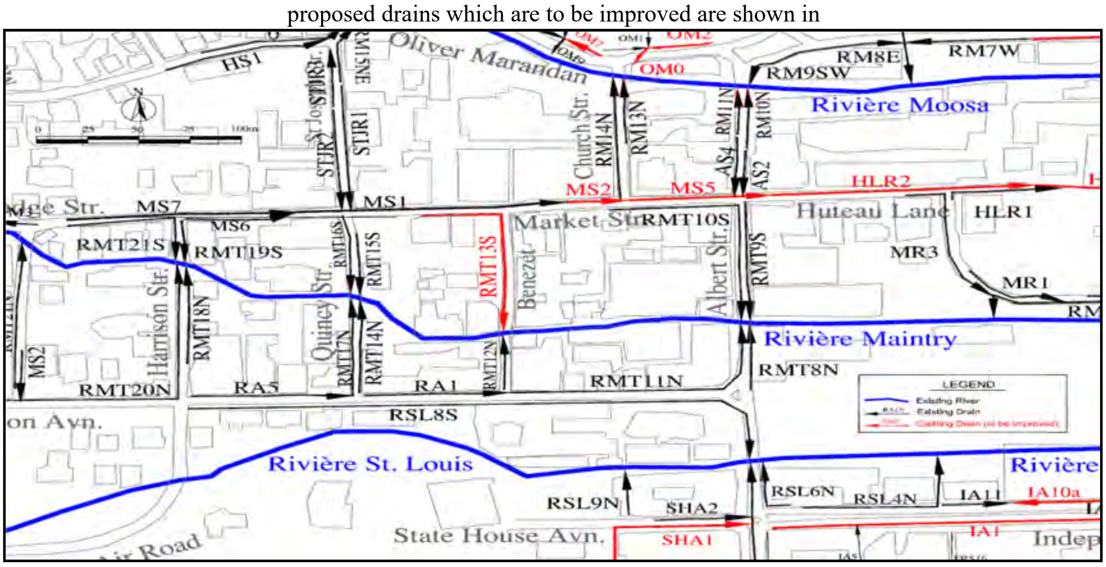


Figure 5-2-3.

Table 5-2-2: Proposed Drainage Improvement Plan for River Maintry Area

Drain Sr. No.	Location	Existing							Proposed							Remark
		Ld	W	H	Beginning Point		End Point		Ld	W	H	Beginning Point		End Point		
		m	m	m	GL	Invert EL	GL	Invert EL	m	m	m	GL	Invert EL	GL	Invert EL	
RMT13S	Benezet Street	125.40	0.50	0.50	2.48	1.98	2.77	1.97	125.40	0.50	**0.60**	2.48	1.88	2.77	1.77	Improvement work -covered drain under walkway - H 0.50m → 0.60m

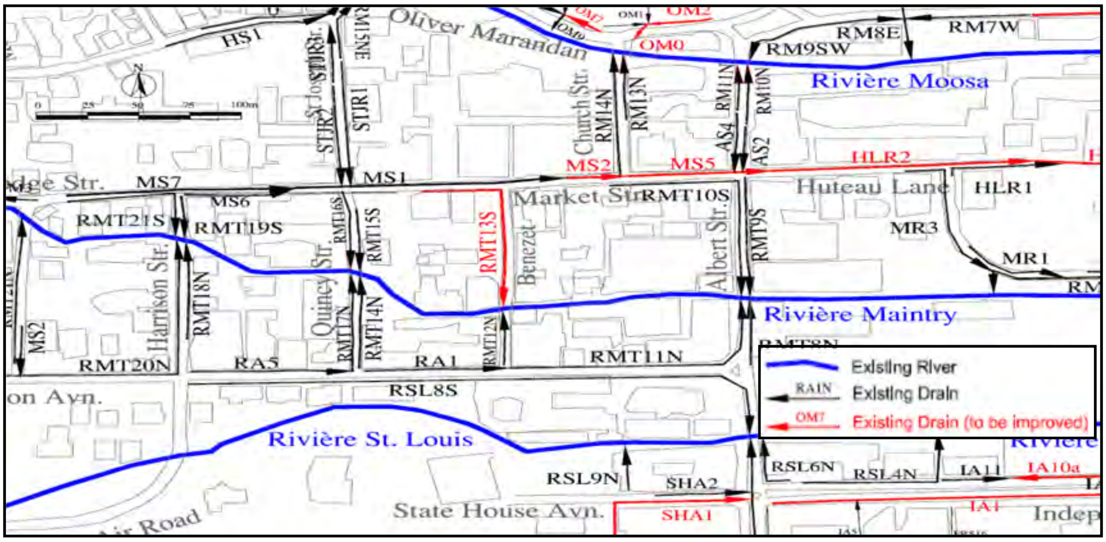


Figure 5-2-3: Location of the Proposed Drains in River Maintry Area

3) River St. Louis Area

The calculated discharges based on the foregoing discussions are shown in the appropriate columns in Table 5-2-3. Some drains have inadequate design discharge. The proposed drainage improvement plans are shown in Table 5-2-3. The locations of the proposed drains which are to be improved are shown in

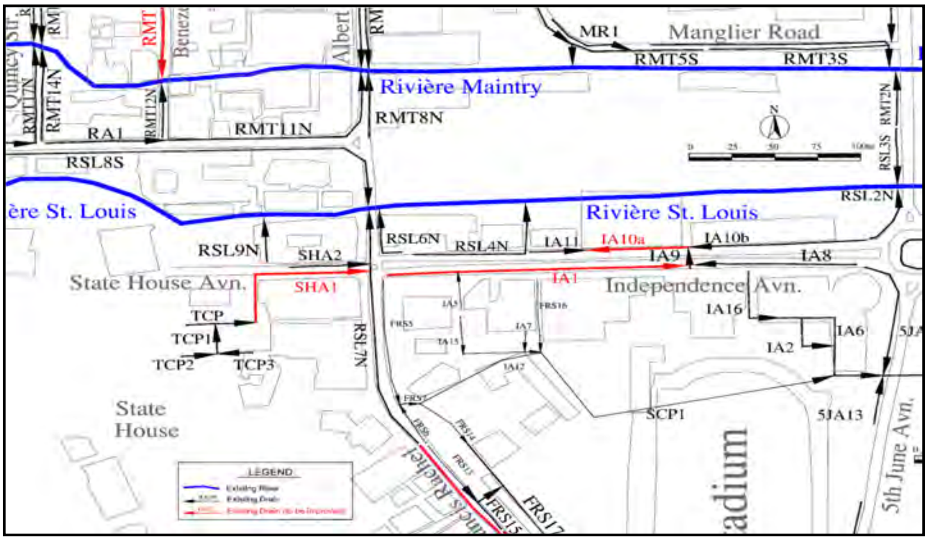


Figure 5-2-4.

Table 5-2-3: Proposed Drainage Improvement Plan for River St. Louis Area

Drain Sr. No.	Location	Existing Ld	Existing W	Existing H	Existing Beginning Point GL	Existing Beginning Point Invert EL	Existing End Point GL	Existing End Point Invert EL	Proposed Ld	Proposed W	Proposed H	Proposed Beginning Point GL	Proposed Beginning Point Invert EL	Proposed End Point GL	Proposed End Point Invert EL	Remark
		m	m	m					m	m	m					
SHA1	State House Avn.	95.50	0.40	0.50	2.00	1.50	1.56	1.06	95.50	**0.50**	0.50	2.00	1.50	1.56	1.06	Improvement work -covered drain under the walkway - B 0.40m → 0.50m
IA1	Independence Avn.	163.40	0.50	0.40	1.58	1.02	1.28	0.88	163.40	0.50	**0.50**	1.58	1.02	1.28	0.78	Improvement work -covered drain under the road - H 0.40m → 0.50m - provide the new grating or concrete cover
IA10a	Independence Avn.	60.00	0.50	0.80	1.24	0.44	1.27	0.37	60.00	**0.60**	0.80	1.24	0.44	1.27	0.37	Improvement work -covered drain under walkway - B 0.50m → 0.60m - provide the new grating or concrete cover

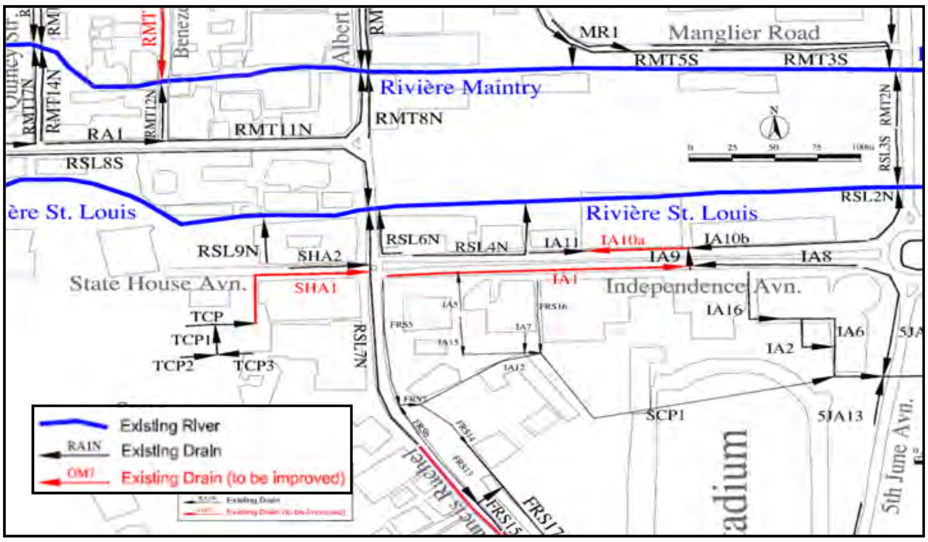


Figure 5-2-4: Location of the Proposed Drains in River St. Louis Area

4) River La Poudriere Area

The calculated discharges based on the foregoing discussions are shown in the appropriate columns in Table 5-2-4. Some drains have inadequate design discharge. The proposed drainage improvement plans are shown in Table 5-2-4. The locations of the proposed drains which are to be improved are shown in

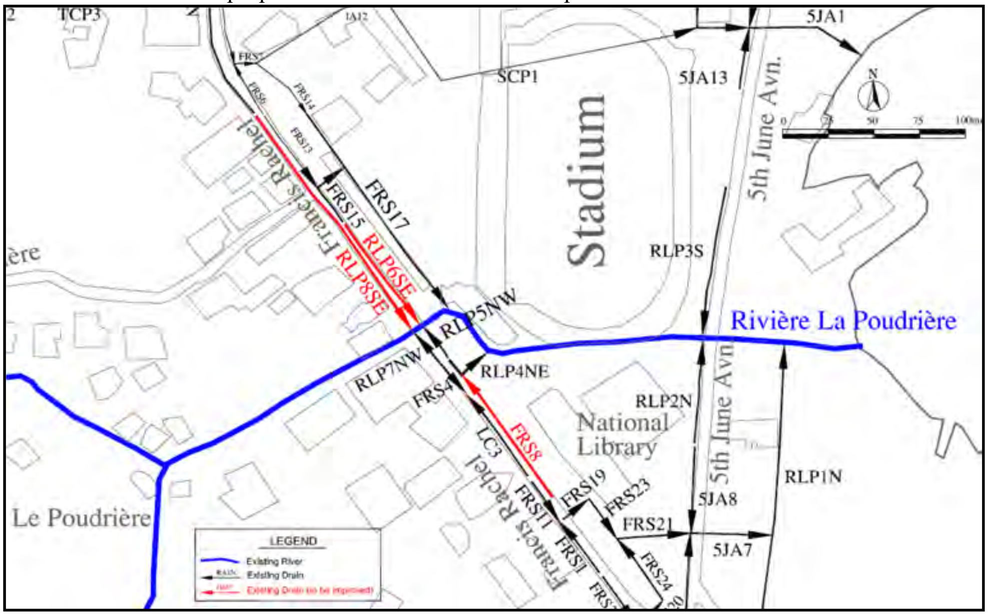


Figure 5-2-5.

Table 5-2-4: Proposed Drainage Improvement Plan for River La Poudriere Area

Drain Sr. No.	Location	Existing							Proposed							Remark
		Ld	W	H	Beginning Point		End Point		Ld	W	H	Beginning Point		End Point		
		m	m	m	GL	Invert EL	GL	Invert EL	m	m	m	GL	Invert EL	GL	Invert EL	
RLP8SE	Francis Rachel	168.10	0.60	0.50	1.50	1.00	1.40	0.90	168.10	0.60	**0.75**	1.50	0.80	1.40	0.60	Improvement work -covered drain under walkway - H 0.50m → 0.75m New construction work -covered drain same as existing drain
RLP6SE	Francis Rachel	58.70	0.20	0.25	1.39	1.14	1.40	1.10	58.70	**0.30**	0.25	1.39	1.14	1.40	1.10	Improvement work -open drain along the road - B 0.20m → 0.30m
FRS8	Francis Rachel	95.30	0.30	0.30	1.51	1.21	1.30	1.00	95.30	**0.45**	0.30	1.51	1.21	1.30	1.00	Improvement work -open drain along the road - B 0.30m → 0.45m

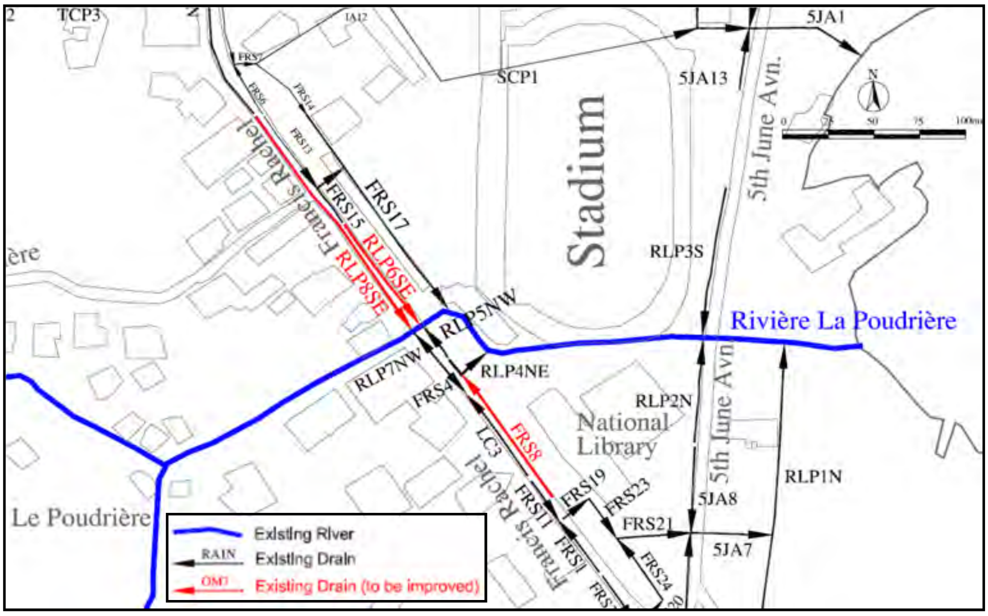


Figure 5-2-5: Location of the Proposed Drains in River La Poudriere Area

(b) Short-Term-Plan (10-year Return Period)

The calculation results for design discharge with a 10-year return period are as shown in Figure 5-2-6. A representative section of each river is shown in the same figure with the design HWL. No overflow was observed which suggests that there is no need for measures under the short-term plan.

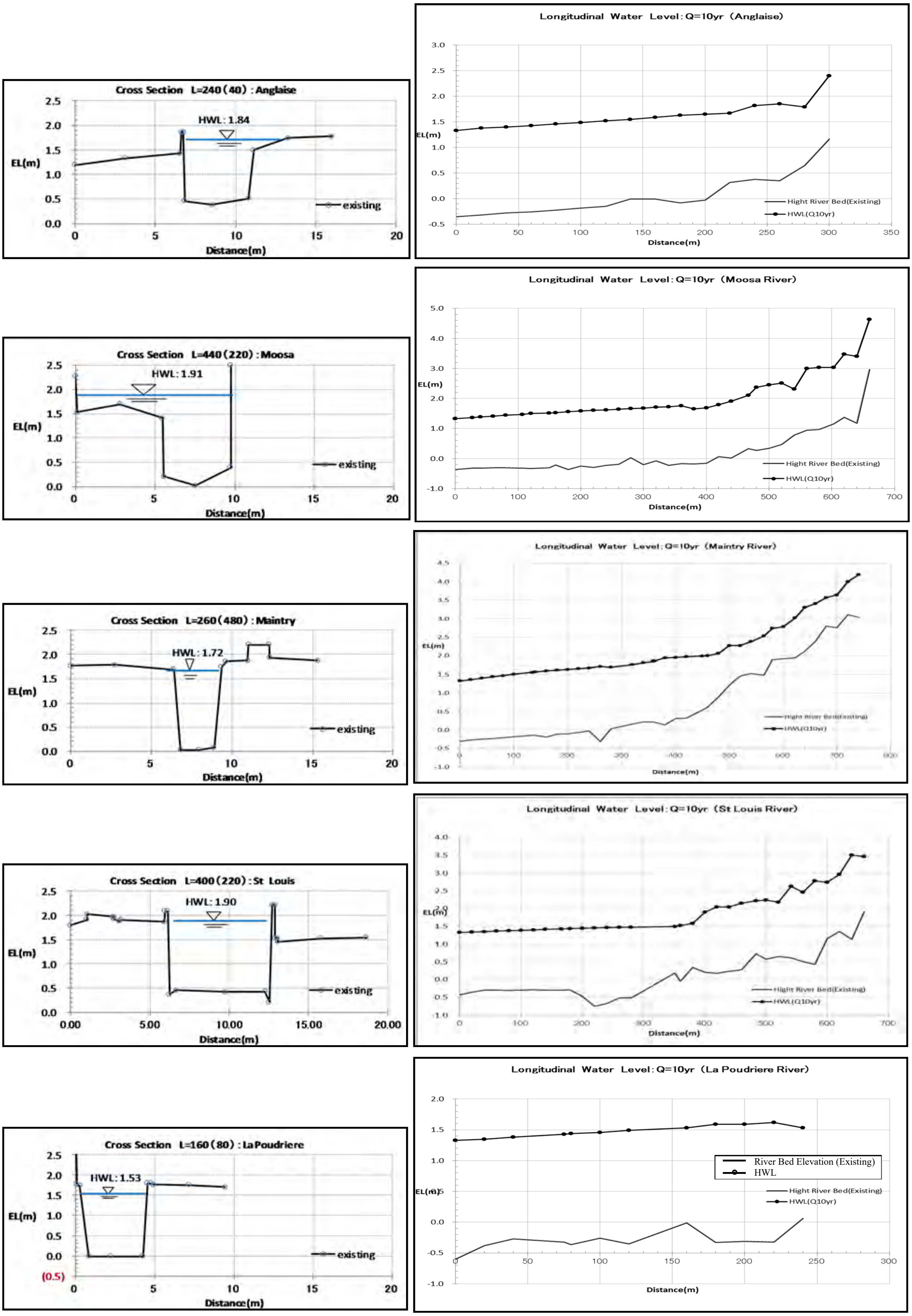


Figure 5-2-6: HWL of Short-Term-Plans (10-year) for 5 rivers

(c) Medium-Term Plan (25-year Return Period)

In the analysis of the results of the medium-term plan (25-year return period), the highest water level is 20 to 30 cm higher than for the 5-year return period, so an overflow section of the river is anticipated. However, since Victoria Town is urbanised and is located by the sea, it is difficult to change the alignment of the river bed. It is planned to lower the HWL below the existing ground level. The proposed structural countermeasures for Victoria Town are listed in Table 5-2-5 and

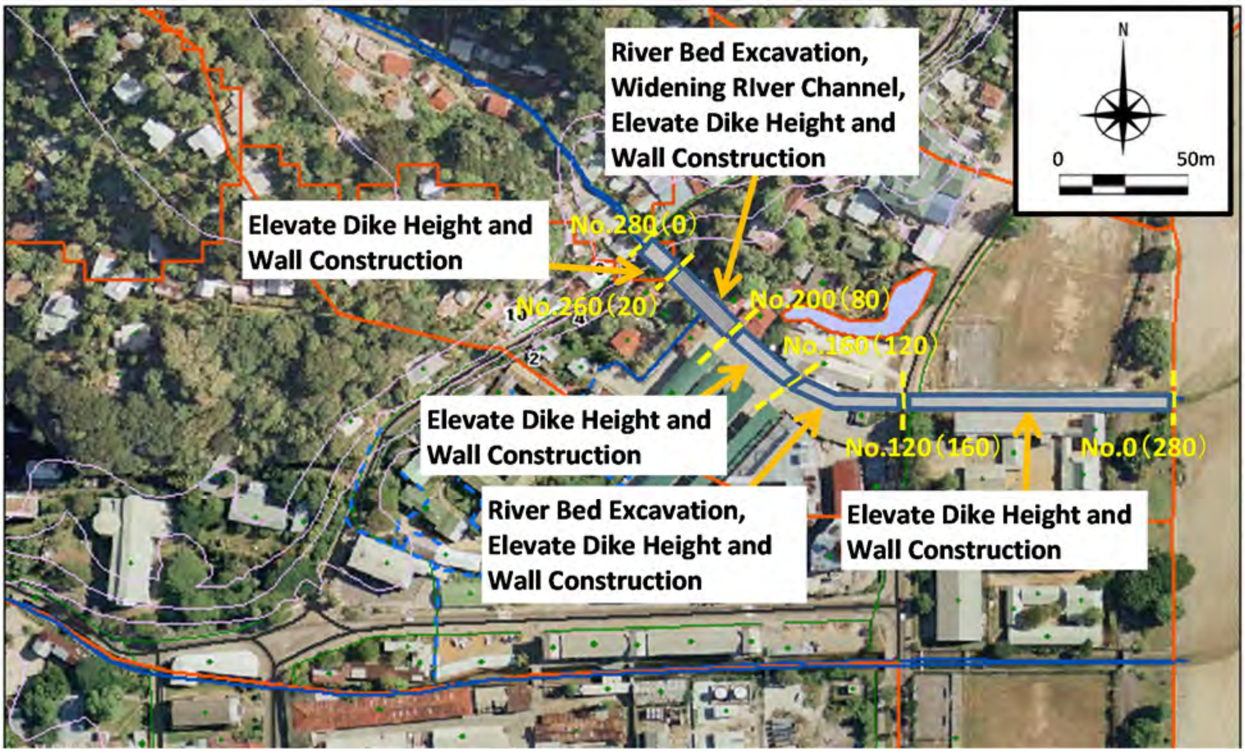


Figure 5-2-7 to

Figure 5-2-11.

Table 5-2-5: Proposed Structural Countermeasures for Victoria Town

River Name	Station No. Start	Station No. End	Length m	Thickness m	Width m	Remark	Amount(SR) Parapet levee	Revetment	underpining	river bed excavation	Bridge	Total
Anglaise	120	160	40	0.1						6,000		6,000
	200	260	60	0.3						28,000		28,000
	200	260	60		1.0					42,000		42,000
		280	280			H=0.5m	390,000					390,000
		280	280			H=2.0m		3,491,000				3,491,000
Moosa	280	300	20	0.15						5,000		5,000
	400	620	220	0.3						103,000		103,000
	400	620	220			H=0.75m	449,000					449,000
Maintry		400	400	0.3					2,026,000	94,000		2,120,000
		280	280		1.0					245,000	2,394,000	2,639,000
		280	280			H=2.5m		4,560,000				4,560,000
	400	420	20	0.15						2,000		2,000
St. Louis	300	540	240	0.3						168,000		168,000
	540	560	20	0.15						7,000		7,000
La Poudriere	120	140	20	0.15						4,000		4,000
	140	160	20	0.3						7,000		7,000
	160	180	20	0.15						4,000		4,000
Total							839,000	8,051,000	2,026,000	715,000	2,394,000	14,025,000

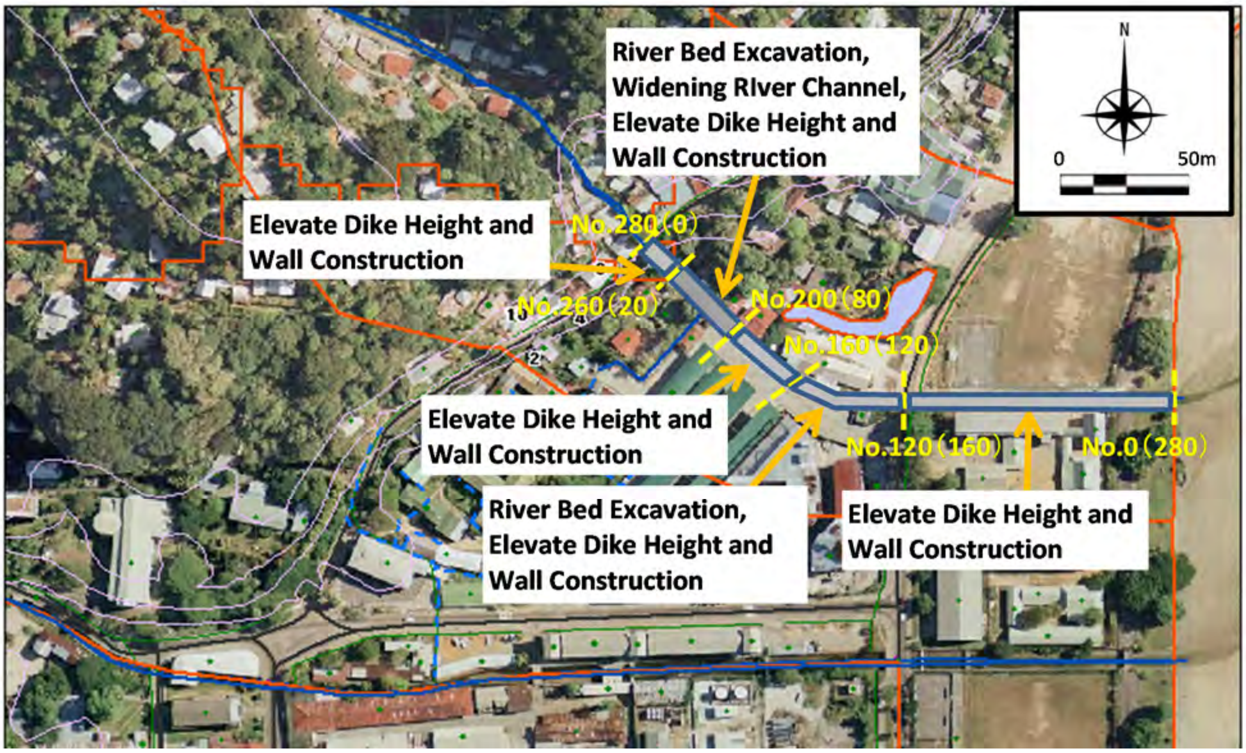


Figure 5-2-7: Location of Proposed Countermeasures in Victoria Town (Anglaise River)

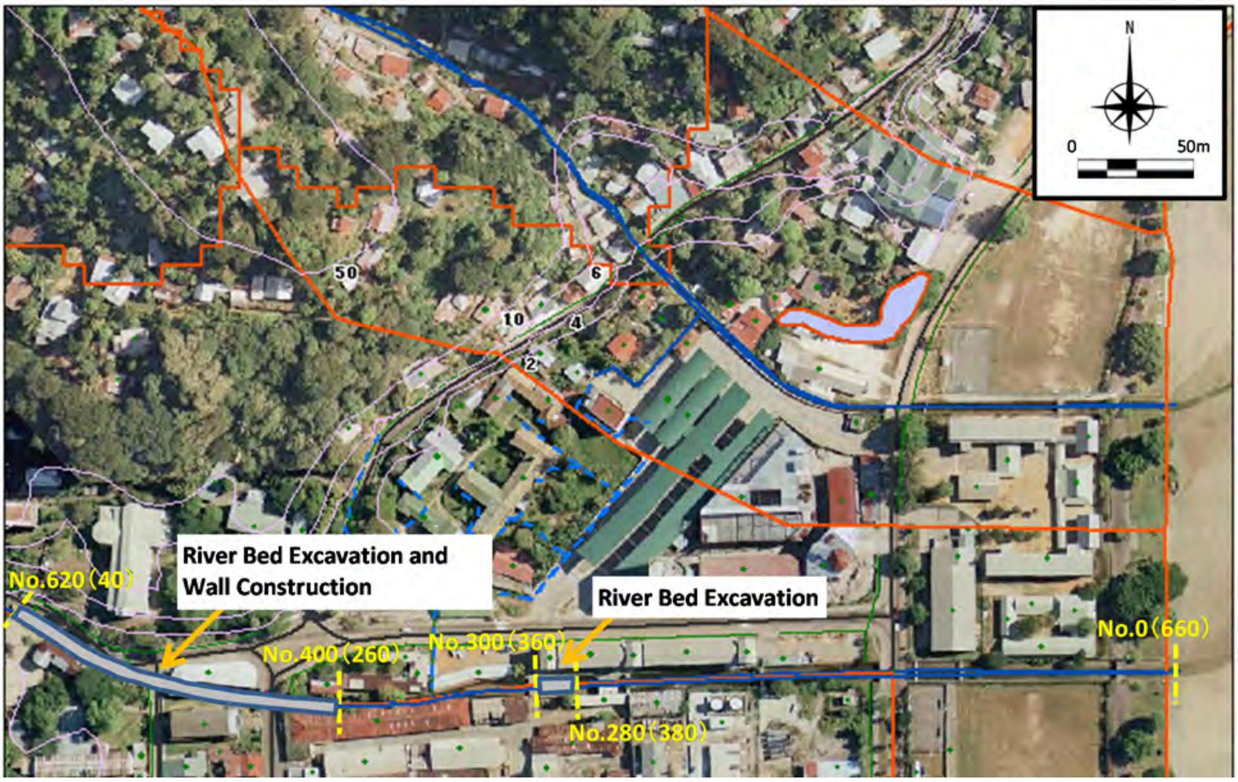


Figure 5-2-8: Location of Proposed Countermeasures in Victoria Town (Moosa River)

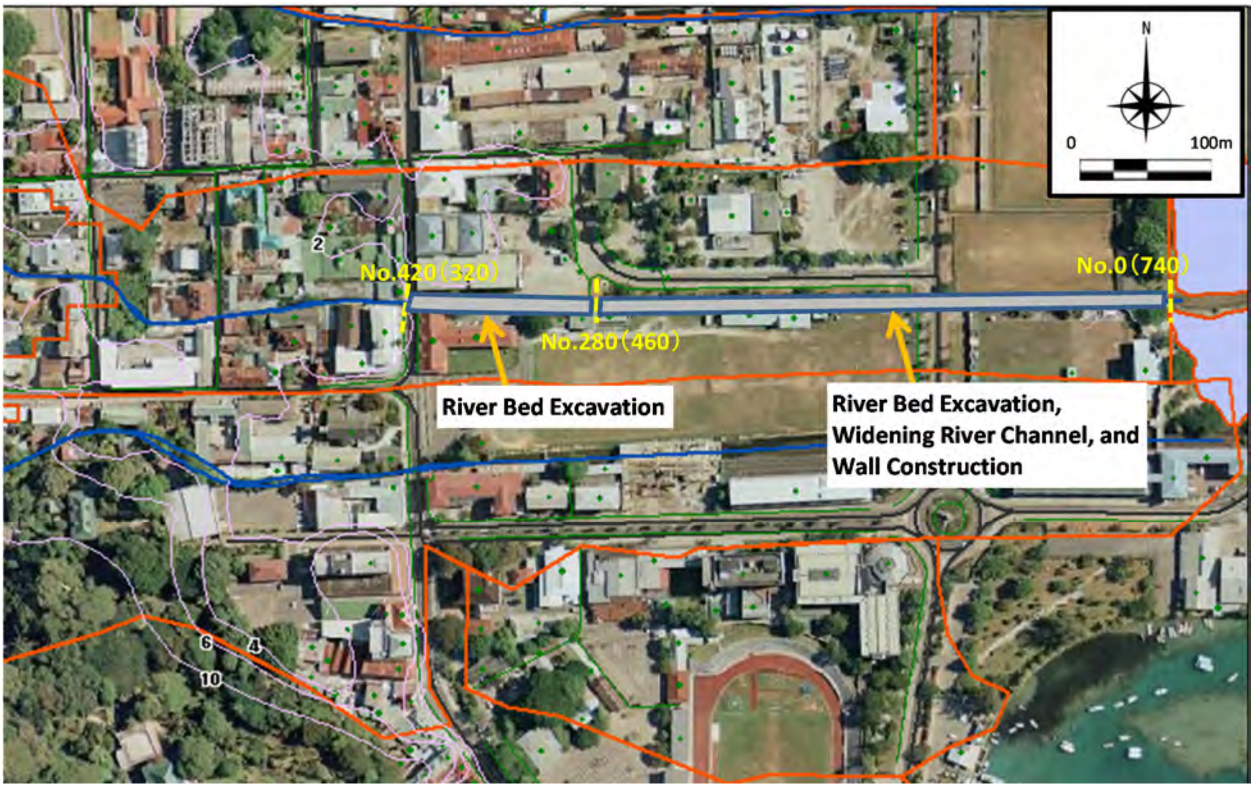


Figure 5-2-9: Location of Proposed Countermeasures in Victoria Town (Maintry River)

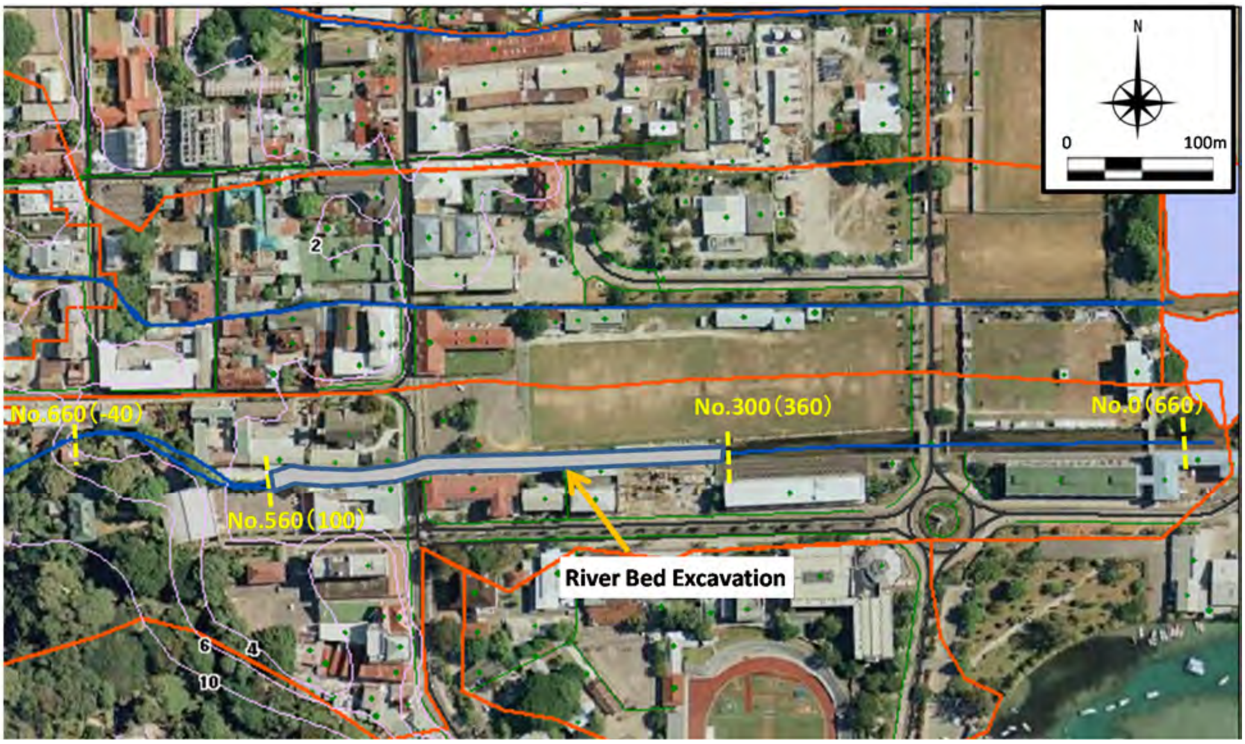


Figure 5-2-10: Location of Proposed Countermeasures in Victoria Town (St. Louis River)

Figure 5-2-11: Location of Proposed Countermeasures in Victoria Town (La Poudriere River)

5-2-2 Pointe Larue

Pointe Larue is an important district for the Government of the Seychelles because of the Seychelles International Airport that is accessed by the main highway (East Coast Road) on Mahe. However, based on the explanation by DOE, the East Coast Road suffers frequently from flood damage by intensive rainfall.

The drainage system at Pointe Larue can be divided into three sections from north to south: Anse Des Genets, Pointe Larue Central and Mirabelle. The location map is shown in Figure 5-2-12.

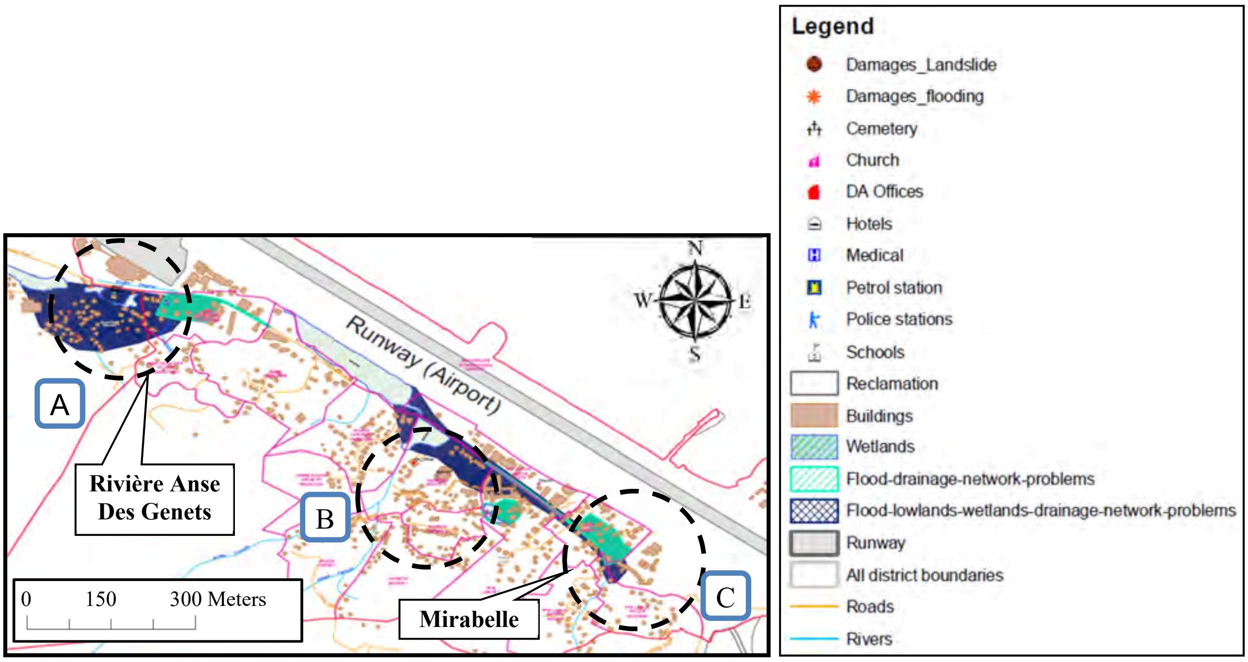


Figure 5-2-12: Location Map of Flood Risk Areas at Pointe Larue

The cause of flooding at each location is as summarised in Table 5-2-6.

Table 5-2-6: Existing Conditions at Pointe Larue

Location	Existing Conditions (Causes of Flooding)	Major Facility at Site
Anse Des Genets (A)	▪ Drainage is unconnected ▪ Culvert is small ▪ Drainage was backfilled by soil	Petrol Station
Pointe Larue Central (B)	▪ Drainage is unconnected ▪ Drainage capacity of airport drains is small	Pointe Larue Secondary School
Mirabelle (C)	▪ Drainage capacity is small ▪ Lack of maintenance of drainage channel	Police Academy Airport

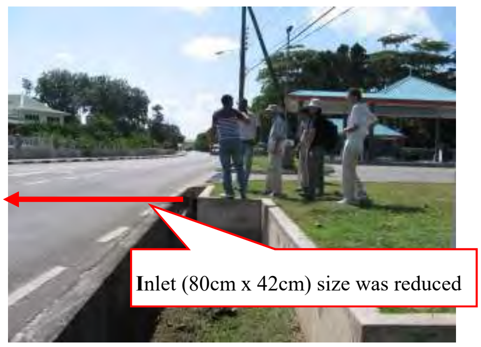


Photo 5-2-6:
Narrowed drainage inlet (A) (April 2011)

Photo 5-2-7:
Airport drain channel (C) (April 2011)

The proposed structural countermeasures for the short term and medium term are as follows.

Short-Term Countermeasures

Estimating the highest water level for a 5-year return period by the existing ground level,

- Pointe Larue A area needs a new drainage ditch from the petrol station to the lagoon area and de-silting of the existing ditches.
- Pointe Larue B area needs the missing road drain to be connected to the wetland.
- Pointe Larue C area drainage system is all connected to the Seychelles International Airport. The drainage system in the airport is not adequate to drain surface water.

Medium-Term Countermeasures

Estimating the highest water level for a 25-year return period by the existing ground level,

- In Pointe Larue A area the highest water level for a 25-year return period was determined as lower than the existing ground level, therefore structural countermeasures are not required.
- In Pointe Larue B area the highest water level is 2.1 m, which is slightly higher than the ground level. The inundation area will depend on the actual ground elevation.
- Since the Study Team was not able to obtain the latest results of an aerial topographic survey from the counterparts, identification of the inundation area will be up to the DOE.

The proposed structural countermeasures at Pointe Larue for the short term and medium term are as summarised in Table 5-2-7 and

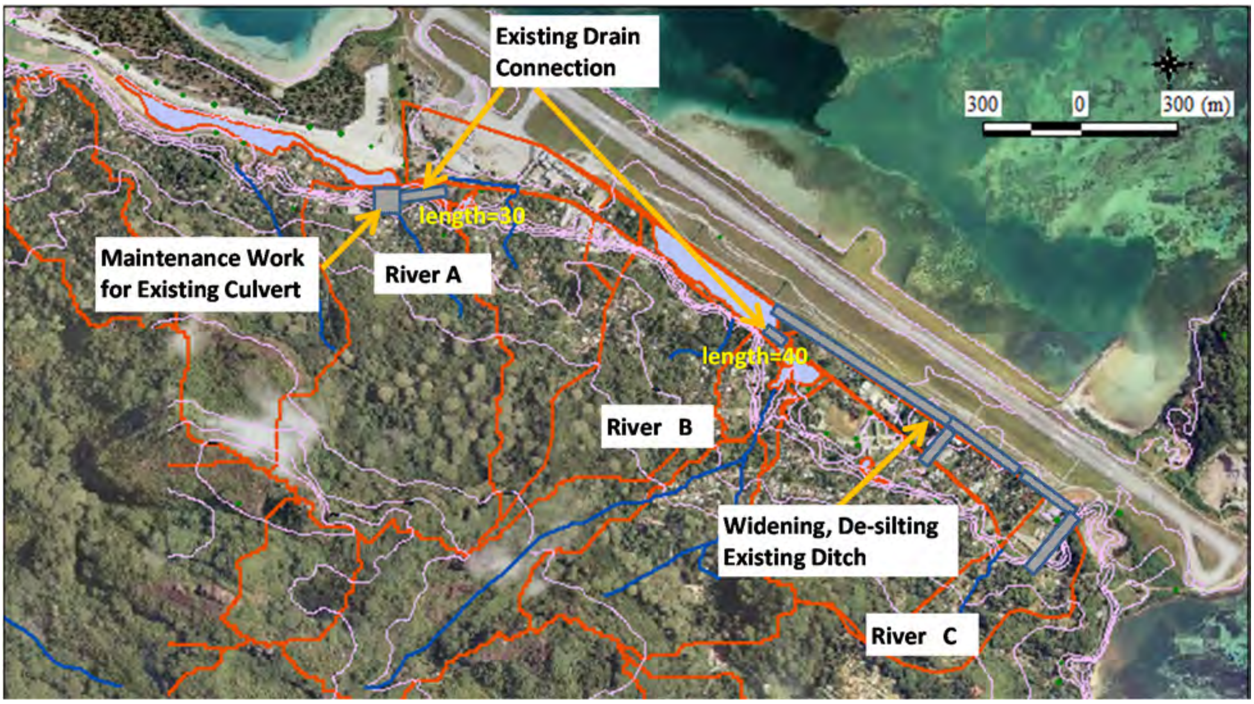


Figure 5-2-13.

Table 5-2-7: Proposed Structural Countermeasures for Pointe Larue

Location Name	Work Item(facilities) Short Term	Middle Term	Size W m	H m	Length m	Type	Remark	Amount Drain	Revetment	Underpining	River bed excavation	Bridge	Land price	Total
Point Laure A	Drainage Ditch (new)		1.0	1.0	30	culvert	construction of new catch basin and connecting under ground ditch from Gas station side to lagoon (direct)	368,000						368,000
Point Laure A	De-silting the existing ditch						OM works of DOE, (south side of Gas station)							
Point Laure A		Enlarge the existing culvert	2.25	1.5	8	culvert	enlarge the culvert in Golden Egg River, existing size is W=1.2m, H=0.45m	231,000						231,000
Point Laure B	Drainage Ditch (new)		1.5	1.1	40	open	extend an existing drainage to wetland	327,000						327,000
Point Laure C	Widen existing drainage ditch					open	inside of Seychelles International Airport							
Point Laure C	De-silting the existing ditch						OM works of DOE, (small hill beside police academy)							

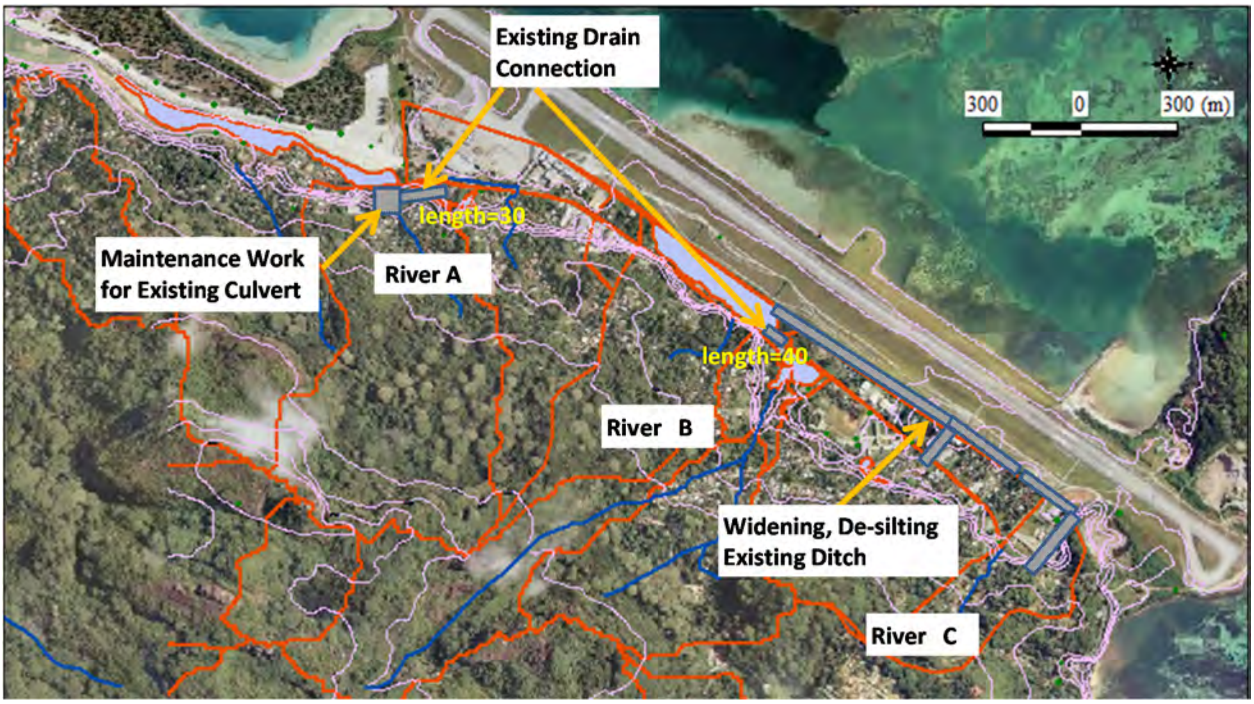


Figure 5-2-13: Location of Proposed Countermeasures in Pointe Larue

5-2-3 Anse Aux Pins

Anse Aux Pins is located to the south of Pointe Larue and flooding is concentrated around the wetland area. The location map is shown below in Figure 5-2-14.

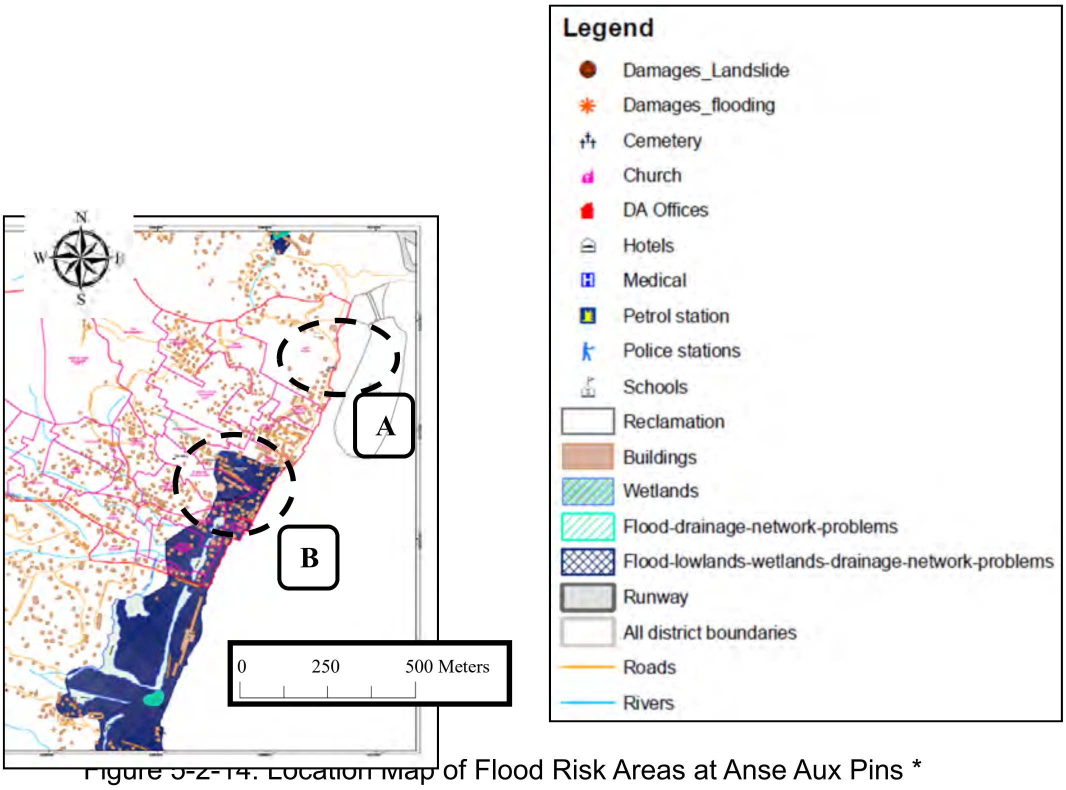


Figure 5-2-14: Location Map of Flood Risk Areas at Anse Aux Pins *

The cause of flooding at each location is as summarised in the table below.

Table 5-2-8: Existing Conditions at Anse Aux Pins

Location	Existing Conditions (Causes of Flooding)	Major Facility at Site
Mondon River (A)	▪ Deposition of sand at the mouth of the channel	DA office
Bassin Grand River (B)	▪ Outlet capacity is small ▪ Residential area is located on low land	Bus Station

The wetland at Anse Aux Pins receives water discharged from the Bassin Grand River and another three rivers. Floodwater gathers in the wetland before flowing out through the river mouth. The residential area around the wetland is basically a lowland area which is always inundated by rainwater during high tides. On the other hand, the Mondon River has been maintained by DOE since 2010.

The proposed structural countermeasures for the short term and medium term are as follows.

<u>Short-Term Countermeasures</u>

Estimating the highest water level for a 5-year return period by the existing ground level,

- Chetty Flat needs new drainage in order to discharge rainwater.
- In Anse Aux Pins A area the highest water level is 2.0 m, which is the same as the ground level. No river improvement is required in the short term. However, riverbed excavation is recommended in order to ensure additional security.
- In Anse Aux Pins B area it was not possible to consider the effectiveness of wetland as a reservoir due to the limited data. The accuracy of the calculation results could not be confirmed,

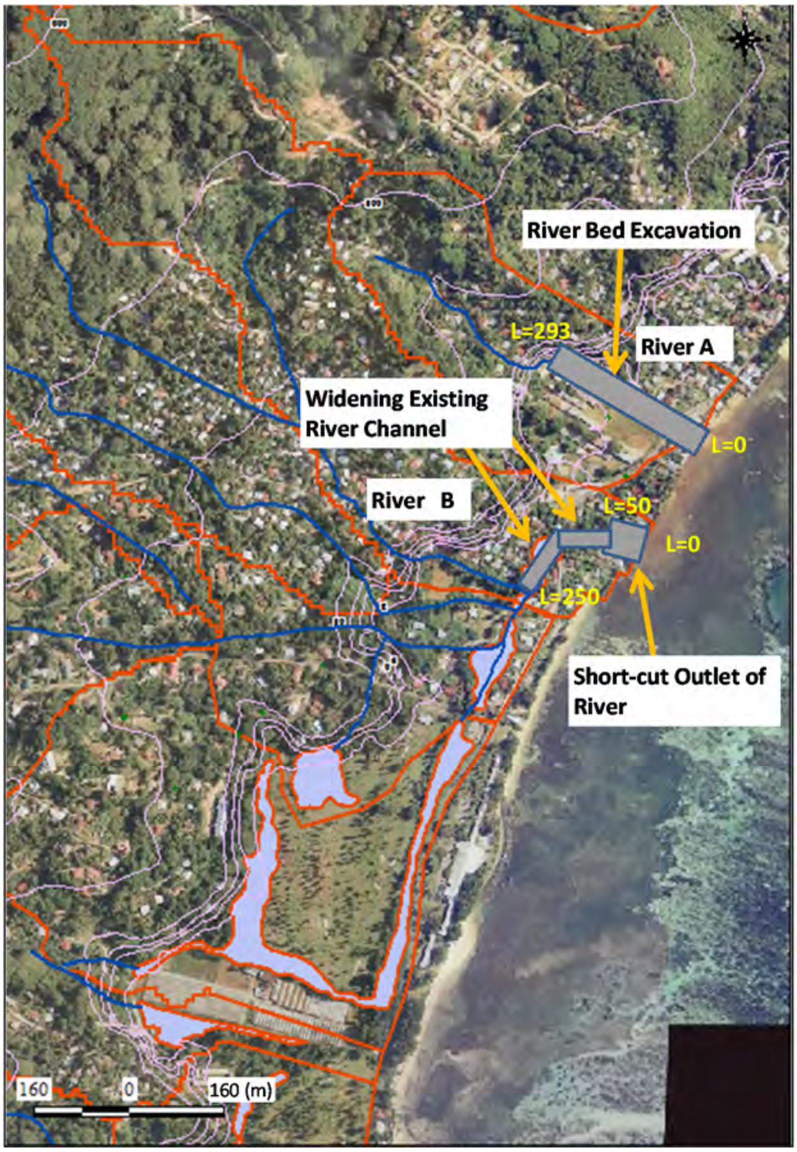
therefore, no structural countermeasures are proposed for the short term.

<u>Medium-Term Countermeasures</u>

Estimating the highest water level for a 25-year return period by the existing ground level,

- Pointe Larue A area requires the implementation of river bed excavation of 0.3 m.
- In Pointe Larue B area, the highest water level will be about 2.3 m which is 0.3m higher than the existing ground elevation. It is necessary to widen the river channel around the river mouth area, while, on the other hand, river mouth clogging cannot be overlooked.

The proposed structural countermeasures at Anse Aux Pins for the short term and medium term are as summarised in Table 5-2-9



and

Figure 5-2-15.

Table 5-2-9: Proposed Structural Countermeasures for Anse Aux Pins

Location Name	Work Item(facilities)		Size		Length	Type	Remark	Amount						
	Short Term	Middle Term	W	H				Drain	Revetment	Underpining	River bed	Bridge	Land	Total
			m	m	m						excavation		price	
Chetty Flat	Drainage Ditch (new)		1.5	1.2	120	open		989,000						989,000
Anse Aux Pins A		River Bed Excavation		0.3	293	open					31,000			31,000
Anse Aux Pins B		Short-cut outlet of river	6.0		50	open	River mouth measures + Wall (2m)		692,000		210,000		150,000	1,052,000
Anse Aux Pins B		Bridge (new) or Box culvert	6.0				1 location					2,394,000		2,394,000
Anse Aux Pins B		widen existing river channel	5.0		200	open	excavation of river channel + wall (2m)		2,767,000		350,000			3,117,000

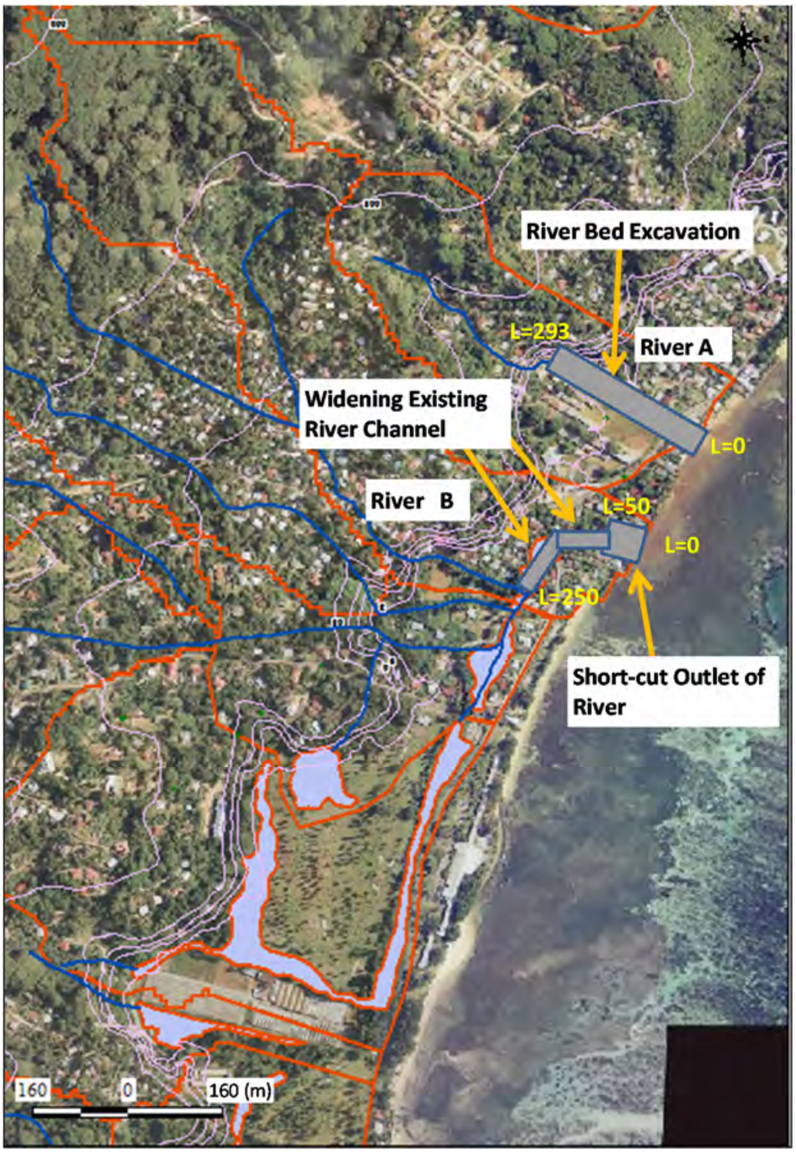


Figure 5-2-15: Location of Proposed Countermeasures in Anse Aux Pins

5-2-4 Au Cap

Au Cap is located to the south of Anse Aux Pins. The district boundary runs from the Reef Estate Road to Pointe Au Sel. The East Coast Road passes though Au Cap along the shoreline and most residents live within 300 m of the coastline. The location map is shown in

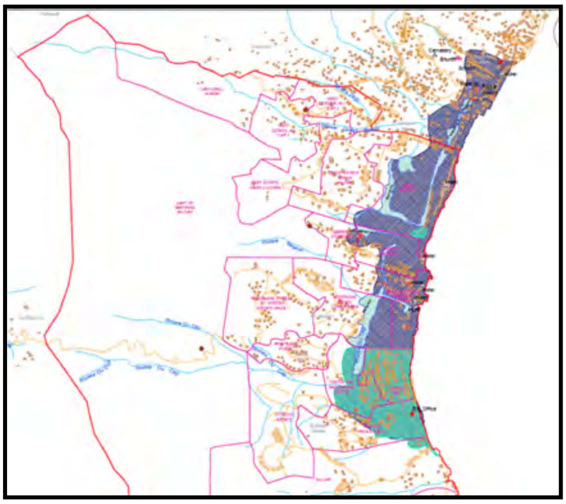


Figure 5-2-16.

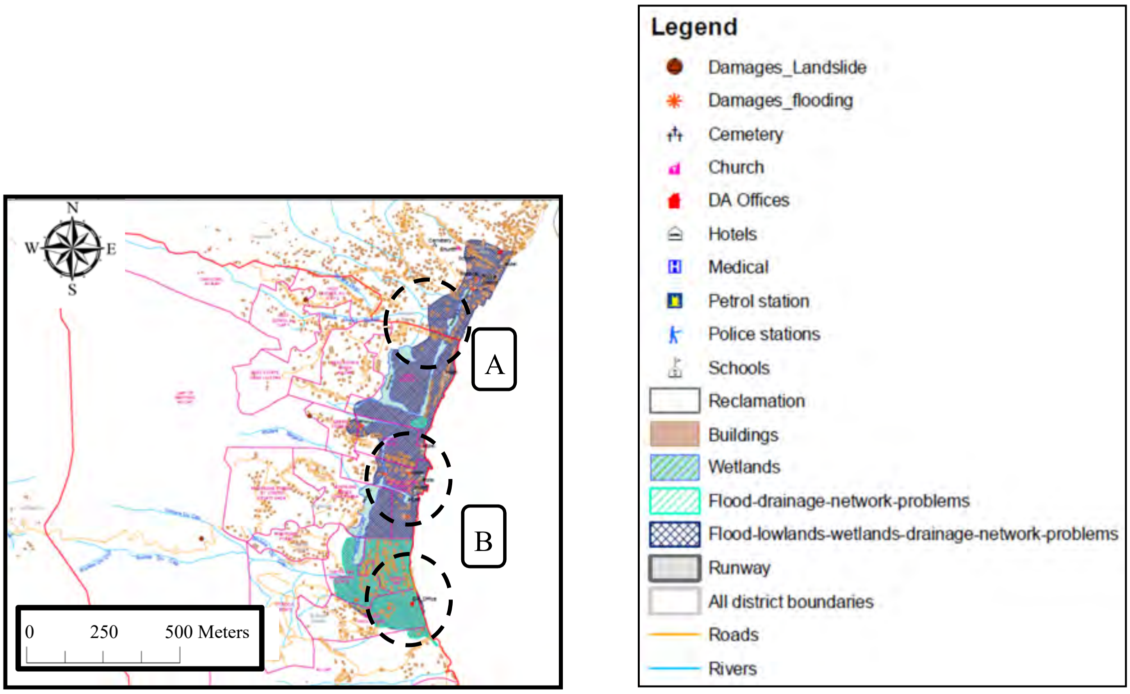


Figure 5-2-16: Location Map of Flood Risk Area in Au Cap

Most of the residential areas are also on low land in flood prone areas. As reported, the new school at Turtle Bay experiences flooding once every two or three years. New countermeasures have been adopted for river mouth clogging at River Au Cap; however, the capacity of the pipes is not enough to discharge the rainwater during the rainy season. The cause of flooding in each location is as summarised in Table 5-2-10 below.

Table 5-2-10: Existing Conditions in Au Cap

Location	Existing Conditions (Causes of Flooding)	Major Facility at Site
Turtle Bay (A)	▪ Lowland area ▪ Outlet capacity is small	Green Estate
Au Cap River (B)	▪ Outlet capacity is small ▪ Channel capacity is not enough	Pipe outlet

Photo 5-2-8: Outlet of Wetland (May 2011)

Photo 5-2-9: Rain Water Discharged by Pipe at River Au Cap (May 2011)

The proposed structural countermeasures for the short term and medium term are as follows.

Short-Term Countermeasures

Estimating the highest water level for a 5-year return period by the existing ground level,

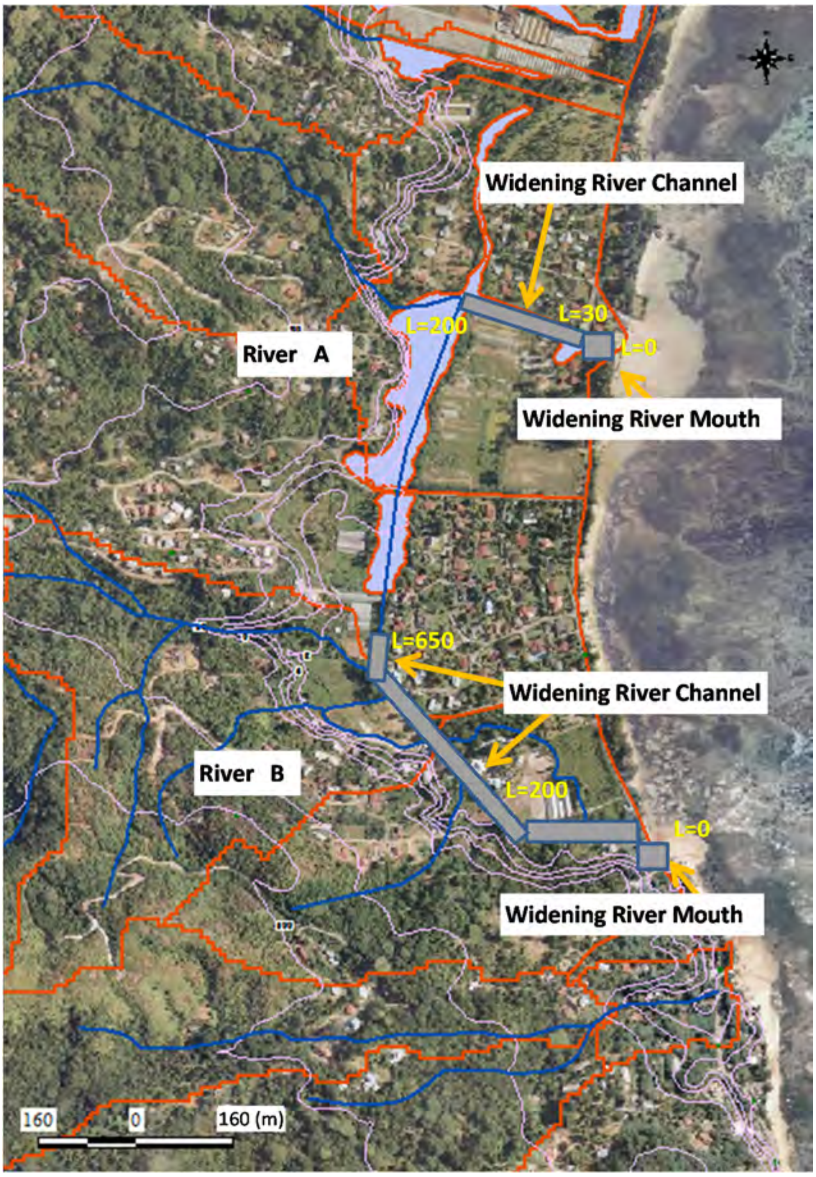
- At Turtle Bay and Tyfoo widening of the existing drainage ditches is recommended. In addition, improvement works are being conducted by the DOE in the Turtle Bay portion.
- At Naiken's Farm extension of the outlets towards the sea is needed for about 50m, in order to improve water discharge due to river mouth clogging. This location was selected for one of the pilot projects in the Study; monitoring works are currently implemented by the Study Team and DOE.
- The highest water level of the other outlets for the short term is estimated at about 2.1m which is slightly higher than the existing ground level. Therefore, there might be some local inundation but nothing serious.

Medium-Term Countermeasures

Estimating the highest water level for a 25-year return period by the existing ground level,

- At Au Cap A area it is necessary to widen the existing river mouth and provide a new 5.0 m-wide outlet channel. Due to the widening of the river channel, the existing bridge will have to be extended.
- At Au Cap B area it is necessary to widen the existing river mouth and provide a new 5.0 m-wide outlet channel. Due to the new channel, it will be necessary to provide a new bridge or a box culvert facility for crossing the main road.

The proposed structural countermeasures at Au Cap for the short term and medium term are as



summarised in Table 5-2-11 and Figure 5-2-17.

Table 5-2-11: Proposed Structural Countermeasures for Au Cap

Location Name	Work Item(facilities) Short Term	Work Item(facilities) Middle Term	Size W m	Size H m	Length m	Type	Remark	Amount Drain	Amount Revetment	Amount Underpinning	Amount River bed excavation	Amount Bridge	Amount Land price	Amount Total
Turtle Bay	Drainage Ditch (enlarge)		1.3	1.0		open								
Naiken's Farm	Extension of drainage (new)	River Month (New)	2.0	1.5	50	culvert	Rubble Armor retaining wall for drainage for first stage widen the retaining wall based on the Au Cap B	1,376,000	1,050,000					2,426,000
Tyfoo	Drainage Ditch		1.5	1.0		open								
Au Cap A		Widening River Mouth	5.0		30	open	River mouth measures + Wall (1.5m), 0.2 m excavtaion		315,000	77,000	102,000		75,000	569,000
Au Cap A		Bridge (extend or new)	16.0				1 location, crossing river, cab be extended existing bridge					6,384,000		6,384,000
Au Cap A		Widening River Channel	5.0		170	open	0.2m excavation				552,000		425,000	977,000
Au Cap B		Widening River Mouth	5.0		200	open	River mouth measures + Wall (1.5m), 0.2 m excavtaion		2,102,000	512,000	762,000		500,000	3,876,000
Au Cap B		Bridge (new) or Box culvert	5.0				1 location					1,995,000		1,995,000
Au Cap B		Widening River Channel			450	open	0.1m excavation				88,000			88,000

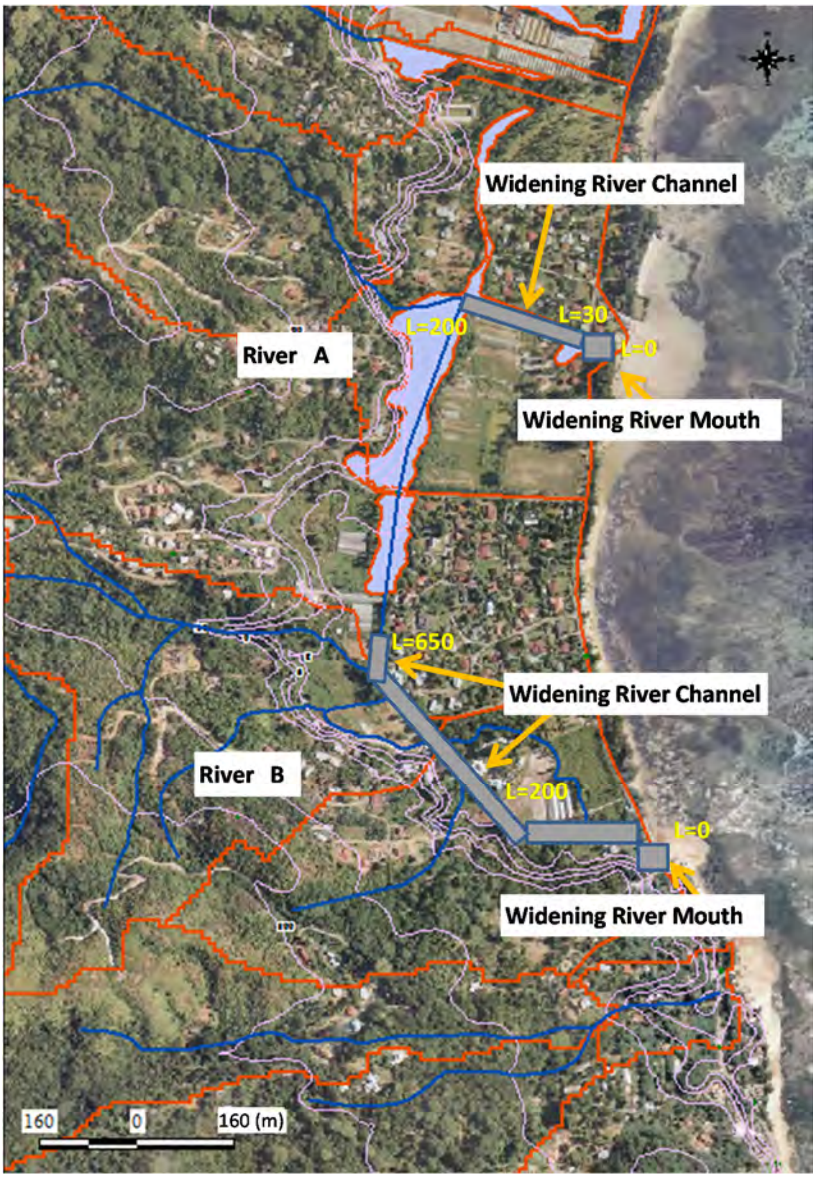
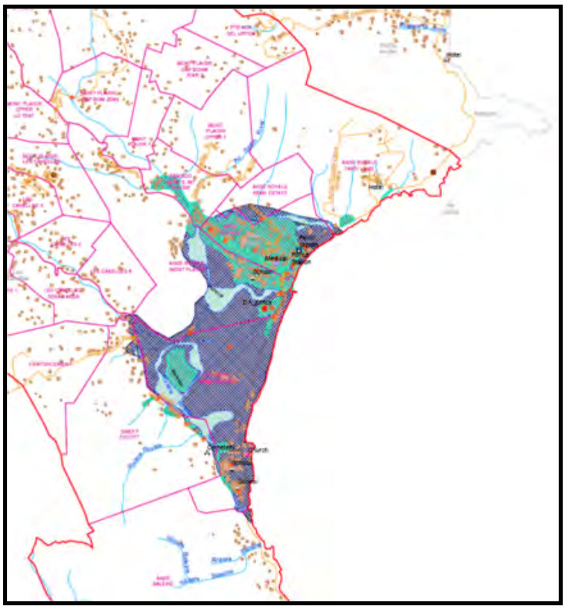


Figure 5-2-17: Location of Proposed Countermeasures in Au Cap

5-2-5 Anse Royale

Anse Royale has the second largest population on Mahe and is famous for agriculture and fishing. Based on recent development, Anse Royale has become the centre of educational, residential and commercial establishments. The location map is shown in Figure 5-2-18.



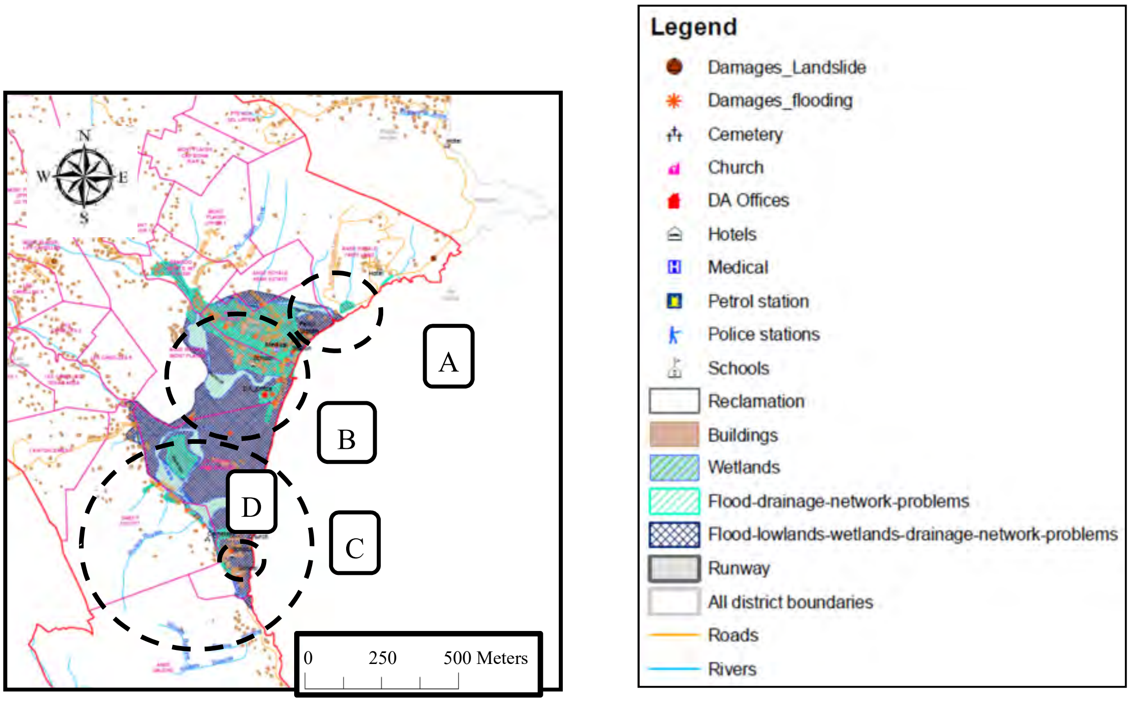


Figure 5-2-18: Location Map of the Flood Risk Areas at Anse Royale

The cause of flooding at each location is as summarised in Table 5-2-12 below.

Table 5-2-12: Existing Conditions at Anse Royale

Location	Existing Condition (Causes of Flooding)	Major Facility at site
Remise Estate (A)	▪ River mouth clogged by sand	
Mont Plaisir (B)	▪ Inadequate outlet capacity ▪ Inadequate channel capacity ▪ Lowland area	University
Anse Royale Secondary School Channel (C)	▪ Inadequate outlet capacity ▪ Inadequate channel capacity	Pipe outlet Church

Anse Royale has three large wetlands that conserve discharge from the upper rivers which flow into the sea via four outlets.

- Location (A) is the outlet for the discharge of rainwater from the Anse Royale Remy Estate and the Anse Royale Hospital. The outlet is totally clogged by sand and water collects under the bridge. Due to the residential development upstream, the balance point between the discharge force and the tidal water has moved to the land side.
- Location (B) is the outlet for the discharge of rainwater from Anse Royale, Mont Plaisir and Bamboo Estate. The size of the outlet was reduced before reaching the river mouth in order to increase the discharge velocity and flush out the sand to the sea, thus maintaining the function of the outlet. However, the outlet structure is under continuous attack by waves and the foundation has eroded.
- Locations (C) and (D) are the outlets for the discharge of rainwater from Sweet Escott, St. Joseph, Anse Baleine and Les Cannelles. Location (D) is near the church and is used for road drainage. The outlet was designed not to face the sea in order to prevent sand clogging. Outlet C adopts the same method as at Au Cap by using pipes for the discharge of rainwater.

Photos of the above outlets are as shown below:

Photo 5-2-10: Outlet A river mouth clogged (April 2011)

Photo 5-2-11: Residential Development at Remy Estate (April 2011)

Photo 5-2-12: Outlet B Structural Damage by Erosion (April 2011)

Photo 5-2-13: Outlet B Reduced width of Outlet (April 2011)

Photo 5-2-14: Outlet D is not in Water (May 2011)

Photo 5-2-15: Outlet D (April 2011)

Photo 5-2-16: Outlet C Discharge by Pipes (April 2011)

Photo 5-2-17: Inlet of Pipes (April 2011)

The proposed structural countermeasures for the short term and medium term are as follows.

Short-Term Countermeasures

Estimating the highest water level for a 5-year return period by the existing ground level,

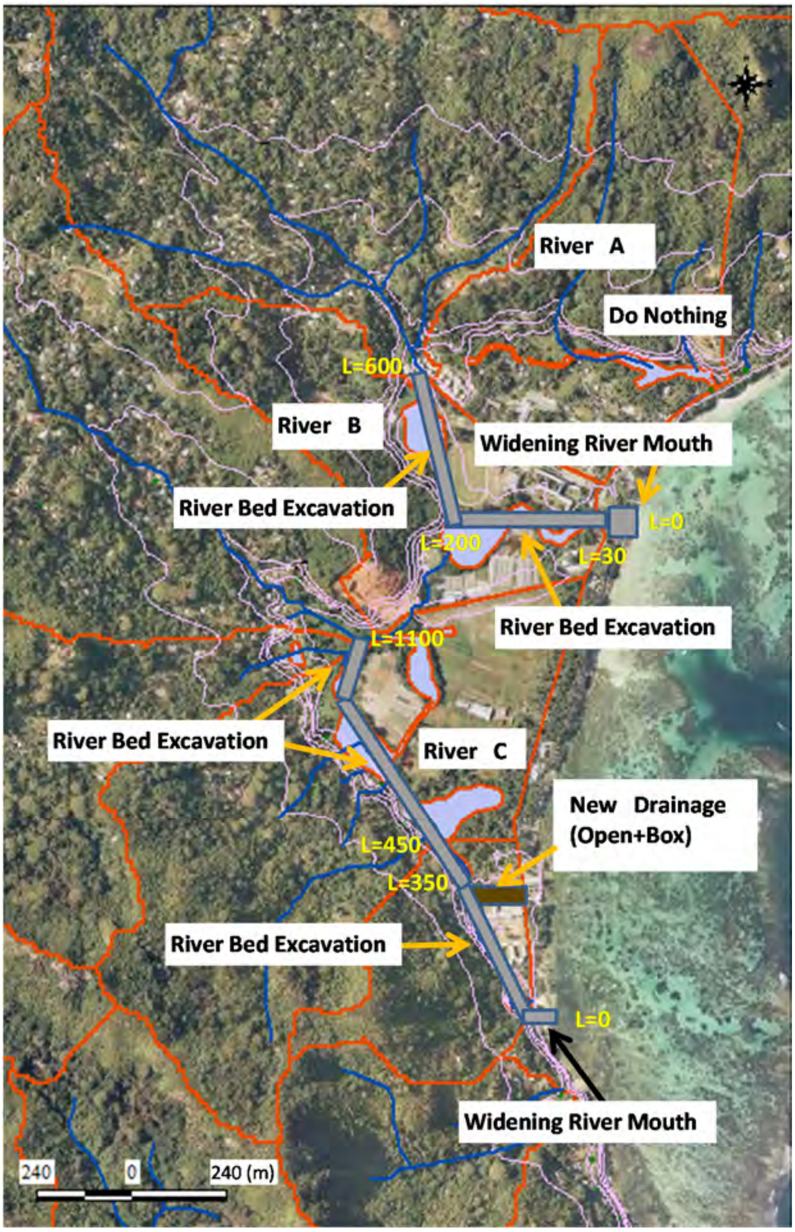
- Anse Royale A has enough capacity to discharge the volume of surface water for a 5-year return period, therefore it is not necessary to improve this channel.
- Anse Royale B has a large wetland before the river reaches the mouth, therefore this river has some wetland storage effect. For the short term improvement works are not considered.
- Anse Royale C needs a new drainage ditch to discharge excess water. The new drainage will be 1.6 m wide and 1.3 m high with a slope of 1/400. The length of the new ditch will be 120 m.

Medium-Term Countermeasures

Estimating the highest water level for a 25-year return period by the existing ground level,

- Anse Royale A area does not need additional improvement works.
- Anse Royale B requires riverbed excavation and widening of the channel with extension of the existing bridge span.
- Anse Royale C requires riverbed excavation and widening of the river mouth

The proposed structural countermeasures at Anse Royale for the short term and medium term are as summarised in Table 5-2-13



and

Figure 5-2-19.

Table 5-2-13: Proposed Structural Countermeasures for Anse Royale

Location Name	Work Item(facilities)		Size		Length	Type	Remark	Amount						
	Short Term	Middle Term	W	H				Drain	Revetment	Underpining	River bed excavation	Bridge	Land price	Total
			m	m	m									
Anse Royale B		Widening River Mouth	3.0		30	open	River mouth measures + Wall (2m), 0.3m excavation		415,000	77,000	81,000		45,000	618,000
Anse Royale B		Bridge (extend or new)					1 location, crossing river, cab be extended existing bridge					7,182,000		7,182,000
Anse Royale B		River Bed Excavation		0.2	170	open					451,000			451,000
Anse Royale B		River Bed Excavation		0.1	400	open					530,000			530,000
Anse Royale C		River Bed Excavation		0.4	350	open	Wall (1.5m)		3,678,000	895,000	273,000			4,846,000
Anse Royale C		Widening River Mouth	10.0	0.4	100	open	Wall (1m)		710,000		459,000		500,000	1,669,000
Anse Royale C		River Bed Excavation		0.1	650	open					355,000			355,000
Anse Royale C	Drainage Ditch (New)		1.6	1.3	120	open	Wall (1.3m),S=1/400	2,268,000						2,268,000

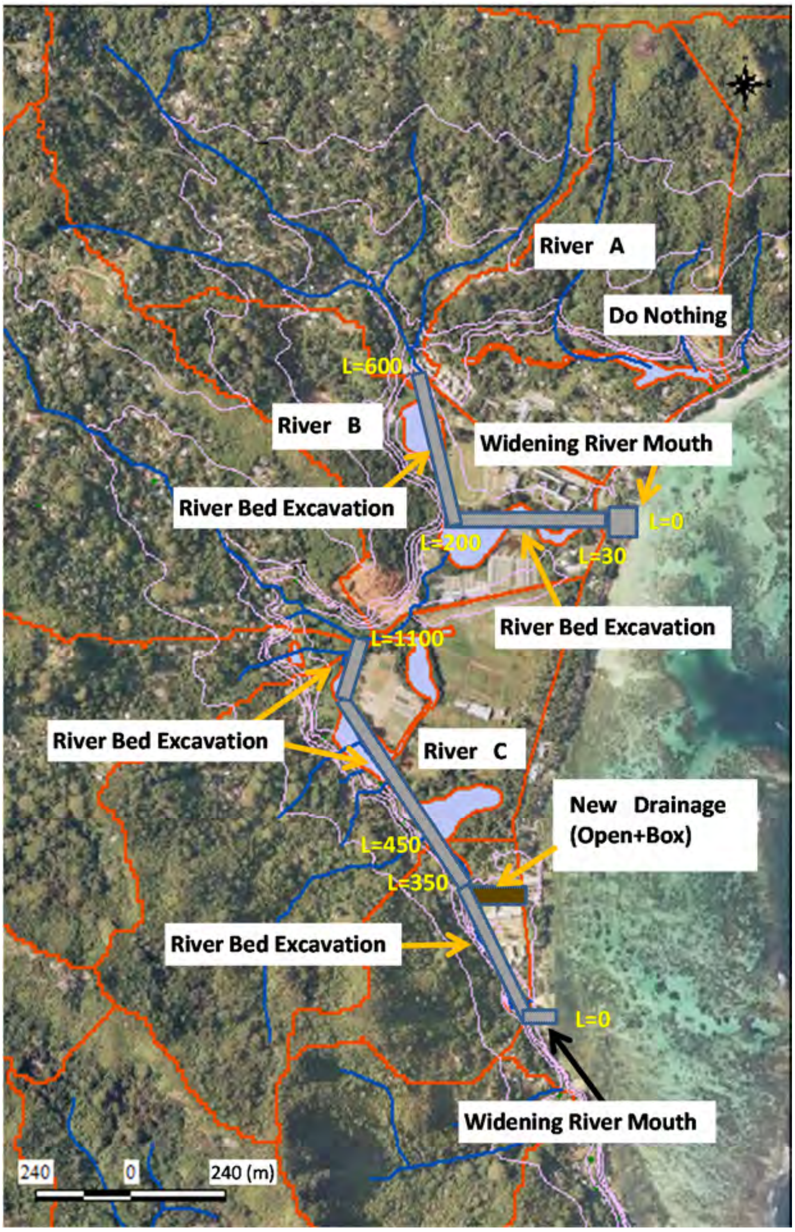


Figure 5-2-19: Location of Proposed Countermeasures in Anse Royale

Chapter 6 Pilot Projects

6-1 Selection of Pilot Projects

In order to confirm the effects and propriety of the coastal conservation and flood management plans, pilot projects were selected from the plan in consideration of urgency, importance and technology transfer.

6-1-1 Coastal Conservation

As for coastal conservation, nourishment at North East Point and a groyne with sand bypass at La Passe were selected from four priority coasts, North East Point, Baie Lazare, Anse Kerlan and La Passe, in view of the purpose of the project.
At North East Point and Baie Lazare, sand nourishment was proposed in the plan. North East Point was selected because of frequent wave overtopping. Because the cause is not clear, the loss of sediment on the coast and its cause were investigated by the monitoring. The introduction of sand nourishment for the first time in the Seychelles was also planned.
The groyne at La Passe was intended to regulate longshore sediment transport by sand bypass from the accreted area to the eroded area because the construction of breakwaters has caused erosion and accretion.
At Anse Kerlan priority coast, it was not adopted because the scale of the project is too large and the land is privately owned.

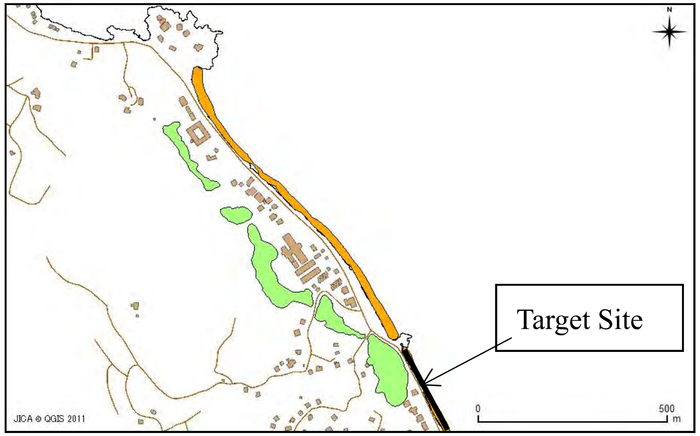
6-1-2 Flood Management

As for flood management, the construction of a culvert at Point Larue and outlet at Au Cap were selected from the five priority areas, Victoria, Point Larue, Anse Aux Pins, Au Cap and Anse Royale. The flooding on the road to the international airport at Point Larue is an important problem. Therefore, the construction of a culvert was selected. Au Cap was selected because outlet improvement is a crucial problem.
In the Seychelles, drainage channels have been constructed but there are problems in planning and designing. The emphasis is on technology transfer through the design and construction of the drainage with the counterparts. As for river mouth improvement, there are few examples for coasts with reefs and the new measures will be tested through the improvement by monitoring. The drainage improvement in Victoria can be implemented by the Seychelles side because there was little damage due to the heavy rain in 2011.
The site and scale of the pilot projects are shown in Figure 6-1-1.

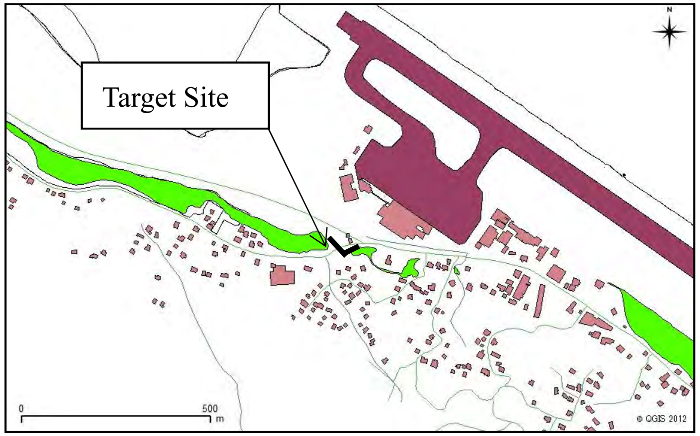
6-2 Detailed Plan and Design

The detailed plan and design were conducted as shown in Figures 6-2-1 to 6-2-4 for each project.

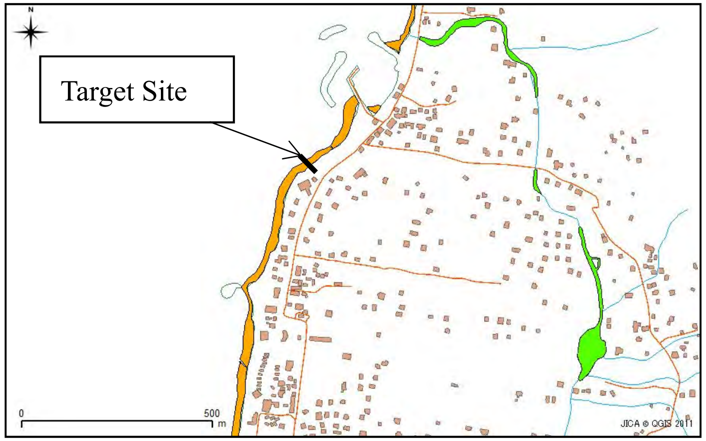
(1) North East Point (Sand Nourishment L = 400 m)



(3) Pointe Larue (Culvert L = 16m, Channel L = 17 m)



(2) La Passe (Groynes L = 50 m, Nourishment 800t)



(4) Au Cap (Outlet L = 25 m)

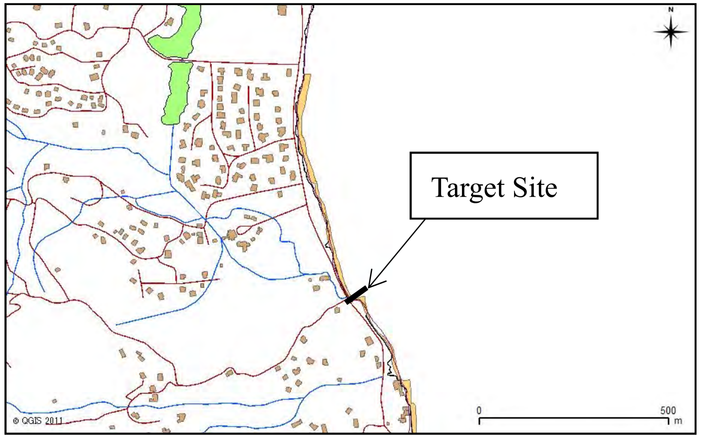


Figure 6-1-1: Site of Pilot Projects and Structures

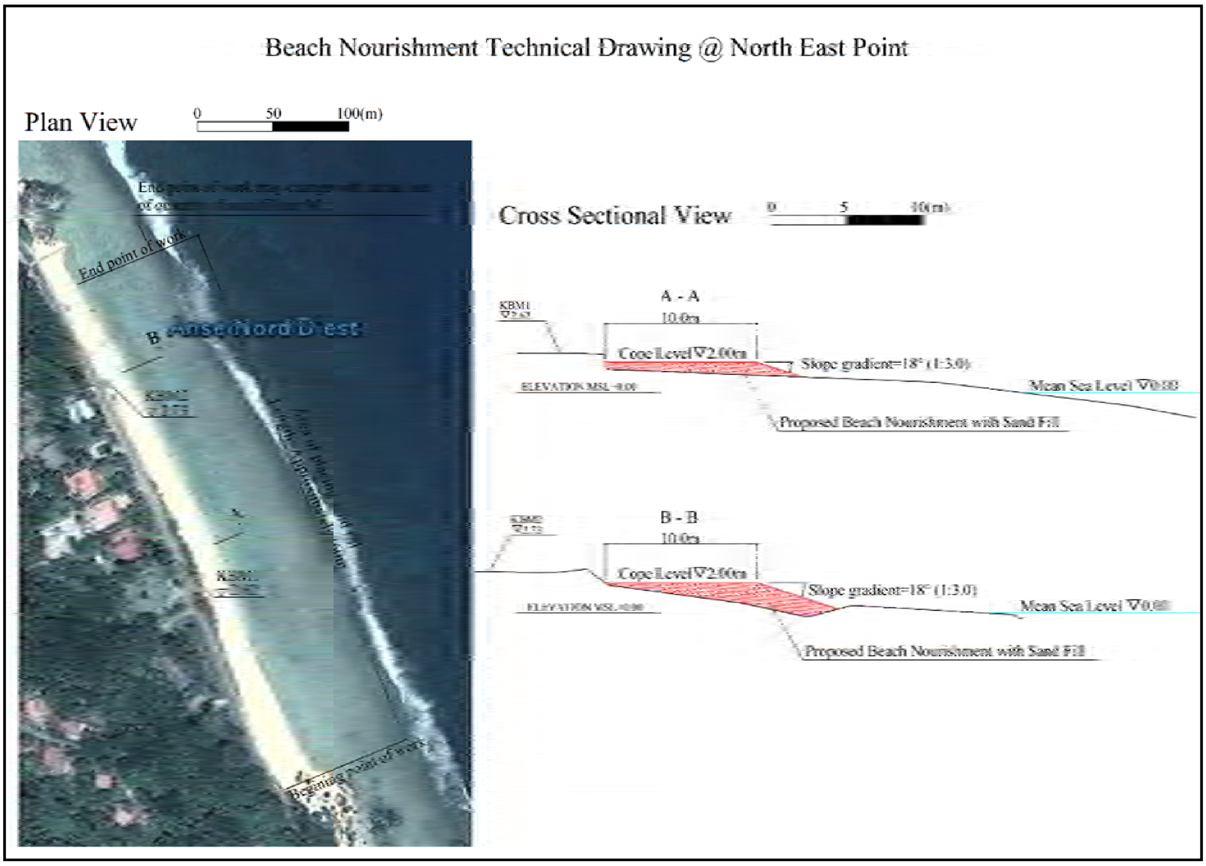


Figure 6-2-1: General Plan of Pilot Project at North East Point

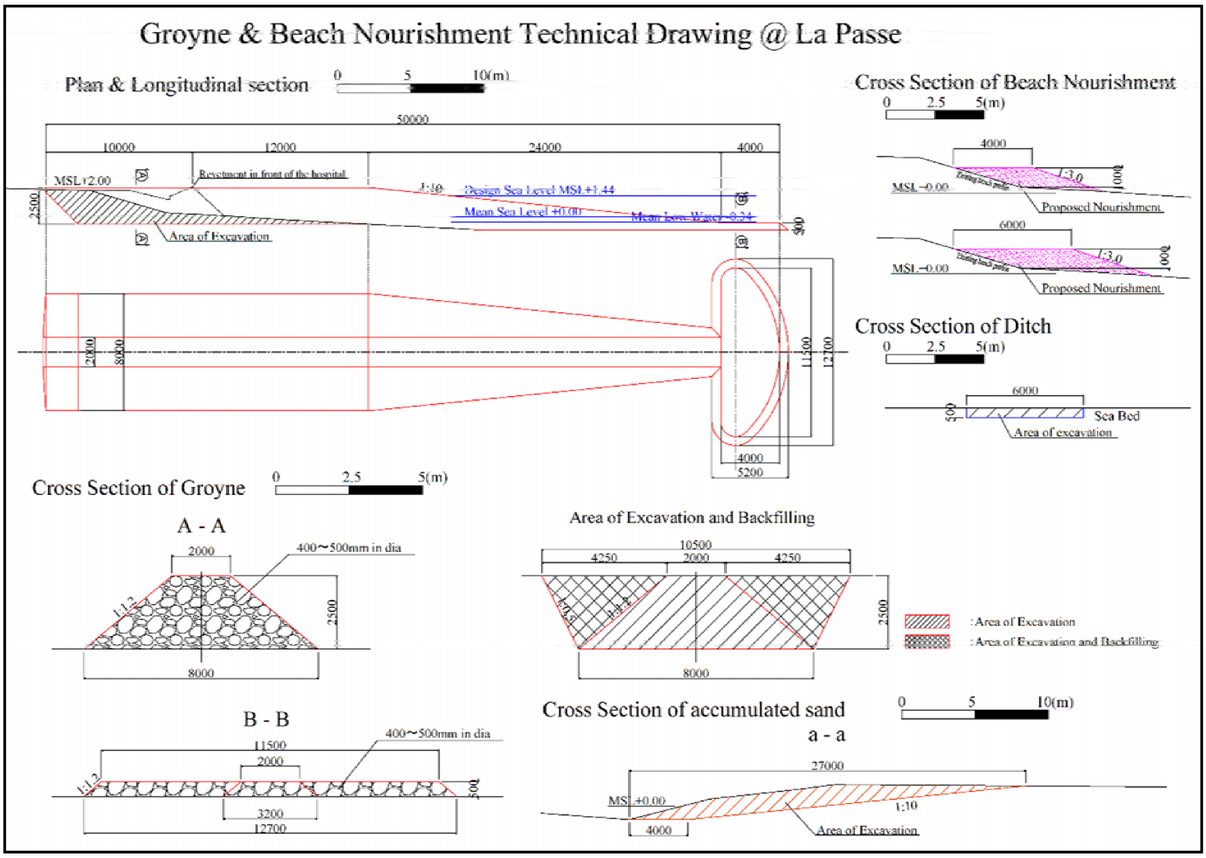


Figure 6-2-2: General Plan of Pilot Project at La Passe

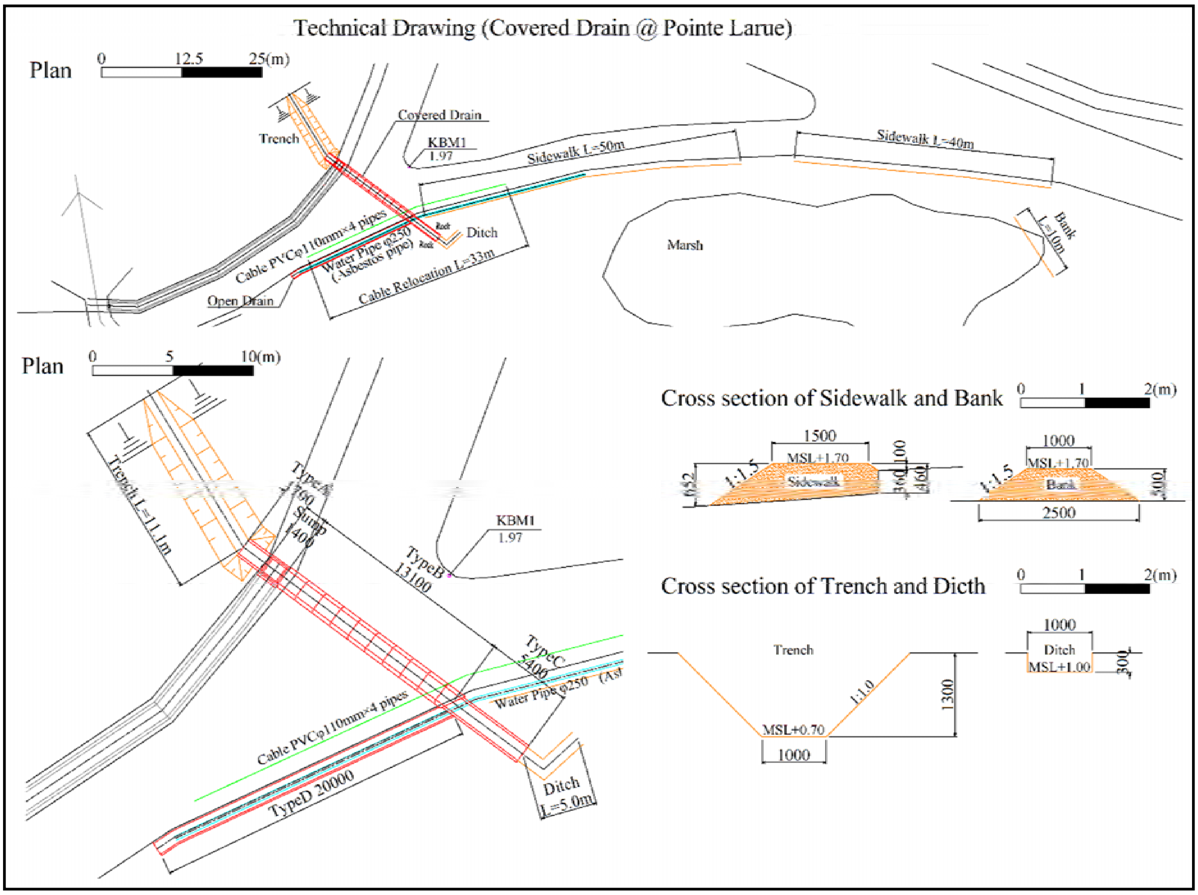


Figure 6-2-3: General Plan of Pilot Project at Point Larue

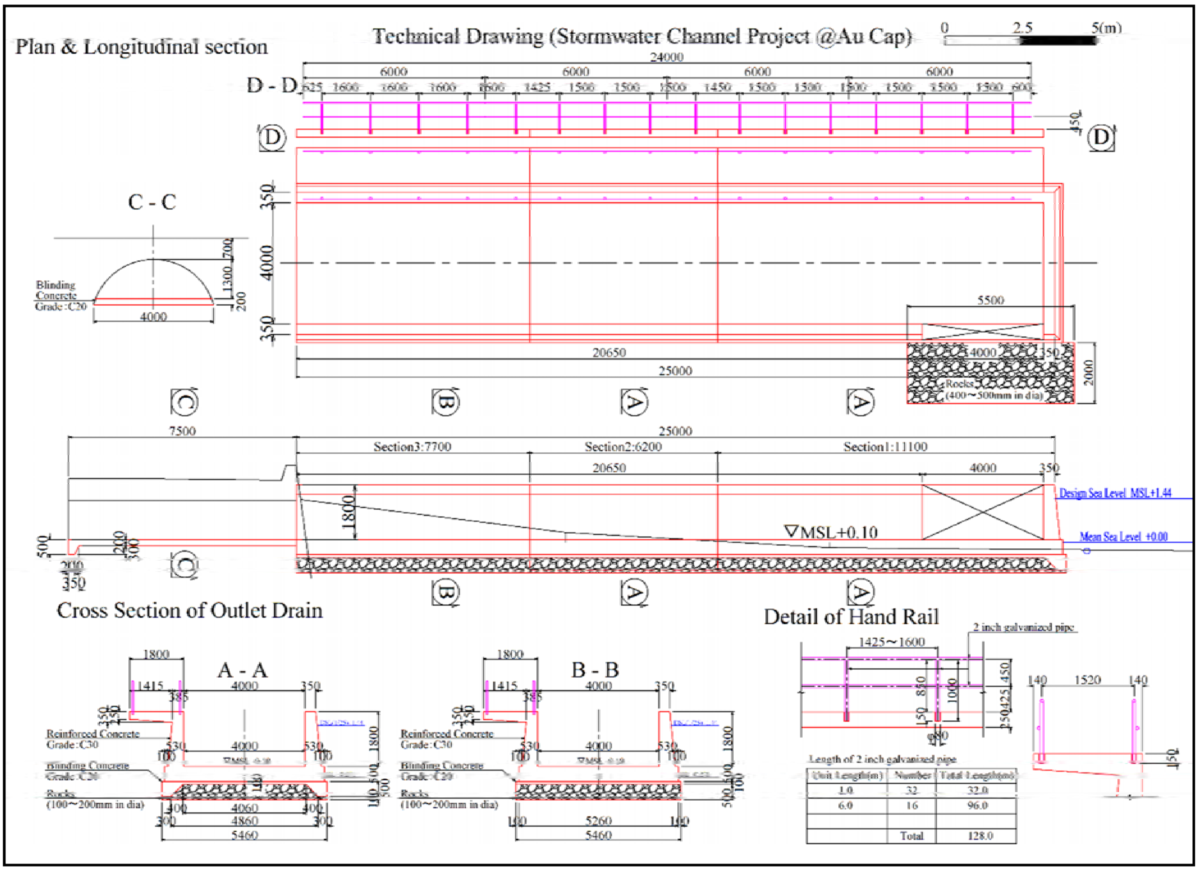


Figure 6-2-4: General Plan of Pilot Project at Au Cap

6-3 Procurement

Procurement was carried out with DOE as the partner because the works are public works and in consideration of maintenance after completion and the technology transfer. Procurement was carried out according to the Public Procurement Act 2008. The procedures involve 11 steps and are expected to take about two months. However, part of the work was delayed because of a claim. At Point Larue the work had to be discontinued because of the objections of the landowner.

At Point Larue part of the channel is located on private land. The landowner is trying to develop his land by major reclamation. After the meeting with the landowner, it was concluded that the project was cancelled in consultation with the C/P because it was difficult to get the landowner’s approval.

The projects were contracted with each contractor at the lowest price after the evaluation.

6-4 Construction

The constructions were undertaken by each contractor with management of the schedule, quality and inspection. At Au Cap, part of the temporary works was damaged by the January flood in 2013. However, the work was completed within the schedule. Several measures were taken for safety and for the environment. At North East Point, passing from the road to the nourished beach was regulated during the working period. At La Passe, to prevent noise, work early in the morning and late at night was abandoned. The relocation of the moored boats and the protection of tree roots were also conducted. At Au Cap, the off-limits area, guiding of traffic during unloading of construction materials and removing of temporary works in times of flood were carried out for safety reasons.

6-5 Environmental Considerations

Environmental Impact Assessment was conducted according to the guidelines of JICA and the Seychelles for the pilot projects. 30 items related to the social environment, natural environment and pollution during and after construction were assessed. If there were impacts, mitigation measures were investigated and implemented.

Impacts during construction concerned trees, water pollution, noise and vibration, and local conflict of interest. As for vegetation, several trees had to be cut down due to obstruction of the work and it was unavoidable because they were not protected species. Water pollution was estimated at North East Point and La Passe due to sand nourishment. The pollution was avoided by putting the sand on the beach and moving it by the waves. The noise and vibration were caused by heavy machines and were avoided by controlling the working hours during the day time. As for the conflict of interest, the anchorage at La Passe was not used during the construction. The owners of the boats agreed to the temporary inconvenience because an anchorage area was expected after the work.

One impact after the construction was the obstruction caused by the groyne to the navigation of fishing boats. For mitigation measures, a small channel was constructed at the head of the groyne. At Au Cap it is very difficult to keep the outlet open all the time and it was explained that sometimes maintenance dredging is necessary.

Public consultations were carried out for all the pilot projects for cabinet members and district administrators and local people in the related areas in July 2012 and their opinions were summarised. At La Passe meetings were held for the fisherman and users of the harbour at the site and they agreed to the project.

6-6 Monitoring and Results

The three pilot projects were completed in April 2013 and monitoring started. At present, the following results of the project have been achieved though it is too soon to evaluate the effects and impacts of the project.

6-6-1 North East Point

In order to mitigate coastal erosion and wave overtopping, introduce and evaluate new measures such as sand nourishment in the Seychelles and study the causes of erosion, a total of 4,000m^3 or 6,600t of sand was nourished to the 400m-long coastline in the south. The nourished sand was transported to the north and formed a wide beach in November 2013. The nourished south beach was eroded and rock armouring appeared.

The long-term volume of erosion is difficult to estimate from the monitoring results for one year because of seasonal changes. It is necessary to continue the beach monitoring. The effect of the nourishment was clear in January 2014 from the accretion by nourishment in the north part where the risk is high.

The directions of the measures are (1) continuous sand nourishment as planned, (2) control of longshore sediment movement by groynes with nourishment in the south and setback in the north, and (3) the construction of rock armouring if the loss of sediment is great. Continuous monitoring will ensure a better solution than the alternatives through understanding and comparison.

6-6-2 La Passe

The objective of the pilot project at La Passe is to mitigate the impact of the breakwaters on coastal erosion and sedimentation at the anchorage. The creation of sheltered areas by the breakwaters causes accretion near the jetty and erosion of the south coast. A 50m-long groyne was constructed to prevent northward sediment movement and about 1,000 m^3 of sand which was dredged at the anchorage was nourished north of the groyne.

It was clear that the groyne prevented longshore transport because it caused accretion in the south and erosion in the north according to field observation. Another groyne which appeared due to sand dredging also prevented northward transport together with the new groyne. The beach created by the nourished sand was used by local people.

6-6-3 Au Cap

The objective of the pilot project at Au Cap was to improve the outlet for flood mitigation, improve the existing measures for outlets especially at the river mouth in the lowland area and improve the design and management capacity of DOE in this kind of work. A 25m-long storm water channel of was constructed.

The drainage at Au Cap consisted of three pipes and they were not sufficient and the sand was dredged during flooding.

An outlet was proposed to prevent waves and accumulation of sediment inside the outlet by making an opening at the side as a pilot structure. Basically, the mouth is maintained by the current action of the river and tides and is clogged by wave action.

The mouth was maintained from April to July 2013 according to the monitoring results because of small waves. In August, high waves were generated by strong winds from the southeast and sediment accumulated in the outlet during neap tide. The outlet is maintained after the dredging in September by small waves and in the rainy season.

Sediment accumulated between the outlet and the adjacent groyne in the south and the opening changed from south to north. Accumulation in the outlet was prevented by this and the flow capacity increased during flooding. The DOE has plans to apply the results to other river mouths.

Chapter 7 Technical Transfer

7-1 General

The technical transfer related to coastal conservation and flood management was conducted as (1) improvement of the technical guidelines, (2) acquisition of engineering knowledge and (3) seminars, workshops and training in Japan. The target members were the counterparts from DOE and the number was limited to about four. Therefore, the target was the members of the technical steering committee. The relevant NGOs also participated.

7-1-1 Improvement of technical guidelines

Five guidelines were improved or created. They are listed in Table 7-1-1.

Table 7-1-1: Items and Contents of Guidelines

Items	Purpose	Contents
(1) Improvement of EIA Guidelines	EIA is not effective because coastal erosion was caused by the construction of structures and flooding was caused by land development. Items were added to regulate such activities in the EIA manual.	The added items are channel dredging in reefs, accretion and erosion in the sheltered area of breakwaters, impact of structures on longshore sediment transport, development of lowlands, development of rivers and wetlands, and obstruction of drains
(2) Improvement of Drainage Design Guidelines	The existing guidelines lack several coefficients for conditions in the Seychelles related to flood run-off.	The added contents are the run-off coefficients for geology and land use in the Seychelles, intensity-duration curves for short and long periods, and estimate methods for detention functions
(3) Beach Monitoring Guidelines	Items on the analysis method and related monitoring measures were added for the planning and management of measures against coastal erosion.	The arrangement of transects for monitoring purposes, method of analysing coastal changes, and estimation of coastal changes are proposed and explained.
(4) Aerial Photo Guidelines	Taking aerial photos from helicopters with digital cameras is effective to obtain long-term coastal changes and land use. The method is explained in the guidelines.	The method and accuracy of taking photos, factors to be considered such as tide and weather, orthogonal transformation methods, and related software are explained.
(5) Bathymetric Survey Guidelines	It is necessary to know the bottom profile of the reef for coastal conservation. The use of echo sounders by fishermen is proposed as a measure.	The measures using echo sounders and the arrangement of survey courses are explained in the guidelines. Cautions for surveying are also stated.

7-2 Acquisition of Engineering Knowledge

Engineering knowledge was obtained through OJT and lectures as shown in Table 7-2-1.

Table 7-2-1: Items and Contents of Engineering Knowledge

Items	Purpose	Contents
(1) Coastal Observation	It is more important to understand the actual condition of the coasts and to study the effect of past structures than to gain knowledge from books on coastal conservation.	During the field observation, the counterparts (C/P) studied how to observe and what to focus on with team members as on-the-job training (OJT).

Items	Purpose	Contents
(2) Taking aerial photographs	In order to master how to take aerial photographs from a helicopter, the counterparts took photos according to the guidelines.	The C/P learned how to take photographs during the basic study. Part of the work was done by the C/P as OJT
(3) Flood Damage Survey	In order to obtain information, a flood survey was conducted of local people who lived in a flooded area by the C/P and the Study Team. C/P learned the survey method.	In the flooded area, the C/P gathered information on past flood conditions and damage through personal interviews based on the predetermined questionnaire.
(4) GIS Training	Training and lectures were given to the C/P to enable them to understand the use of GIS, which is very useful for management.	Training was done under a co-project for environmental impact assessment. Open source GIS software was used.
(5) Structure Design	The capacity in structural design of the C/P was developed to enable them to understand how to calculate the stability of structures.	Training was provided in the design conditions, modelling and calculation method of force and stability through lectures.
(6) Formulation of Management Plan by OJT	In order to understand the process of coastal conservation and flood management planning, training was provided in evaluation of pilot projects and planning methods.	The C/P studied with the Study Team how to monitor the results of pilot projects, to find problems in designing and planning, and to improve the plan through OJT.

7-3 Seminars, Workshops and Training in Japan

7-3-1 Seminars

The first seminar was held in August 2011 to explain the results of the basic study after the end of the study in Progress Report No.1. The presentations covered the actual conditions of coastal erosion and flooding in the Seychelles and Japan's experience in coastal conservation and flood management to obtain the understanding of related organizations and to publicise the study results. There were 33 participants from DOE, EEWS, and DRDM of the Ministry of Home Affairs, Energy and Transport, Seychelles National Park Authority, Landscape and Water Management Agency, Ministry of Foreign Affairs, UNDP-GEF, a secondary school and a public utility corporation.

The participants understood that economic development sometimes causes coastal disasters from the experience in Japan and the importance of monitoring for planning mitigation measures in the Seychelles.

The second seminar was held in July 2012 to explain the outline of the coastal conservation and flood management plans and the progress of the pilot projects after the completion of the projects. At the seminar the results and activities related to the January flood in the Seychelles and the March flood in Mauritius in 2013 were presented to exchange both countries' experiences. The participants of both countries understood the necessity of the coastal conservation and flood management plan and the importance of drainage management. They learned the effectiveness of ordinary drainage management in the Seychelles and coastal zone management in Mauritius from each other.

7-3-2 Workshops

The workshops were held to share the results of the basic study, management plan and pilot projects for technology transfer in collaboration with the C/P. The outline is shown in Table 7-3-1. The precipitants were from MOEE, Landscape and Water Management Agency, National Park Authority, Ministry of Land

Use and Housing, Member of National Assembly, Seychelles Land Transport Agency, District Administrator, NGO, press, and others.

Table 7-3-1: Outline of Workshops

Items	Purpose	Contents
First Workshop (May 2011)	To understand the outline of the project and related present conditions and problems in the Seychelles regarding coastal erosion and flooding	Explained the outline of the project and basic study plan together with the present conditions Weather observation conditions were presented by C/P
Second Workshop (October 2011)	To discuss the problems based on the basic study results of coastal erosion and flooding	Explained the conditions and causes of coastal erosion and flooding Discussed the problems and make direction of each coast and area for planning
Third Workshop (April 2012)	To discuss the contents of the coastal conservation plan and flood management plan	Discussed the overall plan and each management plan for the priority coasts and areas Decided the direction of the plan
Fourth Workshop (June 2012)	To discuss with stakeholders and understand the pilot projects in the management plan	Explained the management plan and the selection of the pilot project sites and measures Discussed and agreed the plan for the pilot projects

7-3-3 Training in Japan

The training in Japan was conducted for the C/P members from DOE twice for two members each time. The first training was from September to October 2011 for 14 days and the second was in September 2013 for 14 days.

The contents included field visits and lectures in basic knowledge of the coasts or areas which have the same problems as in the Seychelles regarding coastal erosion and flooding. Application to the Seychelles was considered. At the first training, lectures in engineering design of coastal and drainage structures were given because the trainees were in charge of structural design. At the second training, lectures in management were given at the request of the trainees.

The fields that were visited were the Shizuoka coast where erosion is severe and detached breakwaters have been constructed as a countermeasure, Toban coast where the beach is used widely and has relatively small waves, and Miyagi coast which was damaged heavily by the East Japan Earthquake tsunami. As for flood management, Tomoe river basin was visited in Shizuoka Prefecture. There the participants were shown river improvement works in a lowland area and the construction of a floodway and retention pond with wetland creation for environmental conservation.

The lecturer in the causes and measures for coastal erosion at the first training was Professor Shibayama of Waseda University. At the second training, the trainees visited the National Institute for Land and Infrastructure Management and received lectures in the design and management of coastal conservation structures and the design of drainage systems with model test observation.

In the summary, the trainees studied the applicability of Japan's experience to the related problems in the Seychelles from the lectures and site visits. After the training, the results were presented at the workshops to disseminate their experiences. The results can contribute to the planning and designing of structures for the application of Japanese technology in the Seychelles.

Chapter 8 Conclusion and Recommendations

8-1 Conclusion

In order to mitigate the disasters caused by coastal erosion and flooding, the coastal conservation plan and flood management plan were formulated after the detailed study, issue identification and evaluation of alternatives. Sand nourishment and groyne construction were proposed to keep the sandy beaches as important resources for tourism in the coastal conservation plan. Pilot projects were implemented to study the applicability of the plan and show its effectiveness though long-term monitoring is necessary. Drainage and river improvement were proposed to mitigate inundation problems in the flood management plan. The river improvement includes increased flow capacity from wetland to the sea. An outlet was constructed as a pilot project and showed its effectiveness together with suggestions for improvement.

The capacity of the relevant officials has been developed during the study through OJT and training. The planning, designing and procurement of the pilot projects were conducted in collaboration with the counterparts and contributed to their capacity development.

At the end of the study, flood disasters occurred in January 2013 and 2014 in the southeast of Mahe and La Digue. As recovery work, river improvement works were started based on the flood management plan proposed in the study. Not only the plans but the outlet used in the pilot project were applied and the experience of the pilot projects was used. The construction works will continue for several years. The results of the study will be applied and contribute to the mitigation of coastal and flood disasters and the development of engineering capacity in the Seychelles.

8-2 Recommendations

The proposed recommendations were selected from among the many suggestions by concentrating on effective recommendations. They are summarised in Table 8-2-1.

Table 8-2-1: Recommendations

Item	Problem	Recommendation
Management Plan	Sometimes the plan has to be revised because fundamental information is limited and the future is uncertain.	The plan should be revised at certain intervals by the use of the adaptive management system by monitoring and evaluation.
Laws & Organisation	Laws and regulations have not been established for land use management and setback which are important non-structural measures for future climate change.	Laws and a management system should be established for development where risks exist because of the changing coastal area or lowland. Also, laws should be established for land acquisition if the land is necessary for public benefit.
Financial Action	The channels have not been maintained regularly though the action is effective. The budget for disaster recovery is dependent on donations.	A budget of a certain amount should be allocated to periodic maintenance and reserved for disaster recovery.

Item	Problem	Recommendation
EIA	Structures on dynamically changing beaches or lowland areas have caused coastal erosion and flooding problems.	EIA should be reinforced in areas with high risk of coastal erosion and flooding. The assessment method should be improved by past examples.
Monitoring	There is insufficient information for understanding coastal erosion and studying the mitigation measures. As for flooding, there is not enough information on the flooding mechanism and the magnitude of damage. This makes it difficult to plan mitigation measures.	Beach monitoring should be continued on eroding coasts. Monitoring of the water level should be continued in wetland and lowland areas. These data elucidate the relationship between rainfall and flooding and the mitigation measures.
Disaster Response	Manuals on disaster response to flooding, landslides and tsunamis were prepared. However, they are not used because the actual conditions are not taken into consideration.	Actually, disaster responses were conducted such as the tsunami warning in 2012 and the disaster response to the flooding in January 2013. From this experience, the manual should be improved to make it more effective.
Public Communication	Past public communication was not effective because it was too general.	Past experiences of disasters should be recorded by school children, such as the tsunami in 2004 and January flooding in 2013 and 2014. This will contribute to conveying their experiences to future generations.