THE REPUBLIC OF MAURITIUS
MINISTRY OF ENVIRONMENT, SUSTANAIBLE
DEVELOPMENT, DISASTER AND BEACH MANAGEMENT
(MOESDDBM)

THE PROJECT FOR CAPACITY DEVELOPMENT ON COASTAL PROTECTION AND REHABILITATION IN THE REPUBLIC OF MAURITIUS

FINAL REPORT

SUMMARY

June 2015

JAPAN INTERNATIONAL COOPERATION AGENCY

KOKUSAI KOGYO CO., LTD.
NIPPON KOEI CO., LTD.
CENTRAL CONSULTANT INC.
FUTABA INC.

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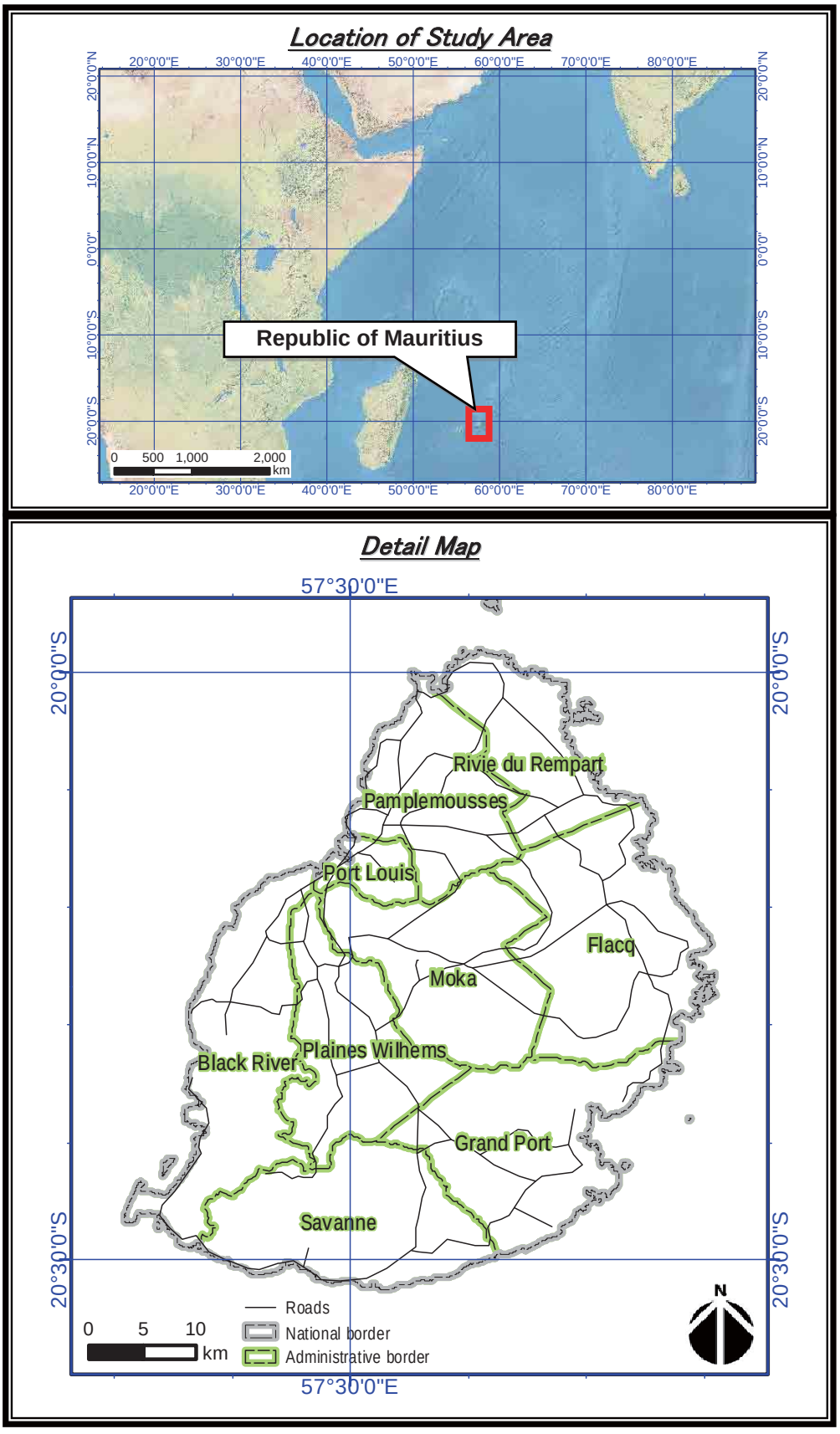

Location Map

Rate of Currency Translation

1 USD = 35.230 Rs

= 124.11 JPY

100 Rs = 2.760 USD

= 342.56 JPY

Rs: Mauritius Rupee

As of June 1st, 2015

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Abbreviations

Abbreviations	English
AAP	Africa Adaptation Programme
AC	Advisory Committee
ACB	Acropora Branching
AF	Adaptation Fund
AFD	Agence Française de Développement
AFP	Adaptation Fund Programme
AFRC	Albion Fisheries Research Centre
AP	Absorption Pit
APHA	American Public Health Association
BA	Building Act
BA	Beach Authority
BLUPG	The Building and Land Use Permit Guide
BOD	Biochemical Oxygen Demand
C/P	Counterpart
CA	Capacity Assessment
CAB	Cabinet
CACI	Compact Airborne Spectrographic Imager
CADMAC	Climate Change Adaptation and Disaster Management Committee
CBR	Cost Benefit Ratio
CC	Crisis Committee
CCD	Climate Change Division
CACI	Climate Change Information Centre
CD	Capacity Development
CD	Chart Datum
CEB	The Central Electricity Board
CDEMA	Caribbean Disaster Emergency Management Agency
CF	Coral Foliose
CIRIA	Construction Industry Research and Information Association
CM	Coral Massive
COD	Chemical Oxygen Demand
CONDC	The Cyclone and Other Natural Disasters Committee
CONDS	Cyclone and Other Natural Disasters Scheme
CSO	Central Statistics Office
CVM	Contingent Valuation Method
CWA	The Central Water Authority
DB	Data Base
DC	District Council
DC	Dead Coral
DEM	Digital Elevation Model
DFR	Draft Final Report
DL	Datum Line
DO	Dissolved Oxygen
DRR	Disaster Risk Reduction
ECMWF	European Centre for Medium-Range Weather Forecasts

Abbreviations	English
E.Coli	Escherichia coli
EIA	Environment Impact Assessment
EIRR	Economic Internal Rate of Return
EMoP	Environment Monitoring Plan
EPA	Environment Protection Act
EPZ	Export Processing Zone
ESA	Environmental l y Sensitive Area
EU	European Union
F/S	Feasibility Study
FAS	First Aid Service
FC	Feacal Coliform
Fs	Safety Factor/Factor of Safety
GDP	Gross Domestic Product
GIS	Government Information Service
GIS	Geographic Information System
GL	Ground Level
GPS	Global Positioning System
GR	Grand River
HFA	Hyogo Framework for Action
HWL	High Water Level
HWM	High Water Mark
IC/R	Inception Report
ICZM	Integrated Coastal Zone Management
IEC	Information, Education, and Communication
IOC(COI)	Indian Ocean Commission (Commission de l'Océan Indien)
ISO	International Organization for Standardization
JBIC	Japan Bank for International Cooperation
JCG	JICA Coordination Group
JET	JICA Expert Team
JICA	Japan International Cooperation Agency
JICE	Japan International Corporation Center
JTWC	Joint Typhoon Warning Center
K	Potassium
K-N	Kjeldahl Nitrogen
LEU	Living Environment Unit
LIT	Line intercept transects
LGA	Local Government Act, 2003
LMHTF	Le Morne Heritage Trust Fund
LMU	Landslide Management Unit
LWL	Low Water Level
M/M	Minutes of Meeting
Mauritius	The Republic of Mauritius
MBC	Mauritius Broadcasting Corporation
MEHR	Ministry of Education and Human Resources
Mg	Magnesium

Abbreviations	English
MGCW	Ministry of Gender Equality, Child Development and Family Welfare
MHL	Ministry of Housing and Lands
MHQL	Ministry of Health and Quality of Life
MID	Maurice Ile Durable
MLG	Ministry of Local Government & Outer Islands
MoAFS	Ministry of Agroindustry and Food Security
MoESD	Ministry of Environment and Sustainable Development
MOESDDBM*	Ministry of Environment, Sustainable Development, Disaster and Beach Management (*Former MoESD)
MoF	Ministry of Fisheries (current MoOEMRFSO)
MoFED	Ministry of Finance and Economic Development
MoFR	Ministry of Fishery and Rodrigues
MOI	Mauritius Oceanography Institute
MoOEMRFSO	Ministry of Ocean Economy, Marine Resources, Fisheries, Shipping and Outer Island
MPA	Marine Protected Area
MPI	Ministry of Public Infrastructure, National Development Unit, Land Transport and Shipping
MPN	Most Probable Number
MMS	Mauritius Meteorological Services
MSL	Mean Sea Level
MSS	Ministry of Social Security, National Solidarity and Reform Institutions
MTEF	Medium-Term Expenditure Framework
MTL	Ministry of Tourism and Leisure
MTSRT	Ministry of Tertiary Education, Science, Research and Technology
MUR	Mauritius Rupee
Na	Sodium
NCAR	National Center for Atmospheric Research
NCCAPF	National Climate Change Adaptation Policy Framework
NCEP	National Centers for Atmospheric Prediction
NCG	National Coastal Guard
NDOCC	National Disaster and Operations Coordination Centre
NDRRMC	National Disaster Risk Reduction and Management Committee
NDS	National Development Strategy
NDU	National Development Unit
NEL	National Environmental Laboratory
NGO	Non-Governmental Organization
NH_4-N	Ammonia Nitrogen
NHDC	National Housing Development Corporation
NO_2-N	Nitrite Nitrogen
NO_3-N	Nitrate Nitrogen
NPV	Net Present Value
NTU	Nephelometric Turbidity Unit
ODA	Official Development Assistance
OJT	On the Job Training
OPS	Outline Planning Schemes

Abbreviations	English
P.Fs	Planning/Designed Factor of Safety
P/R	Progress Report
PB	Public Beach
PBB	Programme-Based Budgeting
PDA	Planning and Development Act
PEFA	Public Expenditure and Financial Accountability
PER	Preliminary Environmental Report
PFM	Public Financial Management
PIANC	World Association for Waterborne Transport Infrastructure (former Permanent International Association of Navigation Congresses)
PIU	Planning and Implementation Units
PL	Pit Latrine
PM	Project Manager
PO_4-P	Phosphate-Phosphorus
PMO	Prime Minister's Office
PMS	Performance Management System
PPG	Planning Policy Guidance
PS	Permanent Secretary
PVC	Polyvinyl Chloride
QGIS	Quantum GIS
R/D	Record of Discussion
RN-COI	Risques Naturels de la Commission de l'Océan Indien
SA	Sand
SAREC	Swedish Agency for Research Cooperation with Developing Countries
SC	Steering Committee
SC	Spot Check
SC	Soft Coral
SCOR	Scientific Committee on Oceanic Research
SIDS	Small Island Developing States
SO4	Sulphate
SS	Sewerage System
SS	Suspended Solid
SSPA	Segridad Salud Proteccion Ambiental
SST	Sea Surface Temperature
ST	Septic Tank
SWAN	Simulating Waves Nearshore
TA	Turf Algae
TAS	Treasury Accounting System
TC	Total Colifrom
TC	Technical Committee
TCPA	Town and Country Planning Act
TDS	Total Dissolved Solid
The Disasters Scheme	The Cyclone and Other Natural Disasters Scheme
The Project	The Project for Capacity Development on Coastal Protection and Rehabilitation in the Republic of Mauritius

Abbreviations	English
TICAD IV	The Fourth Tokyo International Conference on African Development
TICAD V	Fifth Tokyo International Conference on African Development
T-N	Total Nitrogen
TOR	Terms of Reference
T-P	Total Phosphorus
TSHD	Trailing Suction Hopper Dredger
TSS	Total Suspended Solid
UNDP	The United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization -
UoM	University of Mauritius
USD	United States Dollar
UTM	Universal Transverse Mercator
VAT	Value Added Tax
VCA	Village Council Area
VMCA	Voluntary Marine Conservation Area
WCDR	World Conference on Disaster Reduction
WGS	World Geodetic System
WMA	Wastewater Management Authority
WMO	World Meteorological Organization
WS	White Syndrome

Chapter 1

Introduction

1 Introduction

1.1 General

The Project for Capacity Development on Coastal Protection and Rehabilitation in the Republic of Mauritius (hereinafter referred to as 'the Project') started according to the Minutes of Meeting (hereinafter referred to as 'M/M') agreed upon between the Ministry of Environment, Sustainable Development, Disaster and Beach Management(hereinafter referred to as MOESDDBM) of the Republic of Mauritius (hereinafter Mauritius) and the Japan International Cooperation Agency (hereinafter JICA).

JICA dispatched 16 experts who specialize in investigation, analysis, design and countermeasure on coastal erosion. The Project is conducted with the MOESDDBM members as Counterparts from May 2012 to June 2015.

1.2 Background of the Project

In the Hyogo Framework for Action (hereinafter referred to as 'HFA') adopted by the second World Conference on Disaster Reduction (hereinafter referred to as 'WCDR'), signatory countries agreed on a disaster prevention action plan for 10 years under this framework, establishing more effective integration of disaster risk considerations with a special emphasis on disaster prevention as a strategic goal. Based on this framework, the Japanese Government announced the Initiative for Disaster Reduction through Official Development Assistance (hereinafter referred to as 'ODA'), and the Yokohama Action Plan compiled at the Fourth Tokyo International Conference on African Development (hereinafter referred to as 'TICAD IV') which addressed environmental/climate change issues as an urgent challenge. In the Summary by the Chair of TICAD IV, Japan mentioned special considerations to small island developing states

Mauritius is vulnerable to climate change, particularly coastal erosion issues are becoming more serious due to the recent natural disasters resulting from the environmental changes, and deterioration of coral reef resulting from tourism and land development. Although the country wishes to draw plans, understand risks and implement measures based on scientific and technical grounds, it has not yet found a fundamental solution due to the lack of experts and engineers, and the lack of publicity of climate change adaption measures and disaster prevention administration to local communities.

Based on such background, upon the request for technical assistance in coastal protection / rehabilitation from the government of Mauritius to the government of Japan, the Project for Technical Cooperation was started.

1.3 Objectives of the Project

1.3.1 Goal

The goal of the Project is to prepare "Coastal Conservation Plan" which is approved and implemented by the Government of Mauritius.

1.3.2 Project Outputs

The purposes are to identify the affected sites of coastal erosion, to formulate a costal conservation plan, and to select the priority coasts which are necessary for preventive measures based on the plan and to conduct detailed study, demonstration projects and continuous

monitoring. Through these activities, the capacity of governmental agencies is developed for coastal protection and rehabilitation.

1.3.3 Outcomes of the Project

Expected outcomes of the Project are;

1) The affected sites are identified through baseline survey.
2) The coastal conservation plans in the main island of Mauritius are formulated.
3) The effectiveness of the coastal conservation plans is validated through demonstration projects.
4) The technical capacity of the staff in the MOESDDBM and other organizations is enhanced.

1.4 Study Components and Methods

1.4.1 Project Areas

The project area is the Mauritius Island.

1.4.2 Counterparts and JICA Expert Team

The Counterpart (C/P) of the Project is the Ministry of Environment, Sustainable Development, Disaster and Beach Management (MOESDDBM) and the C/P members are composed of the Integrated Coastal Zone Management (ICZM) Division in the Department of Environment in the MOESDDBM. JICA Expert Team is including Mr. Ichikawa of the Chief Adviser, the person in charge of each field, consisting of a total of 16 people.

1.5 Activities and Schedule

1.5.1 Major Activities

The Project executed was divided into four components namely; Component 1 “Basic study”, Component 2 “Formulation of Coastal Conservation Plan”, Component 3 “Implementation of Demonstration Project” and Component 4 “Technical Transfer”.

The basic study was conducted to understand the conditions and problems in coastal zone. Information was collected in relation to the policy of for the integrated coastal zone management, organization, natural and socioeconomic conditions, and past coastal disasters.

The coastal conservation plan was formulated based on the problems in coastal and contained the following activities

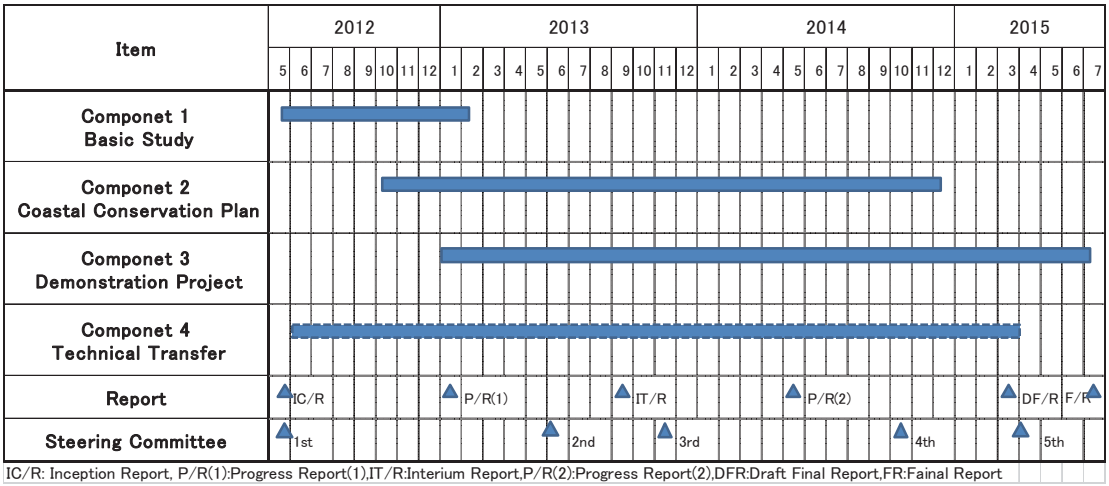
The demonstration project contains the implementation of projects and continuous monitoring to evaluate the conservation plan, to feedback for the applicability, and for the capacity building.

The technical transfer related to the coastal management is intended to enhance the capacity of related governmental organizations in considering the background of technical education. Then technical guidelines were made and seminars were opened.

1.5.2 Work Schedule

The schedule is shown in Figure 1.1. The basic study was conducted from May 2012 to February 2013, the formulation of coastal conservation plan from October 2012 to December

2014, the demonstration projects from January 2013 to June 2015 and the technical transfer from June 2012 to March 2015.



Source: JICA Expert Team

Figure 1.1 Flowchart of the Project Activities

Chapter 2

Basic Study

2 Basic Study

The object of the Project is to conserve the coast of Mauritius in appropriate manners. The purposes are to identify the affected sites of coastal erosion, to formulate a costal conservation plan, and to select the priority coasts which are necessary for preventive measures based on the plan and to conduct detailed study, demonstration projects and continuous monitoring. The capacity of governmental agencies is expected to be strengthened through working cooperatively on the abovementioned activities.

The basic study was conducted to understand the relevant natural conditions, socioeconomic conditions, policies, laws and organizations, and to analyze the coastal erosion and coastal disasters. The conditions of coral and water quality were also surveyed. From the results the affected coast and issue were identified. The results of the basic study were compiled as a coastal environment database. The summary is shown as follows..

Figure 2.1 Outline of Basic Study Results

Items	Outline
1. Natural Condition	(1) Geography and Geology ➢ Geography: The coastline of Mauritius is 322km long and coral reefs are 150km long. Total area is 243km^2. The coast is formed by sandy beaches, gravel beaches, mud flats, wetlands, rocky cliffs and mixtures of these. ➢ Geology: The coast at the northeast was formed by lava of over 20 thousand years ago and at the others by lava of over 100 thousand years ago. (2) Costal Topography ➢ Coast: The reefs are 100m to 1km wide along the northern and western coasts, and over 5km wide along the eastern coast. The coast in Mauritius is classified into four types: type A) sandy beaches with a narrow reef, type B) wide reef, type C) cliff coast without a reef, and type D) silt, mud and cobble coast with a wide reef. Refer to section 2.2.2 for further details. ➢ Bed material: The grain size (D50) of main coasts is 0.2-0.34mm at Mon Choisy, Flic en Flac and Pte. d'Esny, 0.5-0.8mm at Le Morne, 0.4-1.4mm at Pte. aux Piment. The grain size outside of the reef is over 0.5mm at Trou aux Biches and Le Morne. It was confirmed that they are available for sand nourishment. (3) Climate ➢ Climate and rainfall: Mauritius belongs to a tropical climate. There is no division of the dry season and the rainy season. Two thirds of the annual rainfall from December to May. ➢ Wind: Wind of ENE to SSE dominates from November to February and SSE from May to August ➢ Cyclone: Cyclones mostly make landfall from December to March. The severe cyclones were Alix and Carol in 1960, Gervaise in 1975, Hollanda in 1994 and Dina in 2002. ➢ Sea conditions: Tide is semidiurnal. Mean tidal level is high from January to March and low from May to October. The mean sea level rises 3.9mm/year at Port Louis in the past 30 years. Mean significant waves are 1.5 to 2.5m high from SSW to ESE in summer and 2.5 to 3.5m in winter. The

Items	Outline
	waves in a reef are about 0.3m high and the ratio of wave height to water depth is from 0.07 to 0.09. The current in a reef at Pointe d'Esny is under 10cm/s.
2. Socio-economic Condition, Finance, Policy, Law and Organization	➢ Socio-economic Condition: Growth rate of GDP is 6%, the manufacture sector accounts for 16% of the total, and the tourism industry is 6%. ➢ Tourism: Growth rate of tourists is about 4% with 1.04 million tourists per year (2014). The number of hotels registered in Mauritius was 112. There are 52 large hotels with more than 80 rooms, which account for 75% of total beds in Mauritius. ➢ Finance: Budget of MOESDDBM is Rs 570 million in 2013 and allocated Rs 200 million for environment conservation and protection. Increase in staff budget is expected from 2014 to 2016. ➢ Economy: Tourism revenue in 2013 accounts for 12% of GDP and Rs 40.5 billion. The percentage is increasing year by year. The land use of the coastal zone is 23% for agriculture, then bungalows and hotels. (1) Policy, Law and Organization ➢ National policies: National objectives of integrated coastal zone management are indicated in the National Development Strategy and Environmental Policy. ➢ Laws: definition of coastal zone, land ownership, classification of coastal zone, setback regulation, building code and environmental impact assessment are defined. ➢ Organizations: Ministries mainly related to ICZM are 6 among 25 ministries. The role is defined in detail according to the basic study, conservation plan, design and implementation, coastal management and monitoring.
3. Past Coastal Disaster and Measures	➢ Coastal disaster: Past cyclones Carol (1960), Hollanda (1994), and Dina (2002) caused severe damages. ➢ Coastal structures: Transition of structures was small structures from 1960 to 1993, gabions from 1994 to 2003, and rock revetments from 2003 to 2013.
4. Analysis of Coastline	➢ Erosion analysis from aerial photos: Aerial photos were used in 1967, 1975, 1991, 1997 and 1999. Satellite images in 2008 and 2012 were also used. ➢ Method: Digitizing the coastline from aerial photos by GIS. ➢ Result: Long term erosion was 17%, stable coast 59%, and accreted one 23%. Eighteen coasts show erosion of 0.2m/year and the short term change are 0.5m/year on average. ➢ Discussion: Short term change is larger than the long term erosion and the effect of topographic change due to cyclone is remarkable.
5. Reef Environment	(1) Water quality ➢ Monitoring: The water quality is monitored by AFRC in lagoon, NEL for rivers and lakes, WMA for sewerage, CWA for drinking water. Water pollution is significant in the lagoon at Pointe aux Sables、Albion、Baird Sanctuary, Riviere Noire after 2007. At Pointe aux Sables coliform concentration is significantly higher.

Items	Outline
	➢ Water quality: The water quality was measured at eight coasts where the beach is sand beach with reef and expected tourism development. The results show that the coverage of live coral decreases according to the increase of siltation, chlorophyll a, nitrogen and phosphorus in lagoon. The contribution of the pollution load from hinterland, rivers and wetland is high. Measures to reduce the inflow and to prevent eutrophication are important in reef environmental protection. (2) Coral reef ➢ Coral monitoring: Coral was monitored at 50 sites by spot check method. The results show that the coverage of live coral is 27.2% on average of 44 points and lower than the reference. The relation between coral coverage and transparency is positive and sedimentation of silt is negative. The average coverage of 19.2% in 2010 decreased from 51.4% in 2000 significantly. ➢ Problems: The main problems in a reef are the degradation of coral, the decrease of juvenile coral, sharp decline of table coral that was once occupied, regional disappearance of several species, coral bleaching in 2003, 2004 and 2009, eutrophication, abnormal increase of micro algae in summer, deposition of silt, decrease of transparency, and large nets fishing.
6. Public Awareness	➢ The main contents of questionnaire: (1) Damages of coastal areas by the cyclone in the past, (2) Long term trend of coastal erosion, (3) Awareness of coastal disasters associated with the climate change in future (4) Desirable countermeasures against coastal disasters due to climate change, (5) Desirable facilities and willingness to pay for coastal conservation. ➢ Result: (1) & (2) There has been no reports of large scale erosion, (3) About 25% of people show willingness to pay for conservation measures, (4) High awareness of environmental issues as well as coastal protection, (5) 50% of respondents were in favor of conservation measures by hard structures and 30% by beach nourishment
7. Coastal Environment Data Base	➢ Existing database: Administrative district, infrastructure, geological map, soil map, land use map, mangrove map, contour line, observation point, nature reservation map, and public beach. The coordinate system of the data was unified as WGS84, UTM zone 40S since a few different coordinates were applied for the existing database. ➢ New GIS data: Digitized coastline data of 13 target coasts from the aerial photo in 1967, 1975, 1991, from 1997 to 2000 and the satellite image in 2008 and from 2011 to 2012. From the data the sediment budget was analysed.

Source: JICA Expert Team

Chapter 3

Policy of Coastal Conservation Plan

3 Policy of Coastal Conservation Plan

3.1 Problems of Coastal Conservation

Problems related to coastal conservation, rehabilitation and capacity building were investigated based on the basic study. These issues were classified into: (1) coastal management, which relates to all of the issues; (2) coastal conservation, which is the main topic of the project; (3) reef environment conservation; and (4) capacity development, as shown in Table 3.1.

Table 3.1 Problems for Coastal Conservation

Item	Problem
(1) Coastal Management	• Insufficient execution of coastal management and related planning • Partly ineffective management system • Measures for changes due to climate change and economic development in the future • Lack of monitoring • Lack of local involvement

(2) Coastal Conservation	• Harmony with protection, coast use and environment
	• Beach change caused by cyclones and setback
	• Coastal erosion and accretion
	  ・ Long term beach erosion
	  ・ Erosion and accretion caused by longshore drift
	  ・ Channel closure
	  ・ Sediment outflow from lagoons
	  ・ Cliff erosion
	• Wave overtopping and storm surge
	• Beach rehabilitation with removing of structures

(3) Reef Environment Conservation	• Deterioration of coral • Eutrophication in lagoon • Competition between nature conservation and fishing or recreation
(4) Capacity Building	• Insufficient evaluation of EIA report • Lack of engineering ability

Source: JICA Expert Team

3.2 Risk in Coastal Zone

The risk of coastal disasters caused by coastal erosion and wave overtopping were assessed for the present and the future. The results show risks of coastal erosion at present and in the future risks of inundation by storm surges and waves, future sea level rise, the degradation of the coral reef system and future economic development. Because the analysis was based on current data, it is necessary to revise the results after a detailed study in the priority coast.

3.2.1 Risk by Coastal Erosion

As for the risk of coastal erosion, the risk of long term erosion and the risk of temporary erosion, according to approaching cyclones, are assumed. The beaches with long term erosion were identified. Regarding these beaches, the erosion amount can be estimated from the erosion rate and the risk can be investigated.

The erosion rate is divided into two classes: One class is set as 0.2 m/year. This rate can be clearly identified as erosion. Another class is set as 0.4m/year. This rate is assumed to be nearly the maximum erosion rate. The period is divided into three classes; 30 years, 50 years and 100 years respectively. 30 years is the period for the durable year of normal structures. The coastal erosion amounts for 30 years, 50years and 100 years are as follows:

Table 3.2 Relation with Erosion Rate, Periods and Erosion Amount

Erosion Rate/ Period	30 years	50 years	100 years
0.2m/year	6m	10m	20m
0.4m/year	12m	20m	40m

Source: JICA Expert Team

For the temporary erosion amount, according to approaching cyclones, the only quantitative data is the existing material on Cyclone Carol in 1960. The data shows the maximum erosion amount by Carol was about 13m. The stochastic cyclone scale related to Carol is estimated to be about 100 years based on the stochastic analysis of the pressure depletion of the cyclone center. So, the risk by erosion is in range of this scale.

In Mauritius, the beach is mostly state land. The houses and hotels are constructed on leased land. The buildings are under a setback regulation of at least 30m from the HWM. For the beaches affected by erosion, the erosion amount is 30m for the 50 year period, factoring in both the long term erosion amount and the temporary erosion amount. For the severely eroded, the erosion amount is 30m for the 30 year period and is equal to the setback amount. If the period is longer than these periods, the risk of erosion occurs.

For the cliff coast, the rock is basalt and hard enough to resist erosion. Accordingly, the risks are small compared to those of sandy beaches. However, there were examples which showed cliffs collapsing due to the impact of cyclone waves. The risks of cliffs have to be investigated at each coast.

3.2.2 Risk by Wave Overtopping and Storm Surge

Wave overtopping, inundation by high waves and storm surges occur. However the existing data to estimate the influence is limited and a clear outcome cannot obtained. The only existing data to estimate the damage by this disaster are the study results on Carol. According to the study, the maximum wave run-up height was 12 ft (4 m) on the cliff coast and is 9 ft (3 m) on the sand beach. The berm height of the beach is the same as the run-up height but the degree of risk is unclear.

There are coasts in Mauritius with wide reefs where ground level is around 2m or less that are also affected by wave overtopping even though the waves dissipate. At present, the beach profile has been formulated by the action of corresponding waves and tides. It is difficult to say that the risk of the beach is high compared to the other beaches even if the ground level is low. However, the impact of sea level rise will become significant.

a. Effects by the Sea Level Rise

With regard to the sea level rise rate, the present average sea level rise rate of 3.9 mm/year is applied. The future risk by coastal erosion after the next 30 years, 50 years and 100 years are evaluated roughly as follows:

Table 3.3 Future Erosion Amount by the Sea Level Rise

Items/ Period	30 years	50 years	100 years
Sea Level Rise	0.12 m	0.20 m	0.39 m
Coastal Erosion	1.2 m	2 m	4 m

Source: JICA Expert Team

There are several proposed equations to estimate the amount of erosion due to the sea level rise (SLR). Among these, the equation proposed by Per Bruun is generally applied. The equation is as follows;

$E=C\times S$,

Where, E: Erosion amount due to SLR, C: coefficient of beach characteristic and S: amount of SLR. Although the coefficient C is reported to be from 50 to 100, the sediment transport is restricted by the coral reef in Mauritius. So, C is 25 by using 2.5 m for the height of sediment movement and 1/10 for the beach decline. The erosion amount is calculated by using this C. These results will be subject to change depending on future studies.

b. Deterioration of Coral Reef

Coral reefs are a source of sand on the beach and play a key role in coastal protection due to the attenuation capacity of waves. According to the results of long-term coral reef monitoring, the living conditions of coral are rapidly deteriorating and the coverage of coral decreased from 50% in 2000 to 20% in 2010. Also the results of the Project gives the coverage of 27%. Although the deterioration of coral is not likely directly linked to coastal erosion, this leads to a variety of problems in the long term. But there is lack of data to estimate the effects quantitatively and the risk evaluation is very difficult.

3.2.3 Identification of Risk Area

The risks caused by coastal erosion and wave overtopping have been evaluated and the risk of an eroded coast was estimated and the setback was estimated against it. The risk of sea level rise was also estimated.

The long term risks of an eroded coast were identified by the erosion speed. Coastal areas with speeds over 0.2 m/year and with 50 years exceed the present setback value of 30 m and are estimated as high risk. The following 12 coasts are high risk coasts: (1) Ponte aux Piments, (2) Mon Choisy, (3) Pte. aux Cannoniers, (4) Part of P.G. Choisy, (5) Q. Cocos Vge & T. d'Eau Douce, (6) Ile aux Cerfs, (7) Pte. d'Esny, (8) Saint Felix, (9) Le Morne, (10) Wolmar & Flic en Flac, (11) Albion, and (12) Pte. aux Sables from Table 2.2.8. Coasts with erosion speeds under 0.2 m/year are within the setback limit. In some coastal roads, the 30 m setback is not incorporated. The risk of these areas was not identified due to a lack of information.

Coastal roads situated on low-lying land which may have a risk of wave overtopping could not be identified because of a lack of topographical data. In the detailed study, Grand Sable is selected as an example of those coasts and is investigated in more detail.

3.3 Coastal Conservation Strategy

The present strategy of coastal conservation is proposed based on the following basic study results and the related issues for three objectives; coastal protection, coastal development and environmental conservation.

a. To maintain and make use of natural characteristics of the coast

Because erosion along the sandy beach in Mauritius is a natural and reversible process and coastal structures are not necessary, it is important to keep the coast in a natural state. Natural sandy beaches have to be maintained as a resource of tourism, which is one of the main industries in Mauritius. Coral reefs, which have important functions including supplying sand and wave dissipation together with the conservation of the ecosystem and fisheries, should be conserved and rehabilitated in a proper way.

b. To build the abilities for natural and socio-economic changes in future

It is necessary to strengthen the adaptive ability for the future sea level rise caused by climate change and economic development. Adaptive coastal management is going to be conducted by the following procedures: setting precise goals, implementing the plans, monitoring the conditions, and evaluating the results. It has to be done to accumulate and apply the information and past experience, and to develop measures and structures based on natural characteristics.

c. To integrate coastal management with the collaboration of stakeholders

The coastal zone has to be managed in an integrated way for coastal protection, nature conservation and coastal use. MOESDDBM will manage the coastal zone by making decisions and with the cooperation of related organizations. Each governmental organization plays their role for management with the participation of the local people.

3.4 Basic Policy for Coastal Protection Measures

Based on the strategy as stated above the basin policy for the coastal protection measures are summarized as the following.

1. Natural beach without structures s should be preserved with its present conditions because of the superiority of the natural environment and landscape. The only measures are nourishment and reprofiling with no structures.

2. For the coast with structures, the measures are also basically nourishment and reprofiling. If tremendous maintenance is required for beach stability against longshore sediment transport, existing structures can be improved by adding new ones if necessary. The existing structures should be re-evaluated and reduced as much as possible. Reducing existing and new structures can promote the maintenance of the landscape and natural environment. The existing revetments should be setback or improved from vertical to gently sloping and permeable ones.

3. The sand or gravel for nourishment has to be the same particle distribution and color of the existing beach material. The black sand from the volcanic origin is not used for white coral beaches. The diameter of the nourished sand should be larger than the existing one.

4. Structural measures without nourishment do not increase the sediment volume and increases negative effects, which are larger than the positive ones from past experiences. They are not suitable for tourist beaches which have various coastal uses and need a good environment. So structural measures are not applied for tourist beaches. They can be used only for the protection of residences or important public facilities.

5. Sand recycling is recommended only for partly eroded beaches but not in general. So transporting sand from accreted to eroded areas as the solution in a sediment cell is recommended. In this case the beach should be wide enough for the 30 m setback and for accreting without erosion problems by recycling through sand mining.

6. The erode beach in total is nourished and maintained by the sand taken from the outside of the beach.

7. For long term maintenance of the beach, the reef environment will be conserved and improved as a policy to keep a continuous sediment supply. Together with sand nourishment, reef conservation is a priority for beaches where erosion was caused by the deterioration of coral reef.

8. Maintenance of the setback line and review of the land use plan is one of the measures for future long-term climate change risks.

9. The sand for nourishment is procured in the most economical way considering the sediment budget in Mauritius and the mechanism of sediment transport at each coast. At present, the sand has been procured from only two sites of land. On the other hand, the beach sand has increased in total though some beaches have been eroded. It is necessary to urgently review procurement methods which are sustainable and economical and factor in the possibility of sand transfer and the development of a new site.

Chapter 4

Coastal Conservation Plan for Priority Coast

4 Coastal Conservation Plan for Priority Coast

4.1 Selection of Priority Coast

4.1.1 Introduction

For the formulation of the specific coastal conservation plan, 20 coasts were selected for basic study among 58 coasts which were requested from MOESDDBM. Based on the results, 14 coasts were selected as priority coasts for the coastal conservation plan.

4.1.2 Selection of Basic Study Coast

Twenty coasts were selected to conduct the basic study including field survey and data analysis. Based on the existing reports about coastal conditions in Mauritius, the selection was conducted using two criteria; 1) existing conditions of coastal disasters such as erosion and wave overtopping, 2) geographical and geological conditions. Selected coasts include: 1) 13 coasts with erosion problems evaluated as sediment cells, 2) one coast with cliff erosion problems, 3) one coast with wave overtopping problems, 4) Five coasts with PBB projects.

4.1.3 Selection of Priority Coasts

Among 20 coasts for the basic study, 14 coasts were selected for the formulation of coastal conservation plan as priority coasts under the four criteria. They are natural and geographic conditions, reef environment, coastal disasters and coastal utilization. Based on the evaluation standard, 12 coasts in total were selected; 1) 10 coasts with erosion problems on sandy beaches, 2) one coast with cliff erosion problem, and 3) one coast with wave overtopping problem on properties behind. Two coasts of Baie du Tombeau and Bras d'Eau were added from the request of MOESDDBM for the conservation plan. The location of the coast is shown in Figure 4.1.

- Ten coasts with erosion problems on sandy beach
  - Pte. aux Cannoniers (The Vale, No.B2-1)*
  - Mon Choisy (No.B2-5)
  - Q. Cocos Vge (No.B5-12), T. d'Eau Douce (No.B5-13)
  - Ile Cerfs (No.B6-1)
  - Pte. d'Esny (No.B7-2)
  - Bel Ombre (No.B9-2 & No.B9-3)
  - Le Morne (No.B10-1)
  - Flic en Flac (No.B11)
  - Albion (No.B12-1, No.B12-2 & No.B12-3: beach)
  - Pte. aux Sables (No.B13-2)

  *Selected coast No.B2 is divided into Pte. aux Cannoniers (The Vale) and Mon Choisy in accordance with its geographical characteristics.
- One coast with erosion problems at cliff coast
  - Albion (cliff) (No.B20)
- One coast with a problem of wave overtopping impacting infrastructure in hinterland
  - Grand Sable (No.B19)
- Two coasts from the request of MOESDDBM
  - Bai du Tombeau (No.B1)
  - Bras d'Eau (No.B1)

Figure 4.1 Fourteen Coasts for the Formulation of Coastal Conservation Plan

4.2 Planning Process with Stakeholders

In general, the coastal conservation plan should consider the following three functions:

(1) Coastal protection: maintenance of sandy beach and protection of assets such as houses, hotels and infrastructures such as road along the coast

(2) Coastal use: promotion of coastal use such as swimming and recreational marine sports

(3) Coastal environment: conservation of natural environment which includes ecological diversity and land scape

The above requirements have a trade-off relationship. There is no universal conservation plan which can be applied to every coast because the requirement level is different according to the natural conditions and land use of each area.

It is important to formulate a plan after addressing the local problems and then basing it on the requirement levels of the three functions above. Thus, the policy for formulating the coastal conservation plan is to include the stakeholders and to consider the planning process for the capacity development.

4.3 Summary of Characteristics and Coastal Protection Measures for Priority Coasts

The problems, sediment budget and coastal condition, were summarized for the 14 priority coasts. Based on the obtained results of the basic study, the short and long term coastal conservation measures were examined.

The proposed coastal conservation plan for each coasts are described in the Volume 2 individually apart from the this main report of Volume1. Table 4.1 shows the summary for obtained results of short and long term coastal conservation measures for each priority coasts.

Table 4.1 Summary for Category of Coasts, Proposed Coastal Conservation Measures.

No	Coastal Names	Categorization of Problem	Sediment Budget			Category of Beach A: natural beach B: Structures (partial) C: Structures (many)	Recommended Measures	
			Total (1967-2012) (m3/45 year)	Yearly (m3/year)	Category I: Balanced II: Decrease III: Increase		Short Term Measures	Long Term Measures
1	Baie du Tombeau	Partial Erosion	17,700	390	I	B	Improvement of vertical structures	Setback
2a	Pte. aux Cannoniers (North)	Erosion	-2,400	-50	II	B	Periodical Nourishment + Improvement of revetment	Setback. Improvement of water quality
2b	Pte. aux Cannoniers (East)	Erosion	-8,900	-150	II	C	Nourishment with re-arrangement of groins	
3	Mon Choisy	Erosion	-22,400	-500	II	A	Periodical Nourishment	Improvement of Coral Reef Environment
4	Bras d'Eau	Partial Erosion	9,900	210	I	B	Sand recycle	Mangrove rehabilitation
5	Q. Cocos Vge & T. d'Eau Douce	Partial Erosion	17,800	400	I	B	Sand recycle	Improvement of Coral Reef Environment
6	Ile aux Cerfs	Sedimentation	171,300	3,810	III	A	Sand extraction from landside + Sand recycle at partial eroded area	Mitigated Sediment management. Improvement of water quality
7	Pointe d'Esny	Partial Erosion	17,800	390	I	C	Sand recycle with re-arrangement of groins	Setback. Coral preservation. Improvement of water quality
8	Bel Ombre	Partial Erosion	63,400	1,410	III	B	Setback (for illegal facility)	Coral Preservation
9	Le Morne	Partial Erosion	55,900	1,240	III	A	Sand bypassing	Coral Rehabilitation
10	Flic en Flac	Partial Erosion	23,800	530	I	A	Sand recycle	Improvement of Coral Reef Environment. Set back
11	Albion	Erosion	-7,700	-170	II	A	Setback (for new development) + nourishment	Coral Rehabilitation + Control of Fishing Activity. Set back
12	Pointe aux Sables	Partial Erosion	53,800	1,200	III	A	Sand recycle	Set back. Improvement of Coral Reef Environment
13	Grand Sable	Storm Surge	-	-	-	-	Gravel beach (Flexible Revetment)	Reassessment for the area faced on the coast
14	Albion (Cliff)	Cliff Erosion	-	-	-	-	-	Setback (Keep buffer zone)
	Total		373,500	8,300				

4.4 Coastal Conservation Plan for Priority Coasts

The recommendations for conservation of 14 priority coasts are given below. The plans include the coastal protection plan, the reef conservation plan and the beach management plan for each coast as explained in Vol.2.

4.4.1 Baie du Tombeau

The beach is almost stable at present though it was eroded in the past. In the south, two sand bars were formed in the lagoon with an accreted beach. A part of the vertical revetments and trees were damaged though this was limited. The bridge at the north end to the public beach was damaged and it is difficult to access. The water quality is expected to improve as a result

of prohibiting direct wastewater discharge. Also the coral is in relatively good condition. Taking all this into consideration, the recommendations are as follows:

- Improving vertical structures
- Maintaining a setback zone
- Repairing bridges
- Monitoring of shoreline and lagoon conditions
- Planting coral

4.4.2 Pte. aux Cannoniers

The beach at the north has been preserved except for a part that was lost and over half of the beach on the east side was lost because of the decrease of alongshore sediment supply. The vertical revetments in the setback area are probably the cause of the increase in beach erosion at the lease area, which is a large part of the coast. Those measures are not considered comprehensive for the stability of the whole beach and consensus among stakeholders, including residents is required. The hinterland has become a densely populated area. There is concern that eutrophication due to domestic wastewater will progress and additionally the reef environment will deteriorate. With this in mind, the recommendations are as follows:

- Nourishing at the north and nourishing with groynes at the east
- Improving vertical structures
- Maintaining a setback zone
- Reaching a consensus of stakeholders and residents
- Improving the water quality

4.4.3 Mon Choisy

This beach shows long term erosion caused by a decrease of sediment supply. Other problems include erosion at the south, accretion at the north and the formation of beach scarps by cyclones. Further, the decrease of sand supply due to deterioration of water quality and coral reef conditions was presumed as one of the main causes of erosion. Thus, recovering the sand supply is required to improve the reef environment. There is a public beach at this site; management is required such as re-profiling and improvement of beach vegetation. Therefore, the recommendations are as follows:

- Nourishing and re-profiling
- Planting seagrass
- Regulating nautical activity
- Improving the water quality
- Implementing of beach management

4.4.4 Bras d'Eau

The coast is located at the north of the bay which has an opening to the east. A public beach, hotels, and bungalows are located along the coast. The beaches consist of coral sand and head lands of basalt. The sediment budget shows a deposition tendency. However, the change of the beach from erosion and accretion is relatively large due to the decrease of mangroves and seagrass together with alongshore sediment movement to the west. Also the existing vertical revetment has some impact on (namely is considered to contribute to) erosion. Beach scarp was seen in front of the toilets in the public beach. Thus, the recommendations are as follows:

- Maintaining a setback zone
- Reprofiling and sand recycling
- Removing vertical structures
- Relocating public toilets
- Planting mangroves and seagrass
- Implementing beach management

4.4.5 Q. Cocos Vge and T. d'Eau Douce

Large coastal changes of accretion and erosion are problems caused by the change of coral conditions in the reef together with the change of wave conditions. The vertical revetments and groynes constructed for erosion measures sometimes cause part of the erosion. The whole coast is accreting and the accretion is caused by the growth of a coral patch and erosion at the down drift side. The erosion has a tendency to recover but the coral is deteriorating. Accordingly, the recommendations are as follows:

- Maintaining a setback zone
- Improving vertical structures
- Monitoring the reef environment
- Conserving coral
- Implementing beach management

4.4.6 Ile aux Cerfs

The coast is located between two islands and includes a channel between them. Many tourists enjoy sunbathing on the white sandy beaches and playing in the current in the channel. In recent years, this channel has become closed because of sand sedimentation, causing beach use problems as well as erosion on adjacent beaches. The channel has been dredged but it has a tendency of closing up. The dredged sand can be uses as a source of beach nourishment. Therefore, the recommendations are as follows:

- Removing sand and bypassing from the channel
- Implementing beach monitoring
- Managing sand resources

4.4.7 Pte. d'Esny

Although the beach is accreting as a whole, a part of the beach has eroded. Alongshore sediment has moved from the eroded area to accreted areas. The existing vertical revetments and groynes are possibly contributing to the erosion. Also these structures are located in the setback area which ensures dynamic beach changes by cyclones. A large part of the coast is leased land so measures are taken by the individual lessees. When considering the stability of the whole beach, consensus of residents and stakeholders is required. Measures also need to conserve coral which contributes to the stability of the beach but is at risk of degradation due to climate change. Thus, the recommendations are as follows:

- Recycling sand
- Rearranging and removing groynes
- Maintaining a setback zone
- Reaching a consensus of stakeholders and residents
- Planting coral
- Improving the water quality

4.4.8 Bel Ombre

The coast is accreting as a whole and the eroded beach seems to be related with the disappearance of seagrass. At present, the erosion is not serious. However there are possibly several problems. These include the disappearance of seagrass and the impact of revetment and groynes constructed by hotels near the beach erosion. A part of the coastal houses located in low land areas have storm surge damage risks. Parasailing is popular in the lagoon and this possibly has an impact on the coral and seagrass. Accordingly, the recommendations are as follows:

- Maintaining a setback zone
- Relocating houses in the lowlands
- Regulating nautical activities

4.4.9 Le Morne

The coast is accreting and though the problems are limited at present, there are long term issues. These include the degradation of coral which is the source of sand, the change of coral and seagrass in the lagoon and the impact of climate change. The channel and jetty were constructed by the hotel owner and it blocks longshore sediment transport. The beach located north of the channel is experiencing erosion. The coral and seagrass conditions in the lagoon are possibly affected by large nets fishing and parasailing. Thus, the recommendations are as follows:

- Bypassing sand at the jetty
- Maintaining a setback zone
- Planting coral

- Establishing a marine protected area
- Regulating nautical activities

4.4.10 Flic en Flac

The beach at the center shows erosion though in total it is accreting. At the center, the lagoon is deeper than at other parts. This leads to beach erosion because the supplied sand deposits in the deeper parts do not reach the beach. In particular, due to high waves (from cyclones), beach scarps are noticeably easy to form. The coral is the source of sediment and long term measures are required. In particular, at the deep area in front of the eroded beach, planting coral is required to help the bed recover. First priorities will be the monitoring and analysis of the coral, seagrass and water quality. Thus, the recommendations are as follows:

- Recycling sand and re-profiling the beach
- Planting coral
- Regulating nautical activities
- Improving water quality

4.4.11 Albion(beach)

This beach has a tendency to erode as a whole and one of the causes is estimated to be the loss of seagrass bed in front of the beach. The scale of the coral reef is small. The forming of coral is poor because of the fresh water inflow of the river. The coral on the reef is easily impacted by environmental changes such as cyclones and floods. The loss of coral and seagrass is estimated to be caused by the increase of sea surface temperatures, the impact of cyclones, flooding and large nets fishing. Thus, the following are recommended:

- Maintaining a setback zone
- Planting seagrass
- Regulating nautical activities
- Planting coral

4.4.12 Pte. aux Sables

The coast is accreting as a whole. However, a part of the beach has been eroded, though accretion at the east side occurs from the alongshore sediment transport. Also, structures against erosion caused further erosion to the down drift side. The causes of this erosion may be the change of seaweed habitation on the reef, and the decrease of the sand supply from the reef due to coral environmental degradation. Also, the disappearance of the foreshore and promotion of erosion by the construction of the revetments and a slipway, which have been carried out after erosion, may be the causes of this erosion as well. In this coast, eutrophication which is caused by turbidity and waste water is advanced in comparison with other Mauritian coasts and the water quality has remarkably deteriorated. In addition, distribution levels of the coral on the reef has decreased when compared to the past, and the seaweed bed close to the

central land is disappearing. With this in mind, the following is recommended:

- Recycling sand
- Maintaining a setback zone
- Improving vertical structures
- Improving the water quality
- Planting coral

4.4.13 Grand Sable

In terms of the terrain of the projected beach, both sides of the beach are formed by discharge of sediment from the rivers and in the middle it has weathered volcanic rock landforms and is eroded by waves. Since the impact of the coastal erosion is just escarpment degradation, the study found that there is no significant erosion problem on this beach. However, there will likely be overtopping problems because the coastal road, which is considered the primary road from the airport to the southeast tourism area, is established on low elevated land. Accordingly, a flexible revetment was planned and a part of this was implemented. Additionally, trash and seagrass have accumulated on the beach and have caused environmental problems. Therefore, the following measures are recommended:

- Extending the flexible revetment
- Implementing beach management of seagrass

4.4.14 Albion (cliff)

The cliff coast of Albion was selected as the representative coast of cliff erosion. The measures for cliff coasts are mainly utilizing the setback and protecting the cliff base by structures. The setback is adequate because of its cost and applicability for future change. The method to estimate the setback limit is proposed.

- Maintaining a setback zone

Chapter 5

Beach Management Plan

5 Beach Management Plan

5.1 Recommendation on Improvement Plans based on Beach Management Issues

5.1.1 Improvement Plans for Beach Operation and Maintenance

a. Management and monitoring of beach nourishment issues

- To set up suitable foreshore slope and backshore crown height.
- To set up suitable grain size such as equal to or bigger size at existing beach.
- To set up suitable frequency of beach profiling survey and analysis.

b. Formation of scarp issues

- Enhancement of monitoring system under cooperation with institutions concerned.
- Management of plantation on the beach.

c. Plantation issues on the beach

- To set up suitable arrangement and composition of beach vegetation.
- Selection of suitable species of plantation (native species as much as possible).

5.1.2 Improvement Plan on Land Use Management

a. Existing coastal facility issues

- Modification of revetment from vertical type to sloping permeable type with plantation.
- Demolition and modification of groynes depending on effective based on the analysis.

b. Dredging issues in coastal area

- Continuous periodic monitoring.
- Evaluation of monitoring data which is submitted by lessees.

c. Existing facilities/structures issues in dynamic beach zone

- Demolition and relocation by verifying location and construction data of existing facilities and structures by using aerial and/or satellite photos.
- Control and management of boundary at accumulated area. The boundary should not be shifted to offshore side. It is necessary to add this role in lease agreement.

d. Construction of new facilities/structures issues in dynamic beach zone

- Enforcement unit be set up at level of MHL and DC to monitor construction within the dynamic beach zone.
- Periodic monitoring for inadequate facility and structure in dynamic beach zone.

5.1.3 Improvement Plan for Beach Use Management

a. Beach cleaning issues

- Enhancement of awareness of beach cleaning to lessees by using leaflet, etc.

- Periodic inspection by local authority.
- To establish a new beach cleaning system and/or add responsibility of beach cleaning which should be described in lease agreement.

b. Vehicle access issues into public beach

- Step-by-step upgrading of parking space in the whole Mauritius.
- Installation of sign and information board, sharbs and flower trees as boundary.

c. Lack of drainage system

- Planning of drainage facility in consideration of road rehabilitation and improvement plan behind coastal zone
- Installation of soak away type drains between parking areas/road side and public space

d. Removal of sand grass/creepers

- Enhancement of awareness of importance of sand grass to lessees by using leaflet, etc.
- To add responsibility of protection and conservation of sand grass/creepers in lease agreement

5.1.4 Improvement Plan of Organization and Management System in terms of Beach Management

The improvement plan of organization and management system to solve various issues against beach operation and maintenance management, land use management and beach use management were discussed and set up through discussion among related institutions. It is necessary to carefully review and discuss responsibilities and cooperation system of each management item among related institutions such as MOESDDBM, MHL, MLG, Beach Authority, Forestry service, MOF and MOI.

5.2 Recommendation on beach management plan from the point of view of integrated sand management

5.2.1 Basic concept on beach management at priority coasts

- The basic concept of beach management at nine beaches where show tendency of accumulation in the long run is to keep a balance of sediment budget by periodic maintenance such as sand recycling from accumulation area to erosion area.
- The basic concept of beach management at Le Morne and Bras d'Eau where show tendency of erosion in the short run is also basically sand bypassing and/or sand recycling as well as other beaches. But it is necessary to consider procuring sand from out of the beach if the sediment budget will show decreasing trend in future.
- At Mon Choisy and Pte. aux Cannoniers where sediment budget show decreasing trend both in the long run and in the short run, it is necessary to continuously install sand for beach maintenance in order to keep the beaches in good condition. The necessary sand for beach management should be procured from out of the beach.
- The dreading work was carried out at between islands at Ile aux Cerfs in order to keep open channel and hotel who manages that channel has been anxious about disposal of dreaded sand. It is recommended that the sand will be reused as material of beach nourishment for other beaches.

5.2.2 Improvement Plan of Beach Management in Coastal Area

The issues are different if sedimentation and erosion area are public area or leased area individually in case that sand recycling and bypassing are carried out within the beach. The improvement plan against three cases are recommended as follows.

a. Case-1: Sedimentation area (Public area), Erosion area (Leased area)

- Establishment of committee or association which can discuss about management method, cost allocation, procurement of contractor, etc.
- Establishment of beach management structure under the cooperation between the public and private because discussion and coordination between them are needed.
- Study on new management system such as reduction of or exemption from land rent as plan-1 and/or subsidy for a part of maintenance cost as plan-2 from government to lessees in this area in order to reduce cost burden by lessees. Case-2: Sedimentation area (Leased area), Erosion area (Public area).

b. Case-2: Sedimentation area (Leased area), Erosion area (Public area)

- Verification of the position of boundary between the public and private through joint survey between them based on lease contract.
- Installation of stakes as clarification of boudary in order to proceed maintenance smoothly in future.
- Establishment of committee in order to enhance the cooperation between the public and private such as related agencies (MOESDDBM, etc.) and lessees at sedimentation area.
- Sharing of information regarding construction method for maintenance, construction schedule/period, result of monitoring.
- Continuous and smooth monitoring and maintenance through periodic meeting between them.

c. Case-3: Sedimentation area (Leased area), Erosion area (Leased area)

- To gain a better understanding of effect of maintenance through information supplement from related agencies (MOESDDBM, etc.) to lessees regarding monitoring data after beach nourishment in order to go forward maintenance smoothly.
- Verification of the position of boundary between the public and private through joint survey between them based on lease contract.
- Installation of stakes as clarification of boudary in order to proceed maintenance smoothly in future.
- Establishment of committee or association which can coordinate management method, cost allocation, procurement of contractor, etc. at erosion area.
- Lessees of sedimentation area attend to committee or association as observer in order to exchange information about sand extraction and transportation, shoreline change after the extraction, etc.
- Study on new management system such as reduction of or exemption from land rent as plan-1 and/or subsidy for a part of maintenance cost as plan-2 from government to lessees in this area in order to reduce cost burden by lessees. Case-2: Sedimentation area (Leased area), Erosion area (Public area).

5.2.3 Potential of Procurement of Sand in and out of Lagoon and Future Issues

The issues in future and necessity of action are pointed out after due consideration of potential of sand procurement from in and out of lagoon.

1) Sufficient and detail investigation/analysis at potential sites is required in order to grasp quality and quantity of sand.

2) Study of impact on surrounding beaches due to sand extraction and necessity of EIA.

3) Peripheral people's understanding and approval in terms of sand extraction from the technical point of view.

4) Procedure of application as special exception against ban of sand extraction on the lagoon.

5) Establishment of implementation system and cost burden from sand extraction to filling.

6) Surveillance of sand extraction and continuous environmental monitoring during and after extraction.

Chapter 6

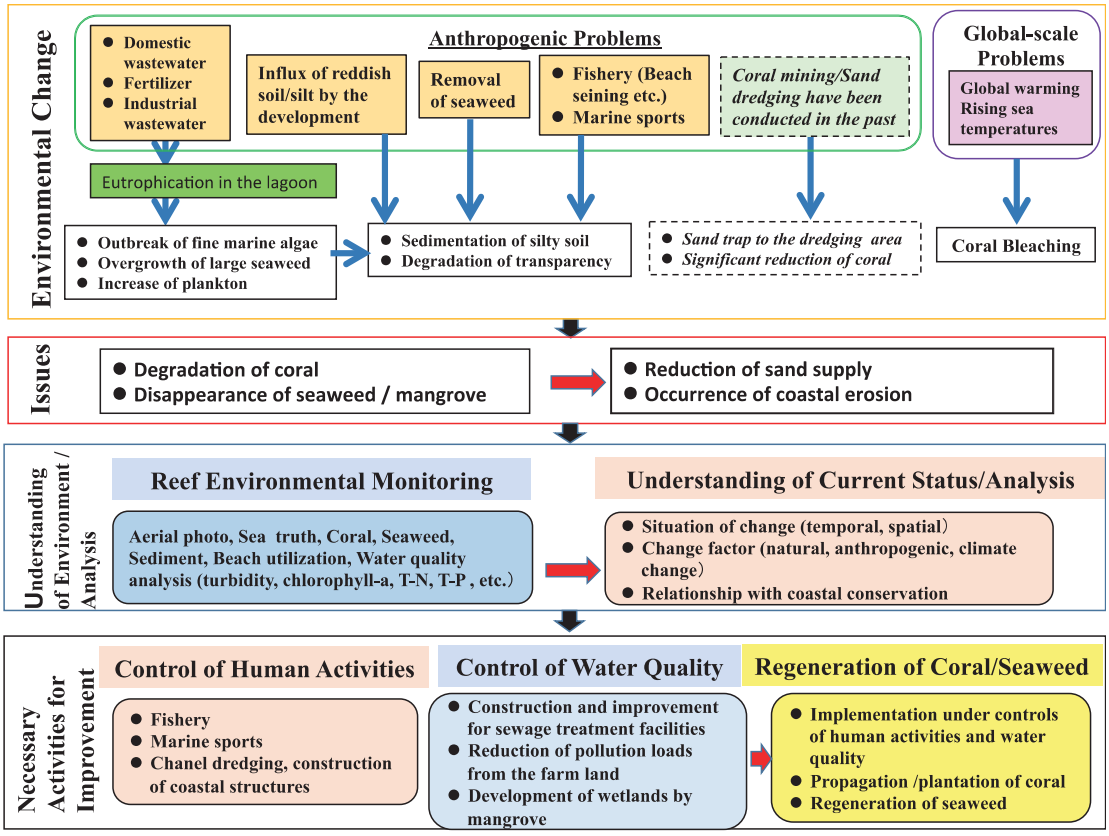
Reef Environment Conservation Plan

6 Reef Environment Conservation Plan

6.1 Background

The basic policy of Mauritius on conservation of the coastline is to consider the coral reef, lagoon and beach as one system. Following the suggestion by Baird (2003), the system must be conserved and regenerated. This survey, in alignment with this essential way of thinking, lays out plans for conservation of reef environments.

Based on the results of coastlines in this survey using the aerial photographs and satellite photographs, coral, seagrass beds and water quality of reef environments are clearly closely related to beach conservation. Namely, coral communities in a lagoon are not the only source of beach sand but also changes in wave height and course current. Consequently, coral community influences the deposition of sand and erosion of beaches. With regard to the seagrass bed, it also contributes to the reduction of waves and to the stability of fine sediment just off the beach, and its disappearance relates to beach erosion. Coral and sea grass cover are influenced by water quality. Eutrophication in the lagoon causes reduction of coral coverage.



Source: JICA Expert Team

Figure 6.1 Problems and Measures of Reef Environment on Shore Conservation

According to the results of the long-term survey on coral coverage (by Albion Fishery Research Center: AFRC), the coral coverage gradually decreased and less than 20 % in average. Consequently, it is a possibility to cause a disaster of beach by decrease in supply of beach sand and reduction of wave height in the future. These facts show that conservation of reef environments is an indispensable factor for preventing disaster of beach, so we discussed on the plan of reef conservation from the viewpoint of this idea. Main problems and its

measures on the conservation of reef environment relating to prevent a disaster of beach are shown in Figure.6.1.

The most insufficient points on reef conservation in Mauritius is that present condition is not clear and that problems have been pointed out but not based on apparent facts. So, continual monitoring survey was planed at first. By the results, we discussed on the relationships between beach erosion and reduction of coral community and seagrass bed. And, cause of the reduction was analyzed and settled on a plan to measures for the ploblems.

6.2 Present Conditions of Reef Environment

6.2.1 Coral

An average coverage of 50% in 1998 decreased gradually in all areas; fore reefs, back reefs and shore reefs. By 2010 these figures had decreased to below 25%. These values of coral coverage are evaluated as “bad or poor” in the benchmark of evaluation by the Japanese Ministry of Environment. Also, the average coverage in the basic survey of this project was 27.2% and was below the borderline of 30% as “bad or poor”. It is apparent by these facts that coral reefs in Mauritius are on the way towards long-term decline due to the many causes.

Results of the basic survey carried out from June 2012 to February 2013 and the results of visual observation by a grass-bottomed boat, the results were compared with the charts offered in 1996 for obtaining increase or decrease of seagrass beds and coral communities during these 18 years on the 13 target coasts. The area of coral communities decreased in all coasts, except for the lagoons at Pte. d’Esny and Bel Ombre. While, area of the seagrass bed increased in many coast during these 18 years. In the lagoon of Pte. aux Sables, chart of AFRC taken in 1994, a seagrass bed located at the center of the coast disappeared in 1996. While, in the lagoon of Albion, the seagrass bed at the north slightly increases but the seagrass bed in front of AFRC disappeared for these 18 years.

6.2.2 Water Quality

Based on the results of water quality survey in this study, the coasts with high chlorophyll a concentration and turbidity that are not suitable for the growth of corals (coral coverage being 10% or less) or are slightly unsuitable (coral coverage being 10 to 20%) consist of the following coasts with a high population density and/or a high concentration of hotels and villas, excluding Grand Sable and Bras d’Eau where the salt content of the water near the coast is low because of the strong influence of rivers.

1. Baie du Tombeau, 2. Mon Choisy, 3. Pointe aux Cannoniers, 12. Pointe aux Sables

It is considered that the high concentration of chlorophyll a along these coasts is largely due to the wastewater from households, villas and hotels that are not connected to the sewerage system. On the other hand, with respect to Quatre Cocos Village, Trou d’Eau Douce and Île aux Cerfs, whose hinterlands are not large population centers but include vast sugarcane farms, since the water quality of these coasts is relatively good, it is considered that the runoff of fertilizers and red soil from the sugarcane farms is unlikely to exert a direct influence on the corals of these coasts.

The coral coverage of Belle Mare/Palmar where the water quality survey was conducted is as high as 50 to 60%, but it has been reported that algae have been increasing along these coasts in recent years. The growth of algae is particularly remarkable in Palmar. According to the results of the water quality survey in this study, the chlorophyll *a* concentration in Belle Mare/Palmar is 0.48 on average and between 0.21 and 1.79μg/L. Also, judging from the correlation between coral coverage and chlorophyll *a* concentration determined in this study, the average chlorophyll *a* concentration in Belle Mare, which is 0.35μg/L, is considered to be slightly favorable for the growth of corals corresponding to a coral coverage of 20 – 50%. On the other hand, the concentration in Palmar, which is 0.72μg/L on average, is not very suitable for the growth of coral corresponding to a coral coverage of 10 – 20%. It is presumed that the coral coverage in Palmar will rapidly decline if the chlorophyll *a* concentration remains high in the future. The cause of high chlorophyll *a* concentration in Palmar must be the wastewater from the hotels and villas and fertilizer runoff from the farmland in the hinterland of the coast that permeates into the ground and flows into the lagoon.

6.2.3 Conservation of Coastal Area and Reef Environment

It becomes clear that three components, namely coral, seagrass and mangrove are biological components, but these are also deeply related to erosion and deposition of the beaches. Especially, coral is not only a resource of coral sand depositing on the beach, but also has a function to stabilize the beaches. Therefore, for analyzing the dynamics of coastline, we need not only to monitor physical process but also to pay attention to these biological components.

6.3 Issues of Reef Environment

6.3.1 Basic Materials

a. Chronological changes

In Mauritius, inventory information covering the entire country (including chronological information) has hardly been developed. Also, conventional inventory information is based on surveys at very limited points. It is necessary to regularly conduct remote (planar) survey by aerial photography from helicopter and on-site survey by sea truth to collect and organize chronological information on various inventories.

b. Water quality indicators

Consequently, in order to adequately evaluate the growth environment of corals in lagoons based on the water quality, it is necessary to add chlorophyll a and turbidity to the water quality monitoring parameters and improve the analysis accuracy for nutrient salts (NO_3, PO_4). Incidentally, transparency is a parameter that helps to determine the cloudiness in water, like turbidity, and it would be effective to measure it in addition to turbidity.

c. Causal relationship

The deterioration of corals is caused by human activities, such as eutrophication, natural phenomena, such as cyclones and floods, and climatic changes, such as bleaching. The impact of each of these causes has not yet been quantified. To quantify such impact, it is necessary to establish a comprehensive monitoring system consisting of spot monitoring of

the water quality and the corals and other ecosystems in lagoons and planar monitoring using aerial photographs and satellite images.

d. Corresponding organizations

Since the structure to promote collaboration between the organizations relating to each ministry and agency in water quality management has mostly been established, it is expected that when common parameters in water quality monitoring implemented by each organization increase, common understanding of the impact of pollutant load from the land will be promoted and the structure for collaboration will be strengthened. However, inadequate communication of information with the local residents and hotels is perceived as a challenge for the future.

e. Practice of measures

The "ICZM Sub Committee on Coral Reefs" comprises representatives from the ministry responsible for fisheries (Fisheries Division), the ministry responsible for the environment (Department of Environment), MOI (Mauritius Oceanography Institute), University of Mauritius, National Coast Guard, Beach Authority, Wastewater Management Authority, Tourism Authority, NGOs and Indian Ocean Commission (IOC). The committee holds meetings regularly. The committee has a role of exchanging information and also has a function to put measures into practice.

Coral plantations were carried out from 2011 by AFRC and MOI and were evaluated sufficiently as a pilot project. But, considering the present condition of Mauritian coral reefs, coral plantations must be promoted in the future. For carrying out these measures smoothly, MOESDDBM organizes the committee for effective measures and cooperate closely with participating organizations.

6.4 Reef Environment Conservation Plan

6.4.1 Basic Policy

As mentioned above, coral itself is not only a resource for coral sand at beaches, but also for the coral community in lagoons and it affects accretion and/or erosion of beaches. It is also suggested that seagrass beds and mangrove forests contribute greatly to stabilizing the beach. In contrast, coral in Mauritius are on a long-term trend of decline We need rapid measures for conserving and rehabilitating coral. Also, seagrass beds and mangrove forests are also facing man-made disasters.

For the measures to the problems, i.e. "decrease in supply of coral sand" and "erosion of beach", we hold up conservation and rehabilitation of both coral reefs and seagrass bed and establish the conservation plan of reef environment.

The main points of the plan:

1. Monitoring surveys for understanding the present conditions of reef environment

2. Controlling human activities for protecting coral reefs, seagrass beds and mangrove forests, in addition to protecting water quality

3. Planting coral and increasing reef generation/ seagrass beds/ mangrove forest

6.4.2 Monitoring Plan

a. Ecosystem monitoring plan

Monitoring is carried out periodically at least one year on the distribution of coral communities, seagrass beds, mangrove forests and sand in the lagoon by the aerial photos using a helicopter or drone, by satellite photos and by direct observation using a glass-bottomed boat. The data collected is analyzed by remote sensing techniques and basic information on the distribution of corals etc. is accumulated. From the accumulated data, the present conditions of the reef and chronological changes in the distribution and its size are analyzed. Then, various kinds of problems are picked up and the possible measures to be carried out are discussed. Finally, the results of these measures must be evaluated. After this the results are made public for promoting understanding for related people and for connecting to our measures. At the same time, we accumulate related information on coral, seagrass, mangrove, bottom conditions, development of coastal areas and coastal vegetation.

b. Water quality monitoring plan

The water quality monitoring in the future should basically be implemented four times a year (twice in the rainy season and twice in the dry season) and should cover all lagoons as in this study.

Table 6.1 Outline of Water Quality Monitoring for Reef Environment Conservation

Item	Method
Sampling depth	Surface: 0.5m below surface,
Water quality parameter	Field measurement: Water Temperature, Salinity, Chlorophyll-a, Turbidity, Transparency, DO, pH Laboratory: NH_4-N, NO_2-N, NO_3-N, T-N, PO_4-P,T-N, COD, Chlorophyll-a
Location	Near the coast, on the patch reef and around the reef edge (same as the coral monitoring sites)
Frequency	Four times a year (rainy season: 2 times, Dry season: 2 times)

Source: JICA Expert Team

6.4.3 Human activity regulation plan

a. Regulations of human activity on the coral reef

Fishing activities and nautical activities are prevalent in the lagoon, and the Ministry of Fisheries and the Ministry of Tourism/Tourism Authority control these activities respectively. The effect of these controls is monitored, and the controls are evaluated and improved by the results of the monitoring survey.

b. Water quality regulations and their improvement

Table 6.2 shows these guideline values as well as the results of the water quality survey in this study. Comparison of the values in this table shows that the guideline values obtained in this study are mostly the same as the other values that have been reported. The draft guideline

values for the protection of coral reefs determined in this study need to be scrutinized in the future after implementing water quality monitoring at a higher accuracy. It would also be necessary to clearly distinguish the waters in which the corals should be protected from the waters of which other usages should be promoted as a priority.

Table 6.2 Reported Water Quality Guidelines (draft) for Coral Reef Conservation

Water Quality Parameters	**Unit**	**Location of Coral Reefs**				
		Mauritius		**Okinawa**	**Caribbean**	**Great Barrier**
		Existing guideline	**This study***	(1)*	(2)#	(3)@
Chlorophyll-a	ug/L		**<0.2**	-	<0.1-0.5	<0.45
Turbidity	NTU		**<0.5**	<0.11	-	-
Transpirancy	m		**-**	>14	-	>10
T-N (mg/L)	mg/L		**-**	<0.08	-	-
T-P (mg/L)	mg/L		**-**	<0.01	-	-
NO_3-N+NO_2-N+NH_4-N	mg/L	<0.2	**<0.012**	<0.01	<0.014	-
PO_4-P	mg/L	<0.04	**<0.007**	<0.006	<0.006-0.009	-

*: This guideline was defined as the water quality value required to maintain 50% of coral coverage.
#: This guideline was defined as the water quality value (the threshold of eutrophication) that the conflict between corals and algae starts.
@: This guideline was defined as the water quality value (the biotic trigger values) that the coral richness (the number of coral species) starts to drop sharply.
Source: (1): Kinjyo et ai. (2011), (2): Mutti and Hallock(2003), (3) Glenn De'ath and Katharina Fabricius (2008)

6.4.4 Water quality improvement plan

a. Countermeasures against eutrophication

Because it takes a very long time to implement the countermeasures to reduce the nitrogen and phosphorus runoff from land such as the sewerage development projects, rapid improvement such as in a ten-year period cannot be expected. Therefore, the water quality improvement plan is divided into immediate efforts represented by the short-term countermeasures and the medium- and long-term countermeasures. Regarding the short-term countermeasures, adding water quality monitoring parameters such as chlorophyll *a*, turbidity, T-N and T-P and strengthening the water quality monitoring by using a highly accurate analysis technique will be conducted. Based on these, the specific area and the cause for deterioration of the water quality will be identified. Meanwhile, for medium- and long-term countermeasures, sewerage development mainly from the reduction of pollution loads from the households will be promoted.

b. Countermeasures against inflow of red soils

The actual conditions of red soil inflow in Mauritius are not clear. Firstly, it is necessary to conduct the monitoring for turbidity and accumulation conditions of red soil in the lagoon in order to identify the specific area that the red soil has become a problem.

Because it takes a very long time to improve the problem of red soil inflow with measures against it taken on land, rapid improvement (improvement in a ten-year period) of the

problem cannot be expected from the implementation of such measures. Meanwhile, it is favorable to advise against the current practice of regular removal of seaweed from the sea in front of hotels because the seaweed beds contribute to stabilization of particulates.

6.4.5 Plantation plan of corals, seagrass and mangrove

a. Plantation of corals

On the plantation method, we adopt the simple method, which a fragment of living coral (donor) is directly planted on the reef using underwater glue. Subordinately, juvenile coral plantation method using asexual reproduction adopted by Japanese Ministry of Environment (see Vol. III) will be tried after a pilot procedure.

For promoting coral restoration of corals affected by the raise of seawater temperature, we promote the coral plantations carried out in Mauritius till now in large-scale. Taking account good water quality and protected area into consideration, coral plantation will be carried out in the lagoon of Le Morne. Water quality is adequate for coral plantation and there is the protected area in the lagoon after appointing the world cultural heritage. Then, coral plantation is planned also in the lagoon of Flic en Flac.

b. Plantation of seagrass

Seagrass is a seed plant. Up to the present, six species are known in Mauritius. There are generally two methods, namely using asexual reproduction and using seeds. In any case, we recommend starting basic experiments for regeneration.

6.5 Systematic correspondence

The “ICZM “Sub Committee on Coral Reefs” comprises representatives of the Ministry responsible for Fisheries MOI (Mauritius Oceanographic Institute), Univ. of Mauritius, Coast Guard, Beach Authority, Water Management Authority, Tourism Authority, NGO and the Indian Ocean Commission (IOC). The committee holds meetings regularly. The committee has a role of exchanging information and also has a function to put measures into practice. We suggest that this subcommittee also should have roles for analysis and discussion on the periodical monitoring data. Additionally, the committee has decision making responsibilities on measures for urgent problems after analyzing like a “Scientific Committee”. We also suggest that the ICZM take the initiative in assuming each share of the responsibility among related organizations and carry out specific measures.

6.6 Summary

By the chronological analysis of aerial and satellite photographs of Mauritius, it was suggested that the existence of coral communities, seagrass beds and mangrove forests in lagoons are deeply related with erosion and accretion of the beach. The decline of coral reefs in Mauritius proceeded after 2000 and the general evaluation on coral reefs fell from “good” to “poor”. The causes of decline seem to be eutrophication in lagoons, inflow of terrestrial sediment into lagoons, fishing activities, marine sports and human impacts. Also, biological factors such as the Crown-of-Thorns Starfish and the coral bleaching phenomena related to global warming are also listed.

To respond to these problems, present conditions will be grasped and analysed by the periodical monitoring surveys on reef environment using aerial and satellite photographs, sea truth and water quality analysis in this conservation plan for reef environment. We suggested an action plan on regeneration of coral reefs, seagrass beds and mangrove forests to bring stable conditions to the beach through specific measures such as water quality control in lagoons, regulations to control nautical activities (sailing and motorized boats) specifically in seagrass bed areas and coral communities and plantation of coral, seagrass and mangroves.

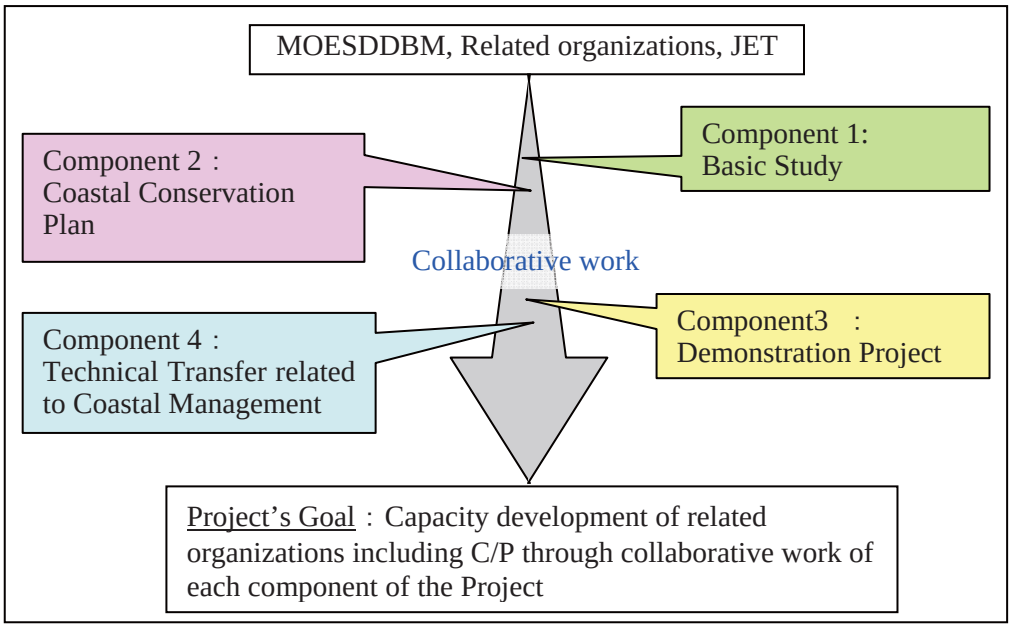
Chapter 7

Capacity Development, Information, Education and Communication (IEC) Plan and Coastal Management System

7 Capacity Development, Information, Education and Communication (IEC) Plan and Coastal Management System

7.1 Capacity Development Plan

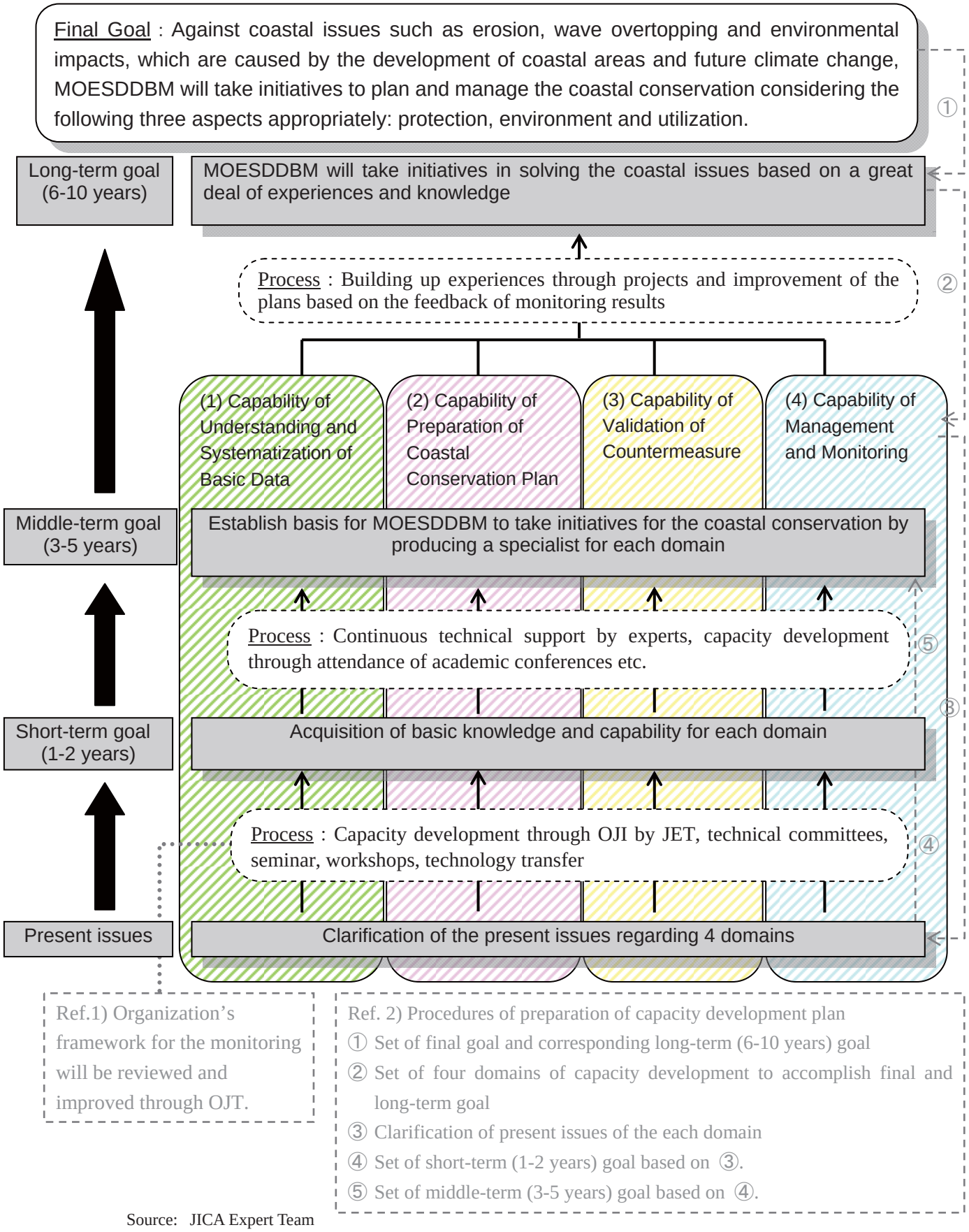
Project's goal is the capacity development of relevant agencies including C/P through collaborative work of each component of the Project. Figure 7.1 shows conceptual diagram of the Project.



Source: JICA Expert Team

Figure 7.1 Conceptual Diagram of the Project

In general, a successful capacity development needs a long period of time because it incorporates the following procedures: 1) acquisition of basic knowledge, 2) implementation of projects applying the knowledge, 3) capacity development through accumulation of those experiences. Considering these characteristic, the capacity development plan is prepared by the following procedures and the overview of the plan is shown in Figure 7.2. The role of the Project is to accomplish the short-term goal of capacity development, which mainly focuses on acquisition of basic knowledge and capacities.



Source: JICA Expert Team

Figure 7.2 Overview of Capacity Development Plan

7.2 Information, Education and Communication (IEC)

IEC activity plan in this study is presented in Table 7.1. It is proposed that MOESDDBM and relative stakeholders shall implement these IEC activities with referring to the practice examples conducted in the Project.

Table 7.1 IEC Activity Plan

	Information	Education	Communication	Public Relations
IEC definition in this study	・ General information about coastal protection and disaster to be provided ・ Considered the first stage of IEC activities	・ A process of learning through which a person gains knowledge and understanding of coastal disaster and protection ・ Interactive survey is applied to aggregate information from person's experience ・ Considered the second stage of IEC activities	・ Consensus building for the proposed coastal conservation plan ・ To gain Consensus building through Communication ・ Considered the third stage of IEC activities	・ To spread the project effect by public relations of the consensus building process as well as the output to organizations and related countries ・ Considered the fourth stage of IEC activities
Target	・ Residents who live around areas with erosion and/or wave overtopping problems ・ 10 coastal areas in Mauritius		・ Residents(same as left column) ・ Two coastal areas: One for Physical measures area and one for Non-Physical measures area in the Demonstration Project	・ Citizens of Mauritius ・ Organizations such as UNDP, IOC
Method of activities	・ Interactive survey for the residents / beach users including tourists		・ Stakeholder meeting at each district	・ Public relations by TV, radio, newspaper outlets and so on.
Details	Ch. 2.7 Public Awareness		Ch.8.3.5 Consensus Building	Ch. 8.3.9 Participatory coastal management and IEC
Implementation body	MOESDDBM、JET To implement effective technical transfer, MOESDDBM mainly conduct activities with instruction by JET.			MOESDDBM, JET and related organizations

Source: JICA Expert Team

7.3 Proposed Coastal Management System, Organization Framework and Legislation

Based on the capacity development through the Project, coastal management and organization framework is proposed as follows. Among those, the "Implementation system for participatory coastal management"(No. 5) is presented as an example in this summary.

<Proposed coastal management and organization framework>

1) Management system of coastal environment database

2) Implementation system of beach profile monitoring

3) Implementation system of wave and current monitoring

4) Implementation system for reef environment conservation

5) Implementation system for participatory coastal management

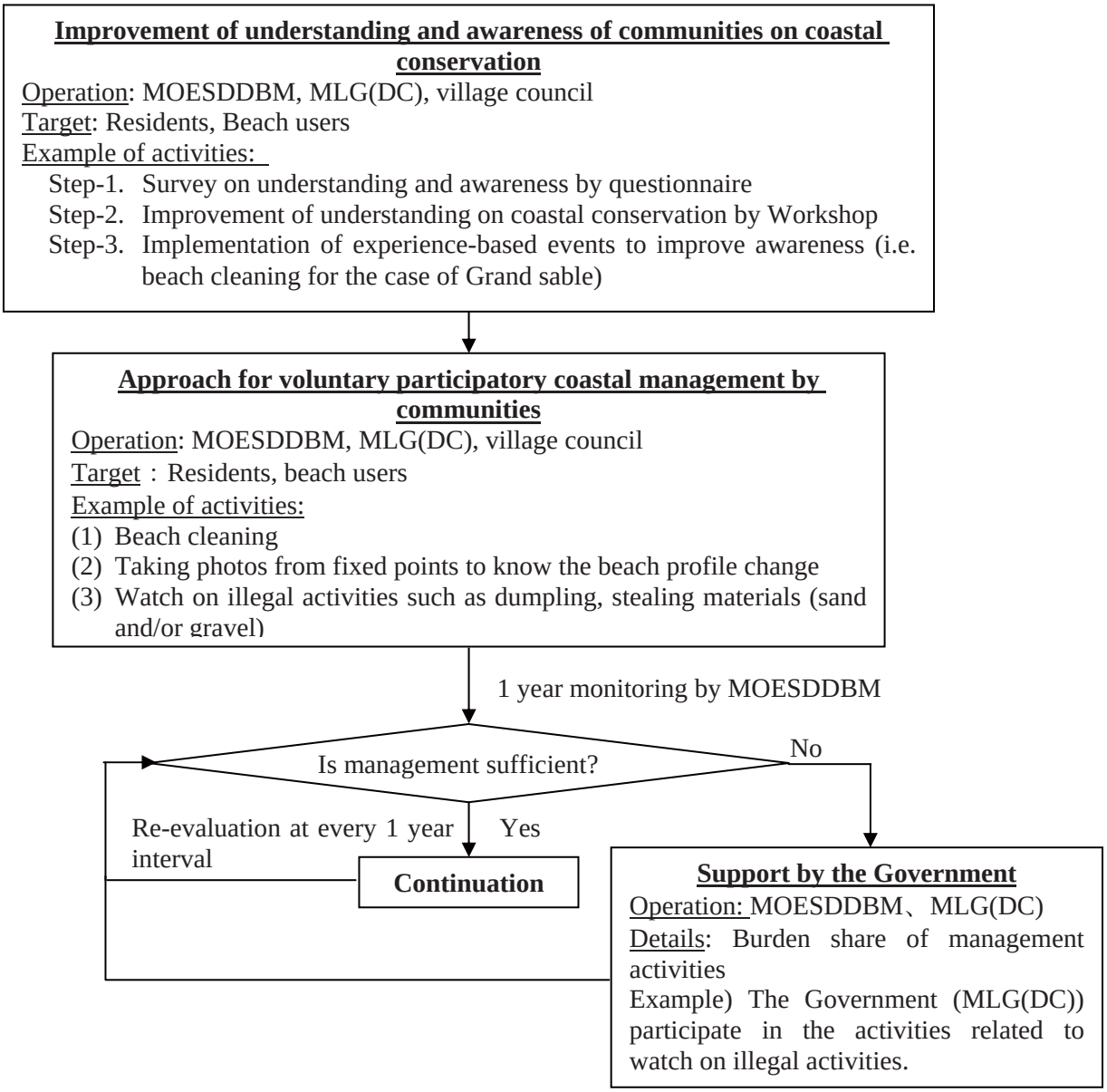
6) Coastal management system with beach reprofiling

7) Improvement on legislation of the contract and usage of leased coastal area

8) Management system of sand reuse.

7.3.1 Implementation System for Participatory Coastal Management

Coastal areas in Mauritius are classified as Public Beaches, Leased Areas, Vested Areas and Uncommitted Areas (see details in Chapter.2). Among these, public beaches are managed by the beach authority, However, the leased area is managed only by its private owner and no specific management body exists for uncommitted areas. In reality, with limited manpower it is difficult for the government to manage those additional coastal areas. Thus, it is strongly recommended to make communities get involved in the coastal management issues and raise their awareness to the fact that the coastal environment belongs to them (sense of ownership). So they need to maintain the coast in a clean state for their own benefit. In this Project, participatory coastal management by communities had been implemented in Grand Sable, which is an uncommitted area. It is important to apply these approaches of participatory coastal management to other coastal areas.



Source: JICA Expert Team

Figure 7.3 Proposed Implementation System of Participatory Coastal Management

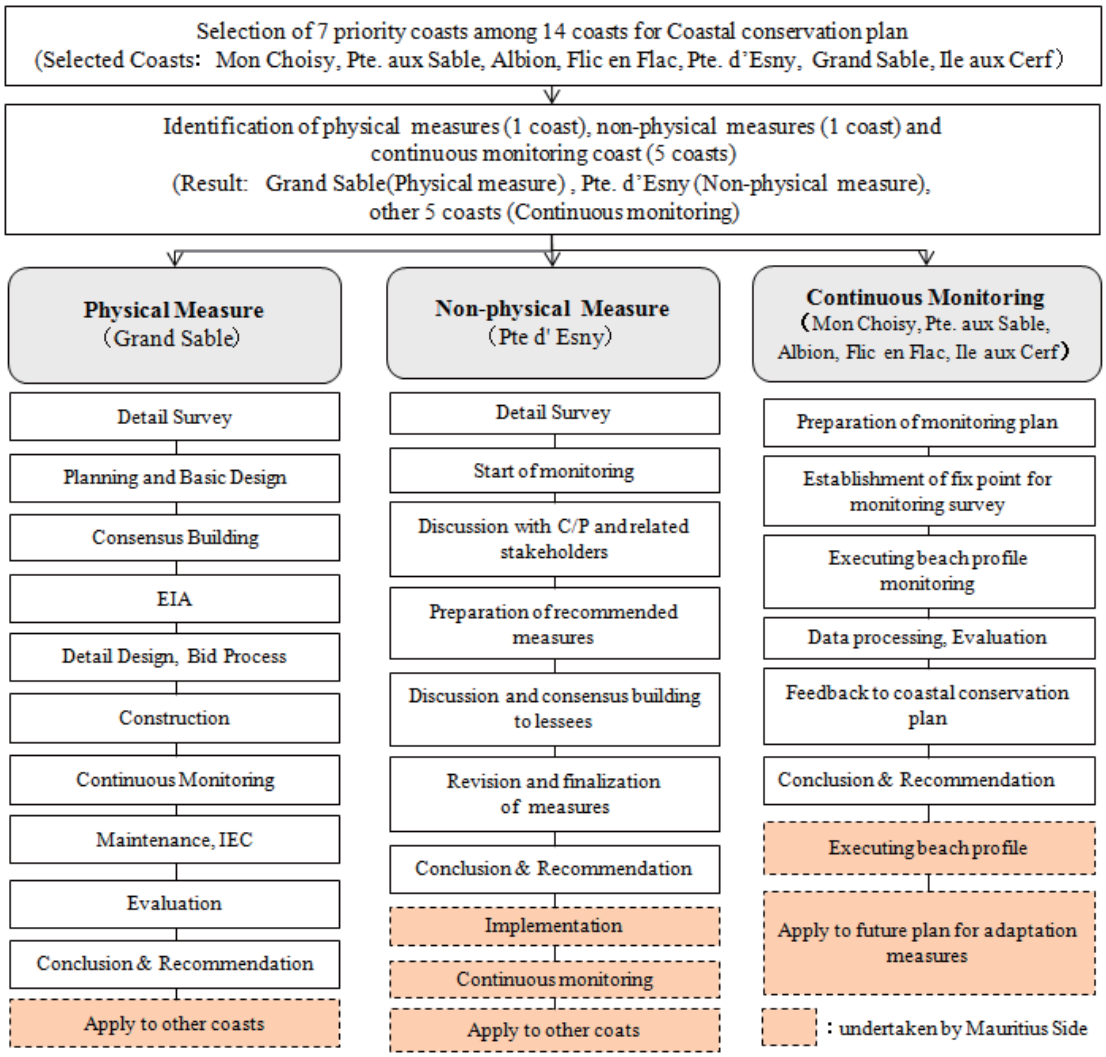
Chapter 8

Implementation of Demonstration Project

8 Implementation of Demonstration Project

8.1 Outline

Figure 8.1 shows the outline for implementation of the demonstration project.



Source: JICA Study Team

Figure 8.1 Study Flow for Implementation of the Demonstration Project

8.2 Technical Transfer and Capacity Development Through Demonstration Project

The purpose of the demonstration project was to conduct technical transfer and capacity development for the C/P and related stakeholders to enhance coastal conservation planning and management skills. Temporary events such as seminars, workshops, etc. are not sufficient on their own for technical transfer and capacity development. The most effective approach for technical transfer and capacity development is continuous on-the-job training through the implementation of each activity for the demonstration project.

8.3 Physical Measure

8.3.1 Site Selection

The wave overtopping and flooding due to high wave attack at the low elevation hinter area is one of main coastal issues in Mauritius. Grand Sable is facing such coastal problem in the selected seven coasts. Thus, the coastal protection measure at Grand Sable was selected as the proposed physical measures.

8.3.2 Proposed Measures

The flexible revetment (gravel beach) was selected as appropriate coastal protection measures against high wave and wave over-topping on the projected site.

8.3.3 Design Condition

The design condition which was obtained both field survey results and numerical modeling are shown in Table 8.1.

Table 8.1 Design Condition

Profile	Design Condition	Remarks
Tide level with return period of 30 years (a)	MSL+0.67m (CD+1.04m)	From extreme statistics analysis using tidal data for 30 years (refer to chapter 2, 2.2.3)
Wave set-up (b)	0.55m	From calculation result for design wave height with return period of 30 years
Predicted Sea level rise (c)	0.12m	0.39mm/year×30years
Design tide level	MSL+1.34m (CD+1.71m)	= (a) + (b) + (c)
Design wave height $(H_{1/3})_{30yrs}$	0.4m	Wave height with return period of 30 years
Design wave period$(T_{1/3})_{30yrs}$	8.0 s	
Topography		Survey results on August 2013

Source: JICA Expert Team

8.3.4 Proposed Layout and Section Drawing

The proposed layout and section drawing are shown in Figure 8.3.Figure 8.2 and Table 8.2 shows the representative dimension and material specification.

Table 8.2 Representative Dimension and Material Specification

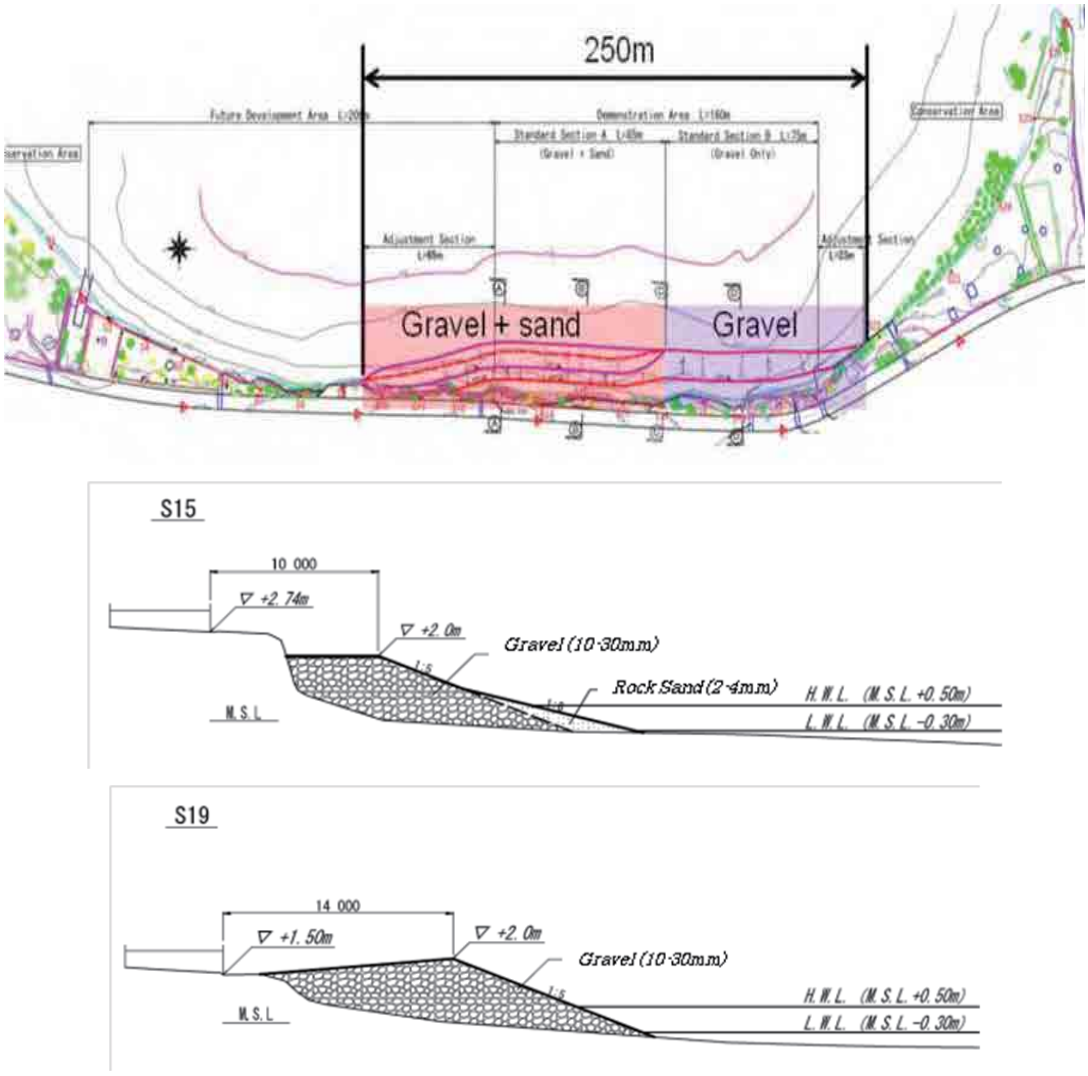
Items	Description
Backshore width	more than 10m from road edge
Backshore height	MSL+2.0m
Initial foreshore slope	1:5 for gravel, 1:8 for sand
Employed Material	Crusher Run and Crusher Sand produced at quarry plant
Grain Size	10～30mm for gravel, 2～4mm for sand

Source: JICA Expert Team

Gravel (10～30mm) Sand (2～4mm)

Source: JICA Expert Team

Figure 8.2 Gravel and Rocksand for the Construction



Source: JICA Expert Team

Figure 8.3 Proposed Layout and Section Drawing

8.3.5 Before and After Construction

The condition of beach before and after the project is as follows.

Source: JICA Expert Team

Figure 8.4 Before and After the Project (before: Sep. 2013, After: Dec. 2013)

8.3.6 Monitoring Result after the Project

Continuous monitoring has been carried out after the Project in order to examine the validity and applicability of flexible revetment in Mauritius. The beach profile survey, wave observation, taking photos form fix points, checking of water quality, beach use condition and sampling of filled material were carried out in every three months by MOESDDBM and JET. The following conclusion was obtained based on the monitoring result.

- The beach profile formed by gravel and sand is quite stable even though two cyclones approached to Mauritius in January and February 2014.
- Desirable enhancement on beach use and coastal environment was observed, such as active use of beach by residents, improvement of water quality, natural grow-up of vegetation, etc.
- Self-control of the beach by the community and residents could be achieved through the Project, such as self-beach cleaning.

Record period	S15 (left side face to sea)	S15 (right side face to sea)
Before project		
1st Monitoring (Dec. 2013, after implmen-tation)		
6th Monitoring (Dec.2014)		

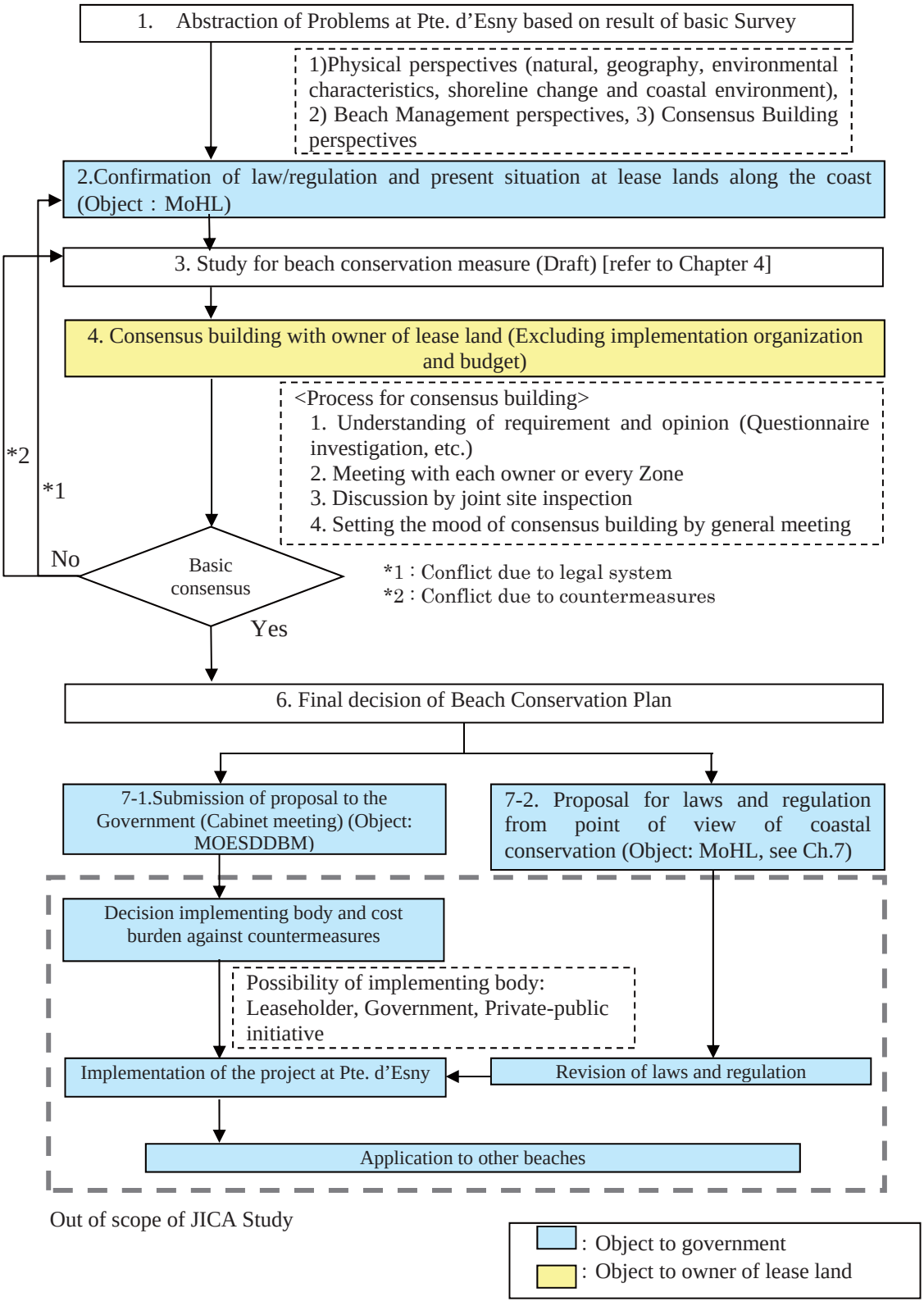
Source: JICA Expert Team

Figure 8.5 Change in Foreshore Condition in the Typical Cross Section (Line No. S15)

8.4 Non-Physical Measure

8.4.1 Procedure

Procedure for Non-Physical measure at Pte. d'Esny is as follows.



Source: JICA Expert Team

Figure 8.6 Process of Study for Non-Physical Demonstration Project at Pte. d'Esny

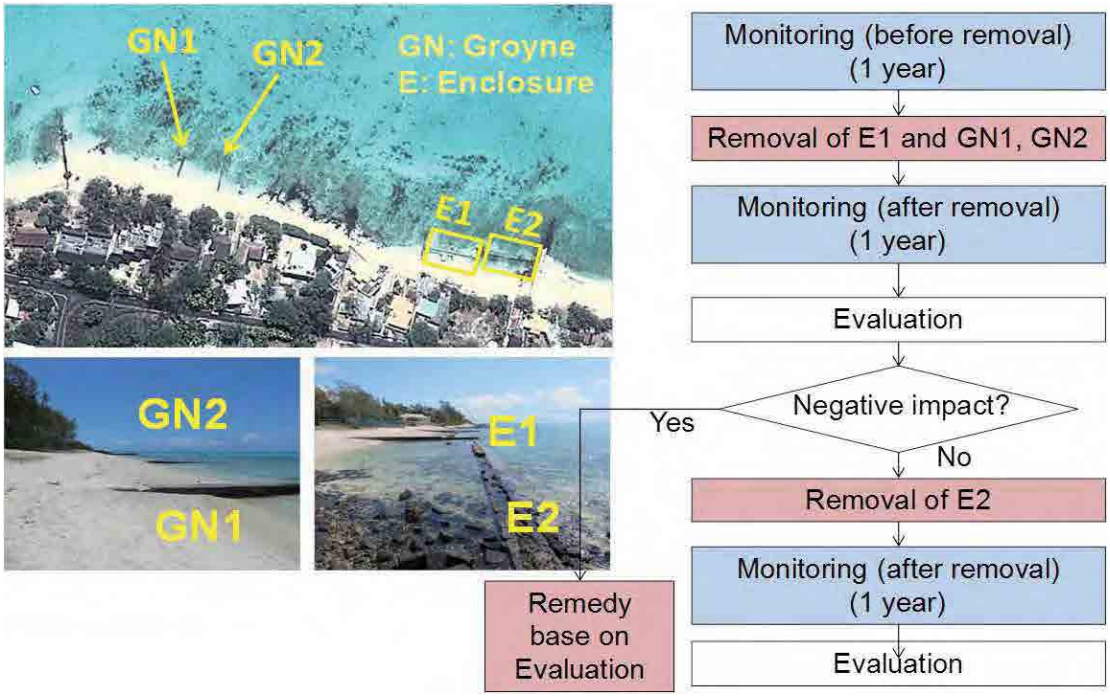
8.4.2 Coastal Conservation Plan Reflecting to Residents' Opinion

Coastal area of Pte. d'Esny was divided into three zones based on existing large size jetty (the place where discontinuity of long shore drift) and coastal conservation plan was finalized reflecting to residents' opinion.

Source:JICA Study Team base on Google Map

Figure 8.7 Zoning of coastal area in the planning

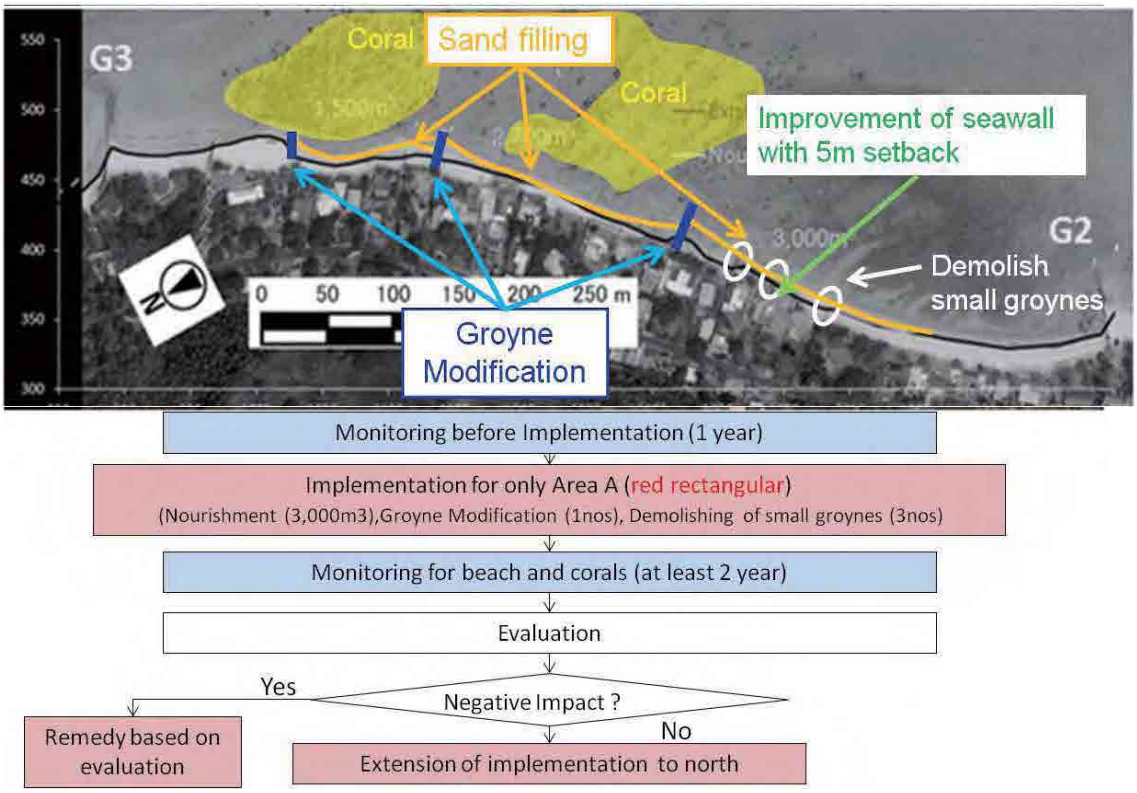
a. Zone 1



Source: Aerial photo) JICA study team base on Google Map, Others) JICA study team

Figure 8.8 Finalized Coastal Conservation Plan at Zone 1

b. Zone 2



Source: JICA Study Team

Figure 8.9 Finalized Coastal Conservation Plan at Zone 2

c. Zone 3

Source: JICA Expert Team

Figure 8.10 Finalized Coastal Conservation Plan at Zone 3

8.5 Implementation of Continuous Monitoring

Seven coasts of continuous monitoring including 2 demonstration project sites (Grand Sable and Pte. d'Esny) were selected as shown in Table 8.3. Thus, the item and purpose of continuous monitoring at six coasts except Grand Sable are shown in Table 8.3.

Table 8.3 Item and Purpose for Continuous Monitoring

No.	Coast	Category	Monitoring Item	Purpose of Monitoring
1	Mon Choisy	Continuous Monitoring	Beach Monitoring Reef Environment Monitoring (carried out by MoF, MOI)	- To obtain the base data to make a beach conservation plan and continuous beach maintenance plan at southern public beach - To obtain the base data for water quality and corals to make middle and long term beach and reef conservation and management plan
2	Pte. aux Sable	Continuous Monitoring	Beach Monitoring Reef Environment Monitoring (carried out by MoF, MOI)	- To obtain the base data to examine the influence of new revetment at public beach to surrounding area, and to make maintenance plan. - To obtain the base data for water quality and corals to make middle and long term beach and reef conservation and management plan
3	Albion	Continuous Monitoring	Beach Monitoring Reef Environment Monitoring (carried out by MoF, MOI)	- To examine the condition of seasonal beach change and forming of beach scarp especially in front of AFRC - To monitor the influence to the change in beach and reef environment change of coral reef due to flushing of fresh water at southern area.
4	Flic en Flac	Continuous Monitoring	Beach Monitoring	- To obtain the base data to make a beach conservation plan and continuous beach maintenance plan at the public beach located at central area. including sand recycle from northern acculturated area
5	Pte. d'Esny	Non-physical Measure	Beach Monitoring Wave-current observation Reef Environment Monitoring (carried out by MoF, MOI)	-To obtain the data (evidence) to be utilized for the socialization with lessees to discuss the suitable beach conservation measures which will be carried out by lessees.
6	Ile aux Cerf	Continuous Monitoring	Beach Monitoring	- To monitor the change of open channel part due to sedimentation, and beach change at surrounding area to make a suitable maintenance plan to maintain good beach condition as highest tourism area in Mauritius.

Source: JICA Expert Team

8.6 Outcome of Demonstration Projects

In this Project, three kinds of Demonstration Projects were implemented; 1) Physical measure at Grand Sable, 2) Non-physical measure at Pte. d'Esny, and 3) Continuous Monitoring at 7 beaches including Grand Sable and Pte. d'Esny. In continuous monitoring, beach profile monitoring was conducted at 7 beaches and wave and current measurement were conducted at Grand Sable and Pte. d'Esny.

Since one of the main objectives of the Project is the capacity development, process to acquire outcome was considered to be important as well as the outcome itself. The outcome and future subject are summarized for each Demonstration Project as follows.

8.6.1 Physical Measure at Grand Sable

a. Outcome in the implementation process

- Demonstration Project as Physical Measure was implemented at Grand Sable to protect hinterland against wave overtopping and high waves. Process required for the implementation (i.e. survey, planning, design, consensus building, preparation of tender documents, EIA, construction management, monitoring after implementation) was conducted together with relative stakeholders and knowledge, understanding and experiences had been improved and accumulated through this process.
- Stakeholders understood how to determine dimensions of gravel beach profile (i.e. backshore height, backshore width, beach slope and gravel size)
- Resident's awareness and willingness to participation on coastal management were improved through IEC activities, several meetings with residents and beach cleaning event.
- Participatory coastal management by residents has been developed and they have already started to conduct beach cleaning at regular intervals.
- MOESDDBM showed positive attitude to participate in the coastal management cooperating with residents and the beach is going to be declared as Public beach.

b. The outcome

- Effectiveness of gravel beach against wave overtopping and high wave is confirmed based on the monitoring results. In addition, effectiveness of the measure in terms of environment and beach use is presented based on the questionnaire results by residents.
- The applicability of gravel beach is presented as a desirable coastal conservation measure that MOESDDBM would apply for future projects.

c. Future subject

- Beach of the Project area is now in good condition due to periodic beach cleaning by residents. Since there is a lot of garbage drifted from sea, it might be difficult to clean them up by only residents. Thus, Government's support and participation in periodic beach cleaning is highly desired.
- There are still some cases that the monitoring data had been updated without confirming its accuracy. Important issues to be checked for monitoring are going to be clearly described in the monitoring guideline prepared in this Project. It is recommended for C/P to use this guideline for monitoring to obtain proper data.

8.6.2 Non-physical Measure at Pte. d'Esny

a. Outcome in the implementation process

- Demonstration Project as non-physical measure was implemented at Pte. d'Esny to prepare coastal conservation plan against beach erosion and interruption of sediment transport by artificial structures at the leased coastal area. The process required for implementation (i.e. survey, planning, conceptual design, and consensus building with residents) was conducted together with relative stakeholders. Their knowledge, understanding and experience had been improved and accumulated through this process.
- Through participation in the process, MOESDDBM accumulated know-how and experiences on building consensus with stakeholders to prepare coastal conservation plan.
- Through several meetings, residents have learned characteristic of sediment transport and the importance of integrated coastal management for beach conservation. In addition, they have learned the adverse effect by groynes at sandy beach.
- In the process of the planning, difference between the Act and actual condition for coastal land use and the lease contract had been realized especially by MHL. Residents' understanding on the regulation of lease contract and land use was also improved through the process.
- Effectiveness of coastal conservation plan was improved by reflecting their local knowledge and opinions from discussion with residents.

b. The outcome

- Coastal conservation plan is finalized by reflecting resident's opinion.
- In the coastal conservation plan, residents agreed on beach nourishment and improvement of existing groynes with monitoring.
- Issues required for proper coastal management were clarified and ideas for improvement on the system of coastal management are proposed including lease contract and land use (see Ch.7.3 for details).

c. Future subject

- In the coastal conservation plan, the removal of exiting groynes has not yet obtained consensus from residents. Residents did understand the importance of continuity of coast through several meetings, however, they assign highest priority to protect their own land and properties. Further detailed discussion on the plan would be needed to obtain consensus, and in some cases, it might need to reach a compromise agreement on it.

8.6.3 Continuous Monitoring at 7 Beaches

a. Outcome in the implementation process

- Relevant stakeholders understood points to be checked for the beach profile monitoring including beach slope, location of H.W.M. and L.W.M., grain size, and vegetation area.
- Relevant stakeholders have learned procedures of beach profile monitoring and the survey method using the auto-level, tape measure, GPS, staffs, and survey poles.
- Relevant stakeholders understood survey items of wave and current measurements and the procedures of the analysis including primary data processing.

- Relevant stakeholders have learned the measurement sequence of wave and current meters, setup of data acquisition, installation and removal of instruments, and data acquisition.

b. The outcome

- For beach profile monitoring, implementation system was organized as joint team of MOESDDBM and LEU. They have learned how to conduct the profile survey and to organize and evaluate those results.
- For WAVEHUNTER and current meters, MOESDDBM, MMS and MOI have learned how to conduct the measurement and to organize and evaluate those results.
- The effectiveness of coastal conservation plan was improved applying those data obtained from beach profile and wave and current conditions.

c. Future subject

- There is some room for improvement on validation capacity on obtained data (i.e. capacity to tell human errors on obtained data). It is important to accumulate experience on monitoring to reduce these errors through practice, using the monitoring guideline prepared in the Project.

Chapter 9

Technical Transfer

9. Technical Transfer

9.1 General

9.1.1 Purpose and Policy

Technology transfer has been carried out to build the capacity for the development of coastal conservation plan and to disseminate necessary engineering knowledge in practice for coastal protection measures, mainly by on–the-job training (OJT) in the course of field investigation, monitoring, data analysis, problem analysis, formulation of plan and conducting demonstration project. The technical transfer also involved development of guidelines, holding of a workshop and seminars in Mauritius, and training in Japan and technical exchange. The technical level corresponded to those in Mauritius.

9.1.2 Items of Technical Transfer

Specific items, purpose and input for the technical transfer are shown in Table 9.1.

Table 9.1 Items, Purpose and Input for Technical Transfer

Item	Purpose	Input
1. Formulation of technical guidelines	The necessary technical guidelines for the implementation of coastal protection projects are formulated to maintain a suitable technical level.	・Survey on technical items and levels for the coastal protection in Mauritius. ・Acquirement of the method for utilization of the guidelines by OJT
2. Formulation of monitoring guidelines	The guidelines to monitor the changes in beach form and the coral reef environments are formulated. The guidelines are utilized to manage the coastal protection.	・Formulation of the guideline to monitor changes in natural and artificial (nourished) beach form ・Formulation of the guideline to monitor the condition on the health and rehabilitation of coral reefs ・Monitoring using the guideline by OJT
3. Formulation of EIA (Technical Guideline for Environment Impact Assessment) guideline	The guideline is formulated to implement the suitable development with consideration to mitigate coastal erosion because the developments in coastal areas have the potential to cause issues such as coastal erosion.	・Review of existing EIA reports and environmental impacts by coastal projects ・Selection of necessary evaluation items and formulation of the guideline ・Training by ex-post assessment of EIA
4. Workshop and seminars in Mauritius, training in Japan, and technology exchange	Promoting the capacity building for each participant as well as raising the awareness of the importance of coastal conservation by conveying the outcomes of the Project to the government officials, municipal organizations, local companies, residents, and NGOs.	・Holding of a workshop ・Holding of seminars ・Implementation of training in Japan ・Implementation of technology exchange with Seychelles

Source: JICA Expert Team

9.1.3 Method of Technical Transfer

a. Confirm of Technical Capacity

Regarding the technical transfer, capacity assessments were conducted for three aspects (C/P, C/P organization, and society) at the stage of the beginning, middle, and end of the Project.

The capacity assessments helped the Project to achieve its goals. The results are summarized in Table 9.2.

Table 9.2 Necessary Capacity and its Evaluation

Necessary Capacity	Beginning of the Project	End of the Project
Understanding and Systematization of Basic Data		
Accumulate and apply the data such as beach profile, waves, water quality, coral reef and others	MMS, MOI (waves) and AFRC (coral and water quality) have the capacity. MOESDDBM and others had no experiences.	MOESDDBM and related organizations understood the observation methods and accumulated the basic data.
Preparation of Coastal Conservation Plan		
Prepare coastal conservation plan with procedures of identification of the area, finding issues, proposing alternatives and evaluation	In the past plans were prepared by consultants. Each organization had no experiences.	MOESDDBM and related organizations understood the planning process and the importance of the consideration for beach use and environment.
Validation of Countermeasure		
Evaluate the validity of the project with concerning environment and achieve the consensus of the stakeholders	The evaluation of the results of consultants was not sufficient and caused problems.	MOESDDBM understood the design method of structures, EIA and consensus building for the conservation plan.
Management and Monitoring		
Manage beaches and illegal activities based on the monitoring results and improve public awareness	The capacity is not sufficient without monitoring.	MOESDDBM and related organizations understood the monitoring method and started to solve the illegal activities and monitoring.

Source: JICA Expert Team

b. Proposed Technical Transfer Stages

The technical transfer in the Project was conducted under a four-stage capacity development methodology (Table 9.3). The capacity development was performed going through these four stages for each countermeasure activity, and this four-stage capacity development process was repeated numerous times for various countermeasures during the Project period. This repetition helped to improve the C/P's ability effectively.

Table 9.3 Stages of Capacity Development

Development Stage
① Acquirement of knowledge for basic management of coastal protection area
② Acquirement of planning and management technology for coastal management
③ Training of planning and works management through the demonstration project
④ Independently implementing, planning and managing surveys

Source: JICA Expert Team

9.2 Development of Guidelines

As the final stage of this project, the guidelines listed below were developed in collaboration with the stakeholders. Each guideline is intended to be useful so that the administrator for coastal zone can fully utilize them for the coastal management. The guidelines are explained separately to this main report, namely in Volume 3, to enable the counterparts to easily use them in their daily work. Please refer to Volume 3 for more details.

1. Technical Guideline for Coastal Protection and Issues

2. Technical Guideline for Beach Monitoring

3. Technical Guideline for Reef Environment Monitoring

4. Technical Guideline for Environment Impact Assessment (EIA)

For worldwide known guidelines related to coastal protection, there are several guidelines such as CEM (2006), Rock Manual (2007) and BMM (CIRIA, ASCE). However, these guidelines are developed for the administrative officers of coastal management and for the consultants who will be engaged with coastal design and planning.

The objective of the development of the guidelines in this project is to establish useful contents for the coastal management works conducted by coastal managers (MOESDDBM). Therefore, it is critical to have the contents of evaluation methodology for feasibility of the plan and selection of construction method for adequate coastal protection considering protection, use and the environment of the coastal zone.

9.3 Conclusions

Technology transfer has been carried out to build the capacity for the coastal conservation and to learn the necessary engineering knowledge in practice, mainly by the OJT in the course of field investigation, monitoring, data analysis, problem analysis, formulation of plan and conducting demonstration project. The guidelines are also planned together with the workshop, seminar, training in Japan and technical exchange. The technical level should correspond to those in Mauritius.

9.3.1 Technology of Planning and Management for Coastal Conservation

The technologies of planning and management for coastal conservation were mainly transferred to the MOESDDBM, related government organizations and academic institutions through Technical Committee. In Mauritius those technologies were limited and not applied to coastal erosion measures before the Project.

Technical Committee was held 14 times from the beginning of the Project on July 2012 to March 2015 and supported the technology transfer and the capacity development of stakeholders in the course of discussions on the coastal conditions, their problems, coastal conservation plans and the implementation and evaluation of the demonstration projects as the progress of the Project.

In Mauritius there was no experience for the formulation of coastal conservation plan for individual coasts. Then for the plan of priority coasts, working session was held three times to each coast and the contents were discussed. Also the plan was checked at the site. The planning technology has been transferred to stakeholders for the understanding of site specific issues and the selection of measures with their capacity development.

Before the Project, the coastal management was not considered fully the coastal erosion problems. It is believed that each organization obtained the knowledge and method for the management of coastal disasters such as the integrate coastal zone management by MOESDDBM, the setback management by MHL, the management of public beach by BA, and the reef conservation by MoOEMRFSO (Ministry of Ocean Economy, Marine Resources, Fisheries, Shipping and Outer Island).

9.3.2 Basic Technology

Basic technologies for coastal conservation are the beach monitoring, understanding of shoreline changes, coral reef and water quality monitoring, wave observation, application of coastal environment data base, sand nourishment and reprofiling, and the designing and planning of coastal facilities. Among these the beach monitoring, understanding of shoreline changes, sand nourishment and reprofiling, and the designing and planning of coastal facilities were not carried out in the past and have been newly introduced in Mauritius. The coral reefs and water quality monitoring have been carried out in Mauritius already, however the spot-check method of coral which is considered necessary from the point of view of coastal conservation and Chlorophyll *a* method for the water quality measurement were introduced as technology transfer. The Offshore waves have been measured in Mauritius, however, the monitoring of water level, waves height and current in the lagoon were not implemented, therefore the measuring technology in a lagoon was transferred. The application method of the existing database of coastal environment was introduced for the coastal erosion management.

In the past the importance of beach monitoring was pointed out, however the beaches were not monitored. During the basic study of the Project, the technology transfer was implemented by conducting the monitoring of the beaches in cooperation with C/P. Also ICZM put it to practical the technology transfer by conducting monitoring of the priority coasts of the coastal conservation plan and coastlines where it had implemented projects in the past. This monitoring was conducted at 3-monthly intervals from November 2013. This data will contribute to understanding of long term coastal changes in Mauritius.

The beach reprofiling is an effective countermeasure for beach scarps caused by cyclones but it had not been implemented before the Project. MOESDDBM organized LEU (Living Environment Unit) and trained its technicians in cooperation with JET by lectures and field training. As a result, reprofiling has been used as beach maintenance works from 2014.

The technology transfer for the observation of waves, currents and tides has been carried out

to the members of MMS and MOI at the time of the Project basic study and with a workshop because they did not have experience. These organizations are planning to continue the observation after the transfer of the equipment. The results will contribute to the accumulation of wave data around Mauritius in future.

9.3.3 Technical Guidelines

The technology related to the basic study and the formulation of conservation plan were summarized as guidelines because there is no guideline for the coastal erosion measures corresponding to the specific conditions in Mauritius. These guidelines consist of the natural and design conditions for the coastal conservation measures, the planning, designing, construction and maintenance for the conservation facilities, beach and coral monitoring, water quality analysis, coral plantation and EIA.

The guidelines were summarized upon considering the characteristics of Mauritius for the MOESDDBM and related organizations in the course of coastal conservation practice. In the future, together with the utilization of the guidelines by MOESDDBM for coastal conservation, the Project proposes to continue to improve the guidelines based on experience it gains from implementing coastal conservation in Mauritius.

9.3.4 Seminar and Training

Workshop was held to dissimulate the information of coastal conservation which was not common in Mauritius. In the workshop for the coastal conservation plan, the contents were discussed with the stakeholders which include residents, and confirmed at the site. In the seminar, the Project's overall description was explained and at the end of the project the results were explained. As technical exchange the C/P attended the seminar held in Seychelles where similar project was held and discussed with the related people. The results will contribute to the development of technical capacity of both countries.

The training in Japan was held in December 2013 with seven participants of Mauritius because of the lack of sufficient knowledge and experiences of the engineers in Mauritius. The participants attended lectures and field observation on the coast of Ibaragi, Chiba and Kanagawa Prefectures and learned the present conditions of coastal conservation in Japan. Also they observed the examples of coastal conservation of coral coast in Okinawa Prefecture similar to Mauritius and exchanged opinions on measures for environment and landscape conservation with the persons concerned. In addition, the participants studied the applicability of these examples to Mauritius. The engineers obtained new perspective and the application is expected in the future.

9.3.5 Demonstration Projects

Flexible revetment was proposed as applicable measures in Mauritius for the physical demonstration project because the nature friendly measures were not investigated. The technology were transferred to C/P through its planning, designing and construction. The flexible revetments of gravel were constructed by ICZM at Riviere des Creoles and Bois Des Amourettes by the application of the demonstration project.

In the past a consensus was formed for the demolish of individual structures but not for the coastal conservation plan for a coast. For the consensus building as non-physical measures of

demonstration project, the meetings were held with the stakeholders and residents and tried to make a plan for the coastal conservation at Pte d'Esny. The experiences can be applied to similar cases in the future though the consensus was not formed.

9.3.6 Recommendation

The capacity development is a kind of a continuous activity. It has to be continued according to the capabilities improvement and IEC plan as explained in Chapter 7. Especially recommended is the selection and development of the capacity which is required in Mauritius because the human resources and budget is limited in Mauritius. This Project will become the start of the development for technical capacities.

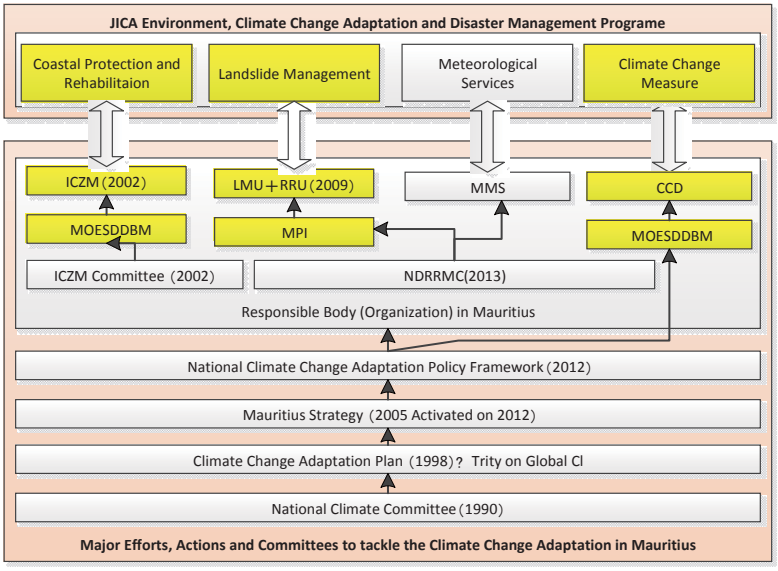
Chapter 10

Environment, Climate Change and Disaster Management

10 Environment, Climate Change Adaptation and Disaster Management

10.1 General

Following the aforementioned global action, the Coastal Protection and Rehabilitation Project was launched as a component of the Program of the Japan International Cooperation Agency (hereinafter referred to as JICA) Environment, Climate Change Adaptation and Disaster Management Scheme. The Project should also share the view of the Climate Change Adaptation, Environment and Disaster Management in Mauritius to produce a synergistic effect with other components (or projects). The effective technical transfer shall first consider the relation with political and administrative capability of Mauritius together with the collaboration of other relevant Projects by other Development Partners. Figure 10.1 shows the relation of JICA Project components and respective Mauritius organizations.



Source: JICA Expert Team

Figure 10.1 JICA Environment, Climate Change Adaptation and Disaster Management Program and Related Mauritius Agencies

10.2 The Project and Related Organizations

The Climate Change Division in the Ministry of Environment and Sustainable Development, Disaster, Beach Management (hereinafter referred to as MOESDDBM) is in charge of all projects related to climate change adaptation such as the Africa Adaptation Programme (hereinafter referred to as AAP). The coastal management projects (Adaptation Fund Programme (hereinafter referred to as AFB) funded by UNDP) are coordinated by the MOESDDBM. The Indian Ocean Commission (IOC) is also one of the stakeholders in the field of disaster risk reduction. The mandate of IOC is to coordinate development objectives, including disaster risk reduction, amongst its five Indian Ocean nations; Mauritius, Comoros, Madagascar, Reunion (France), Madagascar and the Seychelles. The IOC has a unique approach compared to other development partners.

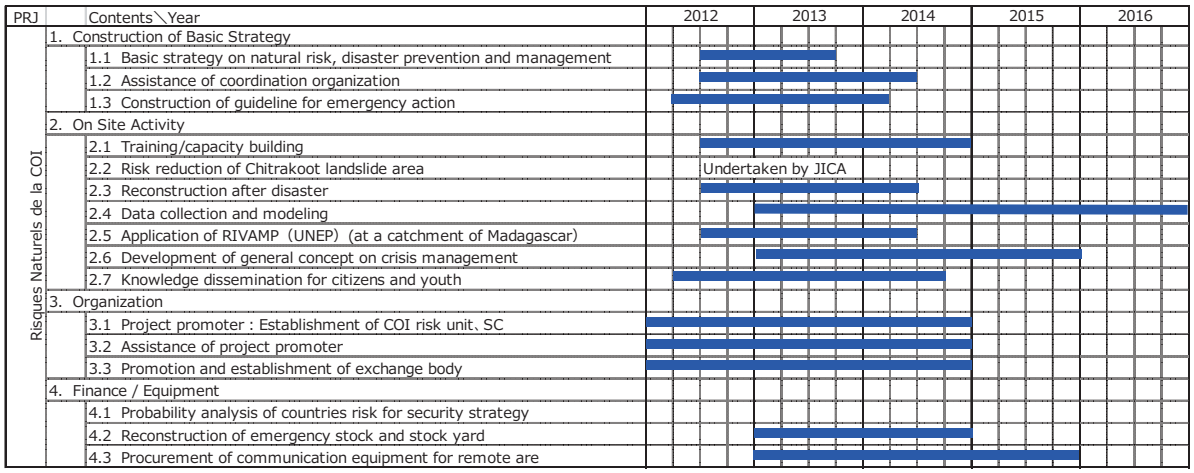
The JICA Expert Team (hereinafter referred to as JET) suggested launching a committee called CADMaC (Climate Change Adaptation and Disaster Management Committee) for collaboration and exchange to avoid overlapping or similar activities which may overburden

the related sectors of Mauritius government organizations. However, this function already existed in the MOESDDBM. Therefore, the JET decided with the recommendation of the counterpart organizations to reduce the tasks of CADMaC into "Climate Change Adaptation and Disaster Management Group" which consists of a Chief Advisor and a Co Chief Advisor of Coastal and Landslide management components. The Group shall grasp the progress of other related projects and share information to reflect their outcome on the Project.

10.2.1 Development Partners

a. IOC (Indian Ocean Commission)

Almost half of the funding comes from AFD (Agence Française de Développement) and EU. IOC is conducting a project on disaster risk reduction and management (Risques Naturels de la COI) in the five island counties of Madagascar, Seychelles, Reunion, Mauritius and Comoros from 2011 until 2016. There are altogether 16 components including the Chitrakoot Landslide Monitoring Program which is currently undertaken by JICA. The project components and schedule after 2012 are shown in the figure below.



Source: JICA Expert Team compiled based on project brochure of COI-RN

Figure 10.2 Major components of IOC program

Other than JICA's project component of Chitrakoot Landslide Monitoring Program, the similar or duplicated components are as follows;

2.1 Training/capacity building

2.3 Reconstruction after the disaster

2.6 Development of general concept against risk management

2.7 Education activities for citizens and youth

Information on these areas of duplication is to be shared with the IOC, and adjustment of the respective actions will be discussed. The Stakeholder meeting was held on 22 June 2012. The current status and the future direction of the Project were discussed. Following the meeting, the site excursion to Chitrakoot was conducted. The explanation of the landslide and the future activities were made by the JICA study team to the stakeholders of the IOC on 23 June 2012.

The final workshop was held in October 2014. The major outputs of the projects are 1) identification on needs and requirements with regard to natural disasters, 2) description of

mission and 3) framework formulation on general management and reduction of natural disasters.

b. Climate Change Adaptation Programme in the Coastal Zone of Mauritius (AFB)

This Project was announced to be started before the commencement of the JICA Project. However, TOR and the implementation organization structure of the Project became effective at the inception workshop which was held in August 2012. The AFB has five components described as follows;

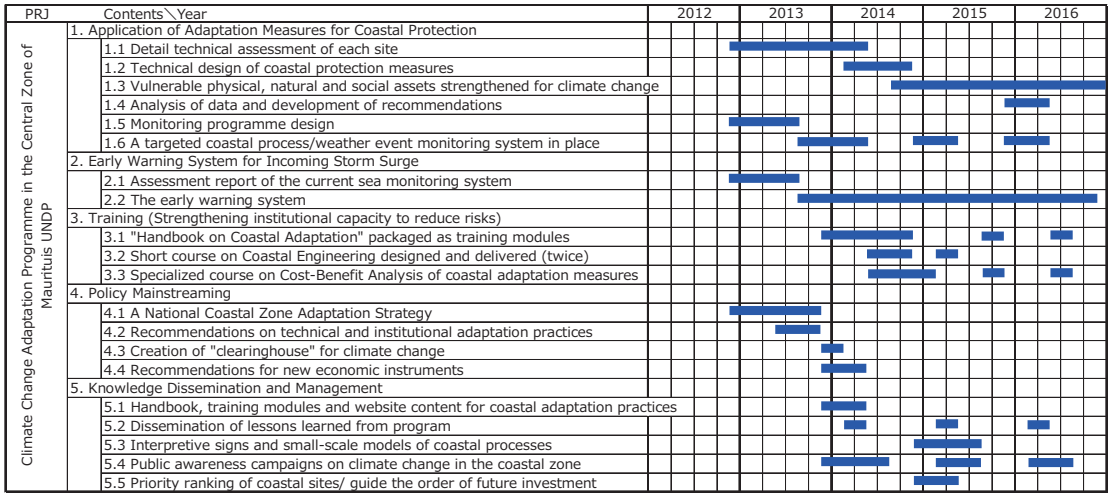


Figure 10.3 Major components of AFB program

It is planned to initiate the design and execute the protection against coastal erosion at the two coasts of Mon Choisy and Riviere des Galets and the construction of a refugee centre at Quatre Soeurs, for which a total budget of 5,755,650 USD has been assigned for the component of *1.2. The evacuation platform against high tides*, which is also under consideration. Several components of the Project are similar to JICA's coastal protection and rehabilitation projects. Therefore, it is necessary to exchange information effectively as well as to accommodate the duplicated programs.

UNDP covers all up stream coordination activities, and the actual implementation will be executed by the Project Manager put in place in MOESDDBM. All issues of respective projects have been dealt with by closely exchanging all available information. The members are now working on the TOR for major activities which will be contracted out to private firms through tendering. Not only coastal areas but also for landslide portions. Also the Project Manager of AFB participated in the technical transfer seminar held by JET.

c. AAP (African Adaptation Program)

This Project was announced to be started before the commencement of the JICA Project. However, TOR and the implementation organization structure of the project became effective at the inception workshop which was held in August 2012. The AAP is targeted to 20 African countries for Climate Change Adaptation funded by Japan. Several components are covered by the program and it was completed in December 2012. The Program is titled Development of a Disaster Risk Reduction (hereinafter referred to as DRR) Strategic Framework and Action Plan, (December 2012, Studio Galli Ingegneria S.p.A. in association with Centro Euro-Mediterraneo per I Cambiamenti Climatici S.c.a.r.l and Desai & Associates Ltd)

Other preliminary consultancy services operated in the AAP are as follows:

−Consultancy Services for Review & Drafting of Climate Resilient Policies and Legislation

-Consultancy Services for Mainstreaming Climate Change Adaptation in the Development Process of Tourism, Fisheries and Agricultural Sectors and also for Rodrigues

-Climate Change Adaptation Planning and Design of Buildings in Mauritius

The result of AAP were projected to the action plan namely "National Climate Change Adaptation Framework for the Republic of Mauritius" （12 December 2012）. This framework is currently conducted by Climate Change Division (CCD) of MOESDDBM. The Climate Change Information Center was established in August 2012 under the CCD.

Including DRR, in total 39 projects are planned within five categories, of which cross sectorial programmes have the highest priority. The project period is set from 2013 to 2015, and the major projects (funded projects) are as follows;

1. Preserve healthy natural environment (45,000,000MUR)

2. Coastal Management Plans for Inundation (45,000,000MUR)

3. Sound Spatial Data Infrastructure (270,000,000MUR)

4. Flood Management Plans (937,000,000MUR)

Currently the Project of Coastal Management Plans for Inundation is active. However, only the project "Preserve a healthy natural environment" has been budgeted and others are still in the preliminary phase without budgets. The other 35 projects, including cross sectorial ones, have not started yet. The goals of these projects are still far from being achieved.

10.3 Summary on Environment, Climate Change Adaptation and Disaster Management by JICA

The major outcomes of this project on coastal protection and rehabilitation are summarized as follows;

1. In the framework of climate change adaptation and disaster management, cyclones, unstable rainfall patterns and inundation caused by the sea level rise may be considered as coastal management. The coastal sediment budget is found to be decreasing in recent years though it was accreted in the past. The causes seem to be the increase of cyclone intensity and the deterioration of (coral) reef environments.

2. The coastal conservation plan is formulated under the framework of the JICA Climate Change Adaptation and Disaster Management package for the Government of Mauritius. The large scale structure for coastal protection may damage the current state of the landscape and coast. In general, coastal management shall maintain the current coast, and if needed, beach nourishment may be applied.

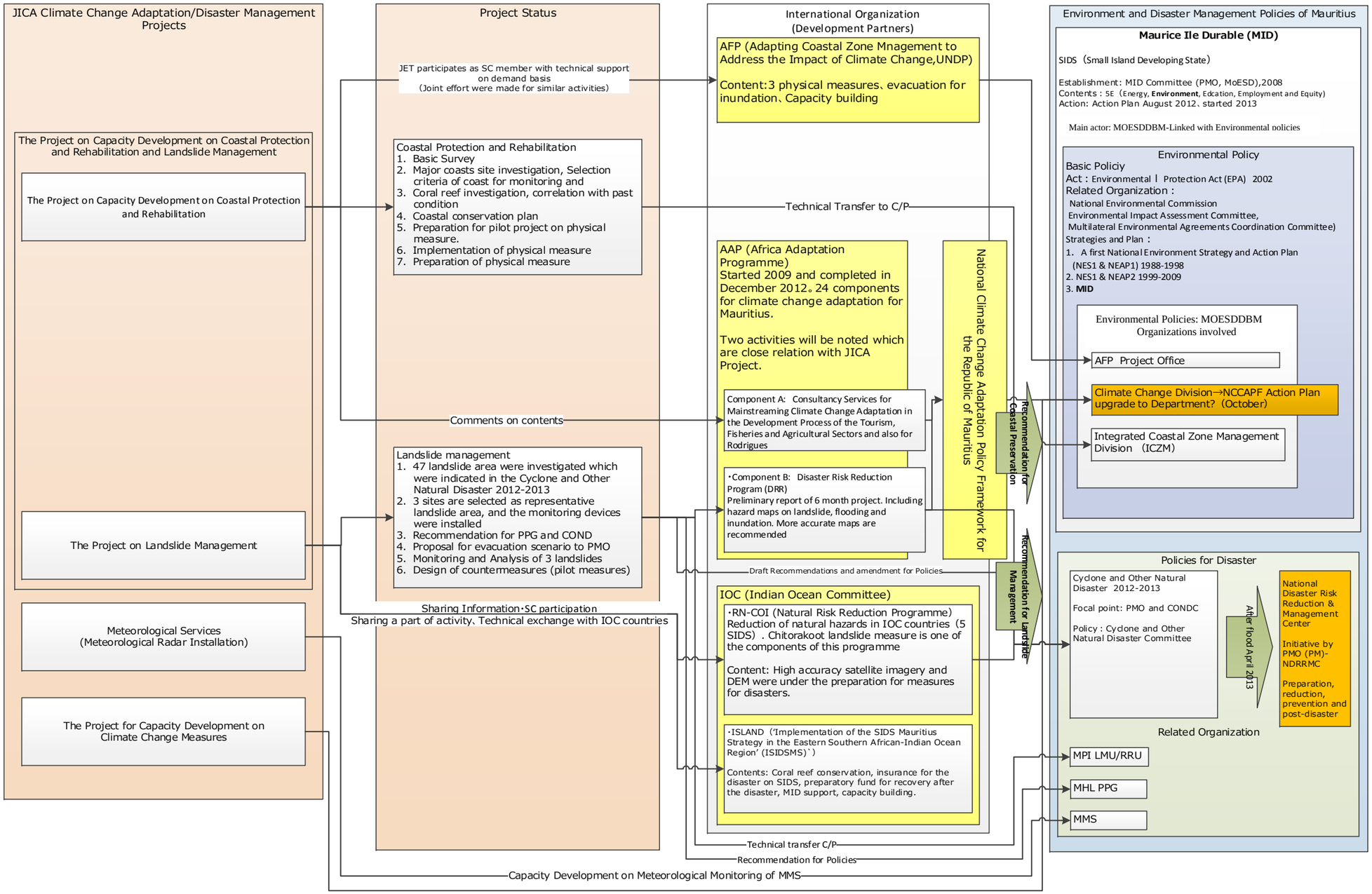
3. The coral reef is the source of beach sand and has a function of wave dissipation. The survey of corals shows that they are in a state of degradation. The causes are the increase of sea surface temperatures and eutrophication in lagoons. It is necessary to start the mitigation measures even though the impact does not appear immediately. Regular monitoring, understanding the situation and the analysis are included in the action plan

because the current information on corals, seagrasses and beach changes is limited. Together with this the plantation of corals and seagrasses is proposed based on the past experiences to rehabilitate the coral reefs.

4. Recommendations for effective coastal management were made. For the priority coasts the coastal conservation plan and management plan were formulated. The setback to reduce the risk faced by coastal areas is important for the adaptation to future changes in the climate. The existing setbacks were evaluated. Then the management of facilities in the setback zone was proposed together with the new setback limit for the cliff coast.

5. Flexible revetment of gravel was proposed to cope with the future sea level rise and wave overtopping. It is easy increase the height of such measures compared to conventional revetments and it can respond to changes. The effects were confirmed in the demonstration project. It is effective from both environmental and beach use perspectives.

These contributions are summarized in the flow chart presented in Figure 10.4.



Source: JICA Expert Team

Figure 10.4 JICA Climate Change Adaptation/Disaster Management Projects and Relation with Other International Development Partners, and the related Policies of Mauritius

Chapter 11

Conclusion and Recommendation

11. Conclusions and Recommendations

11.1 Conclusions

11.1.1 Status of Coastal Conservation

It is necessary to undertake measures to mitigate the degradation of corals and the sea level rise in the future together with the present erosion problems. This is concluded from the basic study of the beach changes, coral conditions in lagoons and the present status of conservation measures in Mauritius.

a. Coastal Change

The coastal changes were analyzed based on a series of aerial photo from six years over a 45-year period between 1967 to 2012 in order to understand the long-term beach changes. The target beaches are sandy coasts of 13 sediment cells and become 67 km in total length. The eroded beaches are 17 %, the accreted ones are 23% and the stable ones are 59%. Three sediment cells of the total sandy coasts are eroded, and the other seven sediment cells are partly eroded and accreted. The sand budget is accreted in total.

The changes in the short-term are larger than the long-term. The causes of these are cyclones, the growth of coral patches and the disappearance of seagrass. On the other hand, as for the changes in the long-term, the beaches accretion were continuing until 1990 and after those beaches became stable. There is a possibility that the beaches will be eroded in the future. Therefore, if there is a change from a state of stability to erosion, then measures will be necessary.

b. Reef Environment

The coral reef has important function for the coastal conservation as it is the source of beach sand and decreases the energy of waves. Therefore, the coverage of live coral was monitored at 44 points by the spot check method. The mean coverage was 27%. The long-term changes of the coverage have been monitored by AFRC from 1998. The results show that the coverage at the fore reef decreased continuously from 50% to under 20% and at the back and shore reef it dropped from 50% to 10% or 20% by the increase of sea surface temperature in 2009.

The eutrophication of water is estimated as one of the causes of coral degradation. The condition is not understood because of the low accuracy of water analysis. The field observation shows that the coral coverage decreases with the increase of turbidity, chlorophyll *a*, nitrogen and phosphorus. Then the conservation of coral reef is necessary.

c. Coastal Conservation

The Cyclone Carol of 1960 caused beach and cliff erosion along the coastline of Mauritius and the erosion became 13 m at its maximum. Gabions of 3.5 km in length were installed after the Cyclone Hollanda in 1994.

In 2003 Baird pointed out after a detailed investigation that the sandy beaches showed a tendency of recovery after an erosion episode, and that these beaches would not recover if the system of coral reefs, lagoons and beaches were impacted by human activities. From these results it was recommended that the coral reefs and the dynamic beaches should be kept in

the natural condition and the structural measures shall be the measures of last resort. The sand mining in lagoons was banned in 2003.

After 2006, as a result of Baird's study results the coastal protection measures of removing of gabion revetments, construction of rock revetments, and sand nourishment were conducted. The implementation of these structural measures in the required coasts have almost finished. The rock revetment has problems of coastal use, environment and landscape because of its larger size, which is necessary for it to resist external forces.

The coastal zone is defined from the high water mark (HWM) to 1 km both in landward and seaward directions in Mauritius. The land from HWM to 81m inland is called Pas Geometriques and is owned by the state. It is used for commercial and private as a leasehold. The 30 m inland from HWM is the setback area where the construction of structures is generally not allowed. The setback before 2004 was 15 m and the existing buildings must be setback by 30 m when their leases come up for renewal. The structures for coastal protection need to obtain an EIA license. The systems are effective to decrease the disaster risk on the coastal zone though there are small problems.

The organizations for coastal conservation are Integrated Coastal Zone Management (ICZM) of MOESDDBM which is responsible for leading, managing and coordinating with related organizations in the coastal zone, the Ministry of Housing and Lands (MHL) which is responsible for land management, the MoF which is responsible for the conservation of reefs environment, the Beach Authority (BA) is responsible for the management of public beaches, the Ministry of Social Security, National Solidarity and Reform Institutions (MSS) and Mauritius Oceanography Institute (MOI) which are responsible for conducting investigations and researches, the Ministry of Tourism and Lager (MTL) which is responsible for tourism development and others. The management system for the integrated coastal zone has been developed, however, it was not observed in this survey that the related organizations were necessarily playing organically its role-sharing. Therefore, in this point of view this study conducted the technology transfer after clarifying the roles of each institution.

11.1.2 Coastal Conservation Plan

a. Strategy

The strategy of coastal conservation is proposed based on the basic study results and the related issues for three objectives which are coastal protection, coastal development and environmental conservation.

- To maintain and utilize the natural characteristics of the coast

Because the erosion along the sandy beach in Mauritius is a natural and reversible process, and the coastal structures are not necessary, it is important to maintain the sandy beaches as natural coasts. The natural sandy beaches are the resources of tourism which is one of the main industries in Mauritius, therefore these sandy beaches have to be maintained. Coral reefs, which have important functions of sand supply and wave dissipation together with the conservation of ecosystem and fisheries, should be conserved and rehabilitated properly.

- To build the abilities for natural and socio-economic changes in the future

It is necessary to strengthen the adaptive ability for the future sea level rise caused by climate change and economic development. Adaptive coastal management is going to be conducted by

the following procedures: setting the precise goals, implementation of the plans, monitoring the conditions, and evaluation of the results. It has to be conducted in order to accumulate and apply the information and past experience, and to develop measures and structures based on natural characteristics.

- To integrate coastal management with the collaboration of stakeholders

The coastal zone has to be managed in an integrated way for coastal protection, nature conservation and coastal use. MOESDDBM will manage the coastal zone by making decisions with the cooperation of related organizations. Each governmental organization plays their role in this integrated management system and strive make this process inclusive of local residents.

b. Coastal Conservation Plan

The coastal conservation and maintenance plans for the 14 priority coasts are formulated from the problems of the coasts, the classification of these coast characteristics and alternative measures.

In the coastal conservation plan, the principle is to keep the natural conditions through the setback and/or sand nourishment because the eroded coasts are limited from the baseline survey and the sandy beach is an important resource for tourism. The reef environment is also deteriorated. So conservation of the reef is included.

Sand nourishment is taken as a measure for coasts which are eroded as a whole. This is applicable for Mon Choisy. In this case the eroded volume is estimated at roughly 500m^3/year which is feasible to implement without interfering with the beach use. Also, a combination of groynes is possible as was done at Pte. aux Cannoniers.

Sand recycling, coral farming or planting of seagrass will be applied depending on the causes and beach characteristics for the partly eroded and stable or accreted coast in total. If the erosion is partly caused by the disappearance of coral, seagrass and mangrove, sand recycling can be applied from the accreted area to the eroded area in the short term and rehabilitation of the coral, seagrass and/or mangroves will become a long term measure. This applies to the Bras d'Eau, Flic en Flac and Pte. d'Esny coasts. At Ile aux Cerfs, the problems are channel clogging and erosion at adjacent beaches caused by the topographic characteristics. The measures are sand dredging from the channel and sand recycling to the eroded beach. At Le Morne, the beach has eroded at one side and accreted at the other side by the jetty for anchorage. In this case, sand bypassing will be applied.

If the coastal changes are caused by cyclones or the degradation of coral or seagrass, it is necessary to apply the setback. From the existing information, the present setback of 30 m is reasonable. However, monitoring of changes to topographical features is required to make any necessary adjustments. In the project, the setback at cliff coast was studied at Albion as an example. The plans includes improvement or removing of vertical revetments to gentle revetments. The removal of facilities in the setback area is also proposed.

Coasts formed by silt or cobble with wide reefs are characterised by low-lying ground in the coastal area. These low-lying areas are considered to be at risk of wave run-up in the future due to high waves and/or sea level rise. As one of the measures, flexible revetment was

proposed. It imitates the local topography and material. The applicability is demonstrated by the demonstration project at Grand Sable.

Coral, which is the source of sand and which acts to dissipate wave energy, is deteriorated by the increase of sea surface temperatures. In order to recover losses, coral farming is proposed by the improvement of water quality and the regulation of activities in lagoons.

During the formulation of coastal conservation plans, technical committees and meeting by working groups were held in order to develop the capacity of related organizations. The basic information for the plan is limited so improvements can be made by evaluation from the demonstration projects and continuous monitoring.

c. Coastal Maintenance Plan

For the maintenance of the coast, reprofiling beach scarp which is easily formed by cyclones is recommended for the earlier recovering and the security of the public. In the setback area, the improvement of the vertical revetment to decrease scouring and the impact to the adjacent beach is recommended. In addition, monitoring and management of illegal construction as well as removing sand from the beach during beach cleaning is recommended.

d. Reef Environment Conservation Plan

From the time series analysis, the coral patch and seagrass bed in lagoons are clearly related to the coastal changes of erosion and accretion. The coral condition in Mauritius changed after 2000 from “good” to “failure” according to the comprehensive evaluation. The causes are estimated to be eutrophication, sediment inflow, fishing and marine sports in lagoons, anthropogenic causes together with the biological factors (crown-of-thorns starfish, etc.), coral bleaching and rises in sea surface temperatures.

To solve these problems, an action plan is recommended. It includes monitoring the reef environment by aerial photo and sea truthing and water quality, analysing monitoring results, regulating human activities in a lagoon, controlling water quality in a lagoon, planting seagrass and coral farming. These activities will contribute to the rehabilitation of the reef environment and to the stability of beach.

e. Coastal Management Organization

For the planning of coastal management system, organization, information, education and communication, the ICZM frame work was already proposed by Landell Mills (2009) and has been approved by the Mauritius government. Implementation should be the focus point as a lack of action is the problem. Issues relating to implementation are the capacity development of responsible officials through the daily work, the exchange of information between related organizations, and the creation of measures based on the characteristics of Mauritius.

11.1.3 Demonstration Projects

a. Physical Demonstration Project

As a physical measure, flexible revetment made of sand and gravel was proposed when taking into account the natural characteristics of the site, the coastal use, the environment and land scape, and the ease to cope with future changes such as sea level rises. In the project, the evaluation of the revetment and the capacity development were considered.

Grand Sable at the southeast was selected as the demonstration site of physical measures. Here the coast is low and the coastal road will easily be impacted by wave run-up and future sea level rise. The revetment plan is 400m long with the height at 2 m and the width at 10 m with the slope at 1:5. A part of 240m portion constructed from October to December 2013. For the capacity development, planning, designing and construction management were carried out with the counterparts. For reaching an agreement and future maintenance, by the local people, meetings and events were held.

The monitoring results after one year show that the gravel and sand mix is almost stable. The sand is partly transported alongshore to the north area without construction but it is not a serious issue. The beach has various uses including boat landings, functioning as a playground for children, and fishing. It is clean compared to the pre-construction state. The smell and water quality has improved. The local people monitor and clean the beach voluntarily. The results can be applied to the other coasts.

b. Non-physical Demonstration Project

For the non-physical measures, the project was aimed at building consensus for the plan among stakeholders which include local residents. Pte. d'Esny at the southeast coast was selected as the site. Bungalows and houses are located along the coast as well as some hotels. Revetments and groynes were constructed for the prevention of coastal erosion in the past. The coast is accreted as a whole but partly eroded and the impacts of structures are expected.

Problems include the lease contract, the setback, the effects and impacts of existing structures, the mechanism of erosion and the conflict between individuals and overall conservation plans. The project tried to build a consensus of stakeholders.

The project direction and its proposed measures include rearrangement of existing structures and sand nourishment based on the erosion conditions and consultations with stakeholders. Several meetings with residence were held which proposed alternatives that took into account the opinions of the lessees. However it is difficult to get everyone to agree on the same thing.

The main problem of consensus building for this plan is removing existing structures and showing unequivocally that there will be necessary no impacts caused by the removal. It is necessary to show the similar examples by monitoring and accumulation of data and to obtain the residents understanding'.

11.1.4 Capacity Development

The Project was conducted to improve the technical capacity and to obtain engineering knowledge required in the practice. On-the-job-trainings were carried out through site surveys, beach monitoring, data analysis, task analysis, planning and the implementation of demonstration projects. Related guidelines were also formulated. Seminars, workshops, training in Japan, and technology exchange were carried out in combination. These are considered to be suitable for the technical level and the conditions in Mauritius. The capacity development is a long continuous process and these activities are believed to give opportunities to start it. Each person is expected to develop the capacity on his own initiative.

The technical guidelines proposed are for the natural and designing conditions of coastal conservation works, designing and planning of coastal structures, the monitoring of beach and coral conditions, water quality analysis, coral farming and EIA for coastal protection.

Improvement of those guidelines are recommended based on the own experiences in Mauritius.

The workshops were opened for the coastal conservation plan with related organization and residents to discuss its contents and to confirm the plan at the site. Seminars were held to inform the outline of the Project at the beginning and to disseminate the results at the end of the Project. The counterparts attended a seminar in Seychelles where a similar project was conducted. They reported the activity in Mauritius by discussions with the related people. These activities will contribute to enhance the engineering capacity in Mauritius.

11.2 Recommendations

In the past there were many recommendations to the coastal erosion and integrated coastal erosion management. It is better to concentrate on the important points with the limited human resources and financial conditions. In the execution of the coastal conservation plan, it is recommended that the actions should be carried out based on the proposed strategy by focusing on the following items.

11.2.1 Coastal Zone Management

It is recommended to emphasize on the coastal management in addition to structures in coastal conservation measures. The problems in the future are mainly caused by the change of environmental conditions and the plan is not effective because it is difficult to predict the future changes. The adaptive management procedures should be applied with monitoring for the improvement of the plan.

The past structural measures such as gabions and rock revetments cause problems and the construction works of these have been already completed at the target coasts. Then the management of coastal zone becomes important.

Setback plays an important role for the management of coastal erosion. The construction of new facilities is not permitted in the setback zone. However, some existing buildings are currently permitted within this setback zone, and this situation needs to be remediated. The 30 m of setback is reasonable at present. In future it is proposed to revise the value of the setback based on the monitoring results of beach changes caused by cyclones and sea level rise at certain intervals.

The beach is stable from a long-term perspective at present. However, it was greatly eroded by cyclones such as Carol in the past. That kind of erosion can be managed by the setback but causes problems of the beach usage. Beach reprofiling should be applied to advance the recovery of the beach after such events. During the project technical training was conducted and one organization (LEU) has been developed. LEU is expected to respond in emergency situations such as when cyclones cause beach changes.

Wave overtopping by long waves has become a clear coastal disaster on the low-elevated coasts where coastal road and fishing villages are located at the back of wide reef. Those areas will be easily affected by the sea level rise by the future climate change. The measures considered are the raising of the coastal road and the construction of revetments. It is necessary to consider not only the coastal protection but also the regional development and environmental conservation. For the specific plan, a topographic survey of coastal land is necessary and proposed with contour intervals of 1 m or 2 m because there are no accurate topographic data in Mauritius. The measures have to be discussed and implemented with

stakeholders which also include local residents such as the case of the consultation for the flexible revetment proposed in the demonstration project.

11.2.2 Monitoring

In particular the monitoring and the development of the results are recommended as a priority for the coastal conservation. The monitoring of beach profile and reef environment is indispensable for the planning of measures and management. The proposed monitoring methods for reef environment in this Project are feasible and practical. In future the application of satellite data and remote sensing techniques can be applied because of its rapid progress.

The monitoring methods of the water quality in the sea are not enough to evaluate its impacts on corals because of the unsuitable index and insufficient accuracy. Also there is no water quality standard for the conservation of corals. Here the measurement of Chlorophyll *a* and turbidity is proposed as indexes to understand easily the eutrophication in a lagoon. The regulation of lagoon water quality with the continuous monitoring are recommended after the establishment of the water quality standard for coral conservation based on the monitoring results.

In the past the monitoring data were stored as GIS data but not fully utilized. It is recommended that as a data center MOESDDBM has to distribute the data widely, to keep the accuracy and to show how to use.

11.2.3 Eco-engineering

The transplant technology for coral and seagrass has to be developed in the reef environment because these play an important role for the production and stabilization of beach sediment. It is proposed to study the reproduction and conservation of coral and seagrass in foreign countries and to consider its suitability for application in Mauritius as an initiative to protect the reef environment.

The development of nature friendly facilities is recommended such as the flexible revetment in the demonstration project as one of the measures in considering the environment and coastal use. From the observation at the actual beach and the improvement through pilot projects, nature friendly measures based on the specific conditions in Mauritius can be considered.

The sediment transport and beach changes are complex and not fully understood in the coral reef. The development of new erosion control measures for the coral reef coast is proposed with the observation of the phenomena by the use of donated wave and current gauges. Most of the beaches are stable in Mauritius. The eroded beach will be stabilized by analyzing and simulating the stable beach.

11.2.4 Stakeholders Involvement

The goal is to cooperate with stakeholders. It is recommended to obtain the participation of stakeholders to the implementation of coastal conservation measures not only by the government agencies but also the local people.

The coral and seagrass will contribute to stabilize the sediment in front of beaches. The hotel owners tend to be proactive in conserving coral and seagrass if they are informed of the

relevant facts.

In the planning and designing of coastal facilities, consultants have an important role for the proper solution. The development of technology for coastal facilities by the Engineers Association should be encouraged by the government. Furthermore, it is recommended that the relevant documents for understanding the specific coastal conservation and geomorphological conditions in Mauritius should be distributed to foreign consultants who are working in Mauritius.