REPUBLIC OF MALDIVES
Ministry of Environment, Climate Change and Technology

# The Project for Building Climate Resilient Safer Islands in the Maldives

# DETAILED PLANNING SURVEY REPORT

January 2023

JAPAN INTERNATIONAL COOPERATION AGENCY

NIPPON KOEI CO., LTD.

PACIFIC CONSULTANTS CO., LTD.

MITSUI CONSULTANTS CO., LTD.

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# Abbreviation Table

| Abbreviation | Official name |
|---|---|
| AE | Acredited Entity |
| ADCPC | Asia Disaster Preparedness Center |
| ADRC | Asian Disaster Reduction Center |
| AFD | Agence Française de Développement |
| BML | Broadcast Markup Language |
| CATV | Cable TV |
| COD | Chemical Oxygen Demand |
| C/P | Counter Part |
| CVI | Coastal Vulnerability Index |
| DA2010 | The Act on Decentralization 2010 |
| DO | Dissolved Oxygen |
| EC | Electrical Conductivity |
| EE | Executing Entity |
| ECMWF | European Centre for Medium-Range Weather Forecasts |
| EE | Executing Entity |
| EIA | Environmental Impact Assessment |
| EIRR | Economic Internal Rate of Return |
| EPA | Environmental Protection Agency |
| EWBS | Early Warning Broadcasting System |
| Fidelis | Fidelis Law Group LLP |
| F/S | Feasibility Study |
| GCF | Green Climate Fund |
| GDP | Gross Domestic Product |
| GII | Gender Inequality Index |
| GIS | Geographic Information System |
| GPS | Global Positioning System |
| H.W.L. | High Water Level |
| HDI | Human Development Index |
| HIES | Household Imcome and Expenditure Survey |
| HVI | Human Vulnerability Index |
| ICZM | Integrated Coastal Zone Management |
| IHDI | Inequality-adjusted Human Development Index |
| IPCC | Intergovernmental Panel on Climate Change |
| ISDB-T | Integrated Service Digital Broadcasting - Terrestrial |
| JET | JICA Expert Team |
| JICA | Japan International Cooperation Agency |
| KOICA | Korea International Cooperation Agency |
| LGA | Local Government Authority |
| M.S.L. | Mean Sea level |
| MERCY Malaysia | Malaysian Medical Relief Society: |
| MBC | Maldives Broadcasting Corporation |
| MECCT | Ministry of Environment, Climate Change and Technology |
| MEE | Ministry of Environment and Energy |
| MEEW | Ministry of Environment, Energy and Water |
| MHAHE | Ministry of Home Affairs, Housing and Environment |
| MLSA | Maldives Land and Survey Authority |
| M/M | Minutes of Meetings |
| MMS | Maldives Meteorological Service |
| MNBC | Maldives National Broadcasting Corporation |
| MNDF | Maldives National Defense Force |
| MNPHI | Ministry of National Planning Housing and Infrastructure |
| MPS | Maldives Police Service |
| NAPA | National Adaptation Programme of Action |

| | |
|---|---|
| NDMA | National Disaster Management Authority |
| NDMC | National Disaster Management Centre |
| NGO | Non Governmental Organization |
| NPO | Nonprofit Organization |
| OJT | On-the-Job Training |
| PDM | Project Design Matrix |
| PMU | Project Management Unit |
| PSIP | Public Sector Investment Program |
| PSC | Project Steering Committee |
| PSM | Public Service Media |
| SAARC | South Asian Association for Regional Cooperation |
| SDGs | Sustainable Development Goals |
| SIDS | Small Island Developing States |
| SLR | Sea Level Rise |
| SST | Sea Surface Temperature |
| TETRA | Terrestrial Trunked Radio |
| TSHD | Trailing Suction Hopper Dredger |
| UNDP | United Nations Development Programme |
| UNESCAP | United Nations Economic and Social Commission for Asia and the Pacific |
| UNFPA | United Nations Population Fund |
| UNICEF | United Nations Children's Fund |
| UNISDR/ UNDRR | United Nations International Strategy for Disaster Reduction/ United Nations Office for Disaster Risk Reduction |

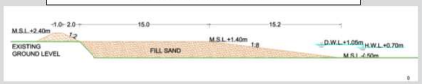
# “the Project for Building Climate Resilient Safer Islands in the Maldives” Project Site Map (8 Islands, 4 Atolls)

## Fonadhoo

Outcome1 Activity1-3
Outcome1 Activity1-4
Outcome2

Beach Nourishment (L=1600m)

Cross-section of Beach Nourishment

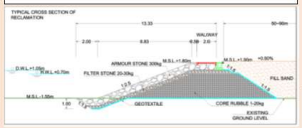


## Maamendhoo

Outcome1 Activity1-4
Outcome2

① Rubble-type Revetment(L=300 m)

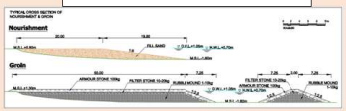
① Cross-section of Reclamation and Revetment



③Reclamation(L=540 m, V=70,000 m³, 2.2 ha), Revetment

② Beach Nourishment(L=400 m), Groin L=50 m × 3

② Cross-section of Beach Nourishment and Groin



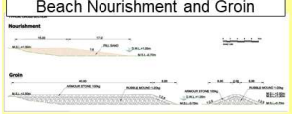
③Cross-section of Ruble-type Revetment

## Meedhoo

Outcome1 Activity1-4
Outcome2

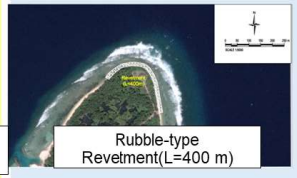
Beach Nourishment(L=1,600 m) Groin L=46.85 m × 1

Cross-section of Beach Nourishment and Groin



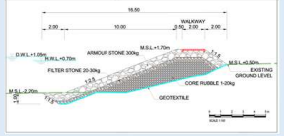
## Isdhoo

Outcome1 Activity1-4
Outcome2



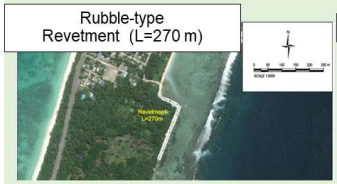
Rubble-type Revetment(L=400 m)

Cross-section of Rubble-type Revetment



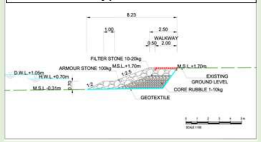
Outcome1 Activity1-3
Outcome1 Activity1-4
Outcome2

Rubble-type Revetment (L=270 m)

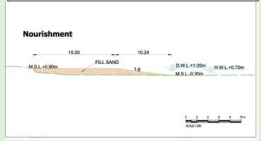


②Beach Nourishment

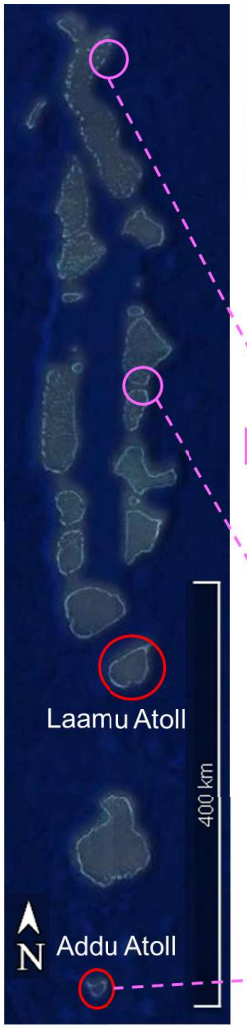

Cross-section of Rubble-type Revetment

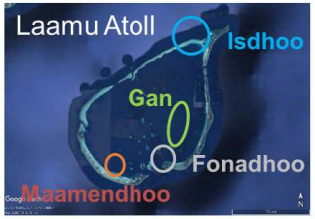


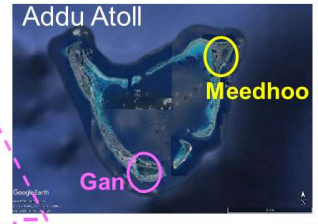
Cross-Section of Beach Nourishment



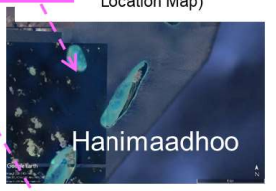
## Maldives




Outcome3 (Wave Observation Location Map)






Outcome1Activity1-3 : Study of ICZM plan on target inhabited islands
Outcome1Activity1-4 : Basic design and related studies on environmental impact assessment
Outcome2 : Establishment of a community-based coastal maintenance management system
Outcome3 : Establishment of a long-term monitoring system for waves, beaches, coral reefs, and land use


Maamendhoo
Gan
Fonadhoo
Meedhoo
Isdhoo

# CHAPTER 1 INTRODUCTION

## 1.1 Background

The Maldives is located in the Indian Ocean southwest of Sri Lanka and consists of 26 geographic atolls (administratively divided into 20 atolls) and approximately 1,200 islands covering 90,000 square kilometers. Of these, 189islands are inhabited by Maldivian citizens (hereinafter referred to as "inhabited islands"). The Maldivian land was formed by waves washing up coral sand and gravel on the fringes of atolls, so the land is low, flat, and narrow, with an average elevation of about 1-2 m above the water surface. In the Maldives, coastal erosion has been a remarkable phenomenon since the 1980s, mainly on inhabited islands. As of 2014, 116 out of the 189 inhabited islands were reported to be experiencing coastal erosion, with 38% of these islands having severe coastal erosion conditions (State of the Environment (2016), Ministry of Environment and Energy).

Even on beaches where beach erosion is not currently a problem, coastal erosion is expected to occur in the future due to sea level rise and increased wave forces reaching the coast as a result of climate change. In addition, climate change is expected to accelerate erosion on beaches where erosion is already progressing. In addition to the natural conditions described above, artificial change such as port construction in coastal areas and associated development such as navigation channel excavation on reefs, land reclamation, etc. have reduced natural wave protection and drainage functions and contributed to coastal erosion. Furthermore, these climate change and increased hazards caused by anthropogenic factors not only destroy coastal ecosystems, but also affect the fishing industry and water resources due to soil and vegetation degradation caused by flooding and sea level rise, which can cause significant damage to economic activities.

Under these circumstances, the Government of Maldives has identified "resilient communities" as one of its key priorities, with the goal of developing disaster risk management and planning that takes climate change into account, in Strategic Action Plan (2019-2023). In addition, land use plans are developed and implemented as specific regulations related to coastal management. However, strict regulations are not in place. Facilities and residences already exist within the coastal buffer zone established in the land use plan for inhabited islands. Moreover, awareness and strategy are lacking with regards to the impact of coastal development on the coastal environment and how development should coexist with the coastal environment. The coastal zone management system, which is necessary to maintain the protective functions of the reefs and beaches that have been maintained over the years, also has not been developed. Therefore, it is imperative to establish a basic wave observation system for the surrounding area and a monitoring system for the formation of the coastal area and land use conditions, to formulate a plan for regional development and disaster prevention based on the analysis of these results, and to implement maintenance and management measures for the inhabited islands based on this plan in order to achieve long-term and sustainable island resilience against future climate change. There is an urgent need to develop a plan for regional development and disaster prevention based on these analyses.

JICA had conducted the "Data Collection Survey on Building Climate Resilient Safer Cities " targeting the Maldives since 2019. In this survey, basic information on the risk of coastal disasters due to climate change, coastal conservation/protection measures, and the current status of coastal management was collected to capture the situations and analyze the issues. In addition, the study also designed four components and accompanying activities: (1) development of Integrated Coastal Zone Management (ICZM) plan, (2) implementation of coastal protection and conservation measures, (3) development of disaster information communication system, and (4) development of basic information and data collection and sharing system related to climate change. The four components and

accompanying activities were developed and compiled into a funding proposal for Building Climate Resilient Safer Islands in the Maldives Development to be submitted to the Green Climate Fund (hereinafter referred to as "GCF").

The funding proposal was adopted by the 29th GCF Board Meeting in July 2021, and JICA decided to implement the project proposed in the funding proposal as a GCF-contracted project. This JICA project for "Building Climate Resilient Safer Islands in the Maldives" covers a part of the GCF-contracted project.

## 1.2 Objective of Survey

The basic planning study for this project was conducted by JICA in late May 2021. Based on the study results, the Minutes of Meetings (hereinafter referred to as "M/M") were signed in May 2021, and the Record of Discussion (hereinafter referred to as "R/D") were signed in July 2021.

The objectives and contents of this survey are as follows

(1) Discuss and agree on the details of the cooperation with the implementing agencies, etc.

(2) Consider revising the Project Design Matrix (hereinafter referred to as "PDM") and the Plan of Operations (hereinafter referred to as "PO") as necessary, and conclude an M/M regarding the establishment of implementation structure for full-scale cooperation.

(3) Collect and organize relevant information necessary for the implementation of full-scale cooperation.

## 1.3 Survey Members of JICA Expert Team

Table 1.3.1 shows the composition of the JICA expert team that conducted the detailed planning survey.

**Table 1.3.1 Composition of Survey Members**

| No. | Position | Name | Organization | Work Period in the Maldives |
|---|---|---|---|---|
| 1 | Team Leader / Regional Planning | Shinichi FUKASAWA (Mr.) | Nippon Koei | i) 2021/12/1～12/14<br>ii) 2022/1/11～2/9<br>iii) 2022/5/10～5/18, 6/14～6/20<br>iv) 2022/7/30～8/29 |
| 2 | Deputy Team Leader / Coastal Conservation Plan/ Integrated Coastal Zone Management (ICZM) 2 | Shingo ICHIKAWA (Mr.) | Nippon Koei | 2022/8/23～9/16 |
| 3 | Coastal Conservation Plan/ Integrated Coastal Zone Management (ICZM) 1 | Susumu ONAKA (Mr.) | Nippon Koei | 2022/5/10～5/31 |
| 4 | Coastal Engineering/Shoreline Change Analysis 1 | Keisuke KUSUHARA (Mr.) | Nippon Koei | i) 2022/1/11～1/25<br>ii) 2022/5/10～5/20, 6/5～8 |
| 5 | Coastal Management/Coastal Monitoring | Daiki TSUJI (Dr.) | Pacific Consultants | i) 2022/5/10～5/24, 6/3～9<br>ii) 2022/9/19～9/30 |
| 6 | Oceanographic Investigation/ Survey 1 | Tomohiro MORI (Mr.) | Nippon Koei | i) 2022/1/12～3/3<br>ii) 2022/5/10～6/1 |
| 7 | Facility Design and Construction Plan/Cost Estimate | Yusuke TOYODA (Mr.) | Mitsui Consultants | i) 2022/1/11～1/25<br>ii) 2022/5/16～6/14<br>iii) 2022/8/23～9/17 |
| 8 | Reef Environment Planning | Ken OKAJI (Dr.) | Nippon Koei | 2022/8/2～8/8, 8/16～19 |
| 9 | Regulatory System/Organizational Cooperation/ GCF Scheme | Ako OMARU (Ms.) | Nippon Koei | 2022/5/10～5/27 |
| 10 | Capacity Development/Training Plan | Chiaki SHIBAYAMA (Ms.) | Nippon Koei | 2022/8/2～8/30 |
| 11 | Environmental and Social Consideration/ Consensus Building/ Gender 1 | Akihito SAKURAI (Mr.) | Nippon Koei | 2021/12/1～12/14 |
| 12 | Environmental and Social Consideration/ Consensus Building/ Gender 2 | Mayumi GOTO (Ms.) | Nippon Koei | i) 2022/1/16～2/9<br>ii) 2022/5/15～6/4<br>iii) 2022/8/26～9/17 |
| 13 | Coastal Engineering/Shoreline Change Analysis 2/ Coordinator 2 | Shogo TOKUNAGA (Mr.) | Nippon Koei | i) 2022/5/26～5/31<br>ii) 2022/8/23～9/17 |
| 14 | Oceanographic Investigation/ Survey / Coordinator 1 | Koki MIYAGAWA (Mr.) | Nippon Koei | i) 2022/5/10～5/31<br>ii) 2022/7/25～8/22 |

Source: JICA Expert Team

## 1.4 Survey Schedule

The schedule for this survey is shown in Table 1.4.1. This survey is a detailed planning survey (Phase 1) of a two-stage planning study, but some of the work in the full-scale implementation phase (Phase 2) is also included at the same time, so the schedule in the table includes both the work in Phase 1 and Phase 2.

(1) 1st Field Survey (December 2021)

Members: Fukasawa, Sakurai

**Table 1.4.1 Schedule of Detailed Planning Survey (1st Field Survey)**

| | Day | Fukasawa | Sakurai |
|---|---|---|---|
| Dec. 1 | Wed. | Arrival at Male from Colombo | Departure from Narita |
| 2 | Thr. | AM: Discussion with MECCT<br>PM: Discussion with JICA Maldives Office | Arrival at Male (via Doha) |
| 3 | Fri. | AM: On-line meeting with JICA HQ | |
| 4 | Sat. | Preparation of Kick-off Meeting | |
| 5 | Sun. | AM: Kick-off Meeting with MECCT, PM: Briefing to Embassy of Japan in the Maldives | |
| 6 | Mon. | Site visit to Laamu Atoll, Kick-off meeting with stakeholders in Laamu Atoll | |
| 7 | Tue. | PM: Discussion with EPA | |
| 8 | Wed. | Site visit to Addu Atoll, Kick-off meeting with stakeholders in Addu Atoll | |
| 9 | Thr. | PM: Interview to ENDhERI project | |
| 10 | Fri. | Team meeting, organizing documents | |
| 11 | Sat. | organizing documents | |
| 12 | Sun. | PM: Discussion with MECCT, Report to JICA Maldives Office | |
| 13 | Mon. | Departure from Male to Colombo | Departure from Male to Doha |
| 14 | Tue. | Arrival at Narita (via Colombo) | Arrival at Narita (via Doha) |

(2) 2nd Field Survey (January to March 2022)

Members: Fukasawa, Goto, Kusuhara, Toyoda, Mori

**Table 1.4.2 Schedule of Detailed Planning Survey (2nd Field Survey)**

| | Day | Fukasawa | Goto | Mori | Kusuhara | Toyoda |
|---|---|---|---|---|---|---|
| January 11 | Tue. | Departure from Haneda | | | Departure from Haneda | |
| 12 | Wed. | Arrival at Male | | Departure from Narita, Arrival at Male | Arrival at Male | |
| 13 | Thr. | Discussion with MECCT | | Move to Laamu Atoll | | |
| 14 | Fri. | Organizing documents | | Preparation for topographic survey | | |
| 15 | Sat. | | | | | |
| 16 | Sun. | Discussion with MECCT | Departure from Nagoya, Arrival at Male | Topographic survey and bathymetric survey at Laamu atoll | Site visit to Maamendhoo island and Fonadhoo island | |
| 17 | Mon. | Discussion with MECCT | | | Site visit to Isdhoo island and Gan island | |
| 18 | Tue. | Discussion with MECCT, EPA | | | Organizing results of the site visit | |
| 19 | Wed. | AM: Move Addu Atoll<br>PM: Discussion with Addu City Council | | | AM: Move Addu Atoll<br>PM: Discussion with Addu City | |

| | | | | | |
|---|---|---|---|---|---|
| | | | | Council | |
| 20 | Thr. | Site visit to Meedhoo island, and move to Male | | Site visit to Meedhoo island, and move to Male | |
| 21 | Fri. | Organizing documents | | Organizing documents | |
| 22 | Sat. | | Organizing documents | | |
| 23 | Sun. | Information Organizing documents collection on ICZM | Information collection on EIA | Topographic survey and bathymetric survey at Laamu atoll | |
| 24 | Mon. | | | Organizing documents | Departure from Male |
| 25 | Tue. | | | Departure from Male and Arrival at Doha | Arrival at Narita |
| 26 | Wed. | | | | |
| 27 | Thr. | AM: Discussion with MECCT<br>PM: Courtesy call to Secretary, Ministry of Foreign Affairs, Maldives | | | |
| 28 | Fri. | Organizing documents | | | |
| 29 | Sat. | | Organizing documents | | |
| 30 | Sun. | Kick-off Meeting with MECCT and other concerned stakeholders | | | |
| 31 | Mon. | Discussion with MECCT | | Topographic survey and bathymetric survey at Laamu atoll | |
| Feb. 1 | Tue. | Briefing to Embassy of Japan in the Maldives | | | |
| 2 | Wed. | AM: Move to Laamu Atoll, Discussion with Laamu Atoll Council<br>PM: Discussion with Fonadhoo Island Council | | | |
| 3 | Thr. | AM: Discussion with Isdhoo Island Council<br>PM: Discussion with Gan Island Council | | | |
| 4 | Fri. | Organizing documents | | | |
| 5 | Sat. | AM: Discussion with Maamendhoo Island Council, PM: Move to Male | | Topographic survey and bathymetric survey at Addu atoll | |
| 6 | Sun. | Discussion with MECCT | | | |
| 7 | Mon. | | | | |
| 8 | Tue. | Departure from Male to Singapore | | | |
| 9 | Wed. | Arrival at Narita | Arrival at Nagoya | | |
| - 15 | - Tue. | | | | |
| - 28 | - Mon. | | | Topographic survey and bathymetric survey at Laamu atoll | |
| - Mar. 2 | - Wed. | | | Discussion with MECCT | |
| 3 | Thr. | | | Departure from Male | |
| 4 | Fri. | | | Arrival at Singapore | |

(3) 3rd Field Survey (May to June 2022)

Members: Fukasawa, Omaru, Onaka, Mori, Miyagawa, Goto, Toyoda, Tsujio, Kusuhara

**Table 1.4.3 Schedule of Detailed Planning Survey (3rd Field Survey) (1/2)**

| | Day | Fukasawa | Omaru | Onaka | Mori | Miyagawa | Goto | Toyoda | Tsujio | Kusuhara |
|---|---|---|---|---|---|---|---|---|---|---|
| May 10 | Tue. | Departure from Narita and Arrival at Male | Departure from Haneda | | | | | | Departure from Narita and Arrival at Male | Departure from Haneda |
| 11 | Wed. | Discussion with MECCT, Briefing to JICA Maldives Office | Arrival at Male | | | | | | Discussion with MECCT, Briefing to JICA Maldives Office | Arrival at Male |
| 12 | Thr. | 1st JCC meeting | | | | | | | 1st JCC meeting | |
| | | PM: Organizing documents | | PM: Move to Addu | | | | | PM: Move to Addu | |
| 13 | Fri. | Organizing documents | | Site survey at Meedhoo island, and meeting with stakeholders | | | | | Site survey at Meedhoo island, and meeting with stakeholders | |
| 14 | Sat. | | | | | | | | | |
| 15 | Sun. | Discussion with MECCT | | | | | Departure from Nagoya and Arrival at Male | | | |
| 16 | Mon. | Discussion with MNPHI | | Move to Laamu Atoll | | | Discussion with subcontractor | Departure from Narita | Move to Laamu Atoll | |
| 17 | Tue. | Discussion with NDMA | | Site survey at Fonadhoo island | | | Move to Laamu Atoll | Arrival at Male, move to Laamu Atoll | Site survey at Fonadhoo island | |
| 18 | Wed. | Discussion with MMS | | Site survey at Gan island | | | | | | |
| 19 | Thr. | Work in Sri Lanka for the other project | Discussion with subcontractor | Site survey at Maamendhoo island | | | | | | |
| 20 | Fri. | | Organizing documents Move to Laamu Atoll | Organizing documents | | | | | | Work in Bangladesh for the other project |
| 21 | Sat. | | Organizing documents | | | | | | | |
| 22 | Sun. | | Site survey and stakeholder meeting at Isdhoo island | | | | | | | |
| 23 | Mon. | | Site survey and stakeholder meeting at Maamendhoo island | | | | | | | |
| 24 | Tue. | | Site survey and stakeholder meeting at Gan island | | | | | | | |
| 25 | Wed. | | Site survey and stakeholder meeting at Fonadhoo island | | | | | | Work in Bangladesh for the other project | |
| 26 | Thr. | | Departure from Male | Move to Male | | | | | | |
| 27 | Fri. | | Arrival at Narita | Move to Addu | | | | | | |
| 28 | Sat. | | | Site survey and preparation for stakeholder meeting at Meedhoo island | | | | | | |
| 29 | Sun. | | | Stakeholder meeting at Meedhoo island | | | | | | |
| 30 | Mon. | | | Departure from Male | Administration works | | Move to Male | | | |
| 31 | Tue. | | | Arrival at Narita | Departure from Male | | Organizing discussion result | Survey on unit-price | | |

**Table 1.4.4 Schedule of Detailed Planning Survey (3rd Field Survey)(2/2)**

| | Day | Fukasawa | Omaru | Onaka | Mori | Miyagawa | Goto | Toyoda | Tsujio | Kusuhara |
|---|---|---|---|---|---|---|---|---|---|---|
| Jun. 1 | Wed. | | | | Arrival at Narita | Arrival at Singapore | Organizing discussion result | Survey on unit-price | Work in Bangladesh for the other project | Work in Bangladesh for the other project |
| 2 | Thr. | | | | | | | | | |
| 3 | Fri. | | | | | | Departure from Male | Organizing documents | | |
| 4 | Sat. | | | | | | Arrival at Nagoya | | Arrival at Male | |
| 5 | Sun. | | | | | | | Survey on unit-price | Discussion with EPA | Arrival at Male |
| 6 | Mon. | | | | | | | Discussion with MTCC | Discussion with MECCT | |
| 7 | Tue. | Work in Sri Lanka for the other project | | | | | | Discussion with Hevey Force | Discussion with MMS | Departure from Male |
| 8 | Wed. | | | | | | | Discussion with Trading Company | Departure from Male | Arrival at Narita |
| 9 | Thr. | | | | | | | Survey on unit-price | Arrival at Narita | |
| 10 | Fri. | | | | | | | Organizing documents | | |
| 11 | Sat. | | | | | | | | | |
| 12 | Sun. | | | | | | | Discussion with MECCT | | |
| 13 | Mon. | Move to Male from Colombo | | | | | | Departure from Male | | |
| 14 | Tue. | Discussion with MECCT, planning for forthcoming activities | | | | | | Arrival at Narita | | |
| 15 | Wed. | | | | | | | | | |
| 16 | Thr. | | | | | | | | | |
| 17 | Fri. | Organizing documents | | | | | | | | |
| 18 | Sat. | | | | | | | | | |
| 19 | Sun. | Discussion with MECCT, Departure from Male | | | | | | | | |
| 20 | Mon. | Arrival at Narita | | | | | | | | |

(4) 4th Field Survey (July to September 2022)

Members: Fukasawa, Shibayama, Okaji, Miyagawa, Nagasawa, Toyoda, Ichikawa, Vuthy, Tokunaga, Goto, Tsujio

**Table 1.4.5 Schedule of Detailed Planning Survey (4th Field Survey) (1/3)**

| | Day | Fukasawa | Shibayama | Okaji | Miyagawa | Nagasawa | Toyoda | Ichikawa | Tokunaga | Vuthy | Goto | Tsujio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jul. 25 | Mon. | | | | Arrival at Male | | | | | | | |
| 26 | Tue. | | | | Procurement | | | | | | | |
| 27 | Wed. | | | | Move too Laamu | | | | | | | |
| 28 | Thr. | | | | Collection/installation of wave hunters | | | | | | | |
| 29 | Fri. | | | | | | | | | | | |
| 30 | Sat. | Departure from Narita and Arrival at Male | | | | | | | | | | |
| 31 | Sun. | Discussion with MECCT | | | | | | | | | | |
| Aug. 1 | Mon. | | Departure from Delhi | | Move to Male | | | | | | | |
| 2 | Tue. | Briefing to JICA Maldives Office | Arrival at Male<br>Briefing to JICA Maldives Office | Departure from Narita and Arrival at Male | Briefing to JICA Maldives Office | | | | | | | |
| 3 | Wed. | Move to Addu, and discussion with Addu City Council | | | | | | | | | | |
| 4 | Thr. | Site survey Meedhoo island and meeting with councils | | Sand borrowing survey at Addu atoll | | | | | | | | |
| 5 | Fri. | Organizing documents | | | | | | | | | | |
| 6 | Sat. | | | | | | | | | | | |
| 7 | Sun. | Site visit at Addu atoll | | | | Departure from Narita and Arrival at Male | | | | | | |
| 8 | Mon. | Move to Laamu via Male, | | | | Discussion with MMS<br>Move to Laamu | | | | | | |
| 9 | Tue. | Meeting with Laamu Atoll Council, site visit to Fonadhoo island and discussion with island council, move to Male (Shibayama) | | Sand borrowing survey at Laamu<br>Move to Male | Sand borrowing survey at Laamu atoll | Meeting with Laamu Atoll Council, site visit and discussion with island council | | | | | | |
| 10 | Wed. | Site visit and meeting with councils at Isdhoo island | Preparation of ICZM Seminar | Quarantine | | Site visit and meeting with councils at Isdhoo island | | | | | | |
| 11 | Thr. | Site visit and meeting with councils at Maamendhoo island | | | | Site visit and meeting with councils at Maamendhoo island | | | | | | |
| 12 | Fri. | Move to Male | Organizing documents | | Organizing documents | Move to Male | | | | | | |
| 13 | Sat. | Move to Manimadhoo | | | Sand borrowing survey at Laamu atoll | Move to Manimadhoo | | | | | | |
| 14 | Sun. | Site survey and meeting with MMS branch office at Manimadhoo island | Preparation of ICZM Seminar | | | Site survey and meeting with MMS branch office at Manimadhoo island | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 15 | Mon. | Move to Male | | Move to Addu via Male | | |
| 16 | Tue. | Discussion with MECCT | | Site survey at Addu | | |
| 17 | Wed. | Discussion with MECCT | | Move to Male | | |
| 18 | Thr. | Team meeting | Departure from Male | Team meeting | Departure from Male | |
| 19 | Fri. | Organizing documents | Arrival at Narita | Organizing documents | Arrival at Narita | |
| 20 | Sat. | | | Administration | | |
| 21 | Sun. | Meeting with MNPHI | | Departure from Male | | |
| 22 | Mon. | Monthly Meeting | | Arrival at Narita | | |
| 23 | Tue | Discussion with Minister, Discussion with NDMA | | | | |

**Table 1.4.6 Schedule of Detailed Planning Survey (4th Field Survey) (2/3)**

| | Day | Fukasawa | Shibayama | Okaji | Miyagawa | Nagasawa | Toyoda | Ichikawa | Tokunaga | Vuthy | Goto | Tsujio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aug. 24 | Wed. | Team Meeting | Discussion with EPA | | | | Departure from Narita and Arrival at Male | Departure from Haneda | | | | |
| 25 | Thr. | Briefing to State Minister, Discussion with MMS | | | | | Briefing to State Minister | Arrival at Male | | | | |
| 26 | Fri. | Organizing documents | | | | | Organizing documents | | | | Departure from Narita | |
| 27 | Sat. | Organizing documents | | | | | Organizing documents | | | | Arrival at Male | |
| 28 | Sun. | 1st ICZM Policy and Planning Seminar | | | | | 1st ICZM Policy and Planning Seminar | | | | | |
| 29 | Mon. | Arrival at Narita | Departure from Male | | | | Team meeting | | | | | |
| 30 | Tue. | | Arrival at Delhi | | | | Discussion with EPA | | | | | |
| 31 | Wed. | | | | | | Preparation of meeting materials | | | | | |
| Sep. 1 | Thr. | | | | | | Discussion with Land Survey Dept. | | | | | |
| 2 | Fri. | | | | | | Move to Laamu | | | | | |
| 3 | Sat. | | | | | | Site visit and Stakeholder Meeting at Fonadhoo island | | | | | |
| 4 | Sun. | | | | | | Site visit and Stakeholder Meeting at Isdhoo island | | | | | |
| 5 | Mon. | | | | | | Site visit and Stakeholder Meeting at Gan island | | | | | |
| 6 | Tue. | | | | | | Site visit and Stakeholder Meeting at Maamendhoo island | | | | | |
| 7 | Wed. | | | | | | Discussion with Laamu Atoll Council | | | | | |
| 8 | Thr. | | | | | | Stakeholder Meeting Follow-up | | | | | |
| 9 | Fri. | | | | | | Move to Addu via Male | | | | | |
| 10 | Sat. | | | | | | Site survey at Meedhoo island | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 11 | Sun. | | | | Site visit and Stakeholder Meeting at Meedhoo island | | | | |
| 12 | Mon. | | | | Move to Male | | | | |
| 13 | Tue. | | | | Interview to contractors | Discussion with EPA | | Stakeholder Meeting | |
| 14 | Wed. | | | | | Discussion with MECCT, Report to JICA Maldives Office | | | |
| 15 | Thr. | | | | | Departure from Male | Discussion with MECCT | Departure from Male | Discussion with MECCT |
| 16 | Fri. | | | | Departure from Male | Arrival at Narita | Departure from Male | Arrival at Narita | Departure from Male |
| 17 | Sat. | | | | Arrival at Narita | | Arrival at Singapore | | Arrival at Nagoya |

**Table 1.4.7 Schedule of Detailed Planning Survey (4th Field Survey) (3/3)**

| | Day | Fukasawa | Shibayama | Okaji | Miyagawa | Nagasawa | Toyoda | Ichikawa | Tokunaga | Vuthy | Goto | Tsujio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sep. 20 | Tue. | | | | | | | | | | | Arrival at Male |
| 21 | Wed. | | | | | | | | | | | Meeting with MECCT<br>Move to Addu |
| 22 | Thr. | | | | | | | | | | | Meeting with Addu City Council<br>Site survey at Meedhoo island |
| 23 | Fri. | | | | | | | | | | | Move to Male |
| 24 | Sat. | | | | | | | | | | | Move to Laamu |
| 25 | Sun. | | | | | | | | | | | Meeting with Laamu Atoll Council<br>Meeting with Fonadhoo island council members<br>Site survey at Fonadhoo island |
| 26 | Mon. | | | | | | | | | | | Site survey at Maamendhoo island<br>Meeting with Maamendhoo island council members |
| 27 | Tue. | | | | | | | | | | | Move to Male |
| 28 | Wed. | | | | | | | | | | | Meeting with MECCT, move to Colombo |
| 29 | Thr. | | | | | | | | | | | Arrival at Narita (via Colombo) |

## 1.5 Concerned Organizations

(1) Counterpart Organization

Ministry of Environment, Climate Change and Technology (MECCT)

(2) Other Concerned Organizations

Ministry of National Planning, Housing and Infrastructure (MNPHI),

Environmental Protection Agency (EPA),

Local Government Authority (LGA)

National Disaster Management Authority (NDMA)

Maldives Meteorological Service (MMS)

Laamu Atoll Council,

Addu City Council

Isdhoo Island Council

Gan Island Council

Fonadhoo Island Council

Maamendhoo Island Council

Meedhoo Town Office

(3) Other stakeholders

Embassy of Japan in Maldives

## 1.6 Summary of Survey Results

### 1.6.1 Outline of Results

In the detailed planning survey, JET discussed with the Maldivian counterpart, MECCT, and other relevant organizations on the project contents, project implementation structure, and JCC structure. Based on these results, the PDM and PO were revised where necessary. The 1st JCC meeting was held on May 12, 2022, and the Minutes on the Meeting of the 1st JCC meeting were signed by MECCT and JET.

Upcoming plan is as follows.

- Revision of Record of Discussion: Febrary 2023

### 1.6.2 Main Discussion Results

(1) Structure and Schedule of the Project Implementation

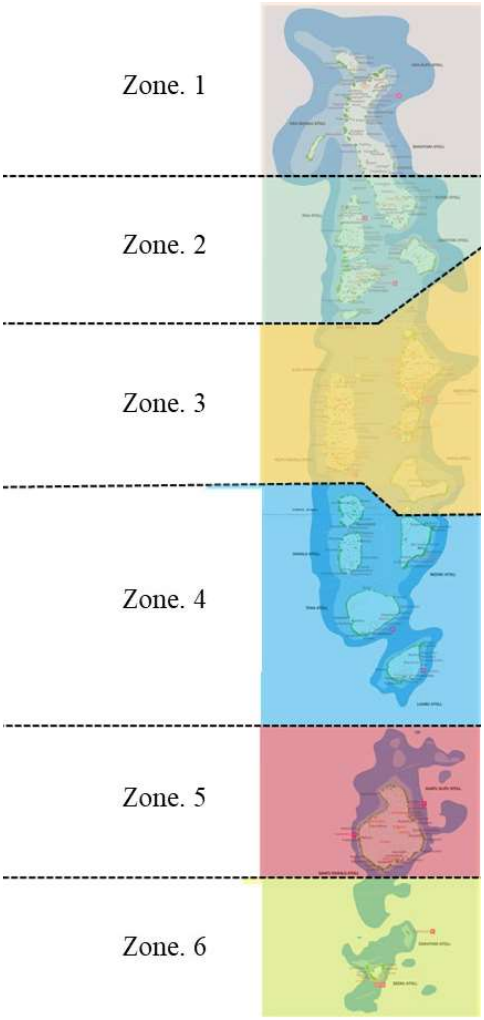
Outline of the Project including implementation structure and work schedules of the Project were explained by the JICA Expert Team (Team), and accepted in principle.

# CHAPTER 2 Current Status and Issues of Coastal Conservation in Maldives

## 2.1 Overview of Maldives

### 2.1.1 Regional Characteristics

Maldives is a Small Island Developing State (SIDS) spanning an area of 115,300 km2, stretching from north to south in the Indian Ocean, consisting of 26 atolls and about 1,200 islands. The land was formed by accumulation of coral sand and gravel due to wave, and is low-lying and narrow, with an elevation of about 1 to 2 m above the mean sea level. Figure 2.1.1 shows all land area of Maldives. In this figure, the atolls and islands are divided into six zones, which are based on the new administrative zones shown in the National Spatial Plan currently (as of September 2022) being prepared by MNPHI. Table 2.1.1 shows the regional classifications and administrative zones in each zone. The characteristics of atolls and reefs vary greatly from north to south depending on latitude. Atolls located in the north tend to have non-continuous margins and are composed of numerous ring-shaped coral reef formations called faroes, while atolls located in the south tend to have continuous islands and a smaller number of faroes.




Source: JICA Expert Team

**Figure 2.1.1 All Land Area of Maldives**

**Table 2.1.1 Regional Classification and Administrative Districts**

| Regional Classification | | Administrative Districts |
|---|---|---|
| Zone 1 | Upper North | 3 atolls<br>Haa Alifu, Haa Dhaalu, Shaviyani |
| Zone 2 | Lower North | 4 atolls<br>Noonu, Raa, Baa, Lhaviyani |
| Zone 3 | Upper Central | 4 atolls<br>Kaafu, Alifu Alifu, Alifu Dhaalu, Vaavu |
| Zone 4 | Lower Central | 5 atolls<br>Meemu, Faafu, Dhaalu, Thaa, Laamu |
| Zone 5 | Upper South | 2 atolls<br>Gaaf Alifu, Gaafu Dhaalu |
| Zone 6 | Lower South | 2 atolls<br>Gnaviyani, Seenu |

Source: JICA Expert Team

### 2.1.2 Population and Major Industries

Maldives has a total population of 533,9411 in 2019, distributed among 189 inhabited islands. Despite its geographical limitations, Maldives has made remarkable progress in its national development. Maldives per capita Gross Domestic Product (GDP) reached USD10,541 in 2019, while the Human Development Index (HDI) for the last decade (2010-2019) has shown an average annual growth rate of 0.86 %. Thus, considerable progress in the areas of health care, education, utilities, and basic infrastructure is reflected in a score of 0.72 on the HDI, placing Maldives in 101st place out of 189 countries. This is supported by an increase in life expectancy at birth of 15.6 years, an increase in average years of schooling of 2.2 years, and an increase in income of 216.2 %.

In 2019, the nominal GDP of Maldives was MVR 812.8 billion at market prices. Real GDP growth was 7%, with growth led by the tourism industry and public administration; the tertiary sector accounted for about 70% of GDP, with tourism accounting for the majority. This is followed by the secondary industry at 11.7% and the major industry at 5.2%. According to the Household Income and Expenditure Survey (HIES), the employment services sector accounted for 75% of the total, followed by the industrial sector at 18% and the primary sector at 8%, with tourism being the highest employer, while the public administration sector was the second highest employer. In the tourism sector, 1.2 million tourists visited the country in 2014, with China (363,000), Germany (98,000), and the United Kingdom (88,000) in descending order (Japan was the eighth largest, with 38,000).

Table 2.1.2 shows key geographic, industrial, and environmental statistics for the six zones. Region 3 has the largest population despite having the fewest number of islands and the smallest land area. The region is home to the capital city of Male, the fifth most densely populated city in the world in 2019. Its overcrowding has hampered urban prosperity and led to depopulation and abandonment in other areas. As a result, major atolls are expected to lose nearly one-third of their population by 2050. The city of Male is also home to Verana International Airport, the largest airport in Maldives and gateway to the country. It has a single runway 3,200 m long and 45 m wide. The largest reef terrain and the largest number of resort islands make tourism a major industry. This also implies that the main resource in the tourism industry in Maldives is the coast, which forms the reef terrain.

Compared to the more populated Region 3, Region 5 has the largest island area but less than half the population and the lowest population density. Region 1 has the largest island area, although the number of islands is small, but the number of resort islands is the second smallest after Region 6, and the size of agricultural islands is the largest. Region 2 has the second largest population after Region 3, where the capital city of Male, is located, but the number of islands and area is larger than in Region 3. The industry is relatively similar to that of Region 3, with many resort

islands, but there are also a large number of inhabited and agricultural islands. When compared overall, Region 4 has the second largest number of islands and inhabitant islands in size overall, and since there are many resort and agricultural islands, both industries are conducted in comparison to other regions. Region 6 has the smallest size in terms of both number of islands and area, and the absence of agricultural islands indicates that agriculture is not practiced there.

Youth unemployment is relatively high at 7.3% (HIES 2019) with low rates of women participating in the workforce. Furthermore, although poverty is declining, 28% of the population is multidimensionally poor, with access to basic services identified as one of the key deprivations. A comparison of the number of inhabited, agricultural, and resort islands, an indicator of islands, shows a similar trend in the number of inhabited and agricultural islands, with the exception of Region 3, where more inhabited islands are also more agricultural.

**Table 2.1.2 Key Statistics for Each Region (Geography, Industry, Environment)**

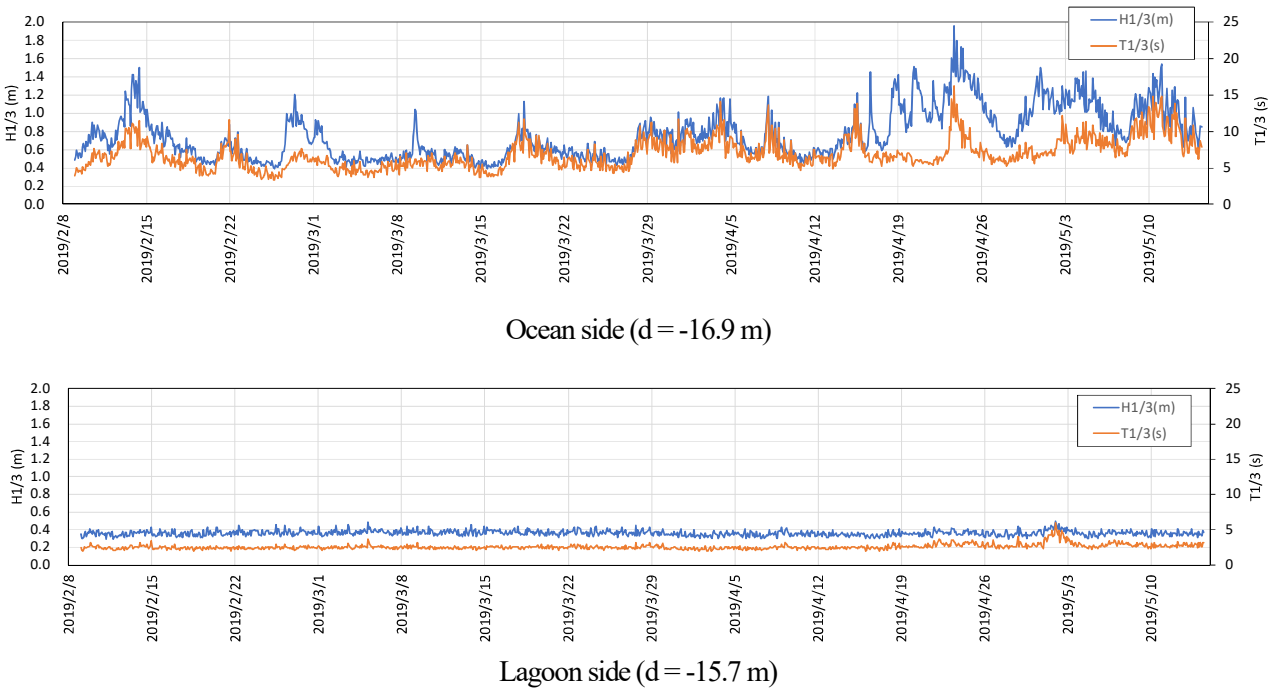
| Region | Total Population | All Islands (Area: ha) | Inhabited Islands (Area: ha) | Agricultural Islands (Area: ha) | Reef (ha) | Resorts (Area: ha) | Airport (Domestic : D) (International : I) |
|---|---|---|---|---|---|---|---|
| Zone 1 | 54,670 | 132<br>(5,895) | 41<br>(4,038) | 7<br>(517) | 56,851 | 21<br>(397) | D: 3<br>I: 1 |
| Zone 2 | 68,900 | 384<br>(4,738) | 45<br>(2,136) | 23<br>(335) | 60,729 | 100<br>(1,337) | D: 2<br>I: 1 |
| Zone 3 | 73,761 | 300<br>(3,112) | 35<br>(1,938) | 3<br>(23) | 125,219 | 109<br>(729) | D: 1<br>I: 1 |
| Zone 4 | 50,072 | 329<br>(4,440) | 43<br>(2,894) | 10<br>(170) | 95,553 | 51<br>(496) | D: 4 |
| Zone 5 | 29,220 | 258<br>(3,228) | 18<br>(1,279) | 4<br>(151) | 39,944 | 32<br>(327) | D: 3 |
| Zone 6 | 35,638 | 37<br>(1,960) | 7<br>(1,508) | 0<br>(-) | 3,940 | 9<br>(140) | D: 1<br>I: 1 |

Source: JICA Expert Team

### 2.1.3 Weather and Maritime Characteristics

The climate in Maldives is hot and humid, with an average temperature of 26 ~ 33 ℃ throughout the year. It is divided into two seasons: the northeast monsoon season from November to April, and the southwest monsoon season from May to October. Strong winds tend to be more frequent during the northeast monsoon season, and the rainy season (May to November), the southwest monsoon season, has more precipitation than the dry season (November to April), the northeast monsoon season. In addition, because Maldives is located near the equator, the probability of cyclones is extremely low, with only 11 occurring between 1877 and 2004, a period of 117 years. Most of these cyclones are concentrated north of 6 degrees north latitude. It is therefore considered that the occurrence of extreme high waves in Maldives is extremely rare. In coral reef areas such as Maldives, waves propagating from offshore go through the reef slope, break at the reef edge, and then propagate along the reef flat before reaching the shore. The wave characteristics change significantly both inside and outside the reef edge due to wave set-up and wave breaking. In addition, since the islands of Maldives are formed on the edge of atolls, the wave characteristics differ greatly between ocean side and lagoon side. In order to clarify these differences in wave characteristics between the reef topography and inside and outside the atolls, seabed-mounted wave gauges were installed inside and outside the atolls and inside and outside the reefs, and simultaneous wave and water level observations were conducted. Figure 2.1.2 shows the change over time of significant wave height (H1/3) and period

(T1/3) from February to May 2019 outside the reef on the ocean and lagoon side.




Source: JICA Expert Team

**Figure 2.1.2 Time series of Significant Wave Height (H1/3) and period (T1/3)**

The results show that wave heights on the ocean side fluctuate in response to meteorological disturbances, with H1/3 = 0.5 m in normal conditions and H1/3 = 2 m during high waves. The period is usually T1/3 = 6 to 8 s, but swells of about 15 s have been measured during high waves. On the lagoon side, on the other hand, there was no significant variation in both wave height and period, with H1/3 being about 0.4 m and T1/3 being about 2 or 3 seconds, almost constant.

### 2.1.4 Coral Reefs

Coral reefs form the basis of land in Maldives and support the main industries of tourism and fisheries. However, they are susceptible to stress due to rising sea temperatures caused by development activities and climate change. Prior to the major coral bleaching event of 1998, only partial bleaching was observed in three atolls in the central part of Maldives. However, in 1998, the most extensive coral bleaching event in recent years occurred in Maldives and throughout the Indian Ocean, and it is estimated that 90% of shallow water corals died as a result of the coral bleaching event throughout Maldives. As a result, coral coverage throughout Maldives is said to have declined from 50 % to 10 %. The degree of damage varied by species, with Acropora species declining while massive corals (e.g. Porites) and encrusting corals (e.g. Pavona, Leptastrea) survived. Thereafter, there were some events that affected coral growth, such as the mild bleaching event in 2010, the tsunami in 2014, and the outbreak of crown-of-thorns starfish in 2015, but overall, corals are recovering, and in 2014, coverage is said to have recovered to the status prior to the 1998 bleaching event. The tsunami in 2014 only reduced the degree of coral recovery and did not result in mortality as did the bleaching event. In addition to the bleaching event, development activities such as sand dredging for development and dredging and reclamation associated with coastal development have also increased damage to corals. However, El Nino of 2015-2016 and the subsequent sea surface temperature anomaly of 2016 caused the

first large scale coral bleaching event since 1998. Rising sea surface temperatures are the main stress that causes coral bleaching, and prolonged increases in sea surface temperatures accelerate coral bleaching. The survey conducted in 2017 found that 73 % of the 71 sites (11 atolls) surveyed had coral bleaching events. The degree of bleaching by depth showed that corals inhabiting depths between 7 and 13 m were more affected by bleaching than those inhabiting depths below 7 m. Comparisons between ocean side and lagoon side showed little difference in bleaching conditions.

## 2.2 Inventory Study on Coastal Conditions

### 2.2.1 Regional Characteristics

Inventory study was conducted to grasp the regional characteristics of coastal conditions and coastal disaster risk for 189 inhabited islands in Maldives. Table 2.2.1 shows categories and indicators used to grasp the regional characteristics. Zone categories (Zone 1-6) were referred to those of MNPHI which is presented in Chap. 2.1.

**Table 2.2.1 Categories and Indicators used to Grasp Regional Characteristics**

| Category | Indicator | Source |
|---|---|---|
| Natural Condition | Wave height due to Cyclone Swell, Tsunami | ERA5 |
| | Coastal erosion | Interview survey to Island Councils, VPA II (2004) |
| Geographical Condition | Average area of Island | Isles 2022 |
| | Elevation of Island | Survey in this study, Japanese book on global warming and natural disasters (Kokon shoin, 2009) |
| Socio-economic Condition | Population density | Data provided by MNPHI (2022, confidential) |
| | No. of beds in resort Islands | |
| | Ratio of reclamation | |
| Environmental Condition | Ratio of reef area | |

Source: JICA Expert Team

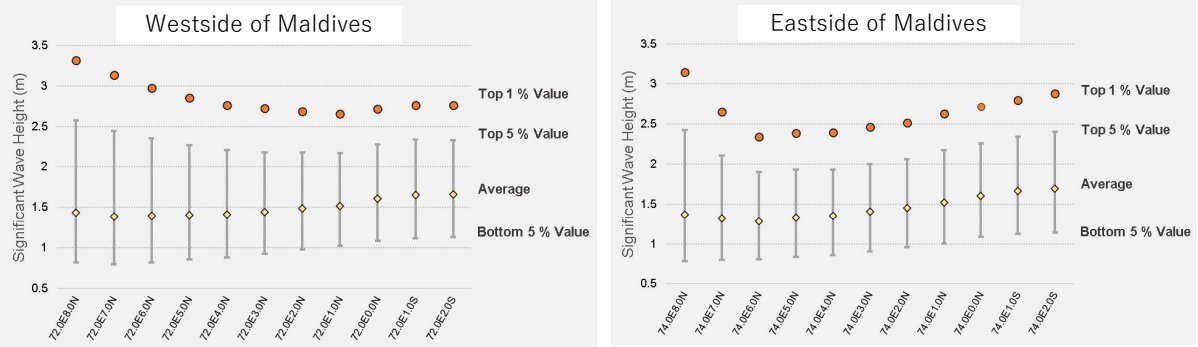
#### (1) Natural Condition/ Wave Height due to Cyclone, Swell, Tsunami

Offshore wave condition in Maldives, significant wave height and wave direction over 40 years were extracted from ERA 5 and organized and plotted in Table 2.2.2 and Figure 2.2.1, respectively.

**Table 2.2.2 Top 5 % Average of Significant Wave Height**

| Latitude | West side | East side |
|---|---|---|
| 8° N | 2.57 m | 2.43 m |
| 7° N | 2.44 m | 2.11 m |
| 6° N | 2.35 m | 1.90 m |
| 5° N | 2.27 m | 1.93 m |
| 4° N | 2.21 m | 1.93 m |
| 3° N | 2.18 m | 2.00 m |
| 2° N | 2.18 m | 2.06 m |
| 1° N | 2.17 m | 2.17 m |
| 0° N | 2.28 m | 2.26 m |
| -1° N | 2.34 m | 2.34 m |
| -2° N | 2.33 m | 2.40 m |

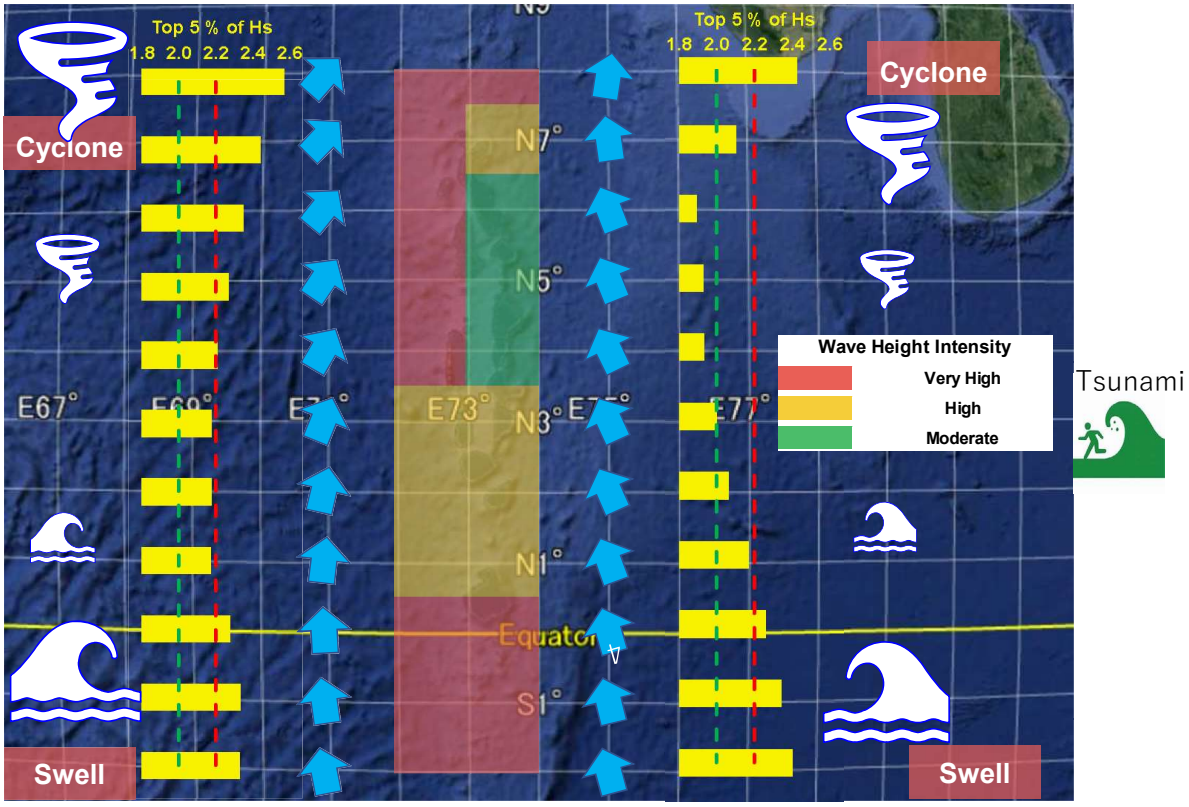
Source: Extracted by JICA Expert Team from ERA5




Source: Organized by JICA Expert Team from ERA5

**Figure 2.2.1 Wave Height for West and East Side of Maldives by Latitude**

Table 2.2.2 shows that in general wave height is higher in the North and South regions and is relatively smaller in the Central regions. In north regions top 1% or 5% average wave height is larger than the others while the normal average wave heigh is lower. This indicates that the northern regions are more affected by Cyclone, which is extreme but low-frequency event in Maldives. The south region near the equator, on the other hand, is much affected by the swell waves developed by SW monsoon.



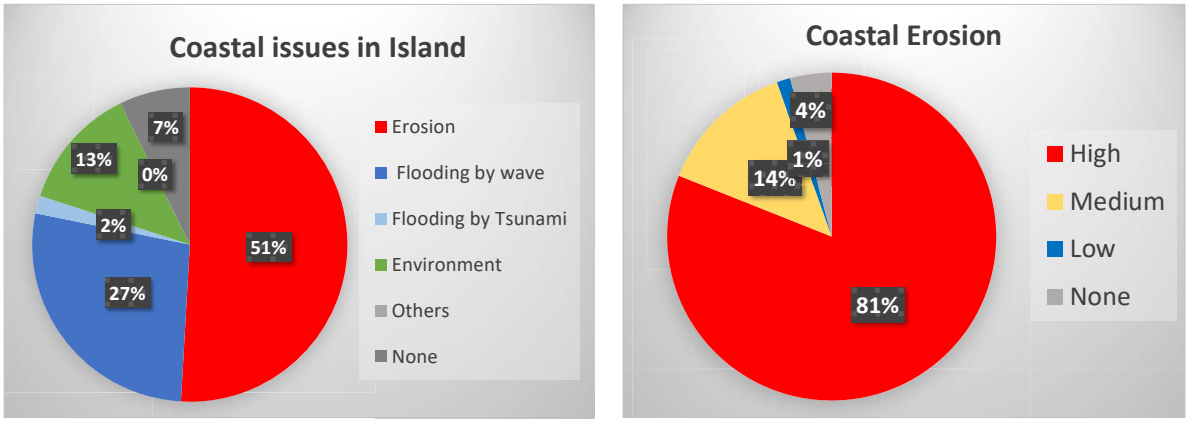

Source: Organized based on ERA5 by JICA Expert Team

**Figure 2.2.2 Wave Height and Direction in Maldives**

### (2) Natural Condition/ Coastal Erosion

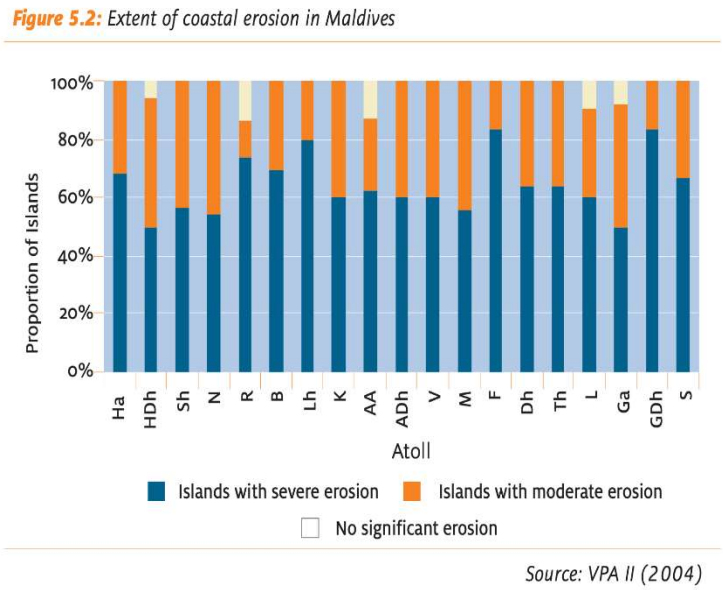
Questionnaire survey was conducted to grasp the situation of coastal erosion in Maldives. About 74 replies out of 189 from the Island councils were collected as of September in 2022. From the tentative results of the questionnaire shown in Figure 2.2.3 (left), more than 50 % of respondents replied that "coastal erosion" is the main coastal issue of the Island and "Flooding by Wave" and "Environment" shared with 27 % and 13 %, respectively.

In Figure 2.2.3 (right), more than 80 % recognized that severity of coastal erosion is "high". Figure 2.2.4 shows a similar questionnaire result conducted in 2004, in which the ratio who answered that "coastal erosion is severe in his/her Island" shared about 60%-70%. If allowing to compare these two results from the same perspective, it indicates that situation of coastal erosion is getting severer with 10 - 20 points in recent years. Regarding the situation of coastal erosion at Island, additional quantitative information such as MECCT's monitoring data will be incorporated in the analysis to obtain more comprehensive results.




Source: JICA Expert Team

**Figure 2.2.3 Questionnaire Survey Results: (Left) Coastal Issues at Island, (Right) Severity of Erosion**




Source: VPA II (2004)

**Figure 2.2.4 Investigation Survey on Coastal Erosion Conducted in 2004**

### (3) Geographical, Socio-economic Conditions

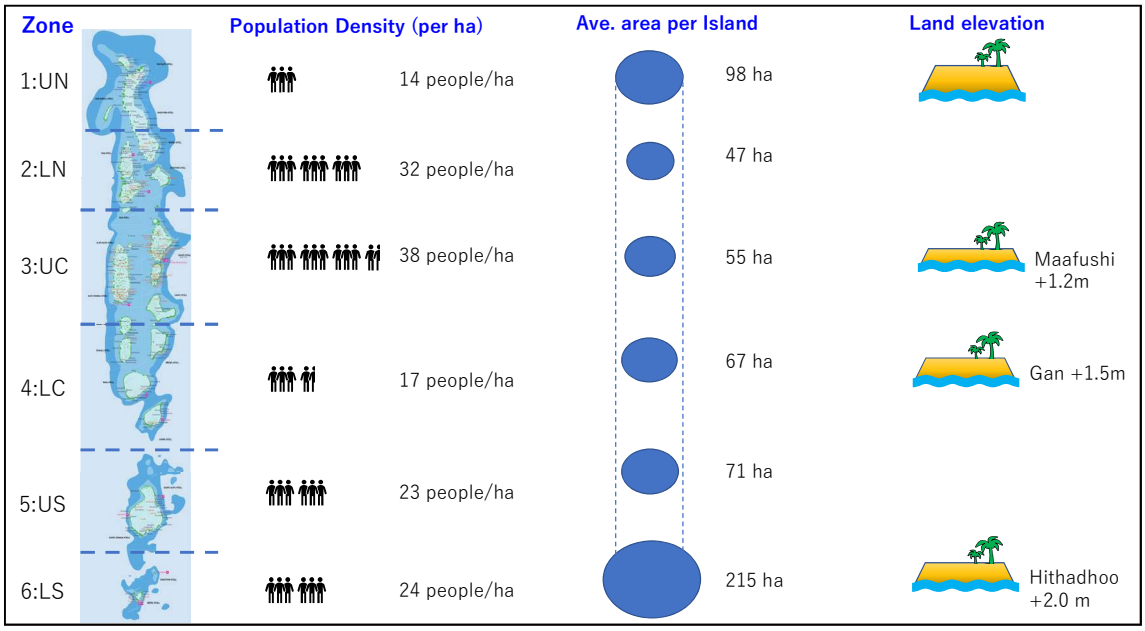
Regional characteristic in geographical and socio-economic aspects, which is mostly extracted from the MNPHI's statistics, are summarized in Table 2.2.3 and Figure 2.2.5 and Figure 2.2.6.

**Table 2.2.3 Summary of Regional Characteristics of Geographical, Socio-economic Conditions**

| Zone | Population Density | Ave. Area per Island | Elevation of Island | Ratio of Reclamation/ Land | Ratio of Reef/ Land | No. of Beds |
|---|---|---|---|---|---|---|
| 1: UN | 14 people/ ha | 98 ha | MSL + 3.0 m | 3 % | 10 times | 750 |
| 2: LN | 32 people/ ha | 47 ha | N/A | 7 % | 13 times | 10,200 |
| 3: UC | 38 people/ ha | 55 ha | MSL + 1.2 m | 15 % | 40 times | 18,600 |
| 4: LC | 17 people/ ha | 67 ha | MSL + 1.5 m | 11 % | 22 times | 3,800 |
| 5: US | 23 people/ ha | 71 ha | N/A | 13 % | 12 times | 1,800 |
| 6: LS | 24 people/ ha | 215 ha | MSL + 2.0 m | 7 % | 1 times | 900 |

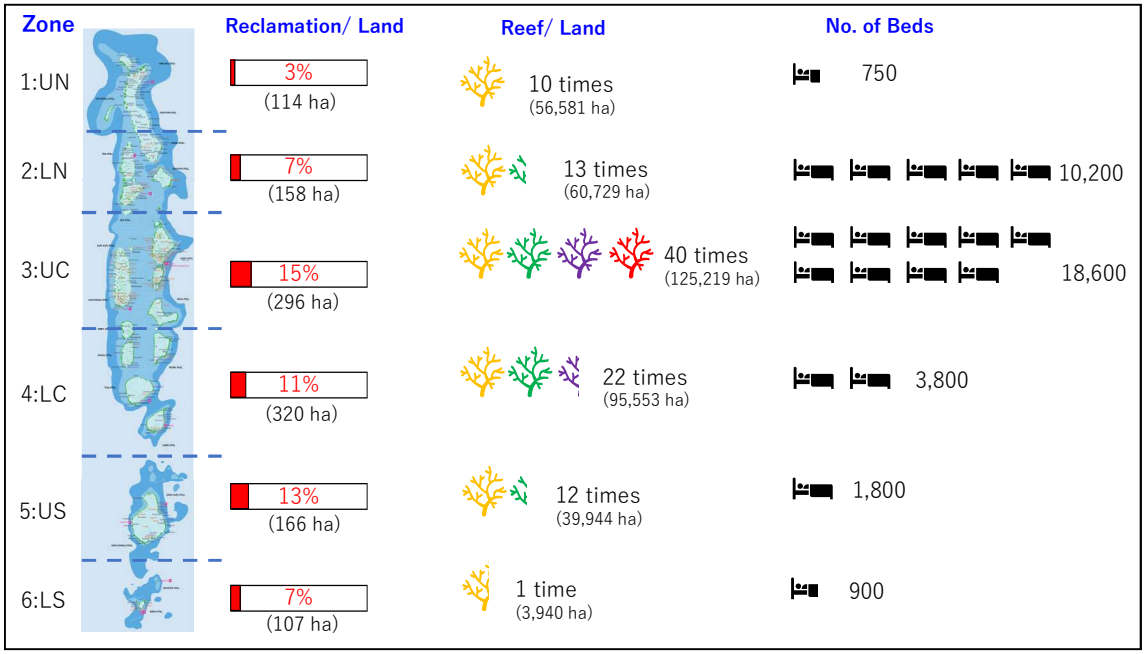
UN: Upper North, LN: Lower North, UC: Upper Central, LC: Lower Central, US: Upper South, LS: Lower South

Source: Organized by JICA Expert Team based on MNPHI data and Isles 2022




Source: JICA Expert Team

**Figure 2.2.5 Comparison of Regional Characteristics 1/2 (population density, Ave. of land area and elevation of Island)**




Source: JICA Expert Team

**Figure 2.2.6 Comparison of Regional Characteristics 2/2 (reclamation ratio, ratio of reef area and No. of beds)**

Regional characteristics are listed as follows and Figure 2.2.7 shows a schematic figure of the trend overall. These results show that regional characteristics in Maldives quite differs from north to south by zones in terms of natural, geographical, socio-economic conditions. This indicates that there are the islands which have different characteristics from Gan and Fonadhoo, which both are in Zone 4 and are the target Islands for ICZM concrete plan. Thus it is important to conduct a field investigation on these Islands to identify and incorporate their characteristics into ICZM plan to realize its broader utility of application to other Islands in Maldives.

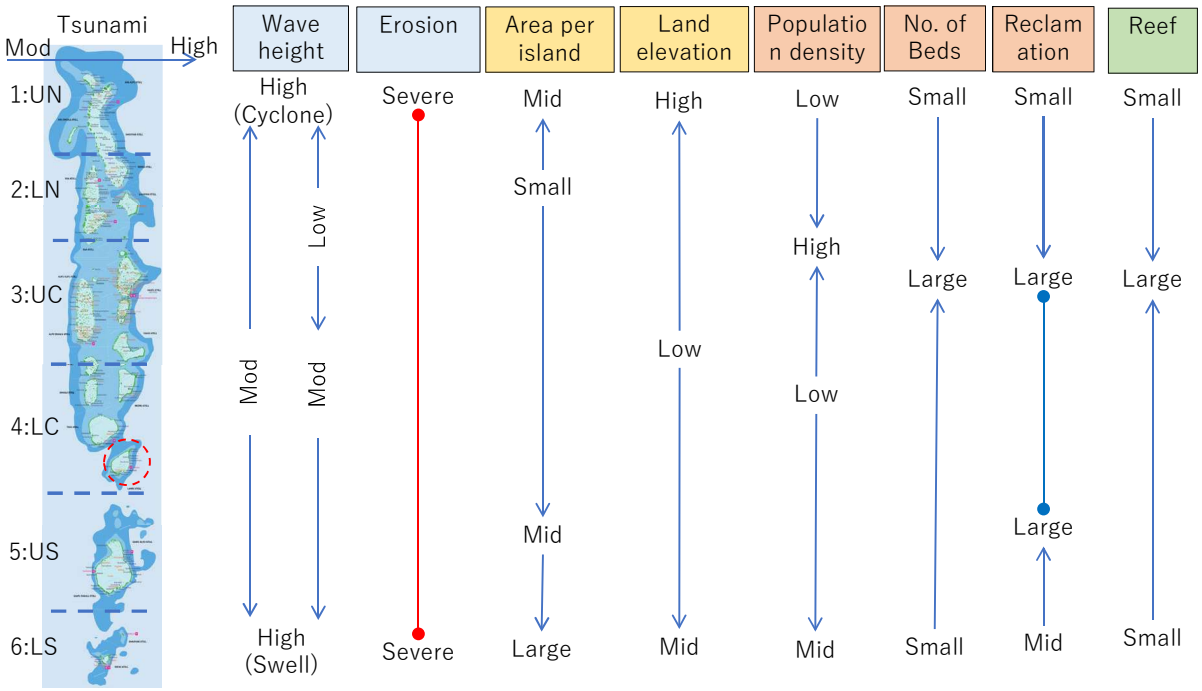
- Population density: Zone 3, at which Male the capital of Maldives is located, shows the highest population density and Zone 2 in north region and Zone 5, 6 in south follows. Zone 1 has the lowest population density.
- Average area per island: Zone 6 in south region has the largest area, which is about twice of the second largest in Zone 1. The top three largest islands are listed below and it can be observed that islands with larger land area are mostly located at south region.

  1st largest Island Gan (Zone 4, Laamu Atoll): 596 ha (Isles 2022)

  2nd largest Island Hithadhoo (Zone 6, Addu Atoll): 527 ha (Isles 2022)

  3rd largest Island Fuvahmulah (Zone 6, Gnaviyani Atoll): 492 ha (Isles 2022)
- Land elevation: North region has the highest elevation and the south region follows, while the central region has the lowest land elevation. Considering that national land of Maldives had been formed by coral rock and sand transported by waves over the years, it is assumed that the distribution of land elevation shows similar trend of wave height (eg. higher land elevation has been formed by higher wave and vise versa). This indicates that the islands of Maldives originally have a function to follow the climate change such as sea level rise or high wave to a certain extent.

- Ratio of reclamation/ land: This indicator was referred as a degree of artificial development at coastal area. Zone 3 has the highest ratio with 15 % and Zone 4 has the largest reclamation area with 320 ha. On the other hand, Zone 1 has the smallest ratio with 3 % and Zone 2 and 6 are about 7 %.
- Ratio of reef/ land: This indicator was referred as a degree of richness of natural environment. Zone 3 shows the highest with 40 times (reef area: 125,219 ha), then Zone 4 follows with 22 times. Zone 1, 2 and 5 shows about 10 times and Zone 6 in south shows the smallest value with 1 time (reef area: 3,940 ha).
- No. of beds of resorts: This indicator was referred as degree of tourism economy of Atoll or Zone to which islands belong. Zone 3 and 2 has much larger number of beds than the others, especially comparing with Zone 1 and 6. Causes for this trend is considered as follows:
  - Resort islands in Zone 3 has the most convenient access from the International Airport for foreign tourists
  - Zone 3 and 2 are located at relatively calm wave region in Maldives
  - There is a lot of islands with small area which are suitable for resorts development at Zone 3 and 2 comparing to the other zones
  - Large and wide reef area exists in Zone 3 and 4 as an attractive destination for tourist




Source: JICA Expert Team

**Figure 2.2.7 Overall Trend of Regional Characteristics in Maldives**

### 2.2.2 Classification of Islands

With consideration of applicability of ICZM plan, inhabited Islands in Maldives were firstly classified into 3 types based on the degree of development of coastal area as shown in Table 2.2.4.

**Table 2.2.4 Classification of Islands by Degree of Development of Coastal Area**

| Type-1<br>Lower developed | Type-2<br>Highly developed | Type-3<br>Intermediate |
|---|---|---|
| • Low population/ density<br>• Natural coast and no or least reclamation | • High population/ density<br>• Reclamation and less natural beach (developed or protected) | • Intermediate population/ density<br>• Some natural coast remains |
|  <br>e.g Mulhadhoo in Haa Alif Atoll |  |  <br>e.g. Fonadhoo in Laamu Atoll |

Source: Organized by JICA Expert Team based on Google Map

Table 2.2.5 shows the evaluation on necessity and urgency to adopt ICZM plan for each type of Island. Necessity to apply ICZM is evaluated as "high" for Type-1 and Type-3 because some natural coast remains in both types, which means there is a certain room to apply ICZM to coordinate with and control on coastal development in future. On the other hand, Type-2 was evaluated as "middle" because most of coastal area has been developed or protected, therefore, there would be less room for the application of ICZM, which could be limited only with ex-post measures such as maintenance and management work.

Urgency to apply ICZM is evaluated as "middle" for Type-1 due to the least development at coastal area. On the other hand, it was evaluated as "high" for Type-3 because coastal development is in progress in these islands, and it has a risk that whole coastal area will be mostly developed similar to that of Type-2 in near future without application of ICZM at early stage. In other words, there is a certain room for Type-3 to conserve coastal area by balancing protection, environment and beach use through ICZM policy and planning. Type-2 was evaluated as middle because most coastal area has been already developed and protected.

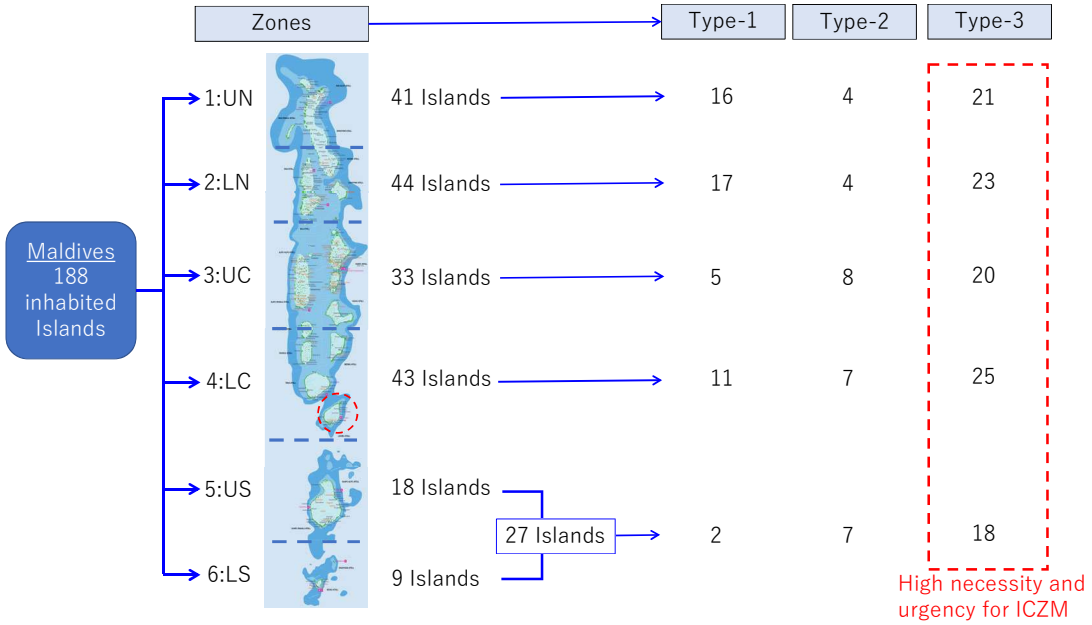
In this study, therefore, the Type-3 is the priority islands for ICZM to apply. Number of Islands for each type is shown in Table 2.2.5 and Gan and Fonadhoo Islands (ICZM target Islands) are classified into Type-3 as well.

**Table 2.2.5 Necessity and Urgency for ICZM to Apply**

| | Type-1<br>Lower developed | Type-2<br>Highly developed | Type-3<br>Intermediate |
|---|---|---|---|
| Necessity of ICZM | High<br>(Room to control development at coastal area) | Middle<br>(Most coastal area developed) | High<br>(room to control development at coastal area) |
| Urgency of ICZM | Middle<br>(Least development progress) | Middle<br>(Most coastal area developed) | High<br>(Development in progress) |
| No. of Islands | 51<br>Population > 1,000 and Population density < 3,000 (median value) | 30<br>· Confirmed on development condition by satellite images<br>· Referred to population and its density | 107<br>Other than Type-1 and 2 |

Source: JICA Expert Team

Figure 2.2.8 shows the classification of islands with zones shown in Sec. 2.1.1 and with island's types shown in the previous Table 2.2.6. When counting number of islands, Zone 5 and 6 were combined for convenience as the number of islands is smaller compared with the other zones. It is concluded that islands in Type-3 for each zone has higher priority to apply ICZM policy and planning.




Source: JICA Expert Team

**Figure 2.2.8 Classification of Islands based on Regional Characteristics and Development Condition at Coastal Area**

Furthermore, the Type-3 islands were classified into 4 categories by geographical and location conditions as shown in Table 2.2.6. Regarding with geographical condition, the area of island was evaluated as "large" or "small" based on the average of land area (0.75 $km^2$ or 75 ha) in Maldives. Since islands with large area have longer shoreline, the application area of ICZM, i.e. effectiveness of ICZM, will be also large for this case. On the other hand, island with smaller area in Type-3 has generally dense population near coastal area, therefore, benefit by applying ICZM is high even though the application area is limited.

Regarding with locations, it was classified as "ocean" or "lagoon". In case of "ocean", in general half of island's shoreline is facing at ocean and the other half is facing at lagoon. Since natural condition such as wave and erosion and even development condition is quite different between ocean side and lagoon side, ICZM has to be formulated considering such characteristics carefully. In case of "lagoon", though wave is smaller compared with that of ocean side, the shoreline is continuous in whole island, therefore, the impact of coastal development could spread all around of the island, which is one of the most important issues to be considered for ICZM for island located at lagoon.

**Table 2.2.6 Classification by Area and Location of Island**

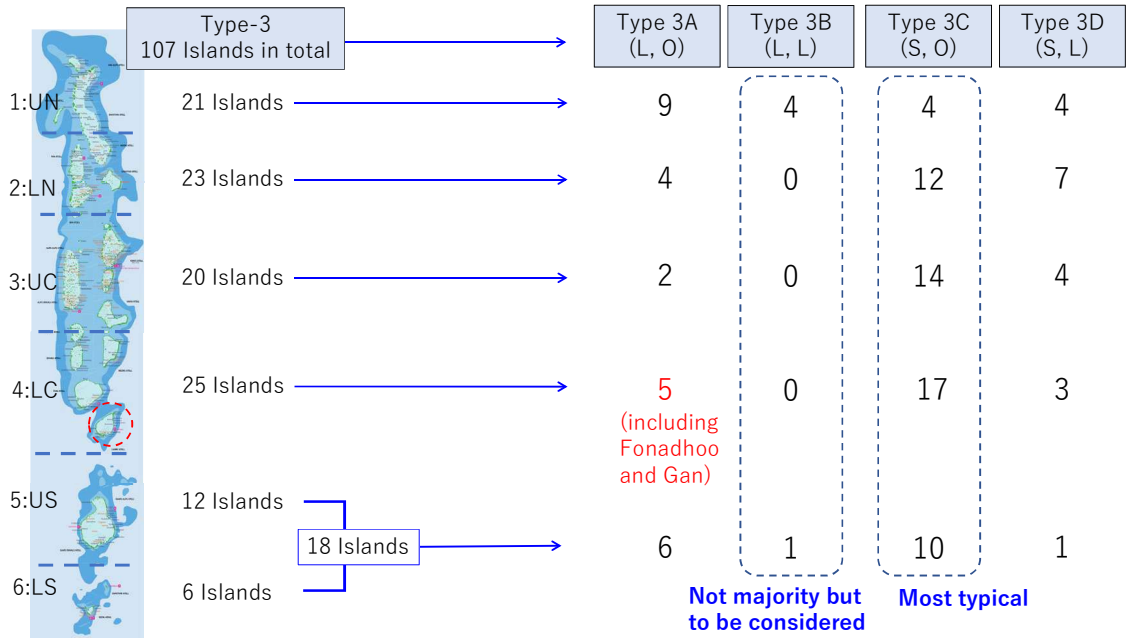
| | Type-3A | Type-3B | Type-3C | Type-3D |
|---|---|---|---|---|
| Area of Island | Large | Large | Small | Small |
| Location | Ocean | Lagoon | Ocean | Lagoon |
| Reference | Fonadhoo, Gan (Laamu Atoll) | - | - | - |

Source: JICA Expert Team

Figure 2.2.9 shows the classification results of Type-3 (107 islands) into the 4 categories (area and location). Fonadhoo and Gan in Laamu Atoll are classified into Type-3A, with large area and facing ocean.

Number of islands of Type-3B, with large area and located in lagoon, is the smallest among 4 categories, however, such islands can play an important role in residential and economic aspects, especially sea transportation, due to large land area and calm wave condition. Therefore, it is also important to understand the characteristics of these islands to reinforce the versatility of ICZM.

On the other hand, Type-3C, with small area and facing ocean, has the largest number of islands, which is the most major type of islands in Maldives. Since Type-3C in general is most vulnerable island against climate change impact, investigation survey to grasp typical characteristics is necessary for these types of islands.




Source: JICA Expert Team

**Figure 2.2.9 Classification of Type-3 Islands in terms of Land area and Location**

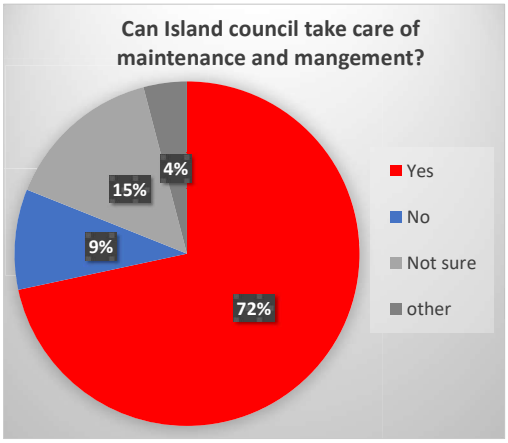
### 2.2.3 Selection of Candidate Island for Field Investigation Survey (in progress)

Among classified islands a few islands will be selected as candidates for field investigation survey. The selection will be conducted together with MECCT as a part of capacity development. Field investigation survey will be conducted after November 2022 together with MECCT. Idea for the selection criteria and candidate island were shown as follows.

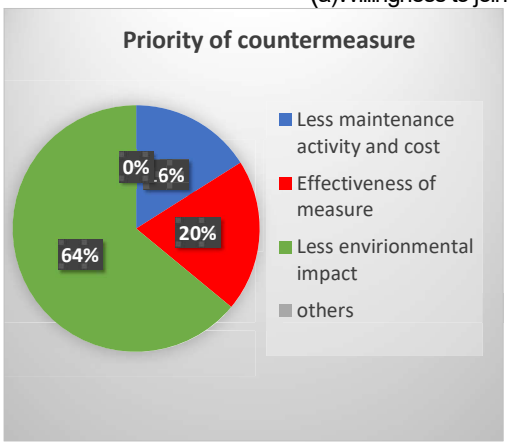
Firstly, the candidate islands are selected from the different types of Gan and Fonadhoo, which were already selected as target islands for concrete ICZM plan, to reinforce the versatility of the plan (i.e. other than zone 4 and/or other than Type-3A). The following selection criteria is considered.

- Selection criteria 1: Policy on coastal development by Island Council
- Selection criteria 2: Willingness to participate coastal management activity by Island Council
- Selection criteria 3: Vulnerability against coastal disaster (degree of severity and frequency)

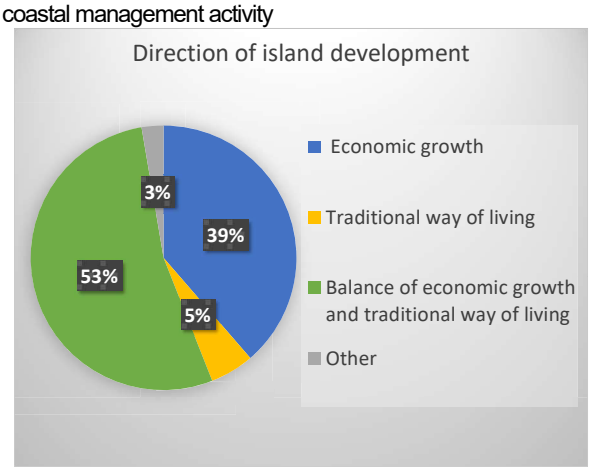
Regarding with the criteria 1 and 2, the questionnaire survey results on coastal conditions (implemented together with MECCT in this study and received sample number was 74 out of 189 as of September 2022) can be used. Figure 2.2.10 shows the tentative results of the questionnaire. As for the criteria 2, more than 70 % of respondents replied that they are willingly to join the coastal management activities as shown in Figure 2.2.10 (a). As for criteria 3, more than 60 % of respondents replied that to minimize environment impact is the factor of priority to select type of coastal conservation measures. As for policy on island development, 50 % of respondents put priority on balancing economic growth and traditional way of living while 40 % of them did only on economic growth. Since these aspects are important factors to realize the ICZM, it will be effective to select islands who showed positive and similar policy for ICZM activities.




(a)Willingness to join coastal management activity




(b) Priority factor for coastal conservation measure




(c) Policy on island development

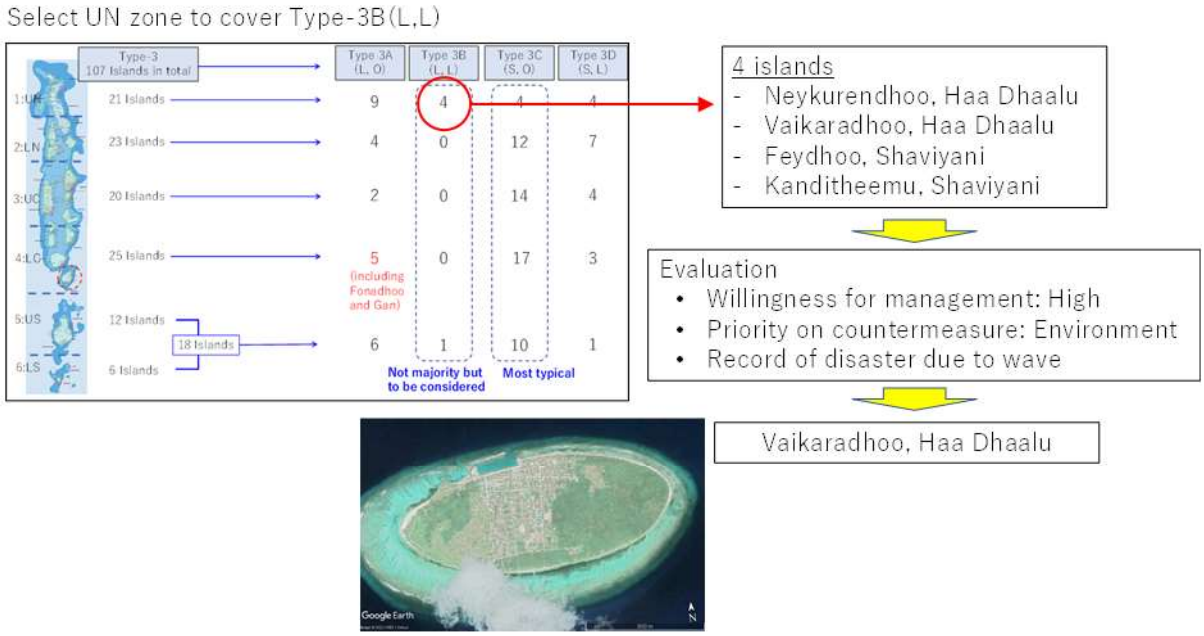
Source: JICA Expert Team

**Figure 2.2.10 Questionnaire Survey Results on Coastal Conditions**

**< Case Examples of the Selection >**

A case example to select island for field survey investigation is shown as follows. This example shows the case to select island from Type-3B.

Since Gan and Fonadhoo are located at southern part, northern part is selected as candidate area considering the difference in regional characteristics. There are four (4) candidate islands in northern part for Type 3B, which are Neykurendhoo, Vaikaradhoo, Feydhoo and Kanditheemu as shown in Figure 2.2.11. Regarding with selection criteria 1-3 abovementioned, Vaikaradhoo (Haa Dhaalu) is selected as 1) willingness for coastal management (criteria 1) is high, 2) putting priority for environment impact (criterial 2), and 3) the island suffered coastal disaster due to high waves recently.




Source: JICA Expert Team

**Figure 2.2.11 Case Example to Select Island for Field Investigation Survey**

## 2.3 Relevant Legislation, Policy and Plan of ICZM

### 2.3.1 Legislation

The legislations of the Maldives are mainly prepared by the national language, Dhivehi, and there are few English translated legislations available. Therefore, the data collection survey of laws and regulations on coastal zone management in Maldives was carried out by outsourcing to the Fidelis Law Group (hereinafter referred to as "Fidelis"), the Maldivian law firm, to study the legal system of the Maldives, collect laws and regulations regarding ICZM, prepare the table of contents and the summary and translate some parts of the collected laws and regulations. In this section, the laws and regulations regarding ICZM that needs to be considered in the Project and may be referred when considering the ICZM are identified by examining the collected and summarized information and understanding the outline of the legal system of the Maldives. The identified laws and regulations will be a base of the Phase 2 activity of the Project, in which ICZM Policy and Plan to be formulated through the discussions with the counterpart and relevant government agencies.

### (1) Legal System of the Maldives

For the fundamental understanding of the legal system of the Maldives that require legislations on ICZM, the Constitution, legislation, law-making power, executive power, judiciary, decentralization, compositions and roles of the decentralized councils, and relation of the international treaties and domestic legislations are described in below.

a) Constitution and Legislation

Maldives is a sovereign, independent, democratic Republic based on the principles of Islam and is a unitary State known as the Republic of Maldives. The current Constitution of the Maldives (Constitution) was ratified on 7th August 2008. Constitution states that all the powers of the State shall be exercised in accordance with it. slam is the State Religion and as such Islam is the basis of all laws of the Maldives and no law contrary to any tenet of Islam can be enacted in the Maldives. The current Constitution of the Maldives guarantees substantive democratic principles such as separation of powers, introducing a presidential governance system with a multi-party system, a parliament (called the 'People's Majlis') entrusted with law-making powers and strong oversight functions and an independent judiciary run by an independent commission.

A very central provision in the current Constitution is the introduction of the decentralized administration system of the Maldives. Article 230 (b) of the Constitution states that in order to provide for the decentralized administration, the President has the power as provided in law to create constituencies, posts, island councils, atoll councils and city councils.

Any amendment to the Constitution maybe introduced by a Bill in the People's Majlis which must be passed by a three quarters majority of the total membership of the People's Majilis. The Bill amending the Constitution passed by the People's Majlis shall come into force upon obtaining the written assent of the President. Furthermore, 'law' is defined in the Constitution as those statutes enacted by the People's Majlis and assented to by the President and those regulations which are authorized by and which fall within the ambit of those statutes. The Constitution states that every Bill assented to by the President shall be published in the Government Gazette on the day of assent and such law shall come into force when it is published in the Government Gazette or on such later date following publication stipulated in the statute.

Any bylaw or decision of a local authority is subject to Acts or Regulation of the People's Majlis. All statutes, regulations, government orders requiring compliance by citizens and government policies shall be published and made available to the public. All information concerning government decisions and actions shall be made public except information that is declared to be State secrets by a law enacted by the People's Majlis. Table 2.3.1 shows the type of legislations, organizations to enact/issue and procedure to entry in force for each type of legislations.

**Table 2.3.1 Types of Legislation, Organizations to Enact/Issue and Entry in Force and Binding**

| Types of Legislation | Organizations to Enact/Issue | Entry in Force and Binding |
|---|---|---|
| Acts of Parliament | - Enacted by the Parliament | - After an Act has been passed via the required majority in the Parliament, the President needs to give assent to it and becomes law after it is published in the Government Gazette/or on a specific date if the Act mentions it.<br>- It is binding law. |
| Presidential Decree | - Issued by the President by the Powers vested in him via the Constitution. | - It is published in the Government Gazette.<br>- Not legally binding on its own. |
| Juditial Precedent | - Judicial Precedents are set by the Court. Lower Courts are obligated to follow the precedents set by the Higher Courts.<br>- It is binding law. | |
| Regulation | - These are prepared by the relevant authorities such as the Ministries, Agencies, Offices and Institutions. | - The Regulations are developed and finalized by the relevant Government Agency. |

Source: JICA Expert Team

b) Law-making power, Executive power and Judiciary

The law-making power of the Maldives is vested in the People's Majlis, a unicameral body of elected members from each constituency of the Maldives for a term of five years. The express powers of the Parliament enshrined in the Constitution includes the power to enact legislation, supervision of the exercise of the executive authority and ensuring that the executive authority is accountable for the exercise of its powers.

The legislative process in the Parliament starts with a Bill introduced by the members of the Parliament. Bills introduced by the ruling party is known as the government Bills and Bills introduced by the rest of the members are known as private Bills. However, any Bill that imposes tax or additional charge on citizens that require a direct expenditure from public funds can only be submitted by the Government.

The executive power is vested in the President of the Maldives as provided for in the Constitution and the law. The President shall be the head of the State, Head of the Government and the Commander in Chief of Armed Forces. The President shall only exercise Executive Authority as provided for in the Constitution and law. The President hold office for a term of five years and no person elected as the President pursuant to this Constitution shall serve more than two terms in office whether consecutive or otherwise. The President shall be elected directly by the people by universal and secret suffrage. Elections for the office of President shall be held one hundred and twenty days to thirty days prior to the expiry of the existing presidential term. The President shall be elected by over fifty percent of the votes. There is a Vice President of the Maldives who assist the President in the discharge of his duties and responsibilities.

The President has the discretion to establish all ministries required within the Government and shall determine their areas of jurisdiction. The President is required to submit all information relating to the Ministries and their areas of jurisdiction to the People's Majlis for approval. The Cabinet consists of Vice President, the Ministers given responsibility for the different Ministries and the Attorney General. The President is required to submit to the People's Majlis within seven days of making appointments to the Cabinet the names of the appointees to the Cabinet for approval of the People's Majlis. Table 2.3.2 shows a list of Government Ministries and Affiliated Agencies of the Maldives.

**Table 2.3.2 Government Ministries and Affiliated Agencies of the Maldives**

| | |
|---|---|
| Attorney General | Ministry of Environment, Climate Change, and Technology |
| Ministry of Finance | Environmental Protection Agency |
| Ministry of National Planning, Housing, and Infrastructure | Maldives Meteorological Services |
| Ministry of Home Affairs | Utility Regulatory Authority |
| Ministry of Defense | Baa Atoll Biosphere Reserve Office |
| Ministry of Economic Development | National Centre for Information Technology |
| Ministry of Arts, Culture and Heritage | Communications Authority of Maldives |
| National Centre for Cultural Heritage | Ministry of Youth, Sports and Community Empowerment |
| Ministry of Transport and Civil Aviation | Ministry of Islamic Affairs |
| Maldives Transport Authority | Ministry of Fisheries, Marine Resources, and Agriculture |
| Ministry of Education | Maldives Marine Research Institute |
| Ministry of Higher Education | Ministry of Health |
| Ministry of Tourism | Local Government Authority |
| Ministry of Gender, Family and Social Services | |

Source: Noo Raajje Legal & Policy Framework Assessment Report - 27th July 2021

The judicial power is vested in the Supreme Court, the High Court and such Trial Courts as established by law. The Supreme Court is the highest authority for the administration of justice in the Maldives. The Chief Justice shall be the highest authority on the Supreme Court. All matters adjudicated before the Supreme Court shall be decided upon by a majority of the judges sitting together in a session. The Judges are independent and only subject to the Constitution and the law. When deciding matters on which the Constitution or the law is silent, judges are required to follow Islamic Sharia.

c) Decentralization and Composition and Roles of the Councils

The Article 230 of the Constitution states that the administration of the divisions in the Maldives should be administered via decentralization, and in this regard, the President has the power by virtue of law to create constituencies, posts, island councils, atoll councils and city councils. The Act on Decentralization 2010 (hereinafter referred to as 'DA 2010') was passed in order to provide for the decentralized governance in the Constitution of the Maldives. Under the DA 2010, the Local Government Authority (LGA) was formed as the respective government body that was assigned with the main oversight function of the councils. The DA 2010 was centred around devolving the government and giving more powers to the atoll, island and city councils to enhance community empowerment and to bring public services closer to the people. Since the introduction of the DA 2010, it was always a piece of legislation that was always targeted by the government of the day and it has experienced a series of amendments that was introduced either to reverse the previous government's policy or introduce new policy changes. The DA 2010 saw a total of nine amendments that have been ratified up to date. The eighth and the nineth amendment to DA 2010 brought notable changes that was seen as the government's effort to pave the country's way towards a fiscal decentralization system in the Maldives.

The Article 3 of DA 2010 sets out the hierarchical structure of the councils: the island councils are accountable to the respective atoll council in the administrative division and the atoll and the city councils report directly to LGA. Councils have ownership of all resources and materials within their respective administrative division. Ownership of all other resources lie with the state. State can take back ownership of land, resources and materials within the

administrative division of council to undertake a development project. In this regards the state should compensate the council for any investments it had undertaken on those land and resources. State can utilize land, resources and materials within the administrative division of a council without any approval from the council for reasons of national security.

Composition of the councils are as in Table 2.3.3. One third of all local Councils (city, island and atoll) are reserved for women.

**Table 2.3.3 Composition of the Councils**

| Type of Council | Council Member | President of Council | Vice President of Council |
|---|---|---|---|
| Island Council (Article 24 and 26 of DA 2010) | Election method: Secret ballot held within the electoral constituency of the island.<br>- Population less than 3,000: 5 members<br>- Population more than 3,000: 7 members | Election method: Secret ballot held within the electoral constituency of the island. | Election method: Secret ballot held amongst the elected members of the Council. |
| Atoll Council (Article 11 of DA 2010) | - Island council presidents of all islands in the administrative division and<br>- Mayor of any city councils within the administrative division. | Election method: Secret ballot by constituents of the administrative division. | ― |
| City Council (Article 41 and 42 of DA2010) | Election method: Secret ballot from the electoral constituency within the city.<br>- Population between 10,000~30,000: 7 members<br>- Population between 30,000~60,000: 13 members<br>- Population more than 60,000: 19 members | Election method: Secret ballot from the electoral constituency within the city. | Election method: Secret ballot held amongst the elected members of the City Council |

Source: The Act on Decentralization 2010

The DA 2010 lists specific responsibilities and the services provided by each type of the Councils. Major items are shown in the Table 2.3.4, Table 2.3.5 and Table 2.3.6.

**Table 2.3.4 Responsibilities and Services Provided by the Island Councils**

| Responsibilities (Article 22 of DA 2010) | Services Provided (Article 23 of DA 2010) |
|---|---|
| • Administer and develop the island<br>• Create development, land-use and financial plan of the island<br>• Manage public resources and funds of the island<br>• Seek loans from financial institutions as per the law to fund development activities and submit financial rights, interests and assets to the loan provider as security and create funds for other undertakings<br>• Determine and collect fees for the services provided or facilitated by the Council<br>• Provide the assistance and support needed by the state institutions and Government authorities established in the island.<br>• Make productive use of the reefs, lagoons and other natural resources of the island | • Maintain the jetty of the island, build and maintain wharf and operate the ferry terminal of the island<br>• Take necessary measures to alleviate the land erosion problem and maintain the jetty and the breakwater of the island<br>• Provide and maintain public utility facilities such as water, electricity and sewage systems<br>• Provide primary health care and other basic health security services<br>• Work with relevant government institutions to reduce disaster risks and increase preparedness at island level<br>• Consult island women development committees to formulate island level policies and regulations as per the responsibilities of the island council<br>• Gather and compile a registry of migrant workers working in the island and provide annual reports to relevant government institutions<br>• Maintain a land register of the island and provide information required by the national and land registration authority<br>• Municipal Service management<br>• Issuing and cancellation of permits and registries that Government ministries provide through the island councils and on matters that fall within the jurisdiction of the island council. |

Source: The Act on Decentralization 2010

One of the notable additions through the recent amendments was now the Ministries should execute Public Sector Investment Programs (PSIP) under MVR 5,000,000 (five million Maldivian rufiyaa) through Island Councils as per Article 69 (a) and (b) of the DA 2010.

**Table 2.3.5 Responsibilities and Services Provided by the Atoll Councils**

| Responsibilities (Article 8 of DA 2010) | Services Provided (Article 9 of DA 2010) |
|---|---|
| • Govern the administrative division and work for the development of that division<br>• Provide guidance and support in planning island development plans<br>• Provide community recommendations to all relevant stakeholders in planning relevant development programmes for the respective administrative division as a whole<br>• Coordinate the activities of the island councils and monitor the functioning of the island Councils<br>• In accordance with the land Act and other laws, acquire, own, invest in, lease out or give to other parties' lands, reefs and lagoons for economic and social purposes and own such investments in the name of the Council<br>• Seek loans from financial institutions within the limits stipulated in the Act to fund development activities and submit council assets as loan securities and create funds for other undertakings<br>• Enter into contracts with business ventures for various parties in order to provide the services mandated to the Council at the level of administrative division<br>• Determine and collect fees for services provided by the Atoll Council and services provided through the Council | • Provide services that have to be rendered to more than one island in the administrative division and undertake tasks that have been mandated to the Council under various statutes<br>• Provide assistance and cooperation required by the State institutions and Government Offices established in the administrative division<br>• Establish and maintain a registration of islands and their lands falls within the administrative division and provide the information required by national land registration authority<br>• Assist Island Councils in seeking technical and financial assistance |

Source: The Act on Decentralization 2010

**Table 2.3.6 Responsibilities of the City Councils**

| Responsibilities (Article 39 of DA 2010) | |
|---|---|
| • Administer and develop the wards of the city in accordance with the Constitution and the laws<br>• Plan and implement development projects and formulate the budget as per the City Development Plan of the Council<br>• Coordinate the activities carried out by the ward offices and monitor the administration of the ward offices<br>• Acquire, own, lease, give and invest in land reefs and lagoons for economic and social use as per the land-use plan, development and the relevant laws | • Seek loans from financial institutions to fund development activities and submit financial rights, interests and assets to the loan provider as security and create funds for other undertakings.<br>• Enter into contracts and business ventures with various parties to provide basic services such as electricity, water and sewerage systems and to carry out other development activities. |

Source: The Act on Decentralization 2010

The other items of the jurisdiction of the Councils are determined in DA 2010 as in Table 2.3.7.

**Table 2.3.7 Other Jurisdiction of the Councils**

| Jurisdiction | Remarks |
|---|---|
| Article 70 (a): Discretion given for the Councils to engage in business ventures to raise revenue. | All business operations need to be conducted via the formation of a Local Authority Company. |

| | |
|---|---|
| | The share that the Local Authority Company hold shall not exceed 20 % of the total shares. |
| Article 79 (a) (1): The 5 % of the annual projected revenue of the central government should be allocated as block grant to the Councils.<br><br>Article 79 (a) and (b): The central government should allocate 40 % of the rent to all the Councils from the lease of land, reefs and lagoons that are not under the jurisdiction of the Councils. | When determining the appropriate fiscal formula for the block grant, the Ministry of Finance should take into account the factors introduced in DA 2010.<br>The factors include as follows.<br>- Population of the city or the island council,<br>- Land area that is being utilised by the council,<br>- Number of islands in the administrative division,<br>- Cost of the provision of services in the administrative division<br>- Cost of the development projects undertaken<br>The fund shall be allocated for the following functions.<br>- Administrative costs of the council offices, expenses<br>- Associated costs of the provision of services mandated by the councils<br>- Development projects undertaken by the councils |
| Article 75: List of areas in which the Council charge fees and rent | — |
| Article 148: The power given to the Councils to formulate regulations on matters which fall within their jurisdiction with advice from the Local Government Authority. | Specific regulations that the Councils can formulate are listed as follows.<br>- Keeping livestock and birds in the island<br>- Waste management and disposal<br>- Holding entertainment and recreational activities in public spaces of the island<br>- Using loudspeakers and playing loud music<br>- Putting up announcements and advertisement billboards on the roads<br>- Protection of environment<br>- Using motor vehicles and non-motor vehicles on the road and the regulation on parking on the road, using public parking spaces and the levying of parking fees<br>- Anchoring and mooring of vessels at the jetty and harbour and levying of fees for such activities |

Source: The Act on Decentralization 2010

d) Regional and International Treaties

According to the Article 93(a) of the Constitution of the Republic of Maldives, Treaties entered into by the Executive in the name of the State with foreign States and international organizations shall be approved by the People's Majlis and shall come into force only in accordance with the decision of the People's Majlis. Article 93(b) states that despite the provisions of Article 93(a), citizens shall only be required to act in compliance with treaties ratified by the State as provided for in a law enacted by the People's Majlis. For many international treaties, the government and the Majlis have not followed through with enacting the necessary domestic laws. This has been the traditional practice. However, there have been recent enactments or amendments to law that give effect to some international treaty obligations.

### (2) Laws and Regulations relevant to ICZM Policy & Plan

To start identifying the laws and regulations necessary to review when examining ICZM in the Maldives, list-up of the relevant legislations that are supposed to form ICZM – mainly, coastal conservation, reef conservation, sediment budget control and land use, were requested to the legal department of MECCT. The total of 37 laws and regulations

listed up by MECCT were reviewed by Fidelis. Through the formal interviews and application for obtaining information to the government offices and informal interviews to the government officials and practitioners, relevancies among the listed legislations and technical descriptions were understood, availability of amendments and the other relevant legislations were confirmed, reviewed and compiled. After the preparatory work, the original documents were collected for the total 32 laws and regulations and final report for the data collection survey was prepared in English. The final report includes the table of contents and the summary of the collected laws and regulations, translation of a part of the collected documents which is considered to be closely related to ICZM and the collected original documents as Appendix.3.

In Table 2.3.8, the laws and regulations regarding ICZM that are considered to be necessary to review in the Project and may be referred when considering the ICZM are identified by examining the final report are listed.

**Table 2.3.8 Laws and Regulations Considered to be Necessary to review in the Project**

| No. | Name of Legislation | Outline |
|---|---|---|
| 1 | Maldives Land Use Planning Regulation<br><br>Authority in charge: MNHPI | • Composed of the Part 1: Guidelines on how to prepare Land Use Plans and the Part 2: Standards to be followed in the preparation of Land Use Plans.<br>• The land use plan shall be formulated with the population projection for the next 20 years. It should comply with the national, regional and sectoral plans.<br>• The documents required to submit for approval of land use plan are; land use plan, the legend and the regulation, and planning report that includes details of the analysis of existing land use and the jurisdiction and rationale for the proposed land uses. |
| 2 | Regulation on Preparing Environmental Impact Assessment Reports (No: R-27/2012)3/6)<br><br>Authority in charge: EPA | • Purpose of this regulation is to provide detailed guidance for proponents, consultants, government agencies and general public on how to obtain approval in the form of and Environmental Decision Statement for a development proposal.<br>• This regulation includes, for example, contents of an Environmental Impact Assessment (EIA) Report, procedure of reviewing EIA report, structure of review format, frequency of environmental monitoring and submission of Environmental Monitoring Report. |
| 3 | Regulation on Reclamation and Dredging of Island and Lagoons (No: R-15/2013)<br><br>Authority in charge: EPA | • Provided for the guidelines on how to mitigate damages caused to the environment due to the dredging of lagoons and island reclamation.<br>• This regulation includes, for example, purpose and necessity of dredging and reclamation to be permitted, required documents to be submitted for permission, areas forbidden for dredging, maximum area and duration allowed for reclamation and dredging, exceptional circumstances and the measures taken when EPA recognize the negative impact to the environment.<br>• The required documents to be submitted are; description of the works to be undertaken, land use plan and details of the reason for reclamation or dredging, and a georeferenced scale chart showing the area before and after the completion of the reclamation and/or dredging.<br>• For the detailed standards for dredging and reclamation it is stipulated as "if there are any standards of dredging lagoons/island reclamation which have been developed and published by a government agency, then any work related to dredging lagoons/reclamation of land must be undertaken pursuant to such standards." |

| | | |
|---|---|---|
| 4 | Protected Area Regulation (No: R-78/2017)<br>Authority in charge: EPA | • Provided for the guidelines for declaration and effective management of protected areas and procedures in establishing a sustainable mechanism to maintain a regulatory framework for protected areas.<br>• This regulation includes different categories of protected areas and formulation of the relevant guidelines for the activities to be conducted in the protected area. |
| 5 | Sand Mining Act (No: 77/78)<br>Authority in charge: EPA | • Stated that sand mining activities in any inhabited islands shall be undertaken with the required permit from the relevant authority.<br>• This act was entered into force in 1977-1978 and it has not been amended or updated.<br>• According to MECCT, legislative proposals on this area is currently underway. |
| 6 | Disaster Management Act<br>Authority in charge: NDMA | • Purpose of the act is to protect the people from natural hazards and man-made disasters and,<br>1) To incorporate guidelines on disaster risk mitigation and preparedness<br>2) To reduce disaster risk and to adapt a preparatory national strategy, to identify responsible parties to manage disaster risk, and to identify their responsibilities<br>3) To provide assistance at emergency situations and to provide assistance on the relief efforts<br>4) To incorporate such guidelines to coordinate such assistance<br>5) To state the roles and responsibilities of the Councils in reducing disaster risk and mitigation in emergency situations<br>6) To create awareness among the people in reducing disaster risk and mitigation I emergency situations, and to incorporate guidelines to protect people from such dangers and enhance coping capacity<br>7) To incorporate disaster risk reduction guidelines and policies within the sustainable national development projects and to make the people responsible and accountable towards disaster risk reduction and mitigation. |

Source: JICA Expert Team

Considering the application of these relevant laws and regulations within the framework of the ICZM Policy and Plan, there are several points that are considered as necessary to discuss in depth in each law together with the relevant organizations of the Project. The points that can be considered at this stage are described in below by corresponding to the numbers in Table 2.3.8.

No.1 In considering the ICZM Policy and Plan for the Project, it is necessary to clarify the relationship between the Land Use Plan and the land considered in the ICZM. This includes direct use of the coastal land, as well as the land where indirect use, such as for reef conservation and sediment budget control.

No.2 With regard to the EIA Report, it is not clear at this stage how the recommendations and comments provided by the report evaluator, relevant government agencies and the general public are examined in the process of determining the report assessment results and a final conclusion is reached. There may be provisions available within the EPA which have not been confirmed or obtained during this study period. Whether or not a technically valid verification has been carried out should be confirmed in the examination stage of ICZM Policy and Plan.

No.3 In the Regulation on Reclamation and Dredging of Island and Lagoons, the exceptions to government project of inhabited island development, which state that generally prohibited sand extraction, reclamation and dredging are permitted if the results of a detailed study on biodiversity, flora and fauna,

and flood risk, as well as a plan for implementing the necessary measures, are approved. At present, detailed standards for dredging and reclamation have not been established. It is conceivable that the necessary provisions may be considered in the ICZM Policy and Plan, including detailed provisions in exceptional cases.

No.4 In the Protected Area Regulation, areas internationally recognized as protected areas, strict nature reserves, wildness areas, national parks, natural monuments, habitats/species managed areas, areas for sustainable use have been cited as the categories of protected area. The coastal area to be conserved in the Project could be considered to have a possibility to be a protected area for sustainable use.

No.5 Regarding the Sand Mining Act, it is informed that the examination of the related legislation is ongoing. Since the name of the law is directly related to ICZM, it is considered that the ICZM Policy and Plan should be considered with a common understanding of whether the related legislation under examination is about the existing laws and regulations or preparing as a new law and/or regulation, and the progress of the examination.

No.6 Disaster Management Act includes the purpose of reducing and preparing for disaster risks. This can be considered a pre-disaster measure. More detailed role of the government and the island council may be better to include in the legislation followed by, if not in the act. Since the ICZM Policy and Plan is considered to correspond to pre-disaster countermeasures, the role of central and local governments in ICZM should be examined in parallel within the framework of disaster management.

In Table 2.3.9, the laws and regulations regarding ICZM that may be referred when considering the ICZM are identified by examining the final report are listed.

**Table 2.3.9 Laws and Regulations may be Referred when Considering the ICZM**

| No. | Name of Legislation | Outline |
|---|---|---|
| 1 | Regulation for the Determination of Penalties and Obtaining Compensation for Damages Caused to the Environment (No: R-9/2011))<br><br>Authority in charge: EPA | • Purpose is to stop the violations under the Environment Protection and Preservation Act of the Maldives and to set out the procedures and guidelines on how to determine penalties and obtain compensation for damages caused to the environment.<br>• If something happens that might cause damage to the environment or if a probability of causing damage to the environment has been discovered through the implementation of a project, the party shall immediately notify the EPA and take all actions reasonably possible to prevent and stop the action which is causing damage to the environment.<br>• When the EPA receives such notification, investigate the matter and issue an order to take certain rectification measures or to stop the project depending on the harm foreseen to the environment. |
| 2 | Regulation on the Protection and Conservation of Environment in the Tourism Industry (20th July 2006)<br><br>Authority in charge: Ministry of Tourism | • Purpose is to protect the environment in the Tourism Industry and to encourage and facilitate sustainable development of tourism.<br>• Extraction of coral stones from any part of the lagoon or the reef of an resort islands for for renovation or repair of any jetty or breakwater built.<br>• To preserve and maintain the natural environment of resort islands, at least 80% of the island shall be spared un-built. |
| 3 | Guideline on the Protection and Nourishment of Beaches in the | • Purpose is to protect and conserve the beaches of resort islands and lay out the procedures in sand mining in such islands to replenish and nourish |

| | | |
|---|---|---|
| | Islands Issued for Tourism Purposes (18th December 2017)<br><br>Authority in charge: Ministry of Tourism | the beaches and inform the Ministry's officials engaging in implementation of this Guideline.<br>• The maximum area of the beach that can be used for nourishment and beach conservation of the resort islands are stipulated.<br>• The proponent shall submit a proposal, including coastal modification application form, description of the works and details, three proposed areas for sand mining, approved concept plans of the proposed work by the Ministry of Tourism, entire concept plan depicted with work area and proposed areas for sand mining and time schedule, to the Ministry of Tourism for approval.<br>• When the works are completed, the proponent shall request a physical inspection from the Ministry of Tourism. |
| 4 | Disaster Management Plan of L. Maamendhoo<br>(as a case of island level plan formulated under the Disaster Management Act)<br><br>Authority in charge: L. Maamendhoo Island Council | • Developed by the L. Maamendhoo Council, National Disaster Management Centre and L. Maamendhoo constituents through the 5-day capacity building trainings.<br>• Purpose is to respond to disaster situations that occur at the island level and also to empower the island community to reduce the risk of disasters and potential hazards materializing at the island level. In that respect, it is intended to conduct a situational analysis of the island to undertake capacity and resource mapping to prevent and prepare for disaster situations.<br>• Consists of strategies and measures that can be taken at the island level to reduce the risk of disasters and mitigate its damages upon its occurrence. |

Source: JICA Expert Team

The points of laws and regulations that are considered to be a reference during the review of laws and regulations in Table 2.3.8 are described in below by corresponding the numbers of laws and regulations in Table 2.3.9.

No.1 If a project is likely to cause environmental damage or is discovered during the course of the project, EPA will be notified of the possibility and investigate the problem, take corrective action or issue an order to cease the project. Although the procedures within EPA have not been confirmed during this study period, it is considered that the evaluation of the investigation results of the problem that cause damage to the environment and the evaluation methods of corrective measures can be confirmed in accordance with the examination process of the ICZM Policy and Plan, and these can be considered to state more explicitly during the review of related laws and regulations.

No.2 Although it is a rule for resort islands, it is considered to be a specific regulation that will be a reference when considering coastal conservation of inhabited islands.

No.3 Same as above – No.2.

No.4 Because it is a disaster management plan at the island level, it contains more specific contents than the Disaster Management Act. However, it seems that there is no description of the matters on pre-disaster response such as disaster risk reduction and disaster preparedness. During the consideration of the ICZM Policy and Plan also within the framework of disaster management, it is considered that the sense of level of specific content stipulated at the island level can be referenced.

Regarding the laws and regulations listed in Table 2.3.8 and Table 2.3.9 and the points that need to be deepened into and points that may be helpful, the materials were just shared at the ICZM seminar held on 28 August 2022,

and questions were asked to relevant organizations. In the course of Phase 2 activities, in parallel with the more concrete implementation of the ICZM study, JET plans to discuss measures to implement the ICZM Policy and Plan in the Maldives and compile a draft of legal changes that are considered to be necessary.

### 2.3.2 Relevant Policy and Plan

The most relevant policies and plans of the Maldives are the National Biodiversity Strategy and Action Plan (2016-2025) and the Strategic Action Plan (2019-2023). The National Biodiversity Strategy and Action Plan seeks to ensure that threats to biodiversity are addressed, biodiversity is conserved, sustainably used and benefits arising from them are shared equitably. The Strategic Action Plan (SAP) was formulated for the use of the government's overarching reference point to steer the national development efforts and raised the 5 priority areas with policy and targets for each area.

In the priority area 4: Jazeera Dhiriulhun (sustainably deriving livelihoods, economies, cultural identity and well-being), there is Sector 3 for environmental protection and preservation. The policies and targets under this sector are shown in Table 2.3.10. The policies closely related to ICZM are Policy 1, 2, 3 and 5.

**Table 2.3.10 Policy and Target of the Strategic Action Plan (2019-2023), 4.3 Environmental Protection & Preservation**

| | | |
|---|---|---|
| Policy 1 | Strengthen the legislative, regulatory, institutional framework and the human resource capacity to facilitate effective environmental protection and sustainable practices | |
| | Target 1.1 | By 2020, integrate environmental protection and biodiversity conservation with the guidelines, regulations and compliance documents on land use planning, local developments planning, building and all infrastructure development projects |
| | Target 1.2 | By 2020, the independent functioning of EPA is ensured |
| | Target 1.3 | By 2023, a comprehensive legislation on chemicals management is enacted covering the entire lifecycle of chemicals |
| | Target 1.4 | By 2023, standards for fuel quality and vehicle and marine emissions are established |
| | Target 1.5 | By 2023, sustainable production standards are introduced for key industries (tourism, fisheries and construction) |
| Policy 2 | Improve conservation efforts to preserve biodiversity of Maldives and ensure maximum ecosystem benefits | |
| | Target 2.1 | By 2023, a comprehensive and functional protected areas system in the Maldives in accordance with the international standards is established |
| | Target 2.2 | By 2022, a comprehensive reef restoration and protection mechanism under the concept of "Jazeera Island Reef" is introduced and implemented |
| | Target 2.3 | By 2023, at least 10% of coral reef area, 20% of wetlands and mangroves and at least one sand bank and one uninhabited island from each atoll are under some form of protection and management |
| Policy 3 | Strengthen research capacity and evidence-based policy making in environmental protection and conservation | |
| | Target 3.1 | By 2023, establish an evidence-based monitoring system to track the status of key ecosystems, species, and genetic diversity as well as protected areas and species found in the Maldives |
| | Target3.2 | By 2023, maintain a database on research findings on biodiversity and ecosystems, and enable access to stakeholders |
| Policy 4 | Develop mechanisms to ensure the sound management of chemicals | |
| | Target 4.1 | By 2023, quality control mechanism for labelling imported chemicals are in place and used across the country |
| | Target 4.2 | 2023, a national inventory on imported carcinogenic chemicals has been established |
| Policy 5 | Strengthen information management and resource mobilisation | |
| | Target 5.1 | By 2023, an up-to-date database on biodiversity and ecosystems of Maldives is institutionalised and is utilised for conservation, monitoring and enforcement |
| | Target 5.2 | By 2023, user pay principle is mainstreamed and integrated into policies and regulations concerning utilisation of biodiversity resources and ecosystem services |
| | Target 5.3 | By 2022, accurate and regular air pollution data are available to public on a real time basis |

Source: Strategic Action Plan 2019-2023

The specific policies of the Government of the Maldives on ICZM are described below, based on the presentations made at the ICZM seminar held on 28 August 2022, on the efforts of MNPHI, MECCT and MMS, the relevant organizations of the Project, the projects currently being implemented, the future plans and the issues recognized at each of the organization.

**(1) MNPHI**

Coastal erosion is prominent and the coastal protection measures are required. The causes of the coastal erosion are understood as natural cause and anthropogenic cause. The seasonal change of wind and wave patterns, extreme wave and storm surge conditions, changes in long-term wave regimes and sea level rise are seen as the natural cause. Removal of coastal vegetation, sand and coral mining, dredging and land reclamation and coastal modification such as harbours and shore protection structures are regarded as the anthropogenic cause. The impact of the erosion is visible such as loss of vegetation and land, damages to human settlement, damages to critical infrastructure, damages to the other infrastructure and flooding and inundation.

To protect the coastal areas from erosion, two methods of the engineering solution are adopted in Maldives. One is the hard measure, with which armoring structures, such as rock boulder, revetment, breakwater and groynes, are constructed to guarantee no further retreat of existing beach lines and wave overtopping are occurred. It is more commonly used and preferred in the public works, though expensive, it lasts long period. Another method is the soft measure, with which shore stabilization structures, designed to modify coastal processes, are constructed. It is mostly implemented in the resorts, though upfront cost is lower, maintenance cost is higher and the commitment for the maintenance is important. As the other soft engineering measure, beach stabilization with geo-tube or geo-bag is proposed to the islands.

The total cost of the coastal protection projects completed since the year 2019 was MVR 119,496,044.71 (approx. USD 8.9 million), with the total length of 4,678 m was covered in the 13 islands as a whole. The total cost of the coastal protection projects on-going as of August 2022 is MVR 309,854,787.62 (approx. USD 20.7 million), with the total length of 10,297.60 m to be covered in the 11 islands a whole. The total cost of the coastal protection projects that the contracts are concluded (before commencement of the work) as of August 2022 is MVR 595,269,453.35 expected in the 15 islands. Within the budget of FY 2022, MVR 7,000,000 (approx. USD 0.5 million) is planned for the 39 islands. Among them, 13 contracts are at the tender stage.

In 2020, MECCT compiled the emergency response island list, requested budget for the FY 2021 for a part of the list by MECCT and the rest by MNPI (former MNPHI) and almost all were approved. The list prioritized the island for Red: the islands at the risk to public infrastructure, Yellow: the islands face erosion and loss of vegetation and Green: the islands have eroding areas far from public infrastructure. The list compiled in 2020 was composed of 6 islands for Red, 4 islands for Yellow and 8 islands for Green. In 2022, MECCT and MNPHI collaborated to prepare a new list of islands which require coastal protection and prioritized depending on the urgency. Among 31 islands listed, 9 islands were budgeted.

From the past experiences in the planning and implementation process of coastal protection project, 1) budgetary restrictions, 2) increase of project cost, 3) reluctancy in adopting soft measure, 4) lack of long-term data and 5) detailed design and implementation of EIA after concluding contract are the major issues raised.

Table 2.3.11 described details of the issues and the current problems.

**Table 2.3.11 Issues in Planning and Implementation of the Coastal Protection Project**

| Issue | Details |
|---|---|
| 1) Budgetary Restrictions | • Budget for the coastal protection measures is limited and there is a fixed budget to the specified islands.<br>• There is no budget to cater the emergency islands therefore special permission have to be requested for these islands. |
| 2) Increase of Project Cost | • The expenses for structural measures are increased. |
| 3) Reluctancy in Adopting Soft Measure | • The effectiveness of the of the soft measure has not been properly demonstrated to the community of islands.<br>• Therefore, the awareness is low in the community and there is no motivation to agree with adopting the soft measure.<br>• They consider the necessity of measurement only when the property is threatened – reactive way of thinking rather than proactive. |
| 4) Lack of Long-term Data | • Difficulty in acquiring long-term erosion data. |
| 5) Detailed Design and Implementation of EIA after Concluding Contract | • Lack of capacity to prepare detailed designs prior to awarding contracts, resulting in discrepancies in estimated cost and actual price.<br>• EIAs are prepared after awarding the contract, resulting in requiring to bring variations to projects. |

Source Presentation material (MNPHI) at ICZM Seminar held on 28 August 2022 edited by JICA Expert Team

Based on the above analysis, the following recommendations are compiled.

As a top priority, it was necessary to allocate funds to the islands that require emergency response, and it was important to identify the most optimal method of protection for the identified islands consider the optimal measures for the protection of the island by evaluating the different options, and to deploy more specialized staff to the site.

Next, it was recommended that it would be necessary to invite financial support from grants and donors, to increase the width of the retreat from the vegetation line to 5 m for tourist islands (actually 10 m) and 20 m for inhabitant islands, and to organize trainings and workshops to raise awareness of coastal protection and various regulations.

For these preparatory items necessary for proceeding the countermeasures, effective use of funds based on proper surveys, ensuring access to data such as erosion, waves and sea level, implementation of surveys to identify the most important islands or locations in coastal protection that consider land use controls and setbacks, retention of coastal vegetation, management of coastal structures on stilts and promoting the exchange of knowledge with other countries, with a focus on raising public awareness of these preparatory measures.

Among the coastal protection projects completed since the year 2019, the major projects are shown in Table 2.3.12.

**Table 2.3.12 Major Coastal Protection Projects Competed Since the Year 2019**

| Island | Project Cost (MVR) | Project Scope | Hard measure | Soft measure |
|---|---|---|---|---|
| Ha. Dhidhdhoo | 10,025,003.00 | 310 m geo-bag revetment | | ✓ |
| N. Henbadhoo | 5,000,000.00 | 235 m revetment with backfilling<br>25 m groyne | ✓ | ✓ |
| N.Fohdhdhoo | 7,612,602.00 | 180 m geo-bag revetment and backfilling | ✓ | ✓ |
| R.Fainu | 8,968,065.34 | 250m geo-bag revetment | ✓ | |
| B. Dhonfanu | 12,909,684.35 | 40m groyne<br>60 m Y groyne<br>536 m revetment<br>beach nourishment | ✓ | ✓ |
| B.Thulhaadhoo | 10,137,775.34 | 280 m geo-bag revetment | | ✓ |
| AA.Rasdhoo | 14,589,523.50 | 175 m groyne<br>39 m revetment<br>beach replenishment | ✓ | ✓ |
| V.Fulidhoo | 16,570,324.39 | 412 m submerged breakwater<br>162 m groynes<br>50 m revetment<br>305 m beach filling, backfilling | ✓ | ✓ |
| V.Rakeedhoo | 10,212,941.00 | 40 m groynes<br>200m breakwaters<br>swimming area dredging | ✓ | |
| M.Mulah | 17,665,935.73 | 411 m geo-bag revetment | | ✓ |
| S.Meedhoo | 5,804,190.06 | 210 m geo-bag revetment | | ✓ |
| Total | 119,496,044.71 | 4,678 m | — | — |

Source Presentation material (MNPHI) at ICZM Seminar held on 28 August 2022 edited by JICA Expert Team

The coastal protection projects on-going as of August 2022 are shown in Table 2.3.13.

**Table 2.3.13 Coastal Protection Projects On-going as of August 2022**

| Island | Project Cost (MVR) | Project Scope | Hard measure | Soft measure |
|---|---|---|---|---|
| Ha. Hoarafushi | 6,399,518.00 | 420 m geo-bag revetment<br>100 m groyne<br>260 m revetment reprofiled to groyne | ✓ | ✓ |
| Hdh. Nellaidhoo | 20,342,491.80 | 882 m rock revetment | ✓ | |
| R. Rasmaadhoo | 13,215,945.0 | 381 m groynes | ✓ | |
| Ha.Hoarafushi airport | 90,566,804.92 | 436 m revetment<br>1,165 m breakwater | ✓ | |

| | | | | |
|---|---|---|---|---|
| | | 455 m groyne | | |
| Th.Buruni | 28,876,557.10 | 399 m rock breakwater<br>220 m rock revetment<br>beach replenishment | ✓ | ✓ |
| B. Kudarikilu | 14,749,900.00 | 836 m revetment<br>30 m groyne<br>50 m breakwater | ✓ | |
| Lh. Kurendhoo | 44,882,495.31 | 802 m revetment<br>361m breakwater<br>142 m groynes | ✓ | |
| B. Kendhoo | 41,112,650.14 | 803 m breakwaters<br>90 m groyne<br>110 m revetment<br>20 x 40 m swimming area | ✓ | |
| B. Dharavandhoo | 22,145,859.20 | 415m breakwater<br>144m revetment<br>beach replenishment | ✓ | ✓ |
| M. Kolhufushi | 22,961,969.21 | 518.8 m revetment<br>202.40 breakwater<br>30 x 60 m swimming areas (2 nos) | ✓ | |
| S. Meedhoo phase 2 | 4,600,596.94 | 237 m revetment (geo-bag) | — | ✓ |

Source Presentation material (MNPHI) at ICZM Seminar held on 28 August 2022 edited by JICA Expert Team

The coastal protection projects that the contracts are concluded (before commencement of the work) as of August 2022 are shown in Table 2.3.14

**Table 2.3.14 Coastal Protection Projects Contracted as of August 2022**

| Island | Project Cost (MVR) | Project Scope | Hard measure | Soft measure |
|---|---|---|---|---|
| Adh. Kunburudhoo | 21,753,166.80 | 430 m revetment, reclamation<br>185 m geo-tube revetment | ✓ | ✓ |
| Sh.Milandhoo | 36,695,523.86 | 954.43 revetment<br>44.77 m groynes | ✓ | |
| S. Hithadhoo | 11,645,907.30 | 570 m geotube revetment<br>swimming area<br>100 m breakwater | ✓ | ✓ |
| Hdh.Kulhudhuffushi airport | 42,375,467.36 | 954.43 m revetment<br>114.56 m groynes | ✓ | |
| N. Kudafari | 15,011,223.92 | 718 m geo-bag revetment | | ✓ |
| L.Gan | 11,527,669.60 | 260 m groyne<br>30 m revetment<br>beach nourishment | ✓ | ✓ |
| Gdh. Rathafandhoo | 27,849,136.20 | 240 m breakwater<br>461 m revetment<br>beach replenishment | ✓ | ✓ |
| Gdh.Thinadhoo | 17,854,200.00 | 468 m revetment | ✓ | |
| Gn.Fuahmulah | 300,343,050.00 | 2,650 m rock revetment | ✓ | |
| Th. Dhiyamigili | 23,164,180.00 | 205 m revetment<br>392 m breakwater | ✓ | |
| Th. Vilufushi | 11,192,295.14 | 184 m rrevetment<br>135 m breakwater | ✓ | |
| V. Fulidhoo phase 2 | 8,072,917.00 | 84 m groyne<br>180 m breakwaters | ✓ | |

| | | | | |
|---|---|---|---|---|
| M. Mulah Phase 2 | 38,968,262.13 | 343.03 m revetment<br>539.9 m breakwater<br>beach replenishment | ✓ | ✓ |
| R. Ungoofaaru | 11,116,856.00 | 120 m breakwater<br>110 m groyne<br>beach nourishment | ✓ | ✓ |
| Th.Gaadhiffushi | 17,699,598.04 | 500 m revetment<br>15 m groynes | ✓ | |

Source: Presentation material (MNPHI) at ICZM Seminar held on 28 August 2022 edited by JICA Expert Team

### (1) MECCT

MECCT is currently formulating the Erosion and Inundation Hazard Maps for the islands and updating the Coastal Vulnerability Index (CVI).

For the hazard maps, the layout of the coastline is drawn by using Google Earth, identifying the land losses and gains over the years by using QGIS based on the information collected from the councils on areas prone to erosion and inundation, and then the information from the Councils are integrated into the hazard map. As of August 2022, 85 islands (45 %) of the total KMZ shoreline layouts are completed and total hazard maps completed are 77 islands (40 %)

With regard to the CVI, desk research on CVIs in other Small Island Developing States (SIDS) was conducted and existing CVI templates were updated. MECCT is currently conducting a reviewing work.

Through these activities, lack of historical data, lack of technical capacity in the islands and necessity to improve inter-agency communications were identified.

### (2) MMS

MMS plays a technical key role in collection, archiving and provision of related data, though no direct intervention to ICZM. Currently, MMS focusing on strengthening observation and forecasting capabilities, especially in marine meteorology in addition to expansion and maintenance of land based Automatic Weather Station network on the Strategic Action Plan, and currently has three tide gauges in Hanimaadhoo, Hulhule and Gan. Additionally, MMS is an implementing partner of the water resource management strategies of MECCT and the resilience building and disaster management strategies of NDMA.

Table 2.3.15 shows the excerpt of the Strategic Action Plan that MMS implements.

**Table 2.3.15 Strategic Action Plan of MMS**

| | |
|---|---|
| Strategy 7.3 | Strengthening Observation Network, data automation and integration [MM 9.2.2] |
| Action 7.3a | Establish a country-wide lightening network |
| Action 7.3b | Establish a marine meteorological observatory |
| Action 7.3c | Develop an ocean weather prediction modelling and forecasting system |
| Action 7.3d | Improve existing communication networks |

Source: Presentation material (MMS) at ICZM Seminar held on 28 August 2022

On marine meteorology, MMS, with the support of the Italian Government, is working to downscale and contextualize wave models to match the Maldives. Wave models can help identify hazardous events related to swell waves and could also be used in the planning process of land use. The data set obtained from the buoy observation network can provide input data to the wave model, which helps to improve the accuracy of the model.

In considering the ICZM Plan, MMS recognizes that data and its analysis are critical to science-backed planning and decision-making. The biggest challenge for MMS is the maintenance and management of equipment installed nationwide and the capacity of human resources within limited funds. The ICZM Plan requires the incorporation of equipment management by each council and the implementation and continuation of human resource development in the specialized fields such as instrumentation and analysis.

## 2.4 Relevant Organizations of ICZM

### 2.4.1 C/P Organization

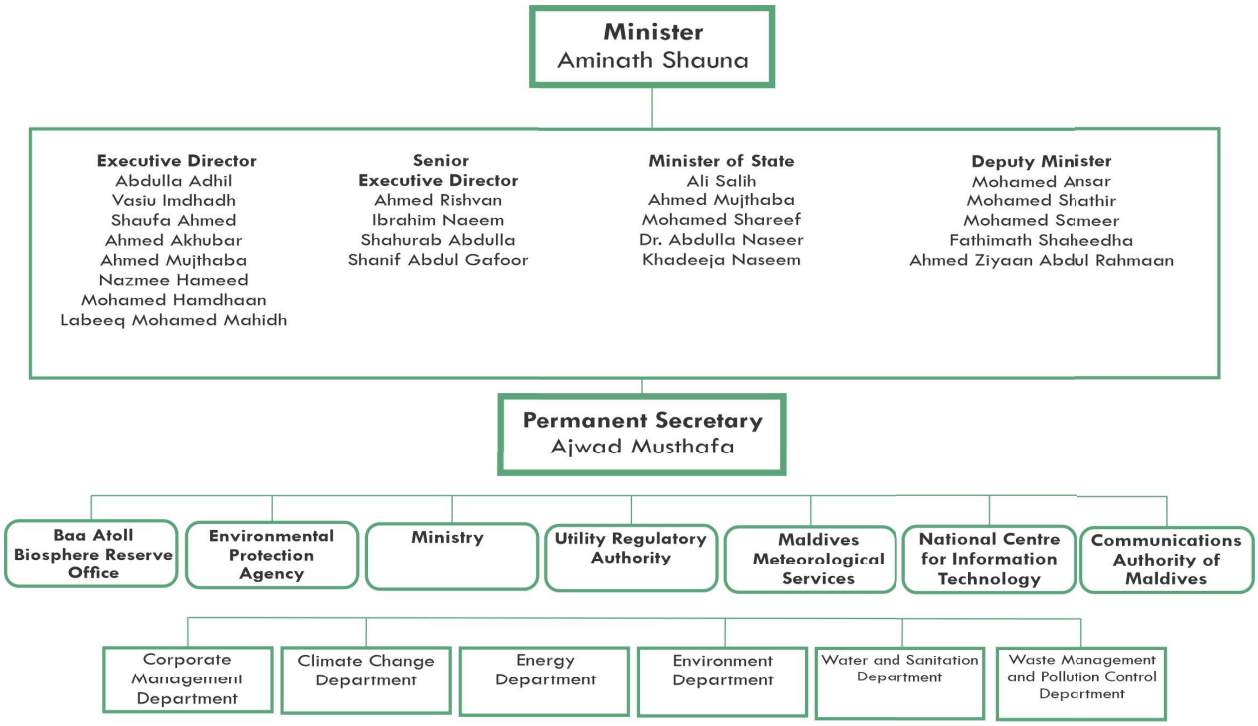
The C/P organization of the Project is MECCT, mainly Environmental Management Department and Climate Change Department, also Environmental Protection Agency (EPA) and Maldives Meteorology Service (MMS), the organizations under MECCT. The mandate of each organization and the organizational structure is described in below.

#### (1) Ministry of Environment, Climate Change and Technology (MECCT)

Since the mandate of MECCT covers 60 items, it was summarized in the following six points as an outline. The complete set of the mandate is described in Appendix.4.

1. Formulation of strategies, policies, action plans, laws, regulations, guidelines and standards relating to the changes in the climate and environment of the Maldives, areas pertaining to energy, water, waste, sewerage, meteorology, science and communication.
2. Implementation and management of the formulated strategies, policies, action plans, laws, regulations, guidelines and standards as above.
3. Support to the government authorities, island councils, service providers, researchers and the general public to carry out activities related to the above through technical and economic advice, grants and environmental improvements.
4. Advocacy at the regional and international level on other activities related to mitigating the impacts of climate change on the Maldives and other small island developing States.
5. Develop projects to mitigate climate change, and acquire financial assistance from international agencies.
6. Carry out all necessary actions to implement international treaties and agreements signed by the Maldives pertaining to the Ministries' scope of work.

Organization structure of MECCT is shown in Figure 2.4.1.




Source: MECCT Homepage

**Figure 2.4.1 Organization Structure of MECCT**

The organizations under MECCT are the 6 organizations shown under the "Permanent Secretary" of Figure 2.4.1. In the Project, the C/P organizations under MECCT are EPA and MMS. The departments under MECCT are those shown below the organizations under MECCT. The main C/P departments for the Project are Environment Department and Climate Change Department. The outline and mandates of these departments and organizations are described in below.

### (2) Environment Department

Established in 1984, the core duty of the Environment Department is to preserve the Maldives' unique natural habitat. The department is to advise the government on laws and regulations, adopts policies, and implement environment-related strategies. This department is composed of two sections and four units as in Table 2.4.1.

**Table 2.4.1 Organization Structure of Environment Department**

| Environment Department | | |
|---|---|---|
| Policy Coordination and Management Division | | |
| | Environment Policy and Multilateral Environmental Agreements Section | |
| | | Environmental policy unit |
| | | Multilateral environmental agreements unit |
| | | Maldives Green fund secretariat unit |
| | Environment Management Section | |
| | | Air quality management unit |
| | | National Ozone unit |
| | | Chemicals management unit |
| | Coastal Zone Management Section | |
| | Knowledge Management, Research and Assessment Section | |
| | | Surveying and research unit |
| | | Environment Information System (ENVIS) and State of the Environmental (SOE) unit |
| | | Communication, Education and public awareness (CEPA) unit |
| Conservation Division | | |
| | Biodiversity Section | |
| | | Biodiversity assessment unit |
| | | Biodiversity conservation unit |
| | Protected Areas Section | |
| | | Protected areas designation unit |
| | | Protected areas management unit |
| | National Parks Section | |
| | | S. Hithadhoo unit |
| | | S. Hulhumeedhoo unit |
| | | Fuvahmulah city unit |
| | | South Marine Park (SAMPa) unit |

Source: MECCT

The Policy Coordination and Management Division formulates policies related to the environment of Maldives, implement the formulated policies and report the details of policy implementation to relevant parties. Also, develop and implement strategies, action plans, and regulatory programs for protection and conservation of the environment of the Maldives in a sustainable manner. Further, providing expert consultation and assistance in developing concepts of projects related to protection and conservation of the environment.

Under the Policy Coordination and Management Division, the Coastal Zone Management Section plans and formulates strategies, action plans, and programs to develop activities related to coastal zone management, in a sustainable manner. Also, the section implements all projects related to coastal zone management, except those including infrastructure. And it takes initiative in planning and implementing awareness programs at national and international level.

### (3) Climate Change Department

The Climate Change Department is in charge of formulating policies and standards to address climate change challenges in line with the legislative framework of the country as well as international practices and conventions. The mandate of this department is as follows.

1. Ensuring and integrating sustainable financing into climate change adaptation opportunities and low emission development measures.
2. Strengthening and developing a low emission system and ensuring energy security
3. Bolstering adaptation actions and opportunities, building climate-resilient infrastructures (including coastal protection) and communities
4. Advocating for a national, regional, and international climate change role in leading international negotiations and awareness in cross-sectorial areas to support the most vulnerable and small island developing states
5. Fostering sustainable development while ensuring security, economic sustainability and sovereignty from the negative consequences of the changing climate
6. Strengthening international cooperation to boost both investment and know-how.

The Climate Change Department is composed of two sections and six units as in Table 2.4.2.

**Table 2.4.2 Organization Structure of Climate Change Department**

| Climate Chance Department | |
|---|---|
| Adaptation and Mitigation section | Monitoring and Evaluation unit |
| | Greenhouses Gas Rreporting unit |
| | Clean Development Mechanism unit |
| Policy and Programs section | Sustainable Development Instruments unit |
| | Communication and Programs unit |
| | Policy and Planning unit |

Source: MECCT Homepage

### (4) Environmental Protection Agency (EPA)

EPA is responsible for regulatory activities for protection, conservation and management of environment and biodiversity, as well as waste management and pollution prevention under the Environment Protection and Preservation Act (4/93). The mandate of EPA is as follows.

1. Plan and organize regulatory activities for protection, conservation and management of environment and biodiversity under the environment Protection and Preservation Act (4/93)
2. Formulate guidelines for EIA data collection, which is a requirement before proceeding with any project that may have a significant impact to the environment.

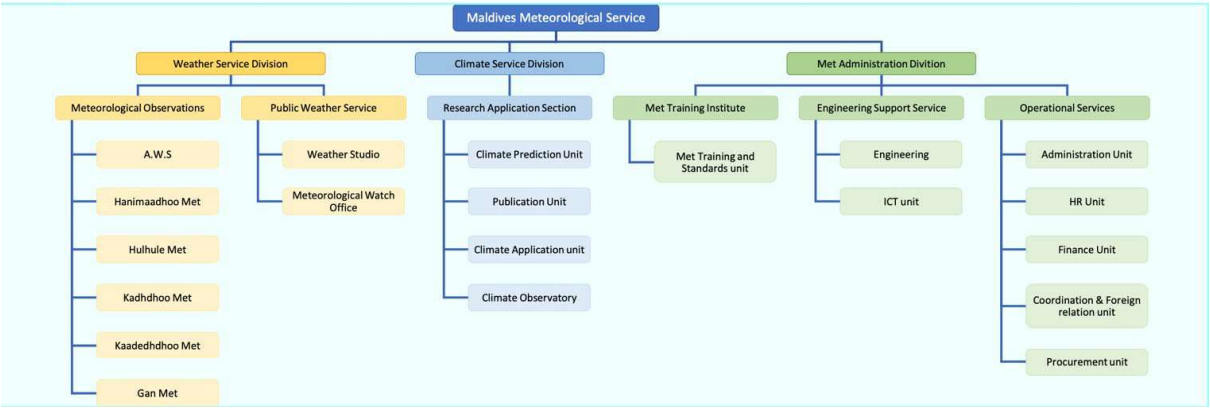
3. Provide expert assistance to relevant authorities pertaining to taking preventative measures based on information related to land erosion, natural and human made environmental problems
4. Valuating the damages sustained by the environment to obtain reimbursement.
5. Implementation of regulations made by the Ministry concerning the environmental protection of Maldivian islands, ensure whether the legislations and regulations are being followed by individuals and governmental authorities, take lawful action where necessary, and provide consultation to government authorities on relevant matters.
6. Carry out scientific research and studies related to Environmental Protection Agency, create and monitor a "Knowledgebase" with the obtained knowledge and arrange dissemination of such information to all relevant persons.
7. Study the changes in coastal regions of Maldivian islands, and the reasons for such occurrences, and give consultation on preventive measures.
8. Collect information pertaining to the formation of islands and any changes that take place in such areas of the Maldives via facilities such as satellite imagery and aerial photography and arrange dissemination of the information required for the Geographic Information System.
9. Carry out research pertaining Land Reclamation, Dredging Reefs, Harbor Construction, and creation of Channel into Harbor in an environmentally friendly manner, and sharing the findings with the relevant parties.
10. Carry out research and studies to understand the pollution in the environment and share the findings and give technical advice to relevant parties.
11. Conduct research pertaining Flora and Fauna and its habitat, and share the experience obtained from the research to relevant parties.
12. Carry out research and studies of Biotechnology and Biosafety related to Maldivian Islands, provide technical consultation of such information.
13. Monitor, record and maintain records regarding the changes in levels of gases, smokes, and particular matter in the atmosphere and arrange dissemination of such information to all relevant persons.
14. Carry out research pertaining water resources available in Maldives, maintain such data and arrange dissemination of this data to relevant persons.
15. Create and publish a knowledge base with environmental related data required to plan the development projects.

### (5) Maldives Meteorology Service (MMS)

A meteorological service was established in the early 1940s. After 1974, Met office adapted to the international standard. The sea area forecasts and the route forecasts were prepared by the Colombo Observatory and sent to the Meteorological Centre. Meteorological office became Maldives Meteorological Service (MMS) in 2009. Today, MMS is responsible for the seismological and meteorological services in Maldives. There are 5 Meteorological offices under MMS, the station in Hulhule' being the main office. Aviation and synoptic observations done in the other four stations are sent to the Hulhule station on their respective time via email or fax. The mandate of MMS is as follows.

1. Plan, administer and develop activities related to meteorology in the Maldives.
2. Maintaining the data on climate, earthquake, and tsunami, required for economically and socially sustainable development.
3. Develop and maintain such a knowledge base and facilitate access to this information to those who require it.
4. Conduct research activities on meteorology and seismology in the Maldives.
5. Provide aeronautical meteorological services to international and domestic aviation requirements as per the required standards of International Civil Aviation Organization and World Meteorological Organization.
6. Monitor weather, earthquake, and tsunami over the region. Issue impact-based forecast and early warning alerts to concerned authorities and general public.

The organization structure of MMS is shown in Figure 2.4.2.




Source: MMS Homepage

**Figure 2.4.2 Organization Structure of MMS**

### 2.4.2 Other Relevant Organizations

The relevant organizations participating in the Project are the Ministry of National Planning, Housing and Infrastructure (MNPHI), the National Disaster Management Authority (NDMA) and Local Government Authority (LGA) from the central government, and island and atoll councils from Addu Atoll and Laamu Atoll where the project sites will locate. In this section, the mandate and organization structure of MNPHI, NDMA and LGA from the central government are described.

#### (1) Ministry of National Planning, Housing and Infrastructure (MNPHI)

Since the mandate of MNPHI covers 54 items, it was summarized in the following 12 points as an outline. The complete set of the mandate is described in Appendix.4.

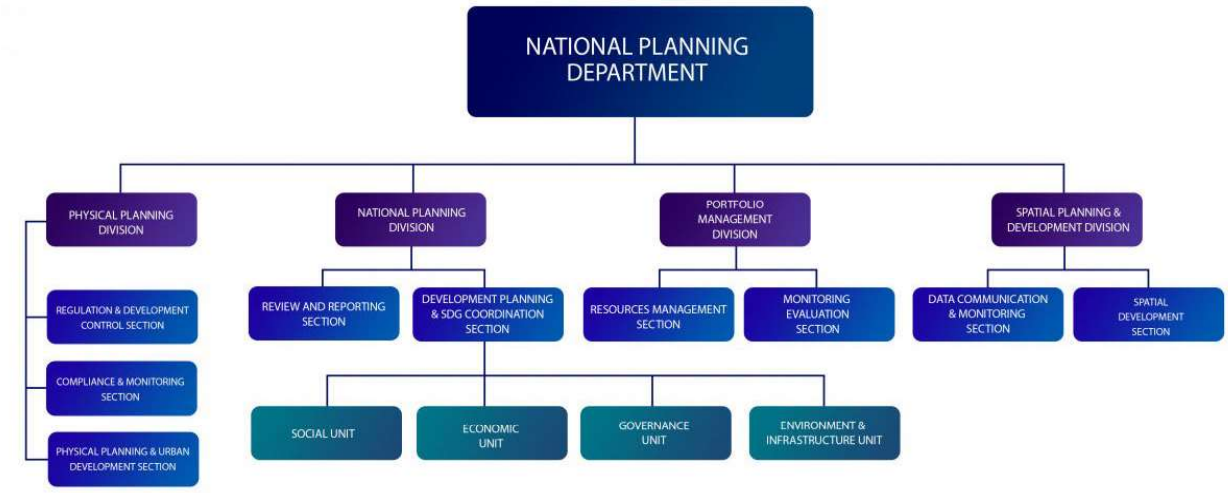
1. Do the necessary research to establish the National Development Plan, make the development plans with the assistance of relevant authorities, work with relevant government authorities to ensure their development plans are consistent with the national development plans, prioritize the development projects, work with the relevant authorities to get the finances to implement the development projects, create

pipelines for the development projects requiring international aid and discuss and provide guidance to use the aid for the relevant authorities and provide technical support and guidance to the relevant government authorities.

2. Evaluate the National Development Plan, Public Sector Investment Program and other development programs and to provide the support to overcome the difficulties faced.
3. Work as the focal point of the government on reaching Sustainable Development Goals, work with the government authorities to reach these goals, oversee these works and to report to the relevant authorities.
4. Prepare the Maldives Regional Spatial Plans, make and revise the master plan of the Urban Area, make the urban redevelopment plan.
5. Prepare the land use plans of islands, approve the land use plans, and make the development controls regarding the plan and to prepare the operational structures
6. Formulate the procedures to maintain the land registries and establish a system to maintain such registers with the relevant authorities, establish the land related policies, rules and regulations that has to be made under the law, make procedures and a system to value the land with the relevant authorities, make housing policies, and plan and carry out ways to implement these policies, plan and manage housing programs under the national housing policies.
7. Provide expertise for drafting bills of the construction industry, establish standards, evaluate the people/workers of the construction industry, register and provide licenses for them, do the necessary research to the construction industry, provide necessary trainings for the people interested to work in the construction industry.
8. Establish the rules and regulations of land reclamation and dredging.
9. Identify and evaluate the disasters, evaluate the damages done to public buildings and other infrastructure and do research to ways to reduce such damages.
10. Manage and monitor projects on public infrastructure (which includes roads, bridge, potable water and sewage service, establishment of energy and communication networks, airports, ports, harbors, land reclamation and coastal protection) and make sure that they are being carried out as per the National Development Plan.
11. Evaluate bids on the development projects by the government offices and give counsel on the tenders, ensure whether the estimated prices provided in the bill of quantities (BOQ) are appropriate.
12. Make necessary arrangements to find a party interested to provide the services and maintain the infrastructure systems.

There are 3 organizations under MNPHI; Maldives Bureau of Statistics, Department of National Registration and Maldives Land and Survey Authority (MLSA), and the one with close relation to the Project is MLSA. MNPHI is composed of Housing Department, Planning Department, Public Works Department, Infrastructure Department, Construction Industry Development Department and Corporate Department

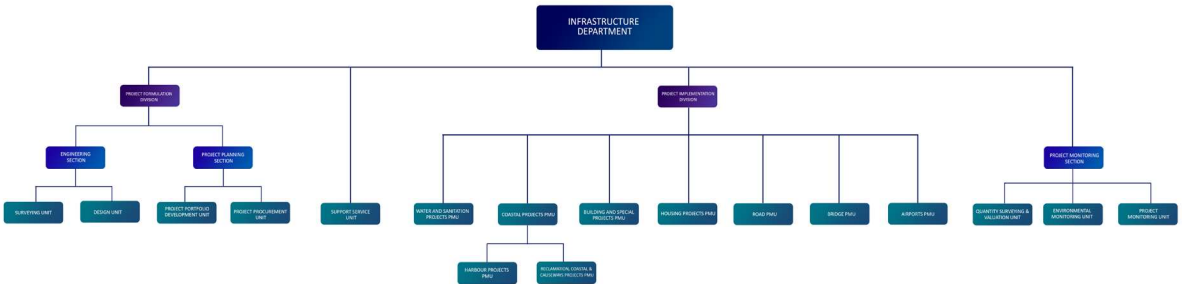
The organization charts and the mandates of Planning Department, Infrastructure Department, Construction Industry Development Department and MLSA, those closely relate to the Project, are shown in below.




Source: MNPHI Homepage

**Figure 2.4.3 Organization Structure of Planning Department**

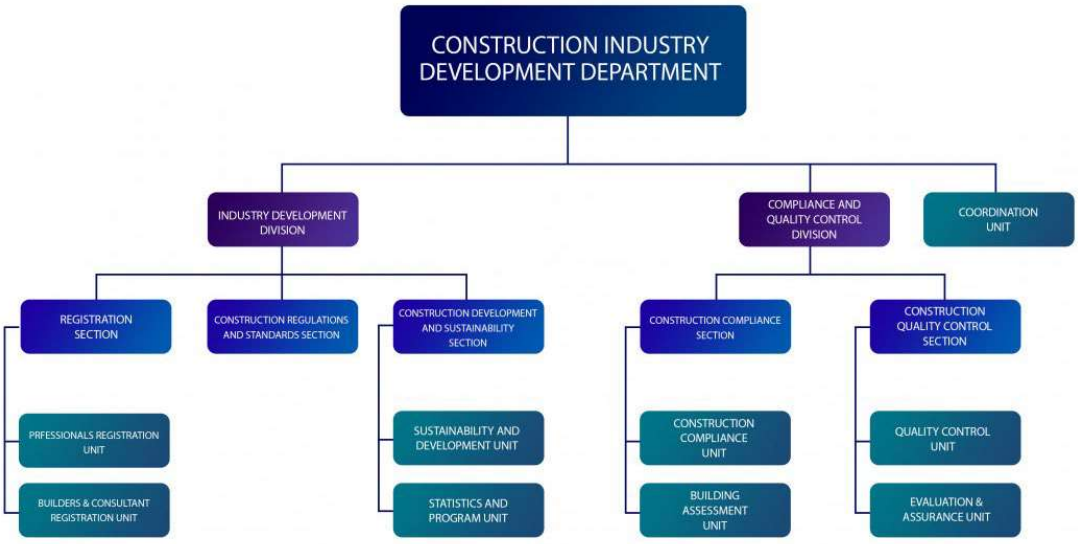
Planning Department makes physical development plan, formulate the procedures to maintain the land registries, prepare the land use plans of islands, make the master plan of the urban area and urban redevelopment plan.




Source: MNPHI Homepage

**Figure 2.4.4 Organization Structure of Infrastructure Department**

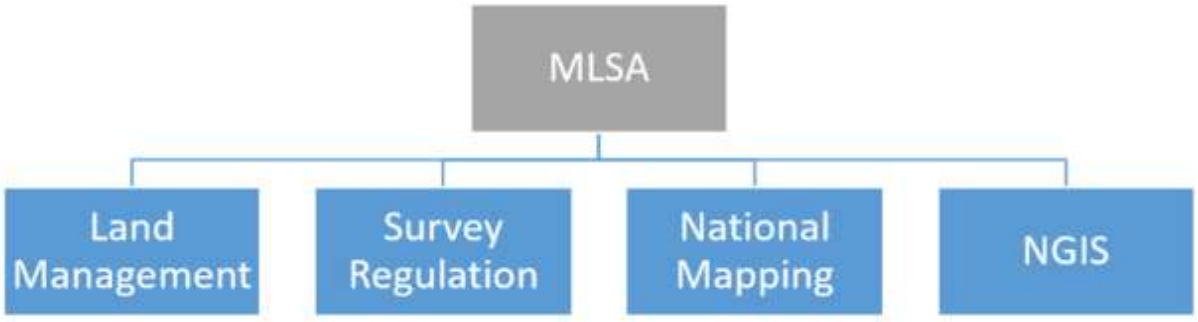
Infrastructure Department plans, develops and manages the designs and projects required to develop the infrastructure, establish a register of the state buildings and other infrastructure, oversee the use of such buildings, provide technical support for the repair works of the buildings and infrastructures by MNPHI. Construction of harbors and all works related to harbor development, harbor repairing, construction of jetties, building flats and houses in islands, providing electricity, water and sewerage for these houses, projects carried out with the help of international aid, road construction in islands, land reclamation and revetment works are the main tasks to be carried out by the infrastructure department.




Source: MNPHI Homepage

**Figure 2.4.5 Organization Structure of Construction Industry Development Department**

Construction Industry Department plans, guides, manages, oversees and develops the policies and strategies, establishes the regulations, codes, standards of the construction industry and oversees and manages them, establishes standards to ensure that the buildings are made to provide a good health and are safe, evaluates the people/workers of the construction industry, provides necessary training, establishes the rules and regulations of land reclamation and dredging and conducted researches to ensure the easy availability of materials needed for construction.




Source: MNPHI Homepage

**Figure 2.4.6 Organization Structure of Maldives Land and Survey Authority**

MLSA centralizes management of land Information and consolidate land research that was previously undertaken by different agencies of the government. The authority also has the mandate of regulating cadastral surveys, national mapping as well as establishing and managing the national geographic information system.

### (2) National Disaster Management Authority (NDMA)

NDMA was established as per the Disaster Management Act (28/2015) on 30 December 2018. One of the most important objectives of NDMA is to mainstream disaster risk reduction at the national level. This includes planning processes, establishing agreed standards, developing procedures and policies.

Much of the work at NDMA is made possible through its partnership with international technical bodies and donor agencies. Particularly of note are the projects being funded by United Nations Development Programme (UNDP), United Nations Children's Fund (UNICEF), UN International Strategy for Disaster Reduction (UNISDR) and the Asian Disaster Preparedness Center (ADPC). NDMA also received training opportunities from South Asian Association for Regional Cooperation (SAARC), United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), Asian Disaster Reduction Center (ADRC), Malaysian Medical Relief Society (MERCY Malaysia) and several other organizations.

The mandate of NDMA are as follows.

1. Organize and conduct various programs needed to prepare the public in the event of disasters both natural and otherwise and raising government and public awareness of such events.
2. Establish and coordinate the legal and administrative system required to have government ministries, private sector, groups and organizations and individual citizens coordinate for any work that needs to be carried out in a centralized manner due to disasters natural or otherwise.
3. In the event of disasters natural and otherwise, identify immediate response and relief requirement, and organize and coordinate ways to provide relief aid with other authorities concerned.
4. Provide temporary shelter to those whose homes become uninhabitable due to disasters both natural and otherwise.
5. Ensure that the basic necessities are provided for those whose homes become uninhabitable due to disasters both natural and otherwise until temporary shelter can be arranged.
6. Organize and coordinate with concerned government authorities the actions needed to be taken to acquire both local and internal aid in the event of disasters both natural and otherwise.
7. Establish a strong mechanism of working in association with concerned government and non-government authorities to ensure that disaster risk reduction remains a top priority.
8. Conduct research on the devastation caused by natural disasters as well as the impact of epidemic and pandemic in a small country like Maldives, and using the outcomes of the research, compile and publish a set of rules and regulations to be followed for any actions taken.
9. Ensure that any developmental programs or a project conducted by various government ministries conforms to the national disaster risk reduction standards as much as possible.
10. Enhance and increase the capacity of the early warning systems for natural disasters, potential pandemic and epidemic, and other disasters.
11. Establish and implement a system to coordinate facilitate and monitor disaster risk reduction activities in a centralized manner.

12. Establish mechanism in coordination with communities and clubs in the islands to increase the safety of vulnerable groups such as women and people with special needs in the face of disasters.
13. Establish a strong mechanism in which regional and international experience, information and other resources can be utilized, to disaster risk reduction.
14. Conduct awareness programs on disaster risk reduction in all regions of Maldives on a continuous basis.
15. Integrate disaster risk reduction and disaster management into the national education system and school curriculum establish means to deliver it.
16. Facilitate training for government employees of relevant sector of disaster risk reduction to enhance their knowledge on disaster management and disaster risk reduction.
17. Establish a disaster information database and making it accessible to public.

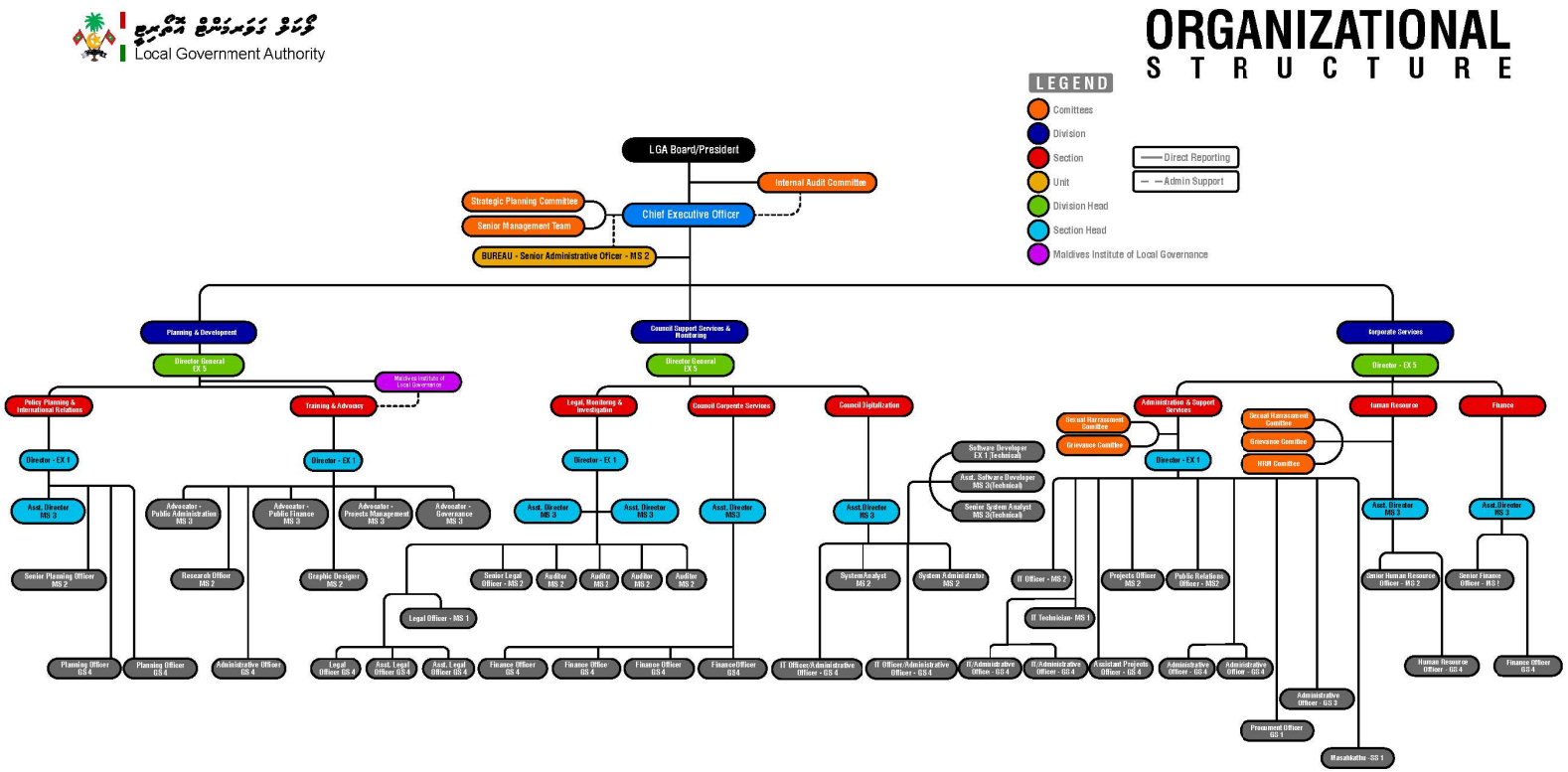
NDMA is composed of 3 units within the organization, such as Early Warning and Emergency Operations, Disaster Preparedness and Risk Reduction and Cooperate Affairs. The Disaster Preparedness and Risk Reduction, which is considered to be closely related to the Project, conducts local and national level programs to prepare and mitigate disaster risks (including handling all matters related to Disaster Risk Reduction Policies, Flood and Fire related issues, Conducting Disaster Awareness Programs.

### (3) Local Government Authority (LGA)

LGA was established under the Decentralization Act to regulate, oversee and develop the local governance system of Maldives as envisioned in the Constitution. The Decentralization Act confers the following mandate on LGA.

1. Money to ensure that the work and activities of councils created under this act function in accordance with the constitution, the decentralization act, and other laws.
2. coordinate the work of the councils at national level.
3. perform all other responsibilities mandated to the LGA under the decentralization act.
4. Monitor and harmonize standards and procedures, work activities, and regulations formulated by different councils.
5. To formulate a mechanism to demark the boundaries of the administrative divisions set forth in the decentralization act.
6. Identify training needs and conduct programs for capacity building of local councils.

Organizational chart of LGA is as in Figure 2.4.7.

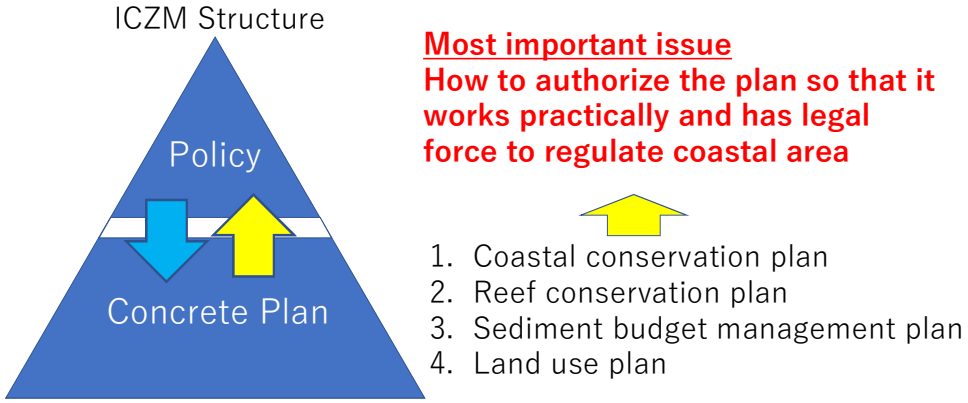



Source: LGA Homepage

**Figure 2.4.7 Organization Structure of LGA**

## 2.5 Issues and Image of Concrete Plan for ICZM

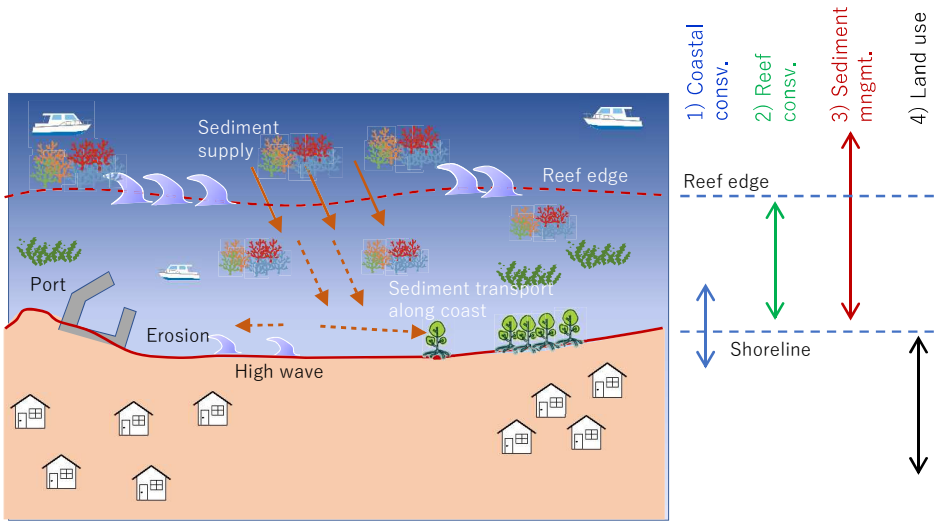
Image of concrete plan of ICZM, which are going to be prepared at Gan and Fonadhoo, is summarized as follows. The concrete plan consists of 1) coastal conservation plan, 2) reef conservation plan, 3) sediment budget management plan and 4) land use plan. In addition, there would be a need to consolidate or modify the legal system, which is described in Sec 2.4, at the policy level (i.e. the central government side) so that these concrete plans can work effectively with legal forth as shown in Figure 2.5.1. This issue is recognized as the most critical issues to be archived in Component 1 in this study.




Source: JICA Expert Team

**Figure 2.5.1 Issue and Structure of ICZM**

Figure 2.5.2 shows the general area to be covered by each plan. Coastal conservation plan (No.1) covers at nearshore area, which includes physical phenomena such as wave and erosion, coastal structures such as port and revetement, vegetation such as mangrove, and buildings and infrastructures at near shoreline. Reef conservation plan (No.2) mainly covers the reef area between shoreline and reef edge. Sediment budget management plan (No.3) covers from offshore as the source of supply to shore where sediment is supplied. Land use plan (No.4) covers hinterland of coastal area.




Source: JICA Expert Team

**Figure 2.5.2 Coverage Area by Each Plan**

### 2.5.1 Image of Coastal Conservation Plan

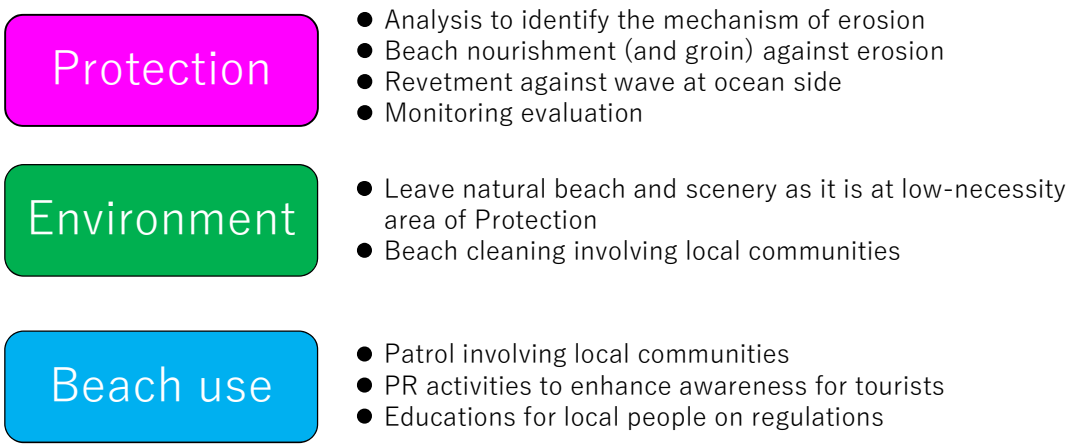
Policy for coastal conservation will be firstly prepared to formulate coastal conservation plan. This policy basically covers whole coastal area of target island. Coastal area of island will be separated by zones considering with characteristics of coastal condition, hazard, coastal use, environment, and socio-economic conditions and the policy for coastal conservation will be prepared by each zone. Example of the policies are shown in the followings and Figure 2.5.3.

- Policy Example 1: Conservation of natural beach against erosion (yellow highlighted)
- Policy Example 2: Promotion of beach use for tourism (purple highlighted)
- Policy Example 3: Conservation of natural environment and scenery (blue highlighted)
- Policy Example 4: Protection against high waves (pink highlighted)
- Policy Example 5: Regulation on beach use (green highlighted)


Source: JICA Expert Team

**Figure 2.5.3 Image of Policy for Coastal Conservation by Zones**

Additionally coastal conservation measures will be prepared in terms of 1) protection, 2) beach use and 3) environment aspects at each zone refereeing to the policy. Figure 2.5.4 shows examples of measures for each aspect.




Source: JICA Expert Team

**Figure 2.5.4 Example of Measures in Protection, Environment and Beach Use**

Finally, coastal conservation measures will be prepared at each zone as shown in Figure 2.5.5. Regarding with physical measures such as beach nourishment and revetment, detailed images such as layout and cross section will be also prepared for the coastal conservation plan.


Source: JICA Expert Team

**Figure 2.5.5 Example of Allocation of Measures based on Policy at Each Zone**

### 2.5.2 Reef Conservation Plan

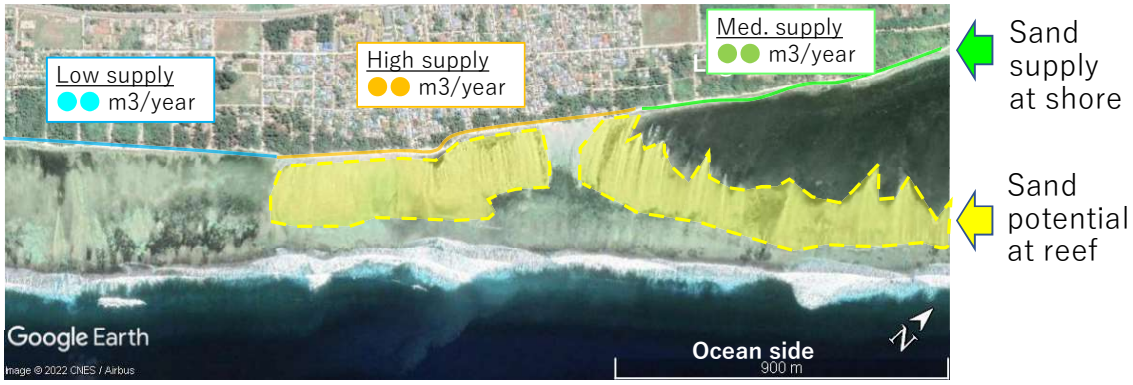
Items listed in Table 2.5.1 will be included quantitively in the reef conservation plan. Image of Item (1) and (2) in the table is shown in the Figure 2.5.6. Sediment amount supplied to shore (i.e. item (1)) will be assumed from the satellite image analysis and field investigation survey and potential sand volume at reef flat (i.e. item (2)) will be analyzed by satellite image and sea-bed condition survey.

In additions to above, the coverage ratio of coral reef, water quality and candidate site for coral transplantation will be surveyed and organized in the map as shown in the Figure 2.5.7.

**Table 2.5.1 Main Items to be Included in Reef Conservation Plan and Survey Method**

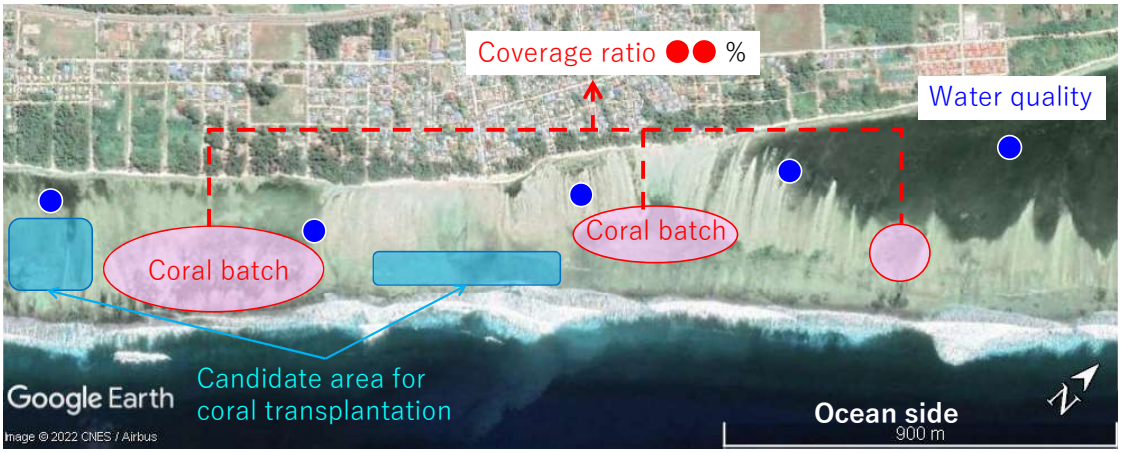
| Item | Survey Method |
|---|---|
| (1) Sand volume supplied from reef to shore ($m^3$/y) | Satellite image analysis, beach profile survey |
| (2) Sand potential volume at reef flat ($m^3$/y) | Satellite image analysis, survey on sand distribution, quality, and thickness at reef flat |
| (3) Coverage ratio of coral reef, water quality, candidate location and method for coral transplantation | Transect survey, dive survey, water quality meter |

Source: JICA Expert Team




Source: JICA Expert Team

**Figure 2.5.6 Example of Map for Sand Supply Volume and Sand Potential at Reef Flat**




Source: JICA Expert Team

**Figure 2.5.7 Example of Map for Coverage Ratio and Candidate Area for Coral Transplantation**

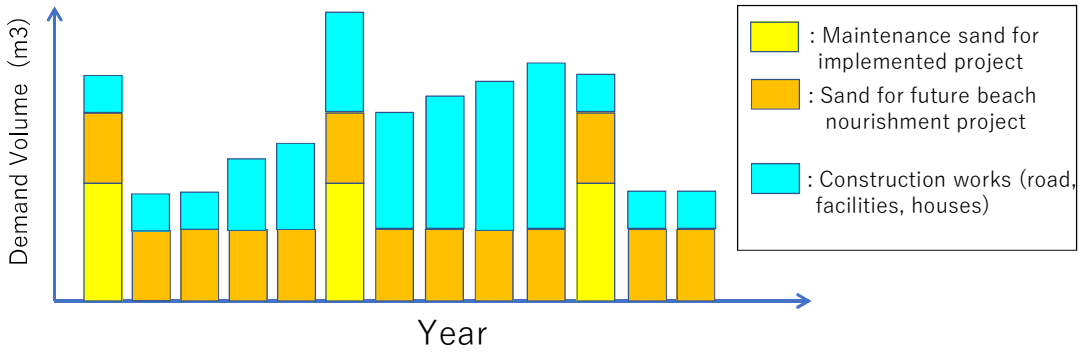
### 2.5.3 Sediment Budget Management Plan

Quantities of both sand demand and supply will be organized in the sediment budget management plan.

Firstly, sand demand volume by purpose of use will be assumed in time series as shown in Figure 2.5.8. Purpose of use can be, for example, 1) maintenance sand for implemented project, 2) sand required for future coastal projects,

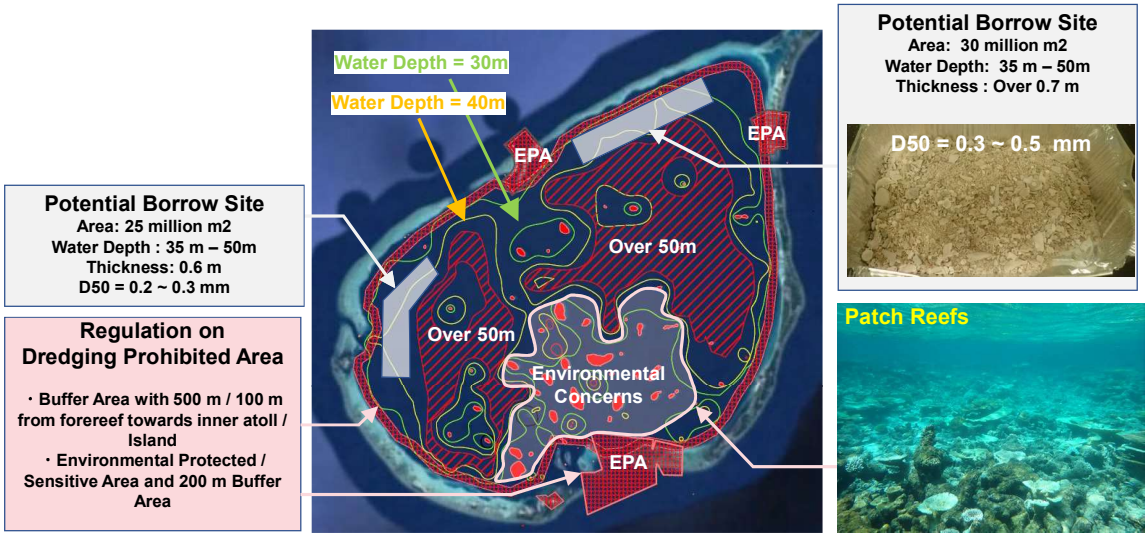
and 3) sand required for construction works such as road, business facilities and houses. It should be noted that requirements for sand will be different by purpose of use, for example, coarse and light-colored sand will be required for beach nourishment project in terms of stability and beach use, while fine sand can be used for the other construction works.

Secondary, in perspective of supply candidate sand borrow site will be identified in this study as shown in Figure 2.5.9. The candidate site is basically studied at lagoon area of the Atoll, to which the target island belongs, considering advantages in wave condition and transportation distance for the works. The restricted area for sand borrow needs to be identified such as deep area in construction works and environmental protected/ sensitive area by EPA and other coral habitat area in environmental aspects. Besides the restricted area, candidate borrow site will be determined by surveys and consideration of workability of construction works. Data for candidate site includes 1) area, 2) water depth, 3) thickness of sand layer, 4) volume, 5) grain size and color, 6) method for dredging, and 7) procurement plan and candidate stockpile site on land.




Source: JICA Expert Team

**Figure 2.5.8 Image of Graph for Sand Demand in Long Period**



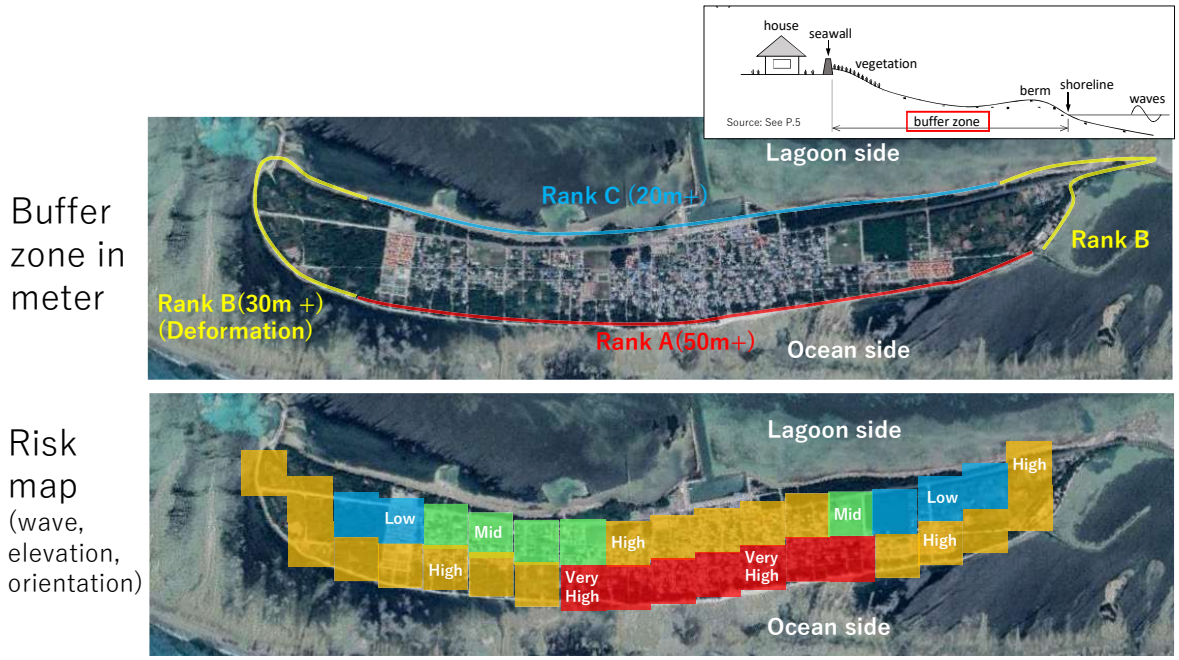

Source: Modified using Google Earth by JICA Expert Team

**Figure 2.5.9 Image of Map for Candidate Sand Borrow Site**

### 2.5.4 Land Use Plan

Land use plan will be designed to include buffer zone (or setback, no construction zone) and risk map for future development as shown in the Figure 2.5.10.

Regarding with buffer zone, coastal area will be classified into several zones considering erosion rate, wave height, land use and environment situation and required buffer zone in meter is set at each zone. Satellite image analysis will be applied to figure out the erosion situation at target coast. The land use plan prepared/ to be prepared by Island council will be applied to understand near-future land use at hinterland. Climate change effect such as sea level rise and acceleration of erosion will be evaluated and incorporated into land use plan. Risk map will be prepared considering degree of wave inundation and coastal erosion, land elevation and location.




Source: Modified using Google Earth by JICA Expert Team and Beaches in Okinawa and Recent Changes, Second Edition, June 202 1, Takaaki Uda, Public Research Center

**Figure 2.5.10 Image of Buffer Zone and Risk Map to be included in Land Use Plan**

# CHAPTER 3 Related Projects by JICA and Other Donors

## 3.1 Assistance Projects by JICA in the fields of Environment, Climate Change Countermeasures, and Disaster Prevention

Assistance Projects in Maldives by JICA in the fields of environment, climate change and disaster prevention is shown in Table 3.1.1. Beginning in 1987 with a seawall construction project in Male, the capital city of Maldives, currently Japan still continues to develop a digital terrestrial television broadcasting network through grant aid, and supports the capacity development in the field of climate change through technical cooperation.

**Table 3.1.1 Representative Indexes Related to Coastal Vulnerability in Several Atoll Countries**

| Project Title | Scheme | Period | Note |
|---|---|---|---|
| The project for the Seawall Construction in Male' Island | Grant Aid | 1987 - 1999 | |
| Basic Design Study for the Coastal Disaster Prevention Plan for Male' Island, Republic of Maldives | Grant Aid | 1993 | |
| Feasibility study for application of photovoltaic power on Male' and Hulhumale' Islands in the Republic of Maldives | Technical Cooperation | 2009 | |
| The Project for Clean Energy Promotion in Male | Grant Aid | 2010 - 2014 | |
| Japan's Non-Project Grant Aid for Provision of Japanese Disaster Reduction Equipment | Grant Aid | 2015 | |
| The Project for the Digital Terrestrial Television Broadcasting Network Development | Grant Aid | 2017 – 2024 | Ongoing |
| Building Climate Resilient and Safer Islands in the Maldives | Data Collection Survey | 2018 - 2021 | |
| Digital Terrestrial Television Broadcasting Operational Capacity Improvement Project | Technical Cooperation | 2019 – 2024 | Ongoing |
| Data collection survey on the possibility of assistance utilizing Okinawa's resources in environment sector in the Maldives | Data Collection Survey | 2020 | |
| Data collection survey on climate-related disasters in the Male's region in the Republic of Maldives | Data Collection Survey | 2021 - 2022 | |
| Project for Safe and Resilient Islands against Climate Change and Disaster | Technical Cooperation | 2021 -2025 | Ongoing |
| Follow Up Cooperation Project for Clean Energy Promotion in Male | Follow Up Cooperation | 2021-2022 | Ongoing |

Source: JICA Expert Team

## 3.2 Related Projects in Maldives by Other Donors

So far, climate change projects in Maldives have been implemented by various international organizations and other donors. The related projects by other donors and related fields to the project are shown in Table 3.2.1.

**Table 3.2.1 Related Projects by Other Donors and Related Fields to the Project**

| No. | Project | Period | Donor | Related field to the project |
|---|---|---|---|---|
| 1 | Integrating Climate Change Risks into Resilient Island Planning in the Maldives | 2008-2010 | GEF | Enhanced capacity of national, provincial, atoll and island authorities and civil society leaders to integrate climate risk information into policy, planning and investment decisions |
| 2 | Present cost-effective, locally appropriate coastal management and drainage management options contributing to climate change resilience of communities in Fares-Maathoda | 2010-2015 | Government of Denmark | ・Identifying and developing locally appropriate adaptation options on coastal management<br>・Implementation of locally appropriate adaptation options |
| 3 | UNDP country program on enhancing national capacity for DRRM in Maldives<br>Scaling up the National Capacity for Disaster Risk Reduction and Management in the Maldives<br>Enhance National Capacity for Disaster Risk Reduction and Management in Maldives | 2011-2018 | UNDP | ・Strengthening the early warning systems<br>・Enhancement of community capacity for disaster response |
| 4 | IMPACT2C project | 2012-2016 | IMPACT2C (Research project) | Sea level rise in Maldives for future coastal design |
| 5 | Climate Change Adaptation Project (CCAP) | 2015 | World Bank | ・Coral reef monitoring<br>・Building awareness and strengthening local government capacity to address climate change adaptation issues |
| 6 | Supporting vulnerable communities in Maldives to manage climate change-induced water shortages, GCF | 2016-2021 | GCF | Early warning system established on the basis of forecasted meteorological information |
| 7 | Coastal protection project of Fuvahmulah City | 2017-2018 | Netherlands Enterprise Agency, Kuwait Fund | Coastal protection |
| 8 | INtegrating SEA-level Projections in climate services for coastal adaptaTION (INSeaPTION) | 2017-2020 | European Research Area for Climate Services (ERA4CS) (Research project) | Information with extreme wave condition and future climate change scenarios |
| 9 | Enhancing National Development through Environmentally Resilient Islands (ENDhERI) | 2020-2024 | GEF | ・Integrated coastal zone management (ICZM)<br>・Marine management area (MMA) |
| 10 | USAID Climate Adaptation Project in Maldives | 2021-2026 | The U.S. Agency International Development (USAID) | Strengthening governance to address climate-related risks |

Source: JICA Expert Team

# CHAPTER 4 Current Status and Issues of Coastal Conservation on Target Islands

## 4.1 Background of selection of target islands

Component 2 of the main project targets two islands, Maamendhoo and Fonadhoo in Laamu Atoll, as GCF projects, and Isdhoo and Gan in Laamu Atoll and Meedhoo in Addu Atoll as co-financing projects by the government of Maldives. In the first stage of the project (Data Collection Survey on Building Climate Resilient Safer Cities, 2021, JICA), the project candidate sites were narrowed down to Laamu and Addu atolls in the southern part of the country from the perspective of 1) climate change hazard and vulnerability and 2) project implementation effectiveness. The candidate sites were narrowed down to Laamu and Addu atolls in the southern part of the country. The selection of islands for the GCF project was based on the following criteria as shown in Figure 4.1.1: 1) vulnerability, 2) coastal development and coastal protection requirements, and 3) importance of the islands in terms of economic and development plans. In addition, Isdhoo, Gan, and Meedhoo were selected as sites for co-financing by Maldives government, based on strong demand from the Island Council and the high importance of the islands in the atoll.

| Evaluation Category | Evaluation Item | Addu Atoll | | | | Laamu Atoll | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Hitadhoo | Maradhoo | Feydhoo | Meedhoo | Gan | Fonadhoo | Isdhoo | Maamendhoo |
| Vulnerability | Topographic characteristics (elevation) | 3 | 3 | 3 | 2 | 1 | 2 | 2 | 4 |
| | Topographic characteristics (area) | 3 | 4 | 2 | 1 | 1 | 3 | 1 | 4 |
| | Exposure of settlements and major infrastructure | 3 | 3 | 2 | 1 | 1 | 3 | 1 | 4 |
| | Other exposure (cultural facilities, archaeological sites, ecosystems, etc.) | 2 | 1 | 1 | 3 | 3 | 2 | 3 | 2 |
| | Severity of beach erosion (amount of retreat) | 3 | 2 | 0 | 3 | 2 | 3 | 2 | 3 |
| | Frequency of storm surge and flood damage | 2 | 1 | 1 | 3 | 2 | 3 | 2 | 4 |
| | Resident awareness, gender issues | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 |
| | Island government awareness, initiatives | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 |
| Coastal development, coastal protection requirements | Population of beaches and reefs, coastal development (coastal artificialization) plans*) | 1 | 1 | 1 | 3 | 2 | 2 | 3 | 3 |
| | Island demands for beach protection | 3 | 2 | 1 | 3 | 3 | 3 | 3 | 3 |
| Degree of importance of the island based on economic and development plans | Future economic viability | 3 | 3 | 3 | 2 | 3 | 3 | 2 | 3 |
| | Future development plans | 3 | 2 | 2 | 3 | 3 | 3 | 2 | 2 |
| Overall evaluation | Socore | 2.5 | 2.2 | 1.7 | 2.5 | 2.3 | 2.8 | 2.3 | 3.2 |
| | Priorities | 3 | 7 | 8 | 3 | 5 | 2 | 5 | 1 |

*) Scores are basically assigned as follows: low to 1, medium to 2, high to 3, and very high to 4. However, the reverse is true for the items marked with *).

Based on the above, two high priority islands, Maamendhoo and Fonadhoo, were selected as climate change adaptation projects.

Source: Data Collection Survey on Building Climate Resilient Safer Cities , Final Report, 2021, JICA

**Figure 4.1.1 Selection of target islands for GCF project targeting inhabited islands in Addu and Laamu Atolls**

## 4.2 Overview of the target islands and beach conditions

### 4.2.1 Maamendhoo (GCF project, Laamu Atoll)

Maamendhoo is the smallest inhabited island in Laamu Atoll with an area of 19 ha and having 896 residents. The island has the highest population density in the atoll with 47.9 persons/ha. As Maamendhoo is located at a nearby atoll channel, this island has an important role as the logistic base for traveling from Laamu Atoll to other atolls. Furthermore, this island also has a role of providing the human resources and goods to a world-famous resort island, the Six Senses, which is located next to this island. Since most of the residential areas and important infrastructure facilities are located very close to the coast, the island has extremely high exposure to coastal hazards compared with the other islands. The land elevation of the island is lower (M.S.L+ 0.7~0.8 m in average) than other inhabited islands. Such geographical characteristics together with extremely narrow area and high population density will induce high vulnerability compared with other inhabited islands. Coastal erosion has been a serious problem in the island and retreat of the shoreline at 0.6 m per year from 1999 was reported[7]. Since the land area is very small, the issue of coastal erosion becomes more serious on both impacts of land loss and flooding due to high waves. The island council and residents are very concerned about the coastal erosion and induced coastal disaster. Because of this, they have strongly requested the implementation of coastal protection. Within the limited island areas, as the coastal areas are closely associated with peoples' lives as places for recreation and playing sports, the people's awareness on coastal environment conservation is relatively higher than in the other inhabited islands. Figure 4.2.1 shows the recent beach conditions. P1 is a photograph of the project area on the east coast. The results of the shoreline change analysis shown in Chapter 5 confirm that sand has accumulated a little more than in 2019, but the reefs are exposed over a wide area (toward the back of the photo), and beach cliffs have formed in the backland, indicating that the area is still affected by beach erosion. P2 and P3 are photographs of the project area on the west coast. In P2, which is closer to the convex part of the island, no significant changes are observed between 2019 and 2022. On the other hand, in P3 on the north side, the beach cliff position receded and some reefs were exposed, confirming that erosion is progressing. In addition, as shown in the same figure, sand sampling was observed from the reef in the vicinity of the planned reclamation site on the north side. It is possible that such illegal sand extraction is having a certain impact on the P3 area in its vicinity.

P1



(The foreground side shows sedimentation trend)

P2



(No significant change)

P3



(Progressive erosion)

Sand Extraction

(Illegal sand extraction from the reef around the proposed reclamation site)

Source: JICA Expert Team

**Figure 4.2.1 The Recent Beach Conditions in Maamendhoo**

### 4.2.2 Fonadhoo (GCF project, Laamu Atoll)

Fonadhoo is the second largest inhabited island in Laamu Atoll, next to Gan, with an area of approximately 163 ha and with 2,266 residents. Average elevation is MSL + 0.9 m. As the atoll capital island, the population density is relatively high (13.9 persons/ha) and it is ranked in 3rd place in Laamu Atoll. In addition, the population is increasing due to migration from adjacent inhabited islands, such as Gaadhoo Island, for the purpose of employment opportunities and integration of social infrastructure. Active land use development such as construction of residential areas along the coastal areas are being promoted in the island. Based on the field survey results, the residential areas are extended to the vicinity of the coastal areas and flooding due to intrusion of high waves has occurred frequently at this residential area. The artificial modifications on the coral reef at several points of the lagoon side were observed such as harbor construction and coral mining on the reef to obtain construction material. On the other hand, natural sandy beaches and coral reefs still exist along the ocean-side coastal areas. According to the interview survey to the island council and residents, the coast at the ocean side is suffering from serious coastal erosion; however, coastal protection measures, except the embankment made by coral sand nearby the residential areas, have not been implemented so far. As the coastal areas nearby the residential areas are being used for recreational purposes by the residents, it is assumed that these people have high awareness on coastal environment conservation, so that these residents conduct beach cleaning activities at the regional level from 2019. Since further migration from adjacent islands to the atoll capital island is expected, further development of residential area is planned in Fonadhoo. Figure 4.2.2 shows the recent beach conditions. Among the project areas, the area around P1 showed a sedimentation trend, with a maximum sedimentation of 20m. In P2, approximately 500 m west of P1, no significant beach change can be confirmed. On the other hand, it was confirmed that erosion is progressing in P3 further west. Thus, in recent years, erosion and sedimentation areas tend to be divided even within the project area. In addition, as shown in the same figure, sand extraction from the beach has been confirmed for a long period of time at the beach in question. It is assumed that this extraction has a certain amount of impact on the beach.


P1



(Maximum sedimentation: 20m)

P2



(顕著な変化なし)

P3



(侵食の進行)

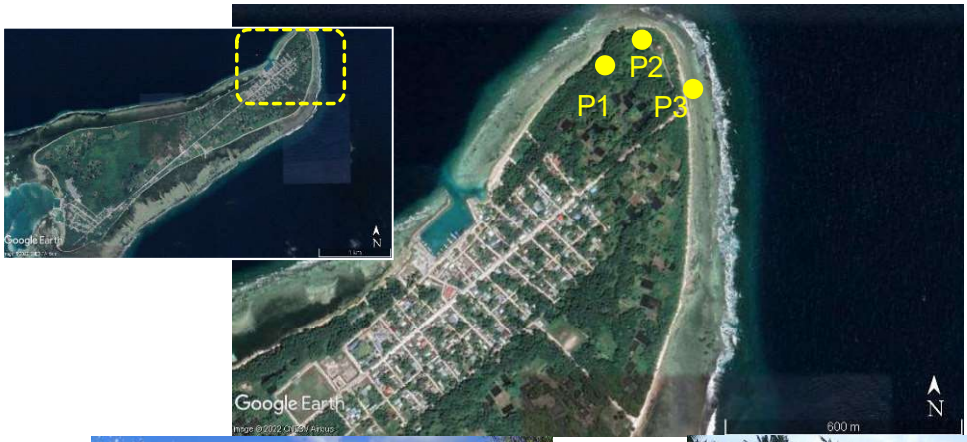
Illegal Sand Extraction

Source: JICA Expert Team

**Figure 4.2.2 The Recent Beach Conditions in Fonadhoo**

### 4.2.3 Isdhoo (Co-financing project in Maldives, Laamu Atoll)

Isdhoo has an area of 146 ha and 958 residents, and the population density is the third lowest in the atoll at 6.6 persons/ha. The residential areas are located behind the two main harbors, and as the roads run inland in the island, the exposure to the coastal hazards is not so high compared with other islands. As the island is in the northernmost area in the atoll, the damage due to coastal erosion has been reported especially at the northern part of the island, where the offshore waves directly hit the area. As there exist historical and cultural heritages behind this coast, the island council has raised strong requests to conserve the cultural heritage sites. Figure 4.2.3 shows the recent beach conditions. At site P1, the existing protection measure, the revetment made of cement bags, has partially collapsed. The low top height of the revetment and some collapsed sections did not provide sufficient protection against wave overtopping and were not effective measures. According to the Island Council, the P2 and P3 sites have recently been subjected to beach erosion, and there is no beach at these sites.




(P1 existing cement bag revetment (partially collapsed))

(P2 gravel beach)

(North side from P3: erosion situation)

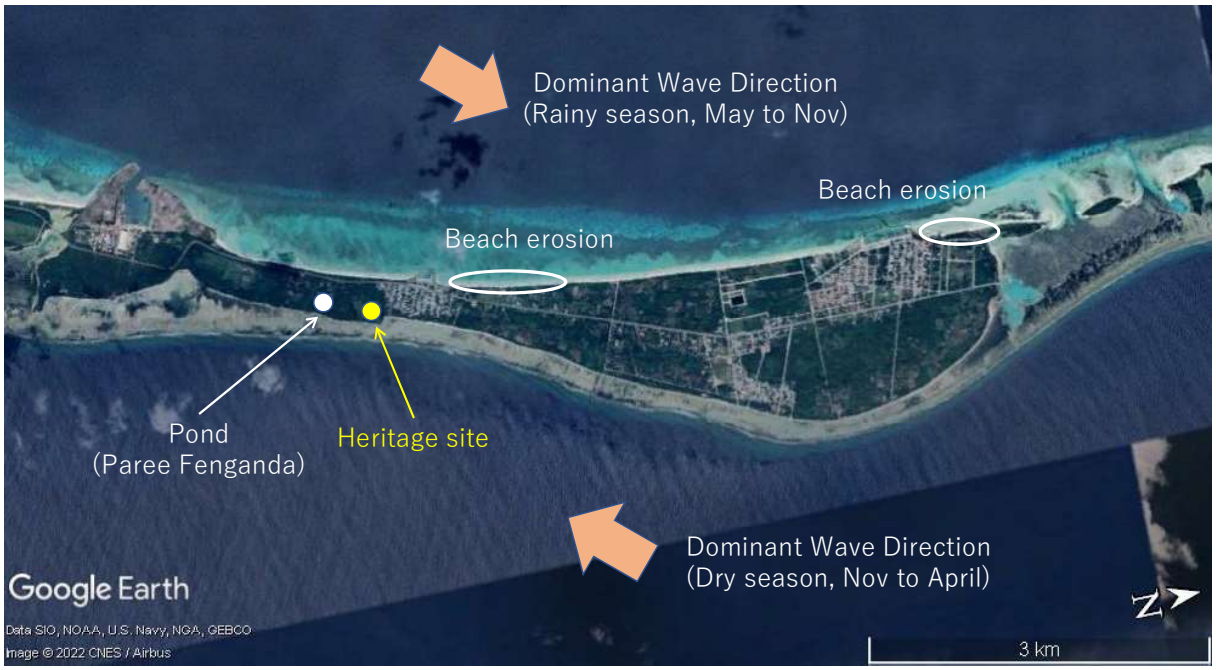
(South from P3: erosion)

Source: JICA Expert Team

**Figure 4.2.3 Recent Beach Conditions in Isdhoo**

### 4.2.4 Gan (Co-financing project in Maldives, Laamu Atoll)

Gan in Laamu Atoll is the largest inhabited island in the Maldives with area of approximately 633 ha and with 3,080 residents. Average land elevation is M.S.L+ 0.9 m. The population density is the lowest in Laamu Atoll with 4.6 persons/ha. Even though the land elevation is lower than the average elevation in the Maldives, the exposure condition to coastal disasters is relatively lower compared with other populated islands as there are still undeveloped areas in the island. At this moment, only limited areas in the island are suffering from the risk of flooding due to high waves. However, coastal erosion, which is caused by artificial modification at the coastal area such as construction of harbor and blockage of inlet between each island by construction of causeway, is increasing. However, since the natural coastlines and coral reefs are still well-maintained compared with other inhabited islands, tourism development will be actively planned in this island. In addition, historical and cultural heritage site exists just behind the ocean side. The revetment was constructed ten years ago but is already damaged by wave action and has collapsed. The island council is highly concerned about coastal erosion and deterioration of the coastal and reef environment so as to be highly conscious of the conservation of the coastal environment for the coastal areas and coral reef. Figure 4.2.4 shows the overall location map of Gan Island. On the lagoon side (west side), the southwest monsoon is thought to be responsible for the predominance of northward coastal drift sand. As a result, beach erosion is occurring on the north side of the fishing port, and the Island Council is currently studying erosion countermeasures. On the ocean side, the northeast monsoon is considered to be responsible for the predominance of southerly coastal drift sand.




Source: JICA Expert Team

**Figure 4.2.4 Overall location map of Gan Island**

(Erosion on the north side of the fishing port on the lagoon side (central part))

(Erosion on the north side of the fishing port on the lagoon side (north))

(Beach in front of the Heritage site and collapse of the seawall due to cement bags)

Source: JICA Expert Team

**Figure 4.2.5 Gan Island Project Sites and Problematic Beach Areas**

### 4.2.5 Meedhoo (Co-financing project in Maldives, Addu Atoll)

Meedhoo/Hulhdhoo are located on the northeastern top of the atoll, far from the abovementioned four connected islands. The land area is 315 ha in total, with a population of 3,113, and a population density of 9.9 persons/ha. The residential areas are mainly located at the lagoon side, and the natural sandy beaches exist along the ocean side coast where the offshore waves occur directly. Several public beach parks are maintained through the support of NGOs, and these parks are used for the recreation of the residents. Tourism development is very active in Meedhoo/Hulhudhoo, and new resort development is currently ongoing at the northwestern area of the island. It has been reported that coastal erosion has become serious along the northern and eastern sides of the coastal areas which face the open ocean. Even though no residential area exists near the northern coast, there exists the oldest graveyards in the Maldives, which is an important historical and cultural heritage site. Furthermore, a plantation land that utilizes freshwater located nearby the coast also exists. Although a seawall has been constructed to prevent shoreline retreat and seawater intrusion caused by coastal erosion, most of the sections have already been damaged. At the eastern side of the island, a rubble-type revetment, with an approximate length of 1.1 km, was newly constructed in 2018. However, this has caused the decrement of the sandy beaches and interference to utilize the coastal areas. Under such situations, the requests from the residents on maintenance of the natural sandy beaches, but not hard-type protection measures, are collected through the hearing survey. Residents in the island have high

awareness and consciousness regarding coastal conservation, and are also keen on coast maintenance activities in collaboration with NGOs. Figure 4.2.6 shows the recent beach conditions. no significant change in the beach is observed in P1 at the western end of the project area from 2019 to 2022. Also, in P3 near the fronted rubble-type revetment in front of the Waste Management Center in the southern part of the project area, there is no significant change in the narrow fronted beach. On the other hand, near P2, where cement bags are installed on the northern beach, concrete shells are exposed, suggesting that beach erosion is progressing. As of September 2022, a sandbag revetment is being constructed around the bend of the project area as an emergency project by MNPHI (see Figure 4.2.7). This revetment also includes reclamation of up to approximately 15 m of the backland. The details of this project need to be confirmed after the completion of the said project. However, since the subject site overlaps with this co-financing project, the handling of the existing sandbag and the beach nourishment width and layout proposed in this project need to be reconsidered during the detailed design.


P1



(No significant change)

P2



(Progress of erosion)

P3


(no significant change)

Source: JICA Expert Team

**Figure 4.2.6 Recent Beach Conditions in Meedhoo**

Source: JICA Expert Team

**Figure 4.2.7 Sandbag Revetment under Construction by MNPHI as an Emergency Project (as of September 2022)**

# CHAPTER 5 Detailed Survey and Basic Design for Coastal Conservation on the Target Islands

## 5.1 Climate, Wave, Topographic Characteristics

### 5.1.1 Climate Condition

#### (1) Temperature

Maldives has a warm and humid climate throughout the year. The average temperature ranges between 26-33℃. The seasons are divided into two periods: the northeast monsoon season (November-April) and the southwest monsoon season (May-October). The warmest period in a year occurs during March-April, and it continues until the onset of the southwest monsoon in mid of May. Temperature, wind, rainfall and tide levels are monitored at three sites in the Maldives: Haa Dhaalu Atoll Hanimaadhoo in the north, North Male Atoll Male in the center and Laamu Atoll Gan in the south. Average monthly temperatures at each site are shown in the graph below.

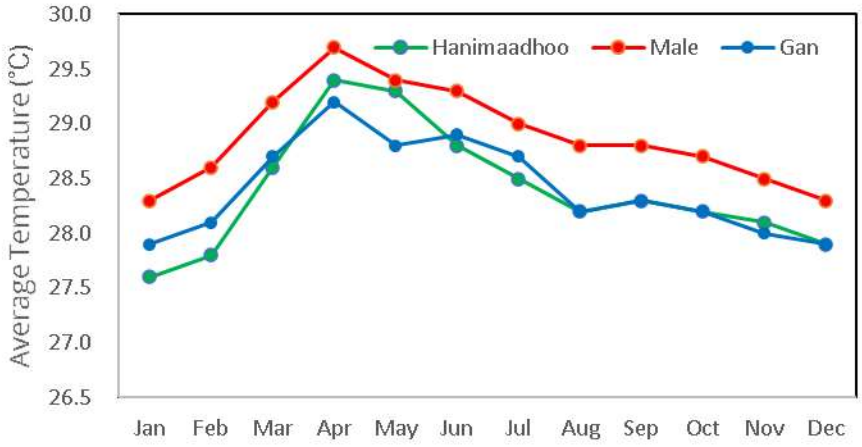
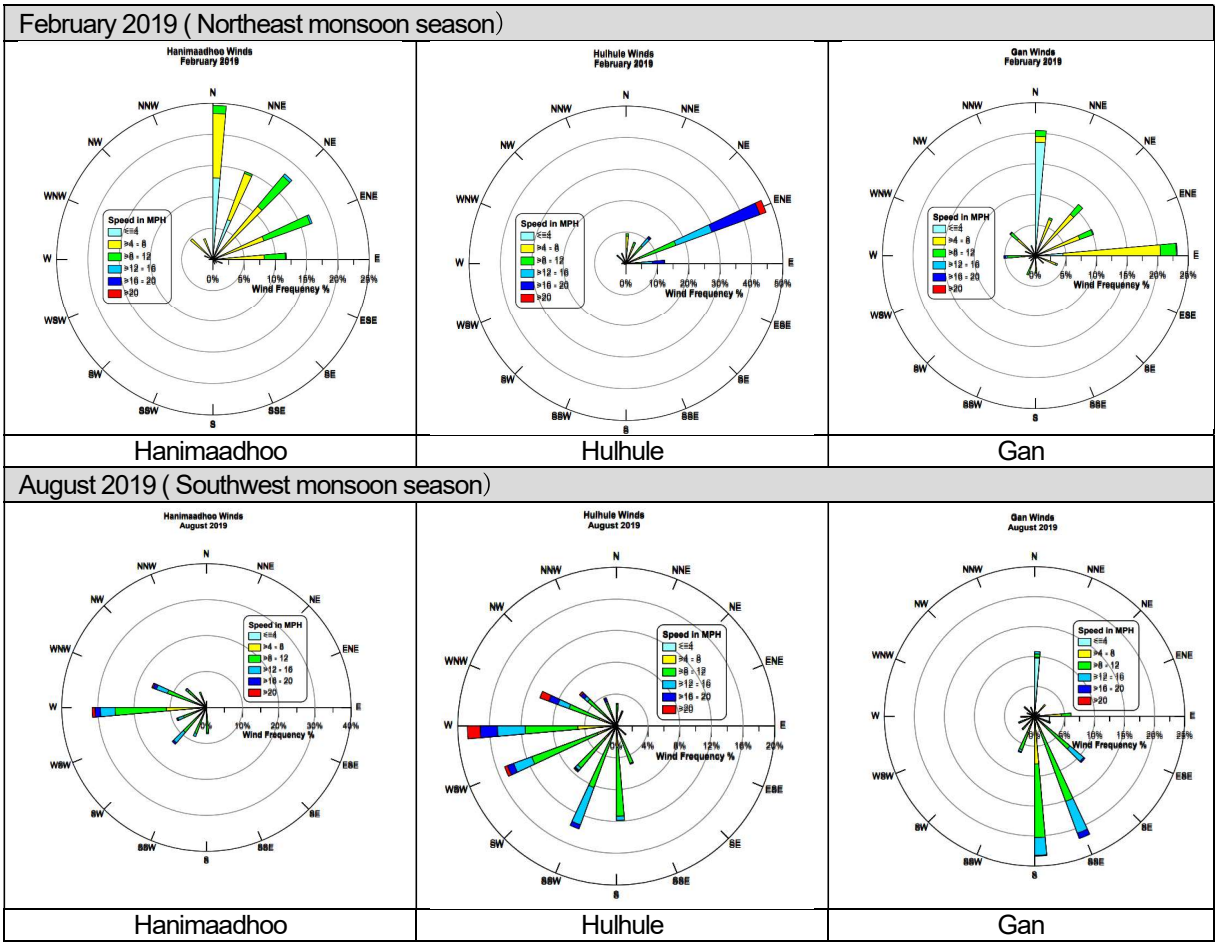



**Figure 5.1.1 Average Temparature in Hanimaadhoo, Male, Gan**

Source: Champion Traveler[1)]

#### (2) Wind Distributing

Figure 5.1.2 shows wind distribution maps for the northeast monsoon season and the southwest monsoon season in 2019 at the three stations, according to the Climate Report[1)] published by the MMS. In the Maldives, northeasterly winds prevail during the dry season from December to April, while southwesterly winds prevail during the rainy season from May to November, and this tendency is also observed in the northern, central and southern regions. In all the northern, central and southern monitored points, there are also variations in wind direction within a single month of observation.




Source: Climate Report (2019) published by MMS[2)]

**Figure 5.1.2 Wind Distribution in Northeaswt Monsoon Season and Southwest Monsoon Season in Hanimaadhoo, Hulehule, Gan**

### (3) Rainfall

Figure 5.1.3 shows annual observations of rainfall in northern Hanimaadhoo, central Hulhule and southern Gan. Rainfall in the Maldives varies according to two seasons. Rainfall increases during the southwest monsoon season from May to October and decreases during the northeast monsoon season from November to April. The graph of rainfall at the three sites shows that monthly rainfall amount tends to increase from north to south.

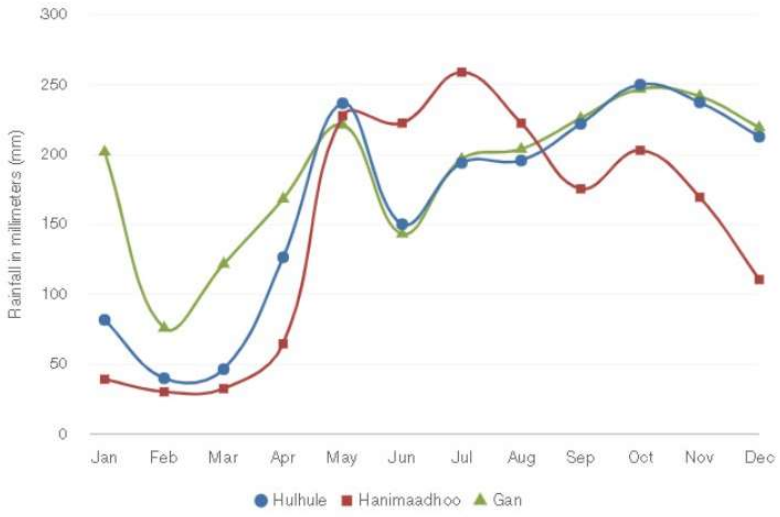



**Figure 5.1.3 Monthly Rainfall Record in Hanimaadhoo, Hulehule, Gan**

Source: Website of MMS[3)]

### 5.1.2 Wave Condition

#### (1) Overview of Wave Observations in Target Atolls

In Maldives, as wave observation data is limited, wave observation have been being conducted under JICA Expert Team to understand wave characteristics at the target atolls, Laamu Atoll and Addu Atoll, and to set the design conditions for design purposes. Wave characteristics of the target atolls is examined from the observation data from 2019 to 2020.

In the wave observation, the equipment called Wave Hunter is used, which is sea mounted type and water pressure type wave observation equipment. The equipment observes water pressure and from water pressure, wave specification such as wave height, wave period can be estimated. Table 5.1.1 summarizes wave observation conditions such as water depths, locations, and observation settings for each location.Figure 5.1.4 - Figure 5.1.5 show the location maps of the observation sites at Laamu Atoll and Addu Atoll.

**Table 5.1.1 Wave Observation Condtions**

| | Laamu Atoll | | Addu Atoll | |
|---|---|---|---|---|
| | Maamenndhoo | Fonadhoo | Hankede | Meedhoo |
| Station name | St.MA | St.FO | St.HA | St.ME |
| Coordinate (degree) | LAT: 1.819 N<br>LONG:73.385 E | LAT: 1.830 N<br>LONG:73.508 E | LAT: 0.644 S<br>LONG:73.100 E | LAT: 0.578 S<br>LONG: 73.233 E |
| Water depth of the installation location | 21.4 m | 33.5 m | 17.3 m | 13.5 m |
| Observation setting | Observation period：20 min<br>Observation interval：120 min<br>Sampling interval：0.5 sec | | | |

Source: JICA Expert Team


**Figure 5.1.4 Wave Observation Location (Laamu Atoll)**


**Figure 5.1.5 Wave Observation Location (Addu Atoll)**

### (2) Wave Characteristics in Target Atolls

This section describes the results of observations at Hankede in Addu Atoll and Fonadhoo in Laamu Atoll, which was used to establish the design conditions. For the establishment of design conditions, the discussion of the basic design in Section 5.5 is referred.

Figure 5.1.6 shows the time series data for significant wave height (blue line in the figure) and significant wave period (red line in the figure) at the observation site.

1) Laamu Atoll

Fonadhoo: The significant wave heights reaches up to 1.6 m. The significant wave period varies beteween12s - 16s. The result indicates clear seasonal variance such as small significant wave heights during the northeast monsoon season, and the wave height of about 0.3 m higher during the southwest monsoon season than the northeast monsoon season.

2) Addu Atoll:

Hankede: The significant wave height has a maximum value of about 2.0m. The significant wave periods vary widely from about 8s to 16 s. There is a seasonal variance with lower wave heights on average during the northeast monsoon season, but it also shows the temporarily high wave heights such as in the latter half of December 2019.

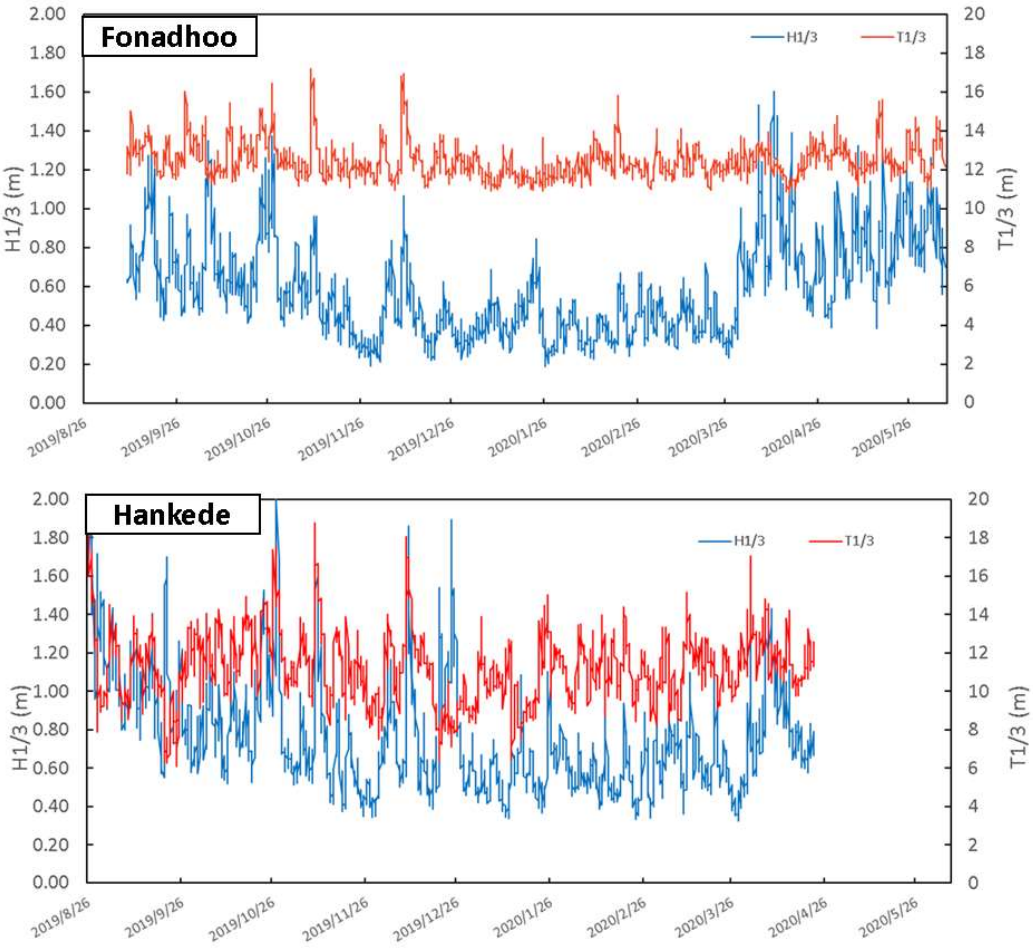



**Figure 5.1.6 Wave Observation Result of Time Series for Significant Wave Height and Significant Wave Period in Fonadhoo in Laamu Atoll and Hankede in Addu Atoll**

Figure 5.1.7 shows the relationship between wave direction and significant wave height during the southwest monsoon season and northeast monsoon seasons. The results are summarized in seasons since seasonal variations in wind conditions cause seasonal variations in wave condition between the two periods. The following description summarizes wave condition in wave direction and wave heigh obtained from the results.

3) Laamu Atoll

Fonadhoo: The wave direction of the southeast is dominant regardless of the season as the observation site is located on the southeast ocean side of Fonadhoo Island. Wave heights increase during the southeast monsoon season, with the most frequent values ranging from 0.6 m to 0.9 m.

4) Addu Atoll

Hankede: The dominant wave direction is from the southwest regardless of the season as the observationsite is located on the southwest ocean side of Hankede Island. Wave heights tend to be higher during the southwest monsoon season than during the northeast monsoon season.

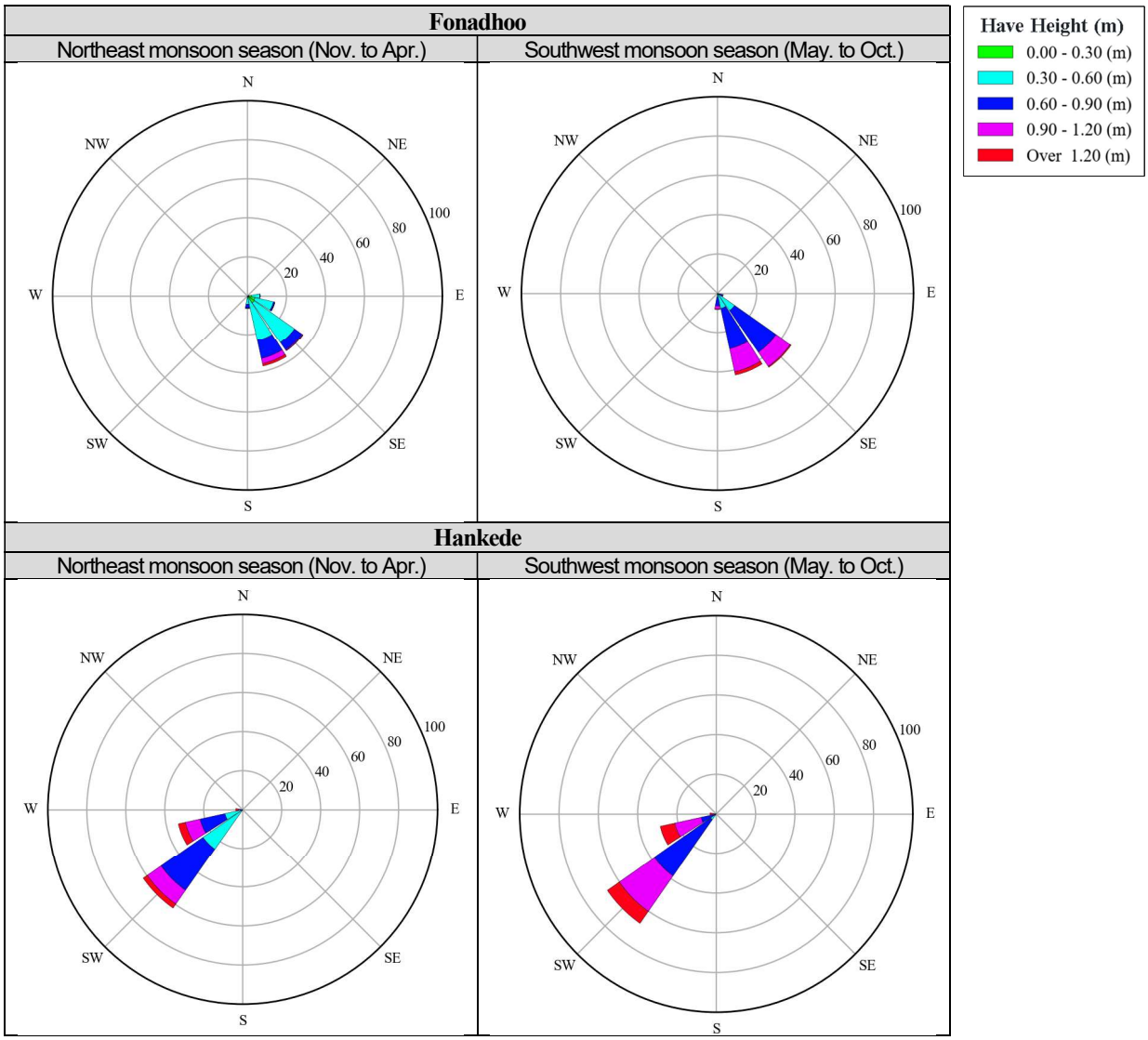



**Figure 5.1.7 Wave Observation Result of the Relation Between Wave Direction and Significant Wave Height in the Northeast Monsoon and Southwest Monsoon in Fonadhoo in Laamu Atoll and Hankede in Addu Atoll**

### 5.1.3 Topographic Characteristics

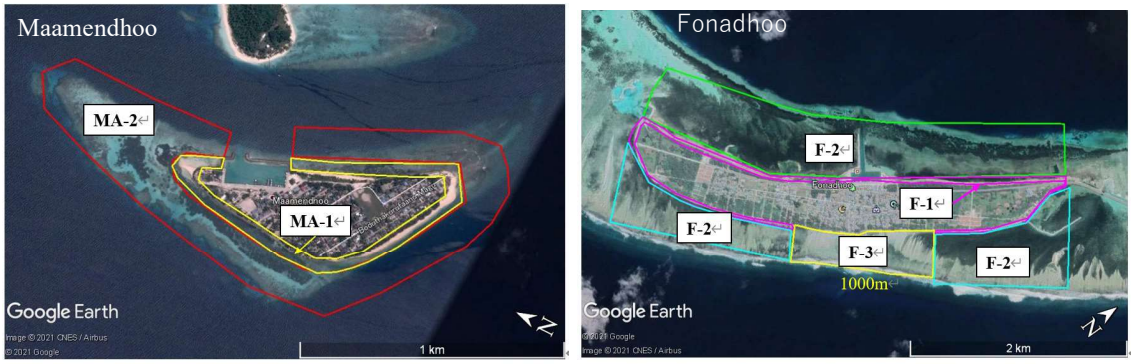
#### (1) Outline of Topographic and Bathymetric Survey

In January to March and May 2022, monitoring surveys were conducted at Meedhoo, Fonadhoo, and Maamendhoo in order to utilize the survey result to basic design and to understand the current coastal conditions of the Maamenshoo, Fonadhoo, Gan, Isdhoo in Laamu atoll and Meedhoo in Addu atoll. In topographic survey, the survey with total station was carried out from the benchmark installed on each island. In bathymetric survey, the survey with single beam was carried out from the boat. In addition, in order to unify the reference surface of topographic survey and bathymetry survey data, tide gauges were installed on each island during the bathymetry survey, and the elevation of the tide gauge was measured by total station. Length and interval of the survey lines are shown in Table 5.1.2 and survey area in each island was shown in Figure 5.1.8 to Figure 5.1.10.

**Table 5.1.2 Details of Survey Area in Each Island**

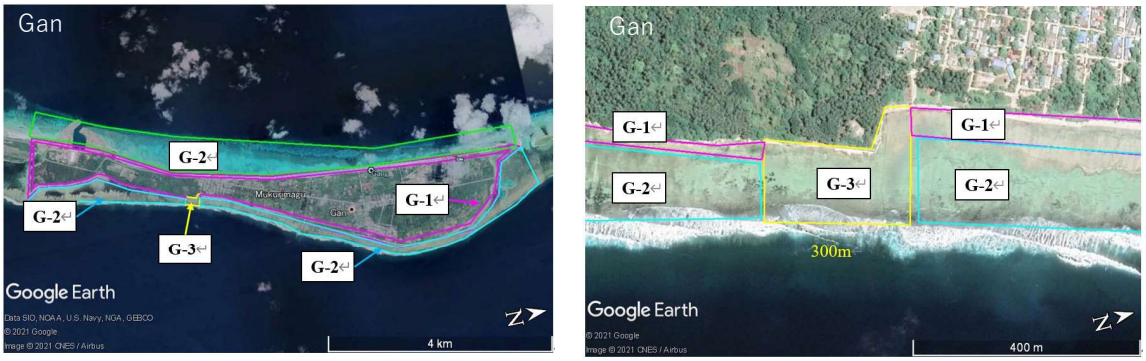
| Survey area | | Length (m) | Pitch of survey lines (m) | Length of one survey line (m) | Area No. |
|---|---|---|---|---|---|
| Laamu Atoll | Maamendhoo(Topo) | 2,000 | 50 | 30 | MA-1 |
| | Maamendhoo(Bathy) | | | 120 | MA-2 |
| | Fonadhoo-All-Lagoon (Topo) | 7,000 | 200 | 30 | F-1 |
| | Fonadhoo-All-Ocean (Topo/Bathy) | | | 470 | F-2 blue: Topo F-2 green: Bathy |
| | Fonadhoo-Target(Topo) | 1,000 | 50 | 400 | F-3 |
| | Gan-All-Lagoon (Topo) | 20,000 | 500 | 30 | G-1 |
| | Gan-All-Ocean (Topo/Bathy) | | | 470 | G-2 blue: Topo G-2 green: Bathy |
| | Gan-Target(Topo) | 300 | 100 | 300 | G-3 |
| | Isdhoo(Topo) | 300 | 100 | 50 | I-1 |
| Addu Atoll | Meedhoo(Topo) | 1500 | 50 | 30 | ME-1 |
| | Meedhoo(Bathy) | | | 90 | ME-2 |

Source: JICA Expert Team



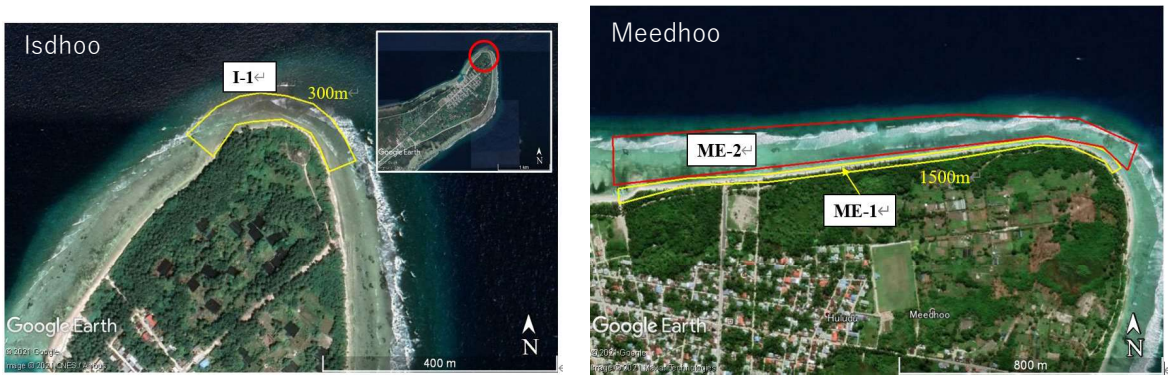

Source: JICA Expert Team

**Figure 5.1.8 Survey Area (Left: Maamendhoo, Right: Fonadhoo)**




Source: JICA Expert Team

**Figure 5.1.9 Survey Area (Left: Overall Map of Gan, Right: Detail Map near G3 )**




Source: JICA Expert Team

**Figure 5.1.10 Survey Area (Left: Isdhoo, Right: Meedhoo)**

### (2) Survey Results

The topographical cross section for each survey line of each island is summarized in Appendix.5 as a result of survey. In previous survey, topographic survey for monitoring of the target coasts was carried out in Maamendhoo, Fonadhoo, and Meedhoo in December 2019. The comparison between the survey results of Maamendhoo, Fonadhoo, and Meedhoo in December 2019 and the survey in 2022 is shown in Figure 5.1.11, Figure 5.1.12 and Figure 5.1.13 respectively. In addition, in order to make an accurate comparison with the results of surveys conducted in the past, the starting position of the survey was set at a fixed point such as a road edge or a manhole. Figure 5.1.14 shows a photograph of the survey work.

The main results obtained by the comparison with the 2019 survey are described below.

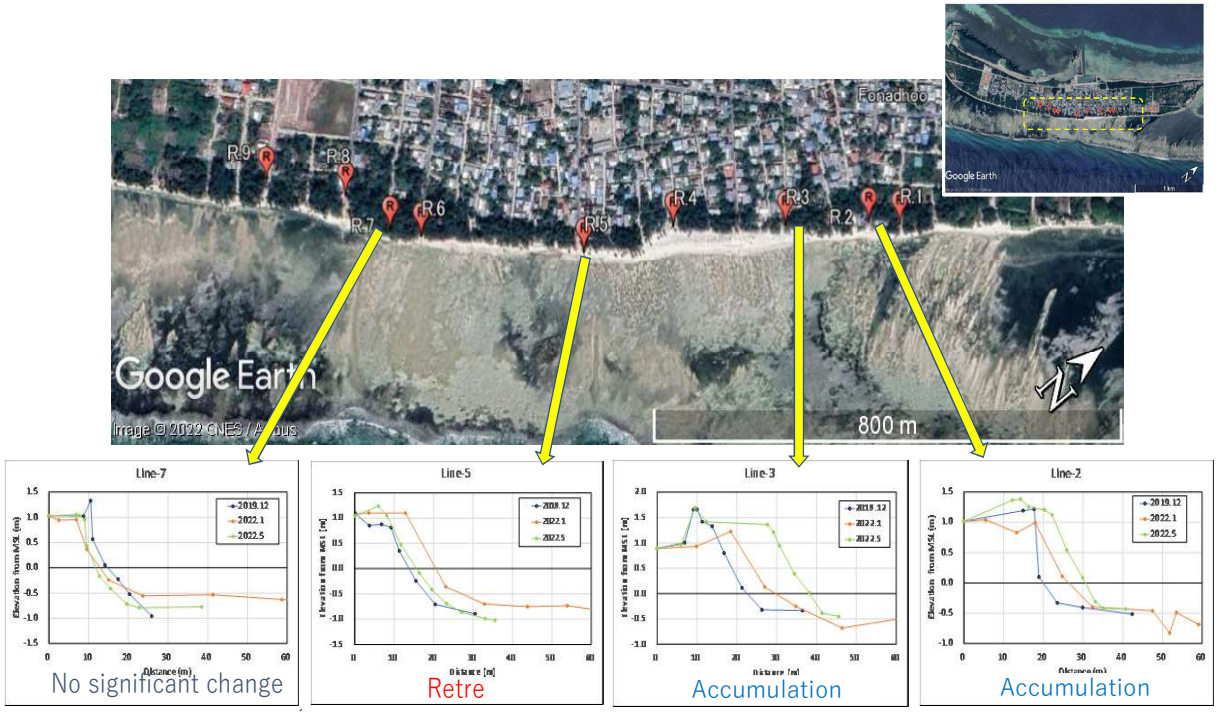
・On Lines 9, 10, and 11 on the west coast of Maamendhoo, the shoreline in 2022 has retreated compared to December 2019. On the other hand, since sand has accumulated on the south coast, the shoreline has advanced about 10m near L7. (Figure 5.1.11)

・On line 3 on the north side of project target sites in Fonadhoo, the shoreline in January 2022 has advanced by about 15m compared to December 2019. On the other hand, shoreline in Line 5 has retreated by about 10m and shoreline in L7 has no remarkable change on the south side. (Figure 5.1.12)

・In Meedhoo, no significant shoreline changes were observed compared to 2019, as shown by Line 1 on the north side of the project target site and Line 4 on the east side. (Figure 5.1.13)

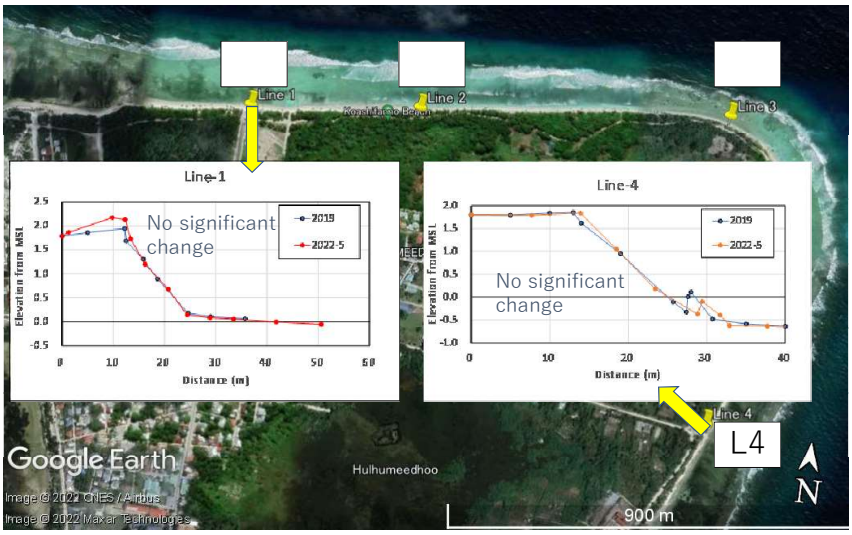

Source: JICA Expert Team

**Figure 5.1.11 Monitoring Survey Results in Maamendhoo (Line7, 9, 10, 11)**




Source: JICA Expert Team

**Figure 5.1.12 Monitoring Survey Results in Fonadhoo (Line2, 3, 5, 7)**




Source: JICA Expert Team

**Figure 5.1.13 Monitoring Survey Results in Medhoo (Line1, 4)**

Source: JICA Expert Team

**Figure 5.1.14 Condition of Survey Work**

## 5.2 Coastal mechanism and its evolution

### 5.2.1 Actual Shoreline Change Analysis based on the Satellite Images

#### (1) Maamendhoo

The analysis of the actual shoreline change in Maamendhoo based on the satellite images from 1969 to 2021 is as shown in Figure 5.2.1.


Source: JICA Expert Team

**Figure 5.2.1 Long-Term Shoreline Change in Maamendhoo**

On the west coast, the shoreline retreat were observed at Xw 900 to 1000 m and the accretion at Xw 600 to 750m were found as shown in the Figure 5.2.2

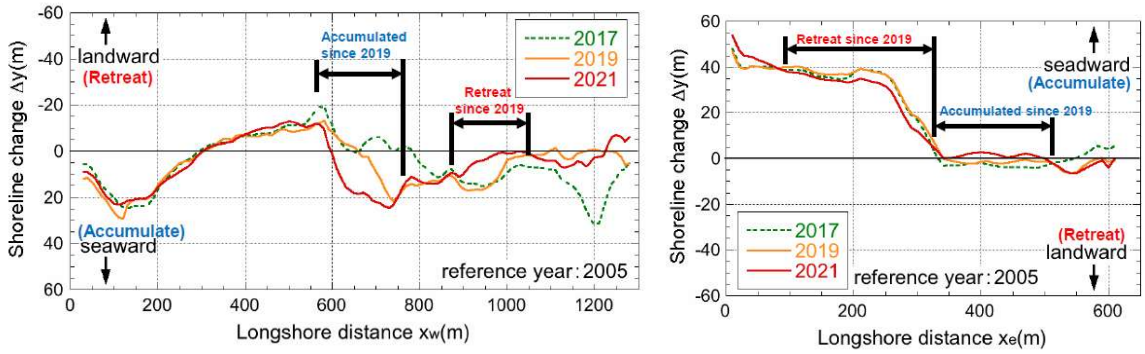
It is assumed that sand from the southwest side of the beach was transported northward and deposited near the bend.

The maximum amount of shoreline advance is 20m at Xw 650m. In contrast, the shoreline change at the north bend is small. The satellite image in 2021 as shown in Figure 5.2.1

shows no sand bar development at the northern end of the island. Sand transport is not considered to have flowed northward beyond the bend.

On the east coast, the shoreline advance up to 7 m were appeared around the southern adjacent area of the port at Xe 0 to 70 m, and the retreat were appeared at Xe 100 to 330 m around the south of the eroded area as shown in the Figure 5.2.2

It is considered that northward sand drift occurred on the east coast as well as on the west coast.




Source: JICA Expert Team

**Figure 5.2.2 Shoreline Change at West Side (left) and East Side (right)**

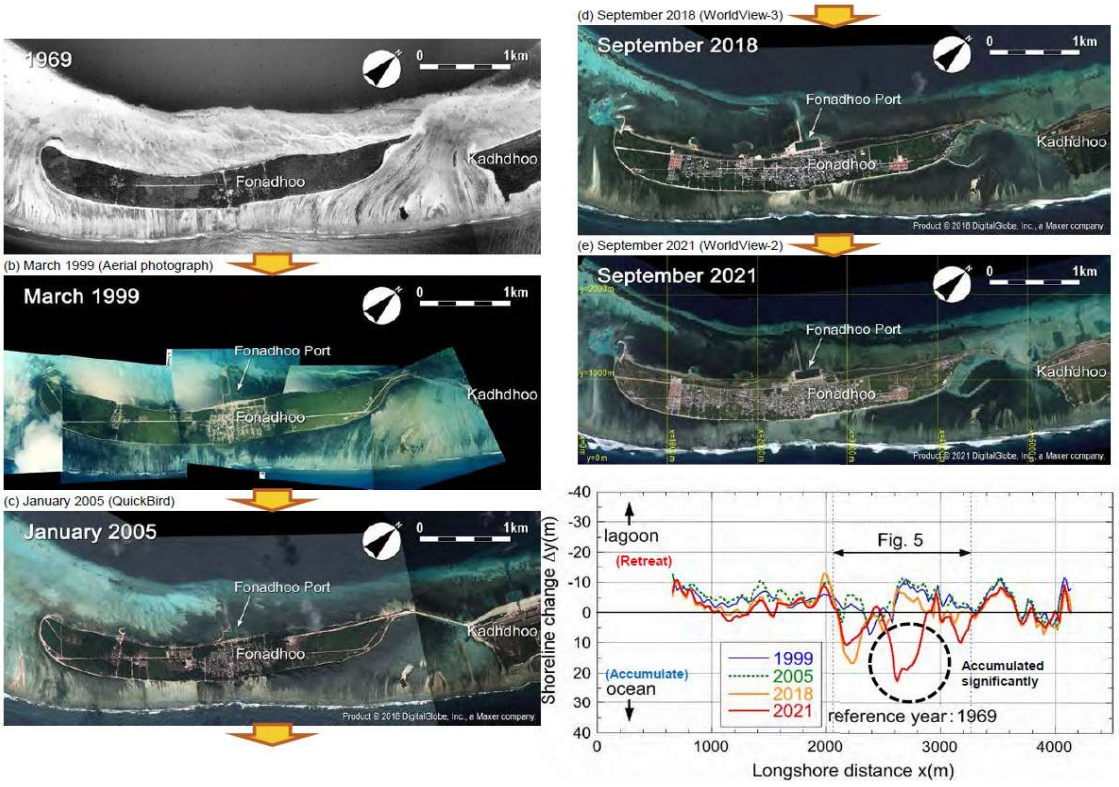
### (2) Fonadhoo

On the ocean side, new sand came from the reef around X 2500 to 2900m by 2021. As the result, significant shoreline advance were appeared as shown in the bottom right figure of Figure 5.2.3

. The maximum amount of shoreline advance from 2018 to 2021 was 25 m. At X 3000 to 3200 m, the shoreline also advanced by up to 10 m due to the sand drifting. In contrast, although the shoreline around X 2200m advanced by 2018, the shoreline retreated slightly from 2018. Shoreline change is generally small in areas other than the above.

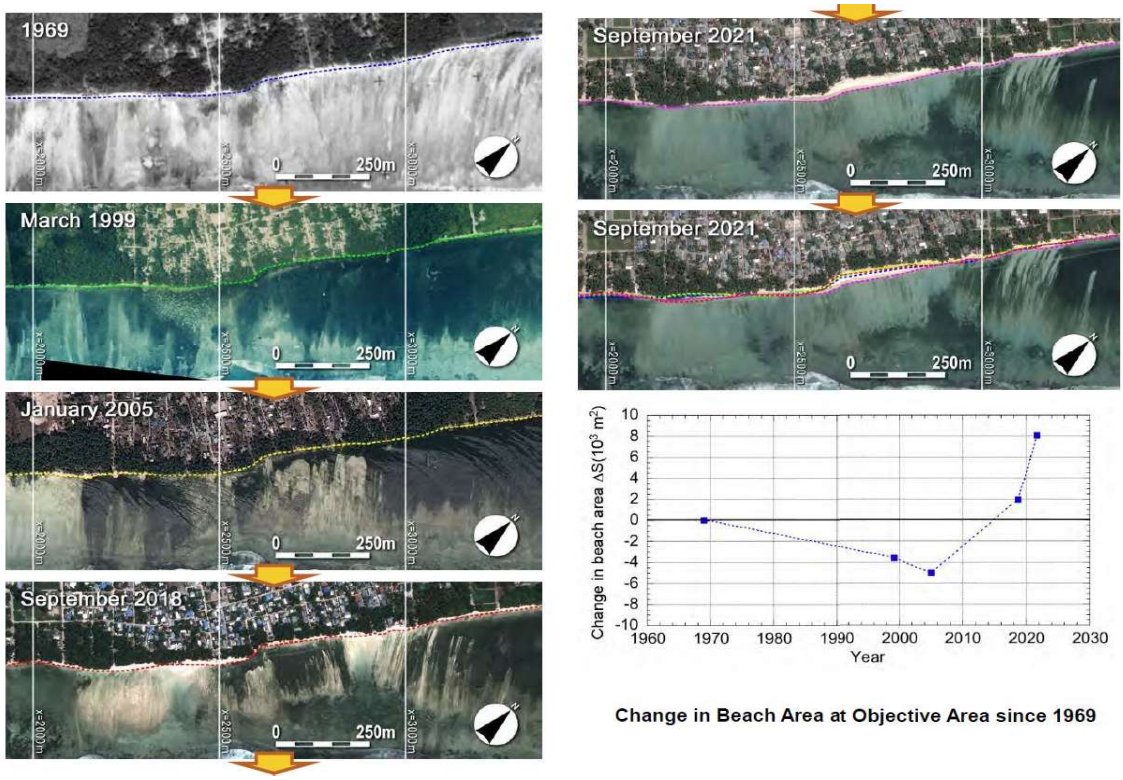
The beach area has been increasing since 2005 until 2021 as shown in the bottom right figure of Figure 5.2.4

. On the ocean side, the area increased by 2.5 x 104 m2 from 2005 to 2021. Assuming a closure depth of 1.6 m, the amount of deposition is 4.0 × 104 m3 were estimated and the accretion rate is 2,500 m3/yr. In the X 2060 to 3260m section, where sand drift is significant, the beach area decreased by 5,000 m2 until 2005, but increased rapidly by $1.3 \times 10^4$ m2 by 2021.




Source: JICA Expert Team

**Figure 5.2.3 Long-Term Shoreline Change in Fonadhoo**




Source: JICA Expert Team

**Figure 5.2.4 Long-Term Shoreline Change in the Adjacent Area of Project Site**

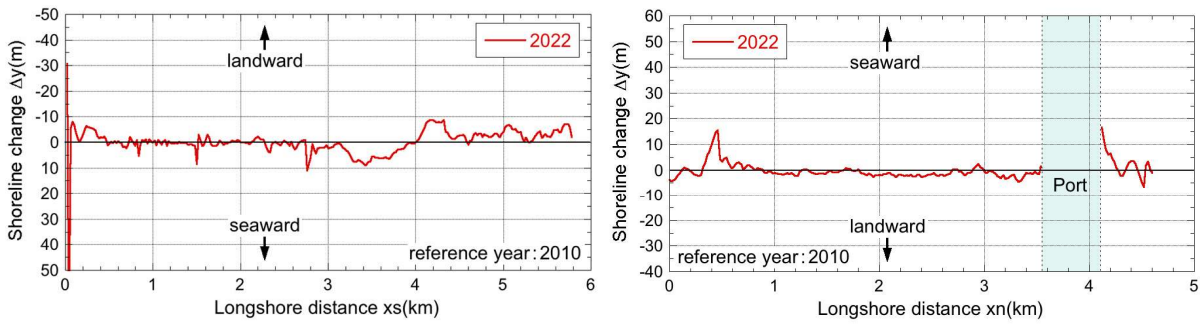
### (3) Isdhoo


Source: JICA Expert Team

**Figure 5.2.5 Long-Term Shoreline Change in Isdhoo**

Shoreline change from 2010 to 2022 as shown in Figure 5.2.5 was an advance at Xs 3 to 4 km and a retreat in east of Xs 4 km, but the amount of retreat was less than 10 m and not significant as shown in Figure 5.2.6

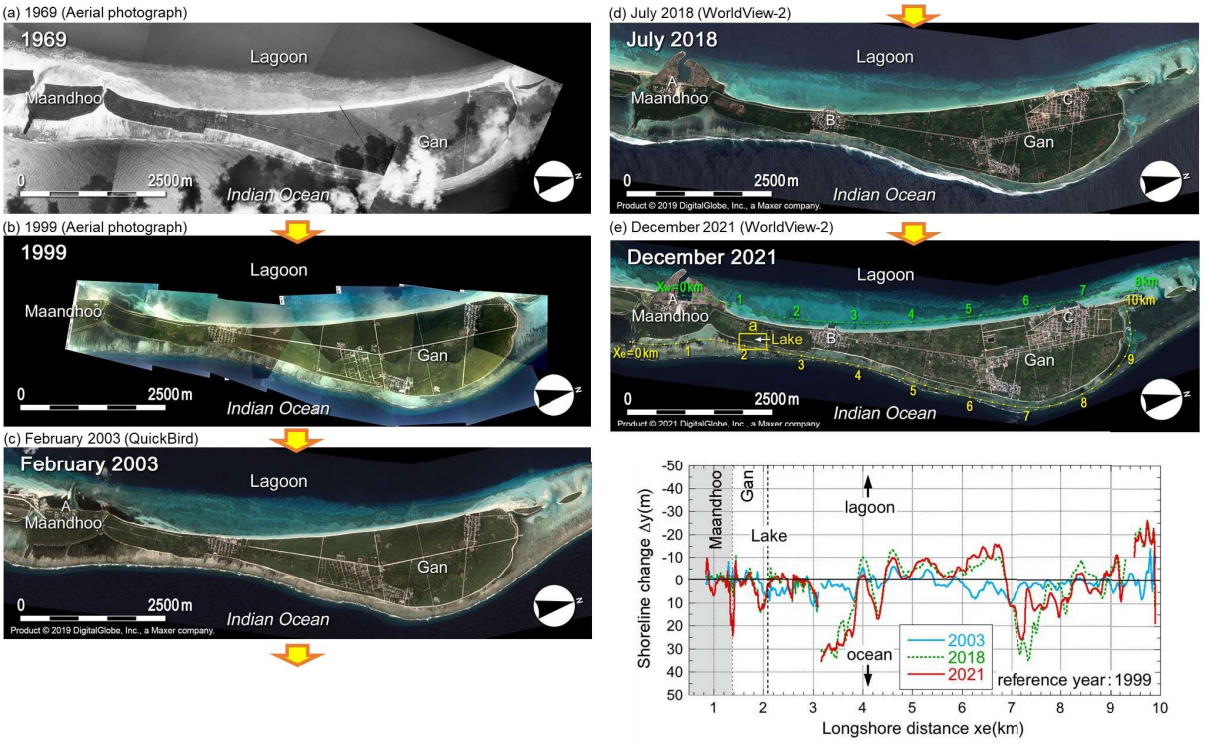
. The shoreline in west of Xs 3 km is stable. In 2010 to 2022, the shoreline retreated slightly in Xn 1 to 3.6 km section, while the shoreline retreated slightly in the Xn 0.6 km section. On the other hand, at Xn 0.4 km, where the shoreline advanced due to the deformation of the spit, and the shoreline advanced by 16m in the area adjacent to the north side of the port.




Source: JICA Expert Team

**Figure 5.2.6 Shoreline Change at South Side (left) and North Side (right)**

## (4) Gan



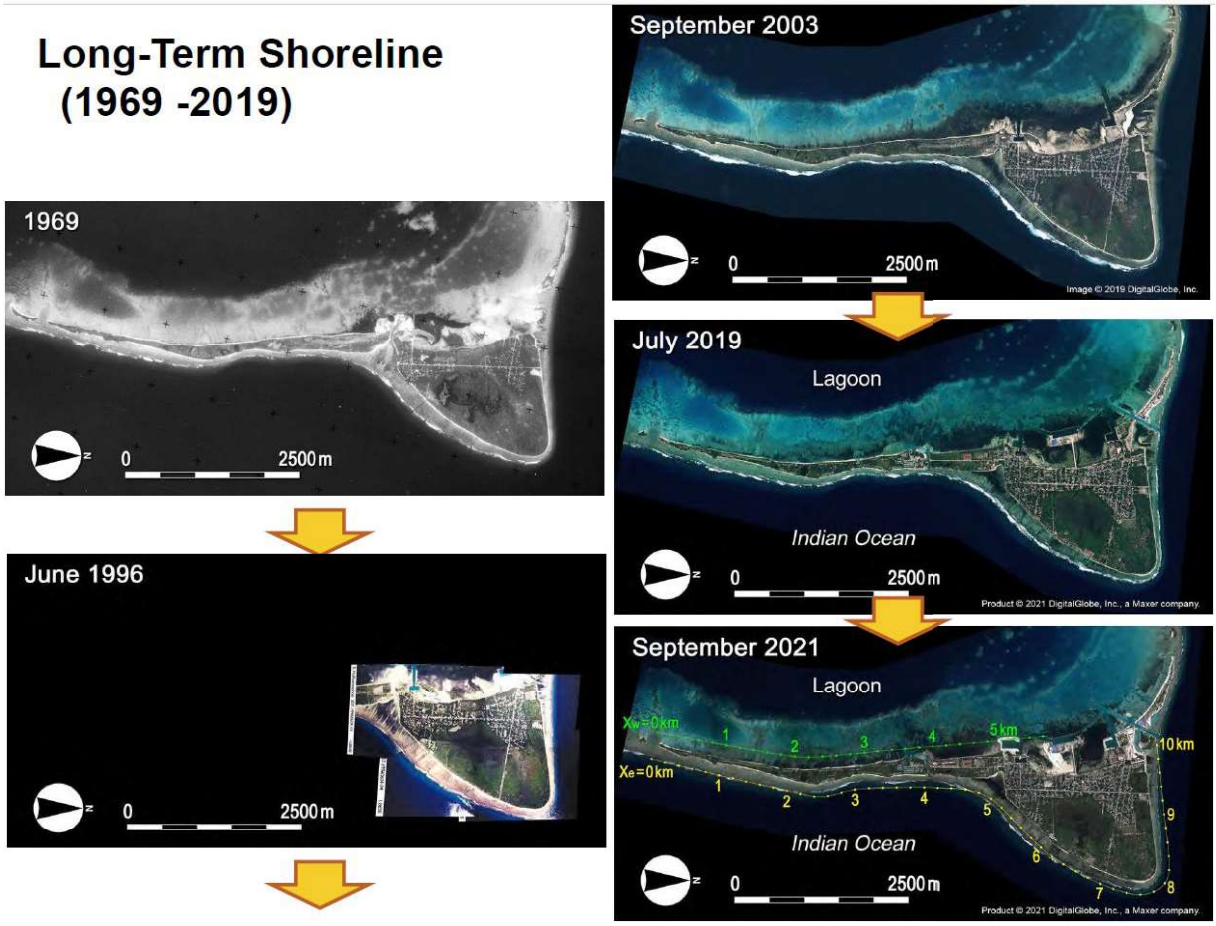

Source: JICA Expert Team

**Figure 5.2.7 Long-Term Shoreline Change in Gan**

According to the shoreline in 1999 as shown in Figure 5.2.7, the shoreline advanced by a few meters in the Xe 1.9 to 3.9 km and 6.0 to 7.2 km sections by 2003. It is assumed that the shoreline advance was caused by sand drifting from the reef to the foreshore. The shoreline change from 2003 to 2021 shows 30 m shoreline advance in the inner bay between Maandhoo Island. Around near the lake at Xe 2.1 km, the advance occurred on the south side of the lake and a retreat on the north side, and at the Xe 3.1 km berm step, the shoreline on its north adjacent Xe 3.1 to 3.8 km section, the shoreline advanced significantly with a maximum advance of 35 m. The unnatural advance of the shoreline in this section around 2015 indicates the possibility of artificial foreshortening.

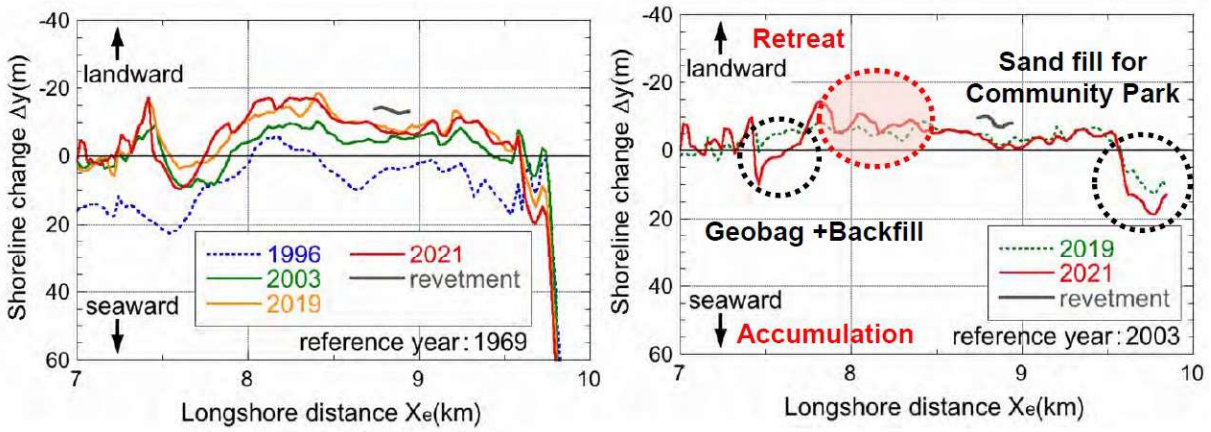
In the northern part of the island, the northern shoreline arcs around the Xe 7 km area, but since 2003, erosion has occurred in the Xe 4.4 to 7.0 km section in the south. In contrast, deposition has occurred in the Xe 7.0 to 8.2 km section in the north. The maximum amount of shoreline retreat and advance is 22 m at Xe 6.7 km and 24 m at Xe 7.2 km, respectively. Sediment from the southern section was probably transported northward through the Xe 7 km point by northward littoral drift. At the northern end of the island, significant erosion occurs on the west side from Xe 9 km, but since the reef surface off the foreshore is widely excavated in a 400 m square area, the erosion is presumed to be due to beach sediment falling into this excavation depression.

### (5) Meedhoo




Source: JICA Expert Team

**Figure 5.2.8 Long-Term Shoreline Change in Meedhoo**




Source: JICA Expert Team

**Figure 5.2.9 Shoreline Change at North and East Side based on the Satellite Image in 1969 (left) and 2003 (right)**

On the east and north coasts, sedimentation occurred on the south side at Xe 7.5 to 7.8 km and erosion occurred on the north side at Xe 7.8 to 8.3 km of the east-end. On the western edge of the north coast at Xe 9.5 to 9.8 km, the shoreline tended to advance from 2003 to 2021, with a maximum advance of approximately 20 m. Other than the above, changes are generally small, and the foreshore remains almost completely lost in the section where the revetment was installed at Xe 5.0 to 7.7km. On the other hand, on the west coast, the south side of the channel separating the resort area showed a sedimentation trend from 2003 to 2019, and this trend continued until 2021.

## 5.3 Basic Policy of Coastal Adaptation Measures

### 5.3.1 Basic Policy

It was common to apply the hard structure measures such as revetment, reclamation, etc. as coastal protection measures in the Maldives. On the other hand, there are issues for hard structure measures as follows.

- The islands in the Maldives were formed by coral sand and gravel which were supplied from coral reef by wave action. Hard structure measures are not to consider such mechanism for sand supply from coral reef and formation of islands.
- Coastal erosion in the Maldives was mainly caused by decrease or disappearing of sand supply to the beach which has been continued in the balance of natural mechanism, by artificial construction and human activities. Even though hard structure measure is applied at the beach where coastal erosion continues, this measure is just "temporary protection", not "permanent protection" with consideration of fundamental phenomena of coastal erosion that is "to improve the decrease of sand supply to the beach". This means hard structure measures are not sustainable and permanent solution as measures for coastal erosion under the condition of climate change in long term with uncertainty.
- The proposed sites for physical measures, Fonadhoo and Maamendhoo are faced on serious coastal erosion and flooding due to high wave. On the other hand, natural sandy beach still exists, and beach is utilized as recreation area of the residents. Construction of hard structure measures will induce the disturbance of such beach use forever. Once natural beach is lost by construction of hard structure measures, it is basically difficult to recover the lost natural sandy beach.
- Apart from the above-mentioned coastal measures at two sites founded by GCF, coastal protection measures at three sites are planned, which are coastal protection measures at the ocean aside of Gan Island and the north tip of Isdhoo Island in Laamu Atoll to protect cultural heritage, and coastal conservation measures at the north side of Meedhoo island in Addu Atoll. The objective coastal area at Gan Island mainly consists of rocky beach and no continuous sandy beach exists. The objective area at the north tip of Isdhoo Island mainly consists of gravel beach. On the other hand, the sandy beach consists of coral sand continues at the north side of Meedhoo Island. Furthermore, this coastal area is utilized as recreation area for residents and some public beach park have been maintained by the local community and NGO.

Based on above mentioned issues, the following points shall be considered for proposed coastal adaptation measure as basic policy.

- Proposed adaptation measure shall consider not only to enhance the protection function, but also to maintain the relationship between people's livelihood and beach (to maintain beach use)

- In order to maintain the beach to next generation, proposed adaptation measure shall consider the natural mechanism on formation of coral beach, maintaining of supply of sand on coral reef and its natural protection function.
- As future scenario for the impact of climate change has uncertainty, proposed adaptation measure is to have a flexibility for actual causing phenomena for climate change.

There is another approach as coastal protection measures, not to use the hard structure measures but to use "beach nourishment" as one of soft protection measures. Table 5.3.1 shows the comparison between revetment as structure measures and beach nourishment as soft measures.

Resident area exists at the hinter area of the beach at proposed sites, Fonadhoo and Maamendhoo, and beach area is highly utilized as recreation area for residents. The beach area at the north side of Meedhoo also highly utilized as recreation area for the residents. Considering such present condition on beach use at these beaches, beach nourishment is basically proposed as coastal protection measures in the Project.

**Table 5.3.1 Comparison between Revetment (as Hard Structure Measure) and Beach Nourishment (as Soft Measures)**

| Measures | Revetment (Hard Structure Measures) | Beach Nourishment (Soft Measures) |
|---|---|---|
| Protection Function | Hinter area will be protected as far as revetment is damaged | Hinter area will be protected as far as nourished beach is maintained |
| Relation for Forming of beach, natural protection function, supply of sand | No relation<br>(Sand supply will be disturbed due to construction) | To enhance such natural mechanism and function |
| Beach Use | Basically, difficult at every implemented coast | Maintain same function on beach use |
| Environment and Land Scape | Artificial view image | Maintain natural view image and possibility to enhance habitat of marine biota |
| Adaptability for uncertain factor for climate change | Basically difficult (as far as to consider improvement of design for future risk such as increase of crown height, enhancement of stability, etc.) | Possible in nourishment area flexibly (as buffer zone) |
| Sustainability of function | Maintained as far as no damage of revetment. However, some improvement (or maintenance) will be required under progress of coastal erosion (30yrs are applied as life cycle for coastal hard structures) | Maintained as far as beach is well maintained.<br>On the other hand, difficult in case of no maintenance) |
| Initial cost | Construction cost in the Maldives is about 1,000~2,000 U$/m<br>(ex.) 2~4 million U$ (for 2 km) | About 10～15 U$/$m^3$ (excluded mobi- and demobi-cost for dredger)<br>(ex.) 2km, 20m0.6~1 million U$ (for 2km, 20m wide)<br>(Assuming 2.6 million U$ for mobi- and demobi-cost for dredger, total3.2~3.6 million U$) |
| Maintenance cost | Basically, it takes same cost after 30yrs<br>If so, 33,000～66,000 U$/yr | Periodical maintenance is required. If assumed 20 % of initial sand volume in every 3yrs, maintenance cost is 21,000 ～64,000 U$/yr |

Source: JICA Expert Team

On the other hand, the objective of coastal measures at the ocean side of Gan Island and the north tip of Ishdoo Island is just to protect the cultural heritage at hinterland. Also, continuous sandy beach doesn't exist at these area. Thus, conducting hard-structure measures locally by applying construction of revetment are recommended.

### 5.3.2 Basic Policy for Target Beaches

#### (1) Proposed Adaptation Measures at Maamendhoo

Maamendhoo has the highest population density in the Laamu Atoll with about 900 residents in the small island area of 18.7 ha. Most of land area was occupied as resident area and there is no empty space in the island. The land elevation is quite low with MSL +0.6 ~ +0.8 m, and coastal erosion is one of serious issues in the Island (Figure 5.3.1). Flooding sometimes occurred during high wave and high tide conditions (Figure 5.3.2). The impact on the loss of land by decrease of sandy beach due to coastal erosion becomes bigger for small island. The impact of sea level rise and progress of coastal erosion will cause further increase of coastal disaster and acceleration of land loss. Based on such conditions, the basic policy for proposed measures in this island is as follows (Figure 5.3.3).

(1) West Side (2) East Side

Source: JICA Expert Team

**Figure 5.3.1 Beach Condition at Maamendhoo (May 2022)**

(1) Around Beach Area (2) Resident Area at hinterland

Source: Maamendhoo Island Council

**Figure 5.3.2 Flooding Due to High Wave**


Source: Processed by JICA based on World View in 2019 procured by JICA

**Figure 5.3.3 Proposed Area for Adaptation Measures in Maamendhoo**

- The purpose to implement the coastal adaptation measures in this island is 1) To protect the land against flooding due to wave run-up during high tide and high waves, and to minimize land loss due to coastal erosion, 2) To secure the evacuation area during the extreme condition (hitting cyclone, Tsunami).
- Based on the result of field investigation, the serious beach area for coastal erosion and flooding is the beach at west side with approximately 600 m and east side with 300 m. The beach at west side has been under coastal erosion as long-term trend. Here, sandy beach still exists even though coastal erosion is in progress, and the beach area is utilized as recreation zone for the residents. Therefore, beach nourishment is proposed as coastal adaptation measures taking into account not only protection function but also beach use and coastal environment. To enhance the stability of sandy beach after the nourishment against wave action, groins are also planned to construct as supplementary coastal facilities.
- The beach at east side is located at following partial reclamation area at north side and the beach consists of beach rock. As the result of satellite image analysis since 2005, no significant retreat was observed at this area. Furthermore, the waves which propagate from outer ocean area directly incident at this area and exiting beach is rocky beach. Considering such conditions, although the possibility to apply beach nourishment will be examined, final recommendation for coastal measures will be as the result of further study.
- It is also proposed to conduct the reclamation to secure the evacuation area against extreme events such as hitting of cyclone and Tsunami. However, it is proposed to minimize the space of reclamation as far as securing enough evacuation area in order to avoid the artificial of natural beach and coral reef. The reclamation area is proposed to set at the north side of existing port considering present land use condition at hinter area (not so utilized as resident area). Furthermore, the land elevation at this reclamation area is planned to increase in order to ensure safety and security as evacuation area. As the planned reclamation area is located on the sand spit at the north tip of island, it will be finally determined after obtaining the consensus with island council and community.

### (2) Proposed Adaptation Measures at Fonadhoo

Fonadhoo is the middle size of island in the Laamu Atoll with about 2,200 residents in the area of 163 ha. The main residential and commercial area are located at the hinterland of the Fonadhoo port located at central area of lagoon side. Undeveloped areas still exist except this central area. However, development as residential area is planned at these areas. Flooding has sometimes occurred at the ocean side of central residential area during high wave and high tide condition, and sand embankment was constructed by the island council. Even though the beach erosion is not so significant, the tendency of beach retreat has been identified. However, it was identified that the coastal erosion area is now moved from original planned area to the north (Figure 5.3.4). On the other hand, the original planned area has been getting accumulate since 2018 based on site check (Figure 5.3.5) and further satellite image analysis to compare the shoreline position between 2018 and 2021. This accumulation was caused by sand inflow from offshore side to the shore. However, such phenomena might be just temporary, and not expect to continue. This means there is still facing the coastal disaster for both impact of sea level rise and coastal erosion.

Considering such condition, basic policy for proposed measures are as follows.

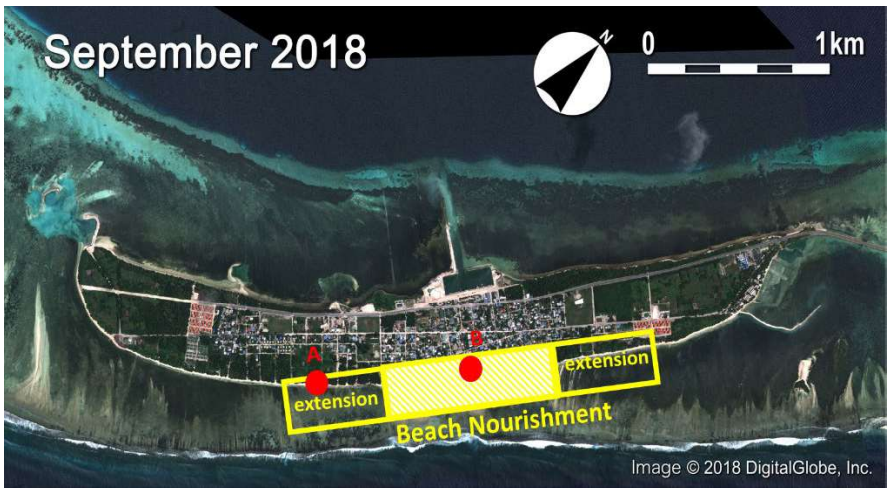
- The purpose for proposed measures is to ensure the safety and security at the residential area faced on the ocean side against coastal erosion and intrusion of high wave.
- Sandy beach exists at the proposed area and the beach is utilized as recreation area for the residents. Therefore, beach nourishment is proposed as coastal adaptation measures taking into account not only protection function but also beach use and coastal environment.
- In the previous study, it was proposed to implement the coastal adaptation measures at the central area of ocean side with approximately 850 m as original proposed plan. However, based on further study and site checking, it was found that the eroded and accumulated area are variable depending on on-offshore sand movement as mentioned above. Further, dominant direction of littoral drift was not observed. Even though the littoral drift exists, the magnitude of littoral drift is predicted to be small about several hundred $m^3$/year. Taking into account such conditions, the objective area will be extended from original proposal with 850 m as shown in Figure 5.3.6. Also, the necessity of groin construction will be examined by numerical analysis.

Source: JICA Expert Team

**Figure 5.3.4 Erosion at point A (May 2022)**

Source: JICA Expert Team

**Figure 5.3.5 Sedimentation at point B (May 2022)**




Source: Processed by JICA Expert Team based on World View in 2018

**Figure 5.3.6 Proposed Area for Adaptation Measures in Fonadhoo (Possibility to Extend)**

### (3) Proposed Adaptation Measures at Ocean side of Gan and North Tip of Isdhoo

The objective of coastal adaptation measures at both ocean side of Gan (Figure 5.3.7) and north tip of Isdhoo (Figure 5.3.8) is just to protect cultural heritage at hinterland. Taking into account this objective as well as current coastal characteristics, the construction of revetment as coastal protection measures locally is recommended as shown in Figure 5.3.9 and Figure 5.3.10. To minimize expected adverse effect due to construction of hard-structure measures, the alignment of revetment will be maintained almost same as present shoreline position (not to be advanced to offshore side). Further, the rubble type sloped revetment is recommended to reduce the reflection waves and resulting scouring, and not to disturb beach use for the residents. Protected area will be finalized taking into account the necessity for protection, impact to surrounding area and obtaining consensus with Island Council.

Source: JICA Expert Team

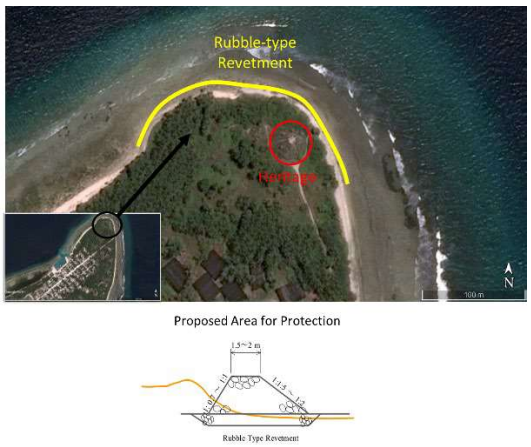
**Figure 5.3.7 Site Condition at Ocean Side of Gan (May 2022)**

Source: JICA Expert Team

**Figure 5.3.8 Site Condition of North Tip of Isdhoo (May 2022)**


Source: JICA Expert Team

**Figure 5.3.9 Proposed Measure at Gan**




Source: JICA Expert Team

**Figure 5.3.10 Proposed Measure at Isdhoo**

### (4) Proposed Adaptation Measures at North side of Meedhoo

Resort development has been on-going at the west area at north side of Meedhoo (Figure 5.3.11). On the other hand, nature condition at hinter area maintained at the east area of north side of meedhoo and the public beach park is well-maintained as recreation area for the residents (Figure 5.3.12). Some area of the east coast of Meedhoo has been protected by construction of revetment with 1.4 km alongshore (Figure 5.3.13) and sandy beach has already disappeared (Figure 5.3.14). On the other hand, natural sandy beach with white colored coral sand is maintaining at the north side (except some part with old seawall), however, the beach has been under progress of coastal erosion. Furthermore, the oldest cemetery in Maldives which was established about 900 years ago exists as cultural heritage at this area however, the risk of coastal disaster due to wave run-up has been increased by progress of coastal erosion. Beach nourishment is proposed to consider the protection with maintaining existing utilization and environment condition. The target area is assumed about 1.4 km from the tourism developed area at west side to the east end (Figure 5.3.15). Even though the necessity of construction of groins will be judged as the result of numerical analysis, it shall be considered to maintain current natural beach as much as possible.

Source: JICA Expert Team

**Figure 5.3.11 Tourism Development Area at West Side of North Coast of Meedhoo (May 2022)**

Source: JICA Expert Team

**Figure 5.3.12 Public Beach Park (May 2022)**

Source: JICA Expert Team

**Figure 5.3.13 North Coast of Meedhoo (May 2022)**

**Source: JICA Expert Team**

**Figure 5.3.14 Coastal Erosion at East Side of North Coast of Meedhoo (May 2022)**

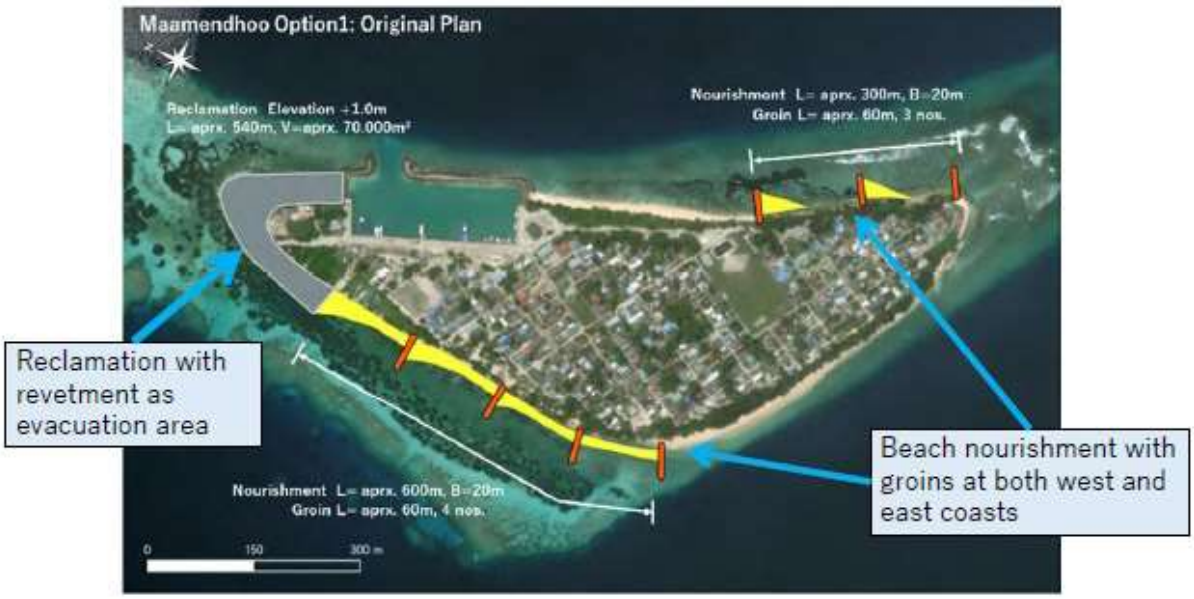

Source: Processed by JICA Expert Team based on World View in 2021

**Figure 5.3.15 Proposed Area for Adaptation Measures in Meedhoo**

## 5.4 Examination of the draft basic plan

### (1) Maamendhoo

The original proposed plan in the Feasibility Study is shown in Figure 5.4.1




Source: JICA Expert Team

**Figure 5.4.1 Original Layout Plan in Maamendhoo**

According to the Island Council, they strongly requested the plan of reclamation with revetment for the emergency evacuation area as the original proposal. Therefore, the original plan for the evacuation area is applied as it is.

For the protection at east coast and west coast, the beach deformation analysis was used to examine reasonable proposals of nourishment and groins.

At first, the case where only beach nourishment was applied without groins at west coast is examined. The sand that was initially put into the area moves and after 30 years the sand is gone and restored as shown in Figure 5.4.2Figure 5.4.2.

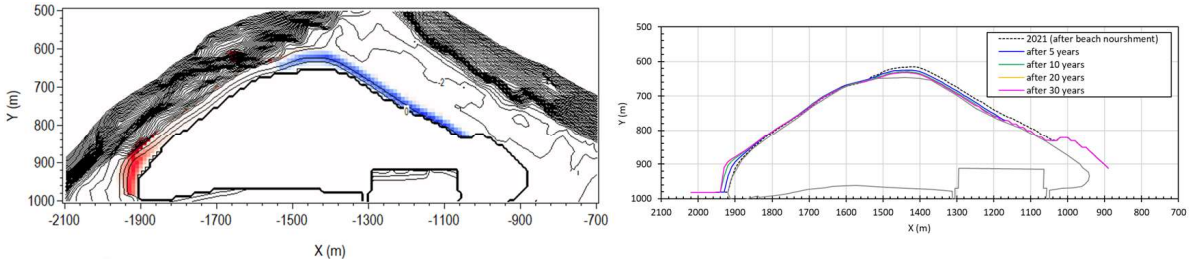
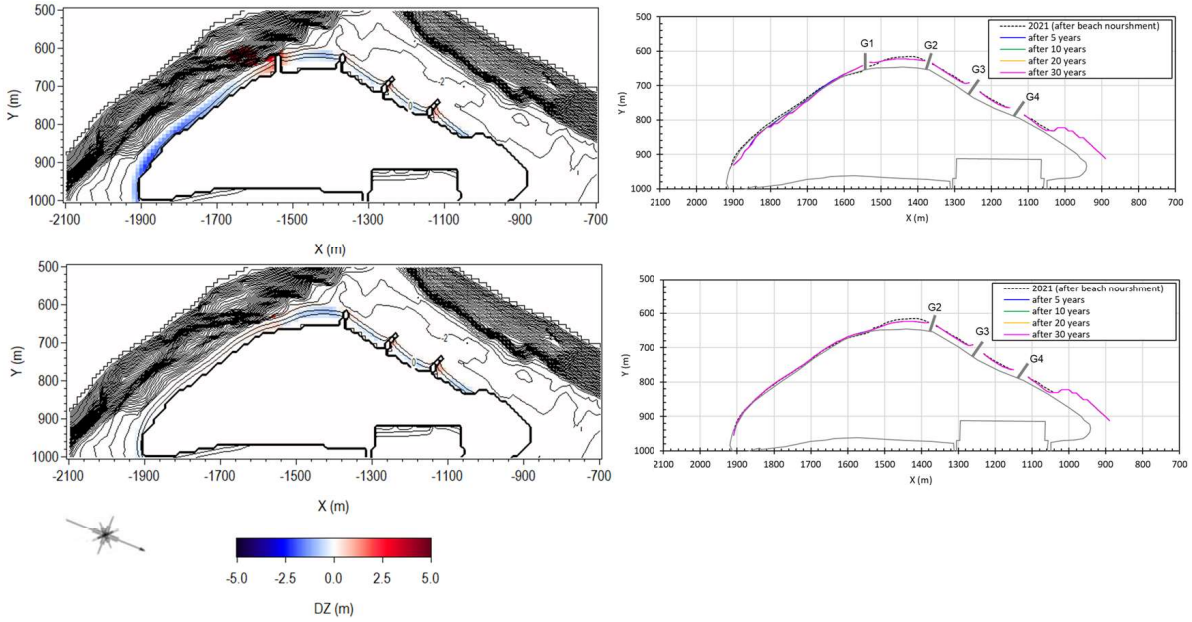



**Figure 5.4.2 Results of Shoreline Change in Case: Nourishment without Groin at West Coast**

As alternative cases, the nourishment with 4 groins and 3 groins are examined by the beach deformation analysis. The shoreline changes during 30 years in each case are shown in the Figure 5.4.3.

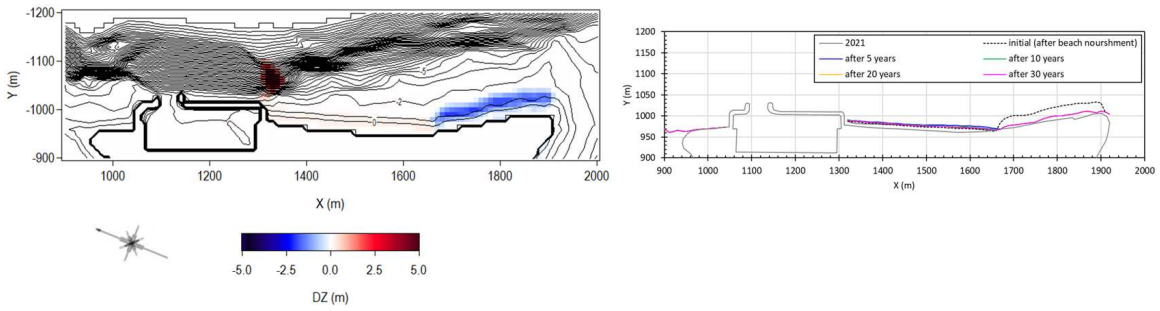
Comparing the two cases, the sand is retained for a long period on the western beach in both cases, while the Case "4 Groins" causes the erosion of the southern beach. Therefore, the Case '3 Groins' are employed in the west coast.




Source: JICA Expert Team

**Figure 5.4.3 Results of Shoreline Change in Case: Nourishment with 4 Groins (Upper) / 3 Groins (Bottom)**

For the protection at east coast, the case where only beach nourishment was applied without groins is also examined. The sand that was initially put into the area moves and after 30 years the sand is gone and restored as shown in Figure 5.4.4.

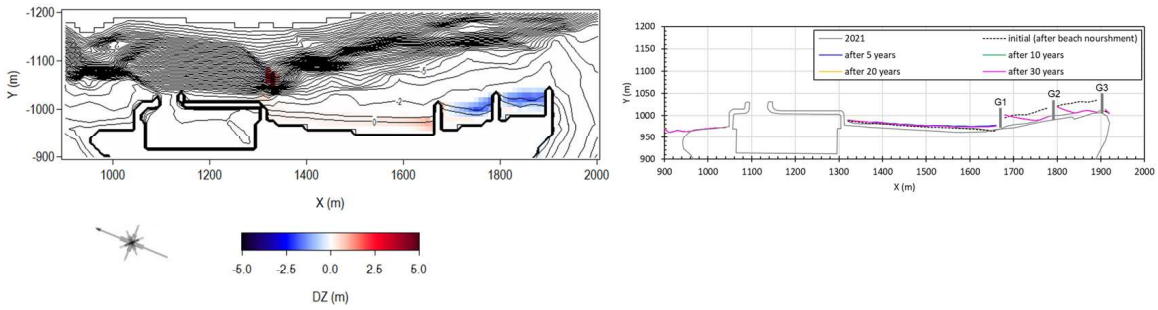



Source: JICA Expert Team

**Figure 5.4.4 Results of Shoreline Change in Case: Nourishment without Groin at East Coast**

As alternative cases, the nourishment with 3 groins are examined by the beach deformation analysis. The shoreline changes during 30 years in each case are shown in the Figure 5.4.5

Figure 5.4.5. It is difficult to retain sand and layout of beach profile even though the groins are installed. Therefore, beach nourishment is not appropriate and protection by revetment is recommended.




Source: JICA Expert Team

**Figure 5.4.5 Results of Shoreline Change in Case: Nourishment with 3 Groins**

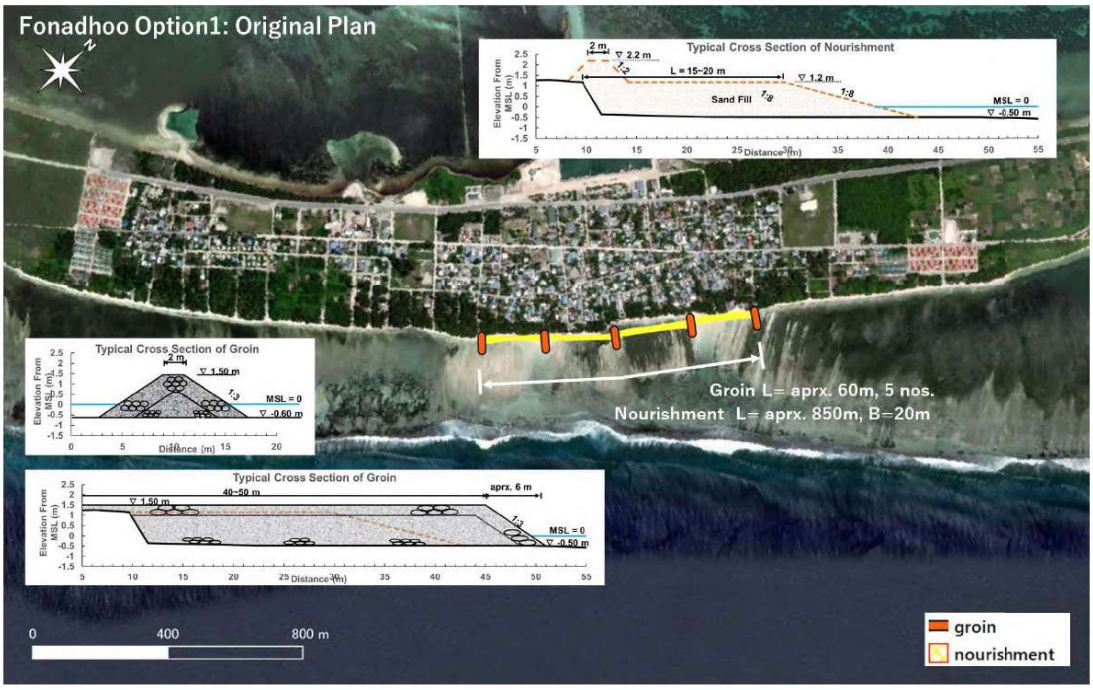
The alternative layout plan is shown in Figure 5.4.6.


Source: JICA Expert Team

**Figure 5.4.6 Alternative Layout Plan in Fonadhoo**

### (2) Fonadhoo

The original proposed plan in the Feasibility Study is shown in Figure 5.4.7.



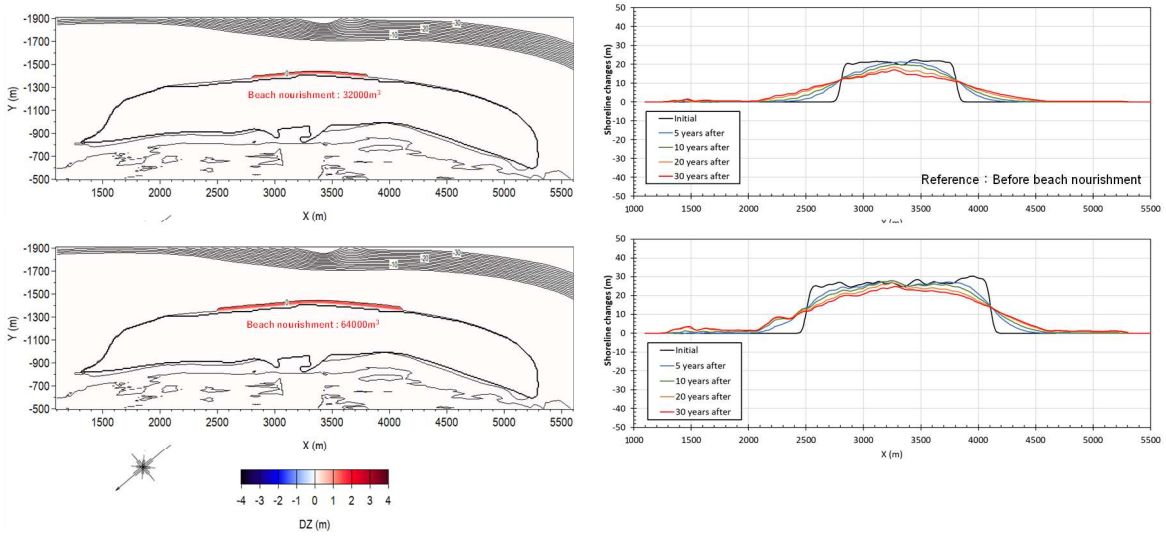

Source: JICA Expert Team

**Figure 5.4.7 Original Layout Plan in Fonadhoo**

The beach deformation analysis was used to examine reasonable proposals. At first, the case where only beach nourishment was applied without groins is examined, because the magnitude of littoral drift at ocean side seems to be not so significant based on the satellite image analysis and wave direction analysis.

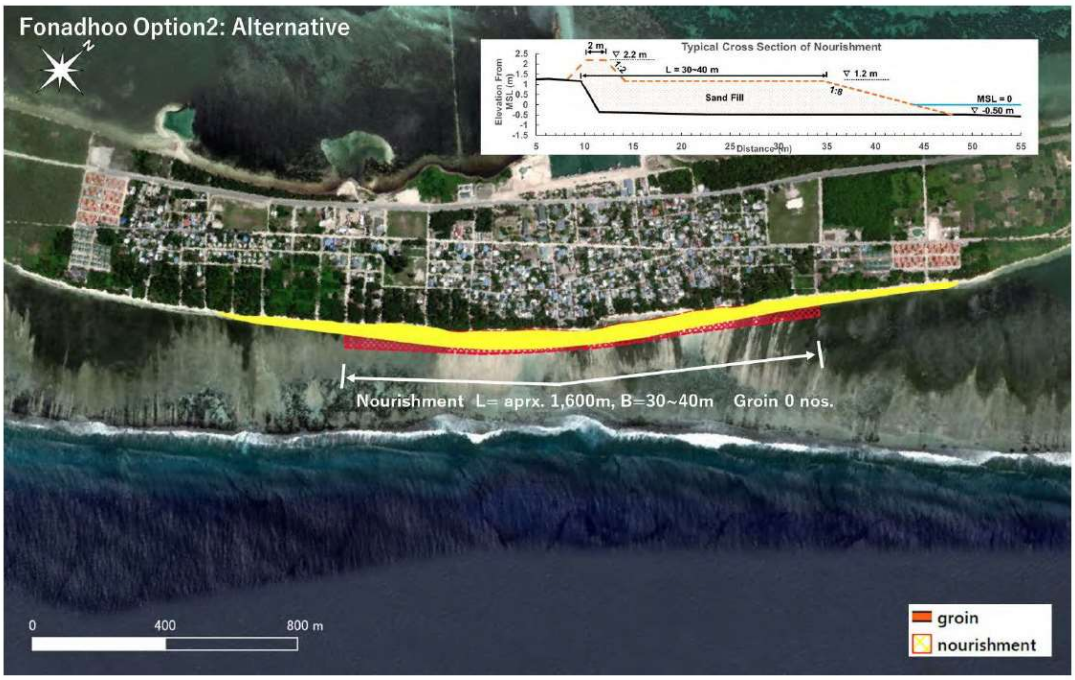
The shoreline changes during 30 years are shown in Figure 5.4.8. The numerical results show that the nourished sand can be maintained for long period in both case, but the case, where 1.6 km and 64,000 m3 of beach nourishment is applied, is more effective than other cases.

The alternative layout plan is shown in Figure 5.4.9.




Source: JICA Expert Team

**Figure 5.4.8 Results of Shoreline Change in Case: Nourishment L=1,0km and 32,000m3 (Upper) / L=1.6km and 64,000m3 (Bottom)**

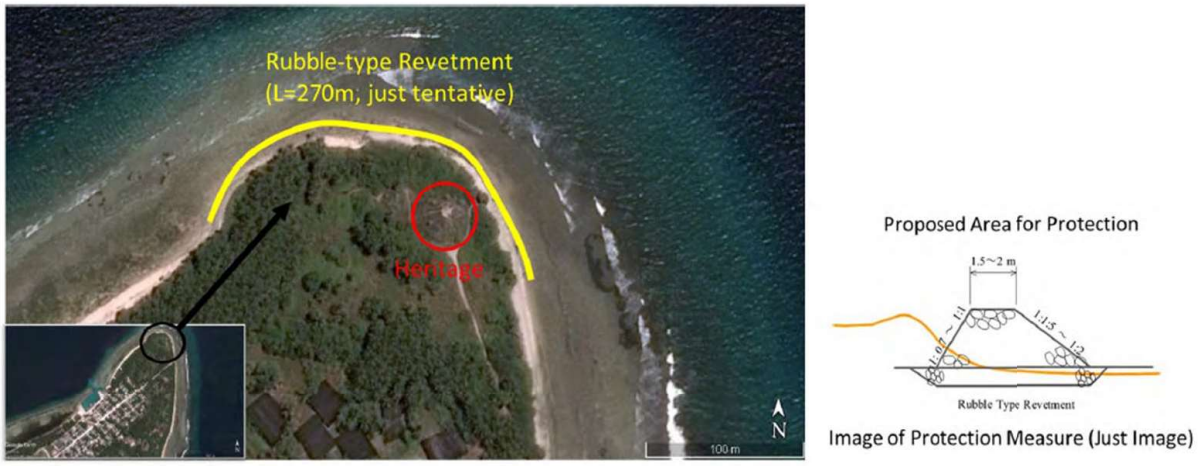



Source: JICA Expert Team

**Figure 5.4.9 Alternative Layout Plan in Fonadhoo**

### (3) Isdhoo

The original proposed plan in the Feasibility Study is shown in Figure 5.4.10. In order to protect the heritage area, the current beach use in this area is not a high priority and only the protection function is sufficient. The proposed site is seaward facing, and the coral reef is narrow and limited. Therefore, hard measures using rubble stone revetments are recommended.




Source: JICA Expert Team

**Figure 5.4.10 Original Layout Plan in Isdhoo**

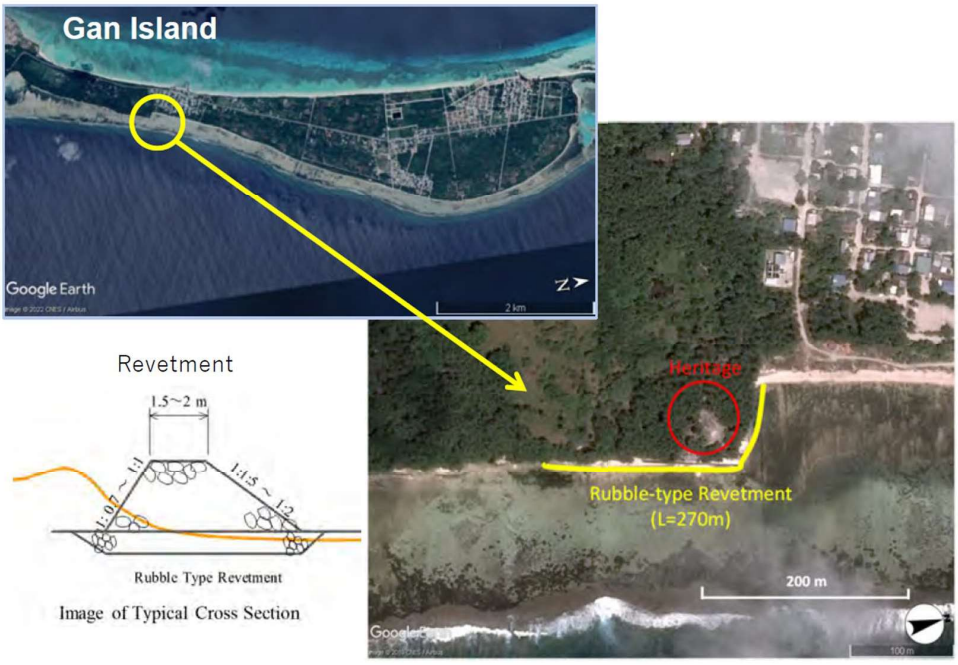
According to the Island Council, they also wanted to protect an area extending 90 meters south of the proposed area as shown in Figure 5.4.11. Since the expansion area is also an area that is eroding recently and future erosion will affect the heritage area, expansion of the relevant area is considered appropriate.


Source: JICA Expert Team

**Figure 5.4.11 Alternative Layout Plan in Isdhoo**

### (4) Gan

The original proposed plan in the Feasibility Study is shown in Figure 5.4.12. To protect the heritage area, beach use at this area is not high priority and it is sufficient to consider only protective functions. Project site is faced on ocean side and the width of coral reef is narrow, and required area for the protection is limited. Therefore, it is recommended to apply hard structure measure using rubble type revetment as originally proposed.




Source: JICA Expert Team

**Figure 5.4.12 Original Layout Plan in Gan**

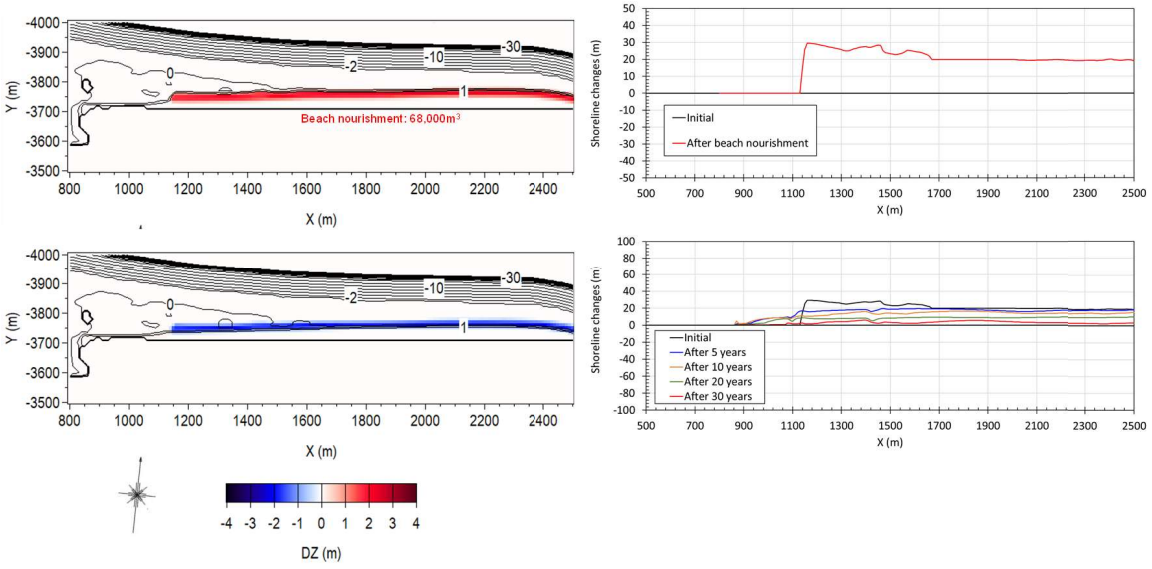
### (5) Meedhoo

The original proposed plan in the Feasibility Study is shown in Figure 5.4.13.


Source: JICA Expert Team

**Figure 5.4.13 Original Layout Plan in Meedhoo**

The beach deformation analysis was used to examine reasonable proposals. At first, the case where only beach nourishment was applied without a groin is examined. The shoreline changes during 30 years are shown in the Figure 5.4.14. The sand that was initially put into the area moves from east to west, right to left in the figure, and after 30 years the sand is gone and restored.



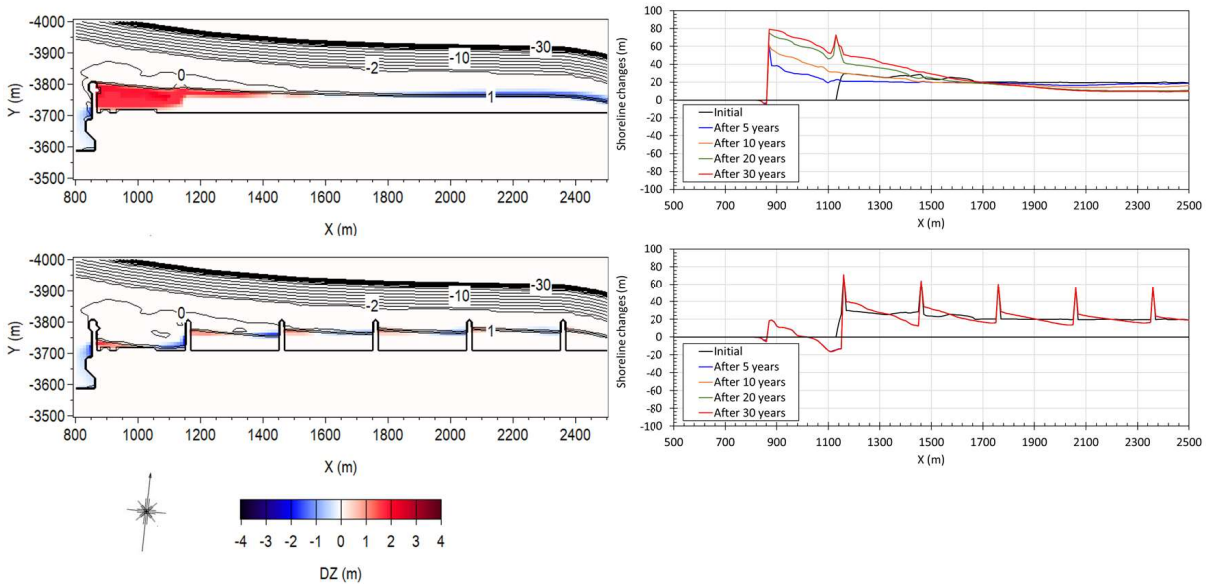

Source: JICA Expert Team

**Figure 5.4.14 Results of Shoreline Change in Case: Nourishment without Groin**

As alternative cases, the nourishment with a groin and 6 groins are examined by the beach deformation analysis. The shoreline changes during 30 years in each case are shown in Figure 5.4.15.

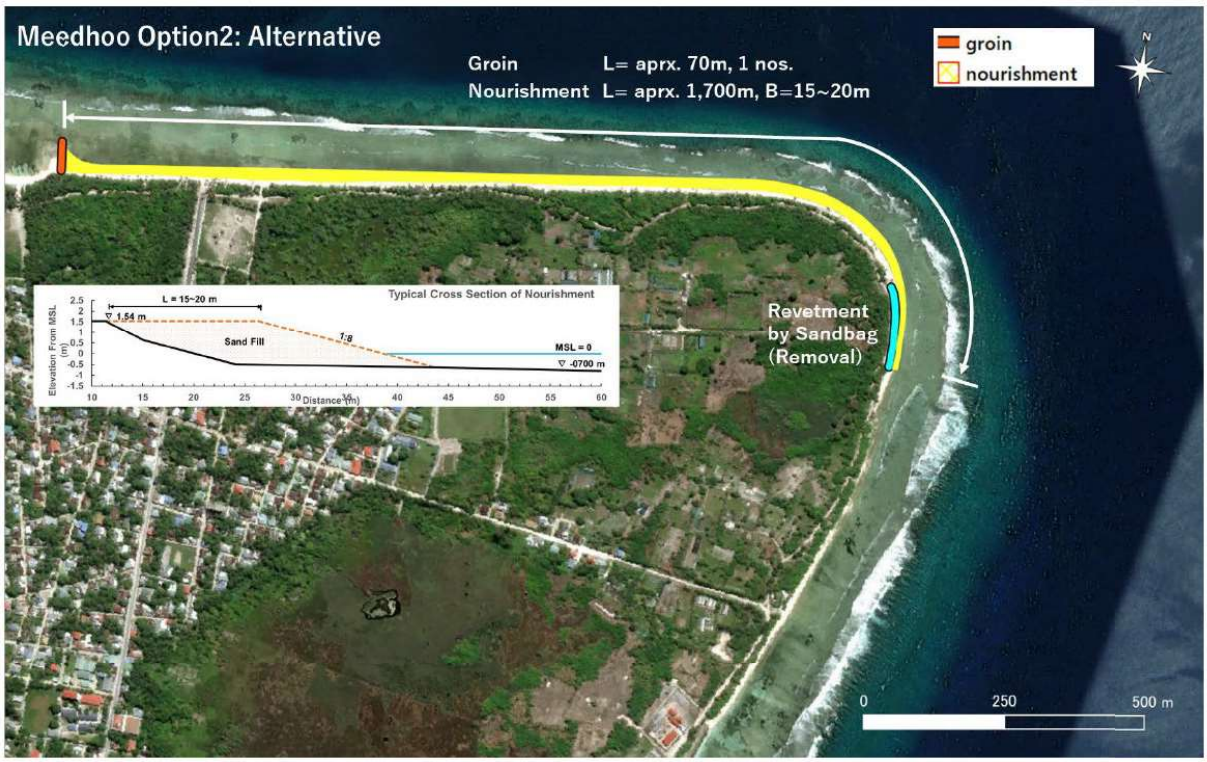
In the Case "6 Groins", shoreline layout will be deformed and not continuous, while the sand that was put in will remain in place for 30 years. On the other hands, in the Case "A Groin", although there is an erosion trend on the east side and an accretion trend on the west side, the input sand will continue to remain in place after 30 years, resulting in a continuous beach profile.

Considering beach use and scenery, the Case where beach nourishment and 1 groin is installed are recommended, and alternative layout plan is shown in Figure 5.4.16.




Source: JICA Expert Team

**Figure 5.4.15 Results of Shoreline Change in Case: Nourishment with a Groin (Upper) / 6 Groins (Bottom)**




Source: JICA Expert Team

**Figure 5.4.16 Alternative Layout Plan in Meedhoo**

## 5.5 Examination of basic design

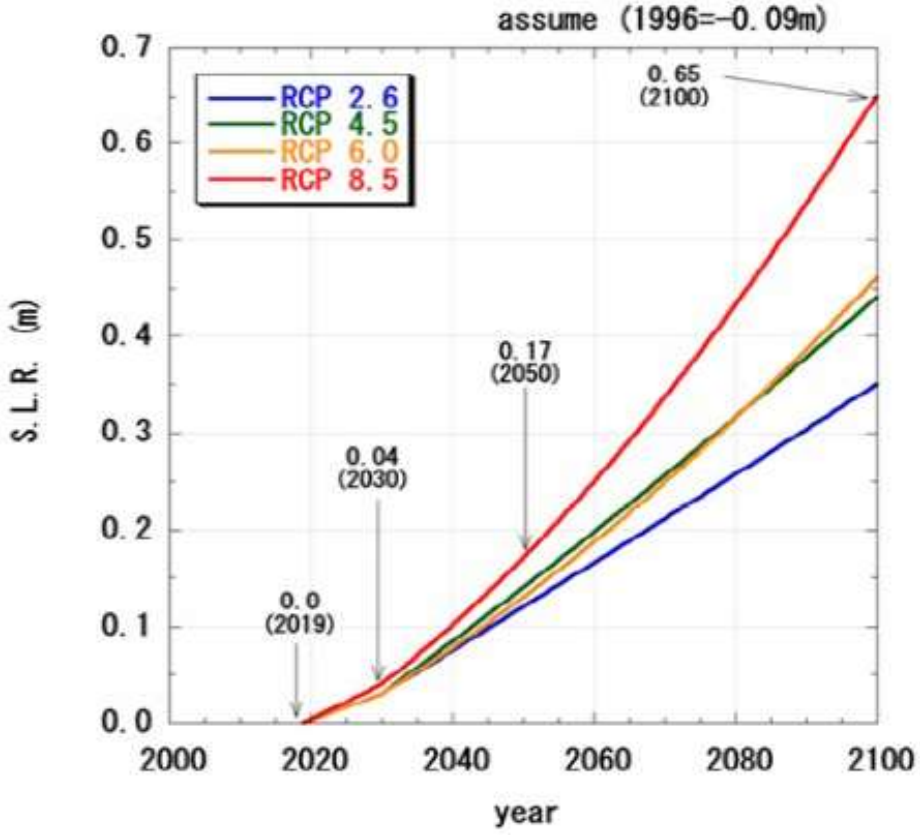
### 5.5.1 Design water level conditions

The design water level conditions at the Project site in Laamu Atoll and Addu Atoll are determined by taking into account the rising water levels caused by surges due to common climatic and oceanographic effects such us wave setup and storm surge, and sea level rise due to climate change in future.

In the Feasibility Study, the tide level at the Project site was examined by the tidal investigation based on the tidal observation data for 30 years and the harmonic analysis. As the result, the mean High Water Level (HWL) is set as 0.70 m in Laamu Atoll and 0.64 m in Addu Atoll.

Surges are evaluated by the difference between the tidal observation record and the estimated astronomical tide level based on the above-mentioned harmonic analysis. The annual maximum level of the surges are extracted and probabilistic surge level with return period is estimated by the extreme value statistics analysis. As the result, the surges with 50-years return period is 0.18 m. This rise in water level could be due to setup after wave breaking or cyclone, but in this area, setup is considered to be dominant.

To determine the Sea Level Rise (SLR) due to future climate change, the future scenario of SLR is referred to as the scenario presented in the 5th report of IPCC [1)]. Here, the base year for the future scenario presented in the 5th report was assumed around 1986 to 2005. In order to convert the base year to the present, the value of 9 mm was deducted from the actual observed SLR from 1996. Figure 5.5.1 shows the future scenario of SLR based on 2019. Even though there is a range for each scenario, the median values are employed in this Project.




Source: IPCC Fifth Assessment Report (AR5), 2014

**Figure 5.5.1 Future Scenario of SLR based on 2019**

The design water level conditions at the Project site in Laamu Atoll and Addu Atoll are summarized as follows.

**Table 5.5.1 Design Water Level Conditions in Laamu Atoll**

| Laamu Atoll | 2030 | 2050 | 2100 |
|---|---|---|---|
| 1) High Water Level（HWL） | 0.70 | | |
| 2) Surge (Return Period 50 years) | 0.18 | 0.18 | 0.18 |
| 3) Sea Level Rise due to Climate Change | 0.04 | 0.17 | 0.65 |
| Design Water Level (＝1)+2)+3) ) | 0.92 | 1.05 | 1.53 |

Source: JICA Expert Team

**Table 5.5.2 Design Water Level Conditions in Addu Atoll**

| Addu Atoll | 2030 | 2050 | 2100 |
|---|---|---|---|
| 1) High Water Level（HWL） | 0.64 | | |
| 2) Surge (Return Period 50 years) | 0.18 | 0.18 | 0.18 |
| 3) Sea Level Rise due to Climate Change | 0.04 | 0.17 | 0.65 |
| Design Water Level (＝1)+2)+3) ) | 0.86 | 0.99 | 1.47 |

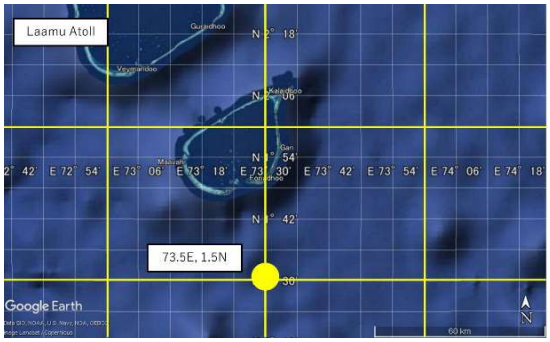
Source: JICA Expert Team

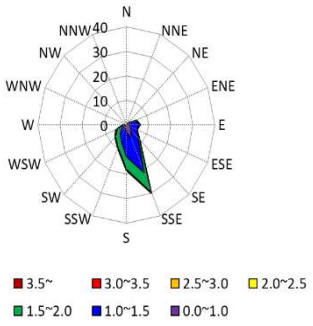
### 5.5.2 Design wave conditions

#### (1) Offshore wave conditions

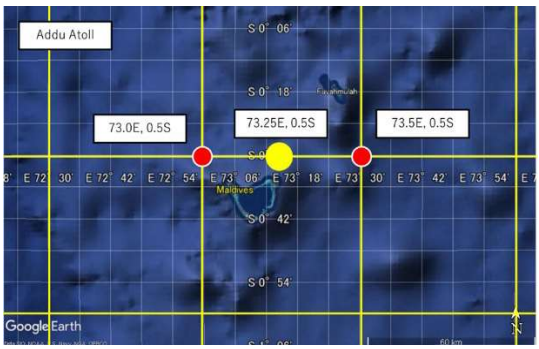
Characteristics of offshore waves around Laamu Atoll and Addu Atoll are obtained by applying the reanalysis data base (ERA5 produced by EXMWF) for 40 years from 1982 to 2021 as shown in Figure 5.5.2, because no long-term wave observation data can be available in the Maldives. The extracted location and characteristics of the offshore wave around each Atoll are shown below.

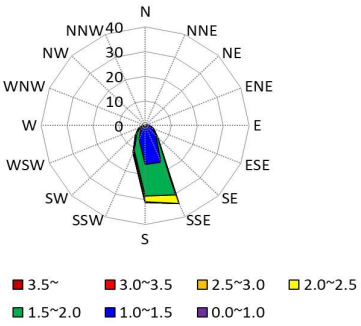
Laamu: 73.5E, 1.5N




Addu: 73.25E, 0.5S *



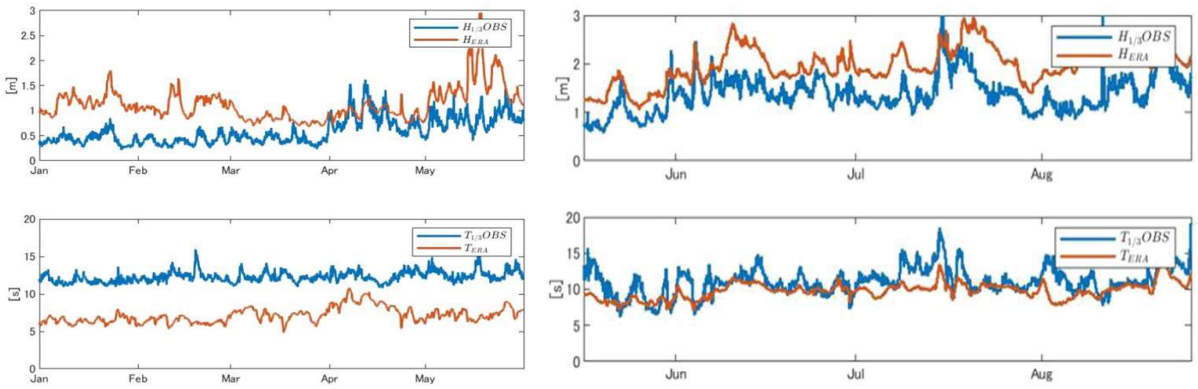




* Note: The characteristics of offshore wave at (73.25E, 0.5S) are estimated by synthesizing both data at (73.0E, 0.5S) and (73.5E, 0.5S).

Source: JICA Expert Team using ERA5

**Figure 5.5.2 Characteristics of Offshore Waves around Laamu Atoll and Addu Atoll**

Some differences between wave estimation results by ERA5 and actual observation results are found as shown in Source: JICA Expert Team using ERA5 Figure 5.5.3. Therefore, the wave data from ERA5 was corrected so that the wave heights and periods obtained from wave deformation calculations using the wave data from ERA5 as input conditions matched the observed wave heights and periods.




Source: JICA Expert Team using ERA5

**Figure 5.5.3 Comparison between the observed waves at Hankede Island from February to August 2019 and ERA5**

The correction factors for each atoll and the comparison between the corrected ERA5 and the observed results are shown below. As the result, it was found that the corrected ERA5 corresponds with the results from the observation as shown in Figure 5.5.4.

Correction factor at Laamu Atoll

H_era(correction)
=H_era.*(0.0185.*T_era.^2-0.1101.*T_era+0.3596);

T_era(correction)
=T_era.*(0.0299.*T_era.^2-0.6735.*T_era+ 5.0041);

Correction factor at Addu Atoll

H_era(correction)
=H_era.*(0.0172.*T_era.^2-0.3175.*T_era+ 2.137);

T_era(correction)
=T_era.*1.5*(-0.0372.*T_era.^2-0.2231.*T_era+ 1.4309);

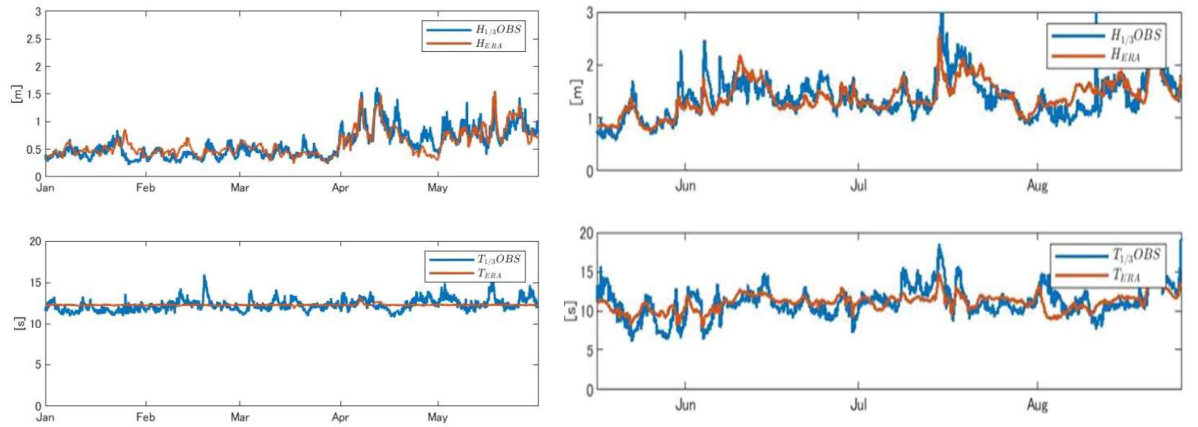



**Figure 5.5.4 Comparison between the observed waves at Hankede Island and Corrected ERA5**

Source: JICA Expert Team using ERA5

Based on the corrected ERA5 for 40 years, the annual maximum wave heights are extracted and the probabilistic wave height is calculated based on the extreme value statistics analysis proposed by Goda. The probabilistic wave height which indicates the return period of wave height at each Atoll are shown in Table 5.5.3. The wave period is set by the maximum value of 12s when waves equivalent to a 50-year probability were recorded.

**Table 5.5.3 Probabilistic Wave Height at Surrounding Area in Laamu Atoll (Left) and Addu Atoll (Right)**

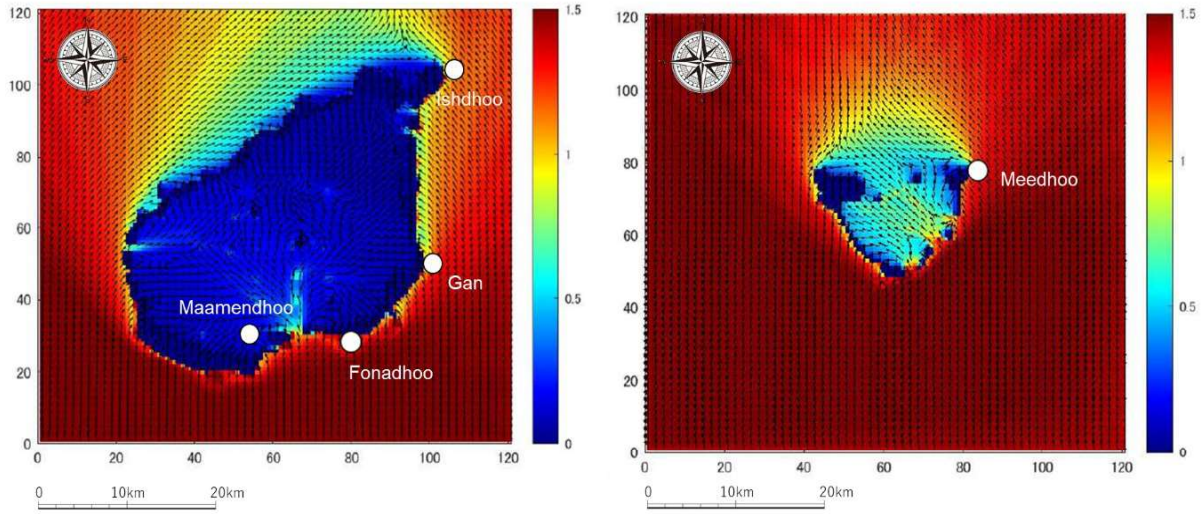
| Return Period (Year) | Significant Wave Height (m) |
|---|---|
| 1 | 2.50 |
| 5 | 3.11 |
| 10 | 3.42 |
| 20 | 3.71 |
| 30 | 3.88 |
| 50 | 4.09 |

| Return Period (Year) | Significant Wave Height (m) |
|---|---|
| 1 | 2.73 |
| 5 | 3.04 |
| 10 | 3.19 |
| 20 | 3.34 |
| 30 | 3.43 |
| 50 | 3.53 |

Source: JICA Expert Team using ERA5

The design offshore wave at each project site are estimated by wave deformation analysis from offshore area to the project site considering wave deformation caused by water depth change in shallow water such as refraction, shoaling, breaking wave and diffraction. The SWAN was used to calculate wave deformation as shown in Figure 5.5.5. Details on the calculation method and other details can be found at the following URL. (https://www.tudelft.nl/).

The wave height ratio between the boundary wave height which means the corrected ERA5 and the wave height at each project site are summarized in Table 5.5.4. The estimated design offshore wave at each project site are also shown in Table 5.5.4. Since Maamendhoo Island is located inside Laamu Atoll, it is considered to be predominantly affected by wind waves generated by monsoon, etc., rather than by direct wave heights from the ocean side. Therefore, in the Feasibility Study, the SMB method, which can estimate wave heights generated by wind speed and distance from the wind area, was used to set the design waves at Maamendhoo, and these values are also used in this project as well.




Source: JICA Expert Team

**Figure 5.5.5 Wave Deformation Calculation around Laamu Atoll (Left) and Addu Atoll (right)**

**Table 5.5.4 Design Wave Height at each Project Site**

| Location | Fonadhoo | Maamendhoo (West) | Maamendhoo (East) | Gan | Isdhoo | Meedhoo |
|---|---|---|---|---|---|---|
| Wave Height Ratio (m) | 0.93 | 0.73 * | 0.73 * | 0.74 | 0.76 | 0.82 |
| Design Offshore Wave (m) | 3.80 | 2.99 | 2.99 | 3.03 | 3.11 | 2.90 |

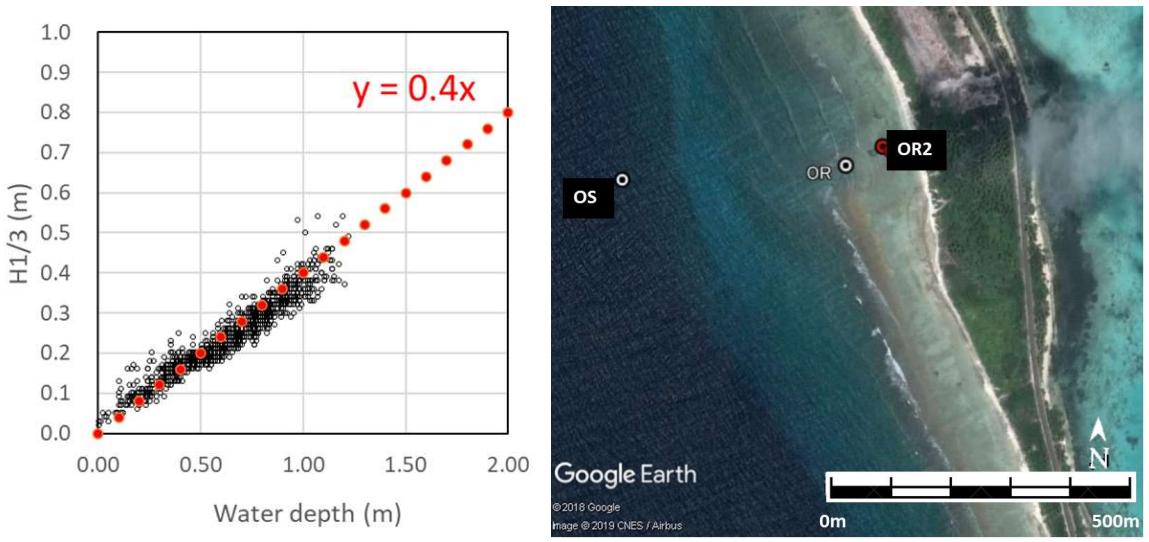
* Based on the result of Feasibility Study

Source: JICA Expert Team

### (2) Design wave conditions for the structures

According to the past study results, it was known that the constant value γ was 0.35 ~ 0.4 [2]. Here, the value of γ was set to 0.4 based on the relationship between observed waves at outer reef (OS) and inner reef (OR2) in Hankede from February to August 2019.

Based on the characteristic, the design waves at each project site are estimated as shown in Table 5.5.5.




Source: JICA Expert Team

**Figure 5.5.6 Characteristics between Wave Height and Water Depth on Reef**

**Table 5.5.5 Design Waves at each Project Site**

| Location | Fonadhoo | Maamendhoo (West) | Maamendhoo (East) | Gan | Isdhoo | Meedhoo |
|---|---|---|---|---|---|---|
| Water Depth (m from DWL) | 1.55 | 2.65 | 2.35 | 1.70 | 3.25 | 1.86 |
| Design Wave Height (m) | 0.62 | 1.06 | 0.94 | 0.68 | 1.30 | 0.74 |

Source: JICA Expert Team

### 5.5.3 Design Concept

#### (1) Beach Nourishment

- The backshore berm heights which is one of the main specifications are set to the same as the berm height of natural beaches obtained by the field surveys because the berm height of natural beaches is formed by the action of the wave and flow for long period.
- It is known that the foreshore slope depends on the grain size of the sand which constitutes of the beach. The grain size of the sand for beach nourishment is set to the same size as near natural beaches. For these reasons, the foreshore slope is also set to the same as the one of natural beaches obtained by the field survey.
- The berm width is set based on the results of beach deformation analysis as well as considerations of the location of original coastline, the buffer zone for protection of backward, the beach usage for residents, etc.
- The volume of the sand stock is set as the volume to maintain for 30 years considering to the basic service life for the civil structures. Though it is necessary to evaluate the volume and frequency of the additional nourishment quantitatively by the detailed prediction study of future trend of the coast line, the volume of the sand stock is set based on the results of beach deformation analysis.

#### (2) Groin

- The structure type of the groin adopts the rubble mound groin which was constructed in the Maldives recently considering to the workability and scoring by reflected waves.
- The interval of the groin is set based on the results of beach deformation analysis as well as considerations of the landscape and usability in this study by reference to the similar coastal protection project.
- Though the length of groin depends on the berm width, the interval of groins and stable coastline condition after nourishment, it is basically set to the length with a certain margin (about 10-20 m) from the coastline after nourishment.
- The crown height is set to the berm height + 0.5 m in terms of protection of the discharging the beach sand. The crown width is set to 2 m as the minimum length to ensure the stability of armored stones. The crown slope is set to 1:2.5 as the gently slope enough to climb easily considering the usability.

#### (3) Revetment and Reclamation

- The elevation of revetment and reclamation is set based on the overtopping waves and allowable volume of water discharge due to the overtopping waves. The detailed study are shown in (4) below.
- The area of reclamation area is set to about 2 ha (about 10 % of the area of Maamendhoo) considering to number of the residents of Maamendhoo (about 900 people), required evacuation facility space and percentage of total island area, etc.
- The structure type of revetment adopts the rubble mound for the same reasons of the groin. The cross section is trapezoidal considering to the reclamation works after constructing the revetment. The slope for the fore side is set to 1:2.5 for the same reasons of the groin, and for the back side is set to 1:1.5 considering to the stability of the rubble mound.

### (4) Determination of Required Elevation of Revetment and Reclamation

The crest height was evaluated using the Technical Standard aforementioned and a wave of 50 years return period was used considering the purpose of the measure. The evaluation details are shown as followings.

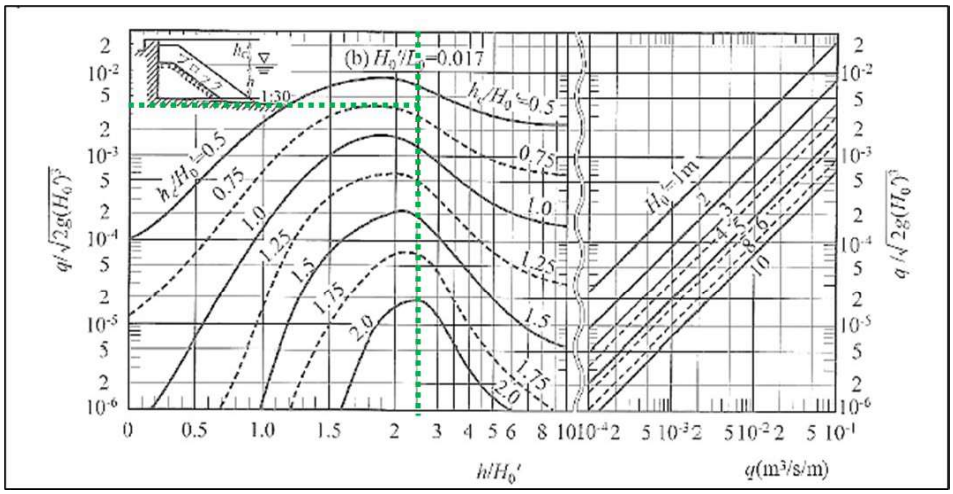
There are some reference values for allowable overtopping rate as shown in Table 5.5.6 and mostly are ranging between 0.01 and 0.05 (m3/s/m). In this study, the value of 0.02 (m3/s/m) for the reclamation in Maamendhoo and 0.05 for other facilities were selected with consideration both of economic efficiency and safety side of design concept.

**Table 5.5.6 Reference Values for Allowable Overtopping Rate**

| Allowable overtopping rate (m3/s/m) | Target |
|---|---|
| 0.01 | Region where houses and important public facilities are densely located, and severe damage is expected due to wave overtopping and inundation. |
| 0.02 | The important region other than above |
| 0.02~0.06 | The region other than above |

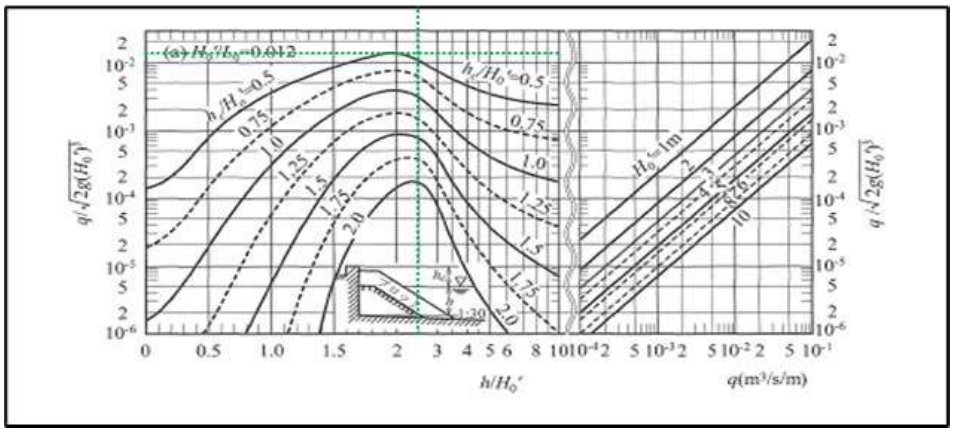
1) Reclamation in Maamendhoo

| | | | |
|---|---|---|---|
| Crest Height | | 1.80 | m |
| Design Water Level | | 1.05 | m |
| Hight from Water Level | hc | 0.75 | m |
| Bottom Slope | | 1/30 | |
| Ground Elevation | z | -1.60 | m |
| Water Depth | h | 2.65 | m |
| Equivalent Offshore Wave Height | H0' | 1.06 | m |
| Wave Period | T | 10 | s |
| Wave Length | L0 | 156 | m |
| Wave Steepness | H0'/L0 | 0.019 | |
| | hc/H0' | 0.71 | |
| | h/H0' | 2.50 | |
| Allowable Overtopping Rate | q0 | **2.0.E-02** | m3/s/m |
| | q/√2g(H0')^3 | 4.0.E-03 | m3/s/m |
| Estimated Overtopping Rate | q | **1.7.E-02** | m3/s/m |



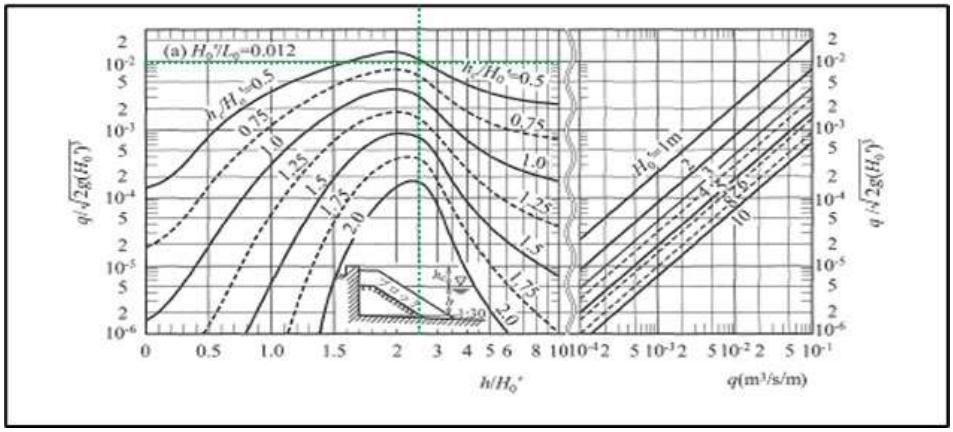

2) Revetment in Maamendhoo

| | | | |
|---|---|---|---|
| Crest Height | | 1.50 | m |
| Design Water Level | | 1.05 | m |
| Hight from Water Level | hc | 0.45 | m |
| Bottom Slope | | 1/30 | |
| Ground Elevation | z | -1.30 | m |
| Water Depth | h | 2.35 | m |
| Equivalent Offshore Wave Height | H0' | 0.94 | m |
| Wave Period | T | 12 | s |
| Wave Length | L0 | 224.64 | m |
| Wave Steepness | H0'/L0 | 0.013 | |
| | hc/H0' | 0.48 | |
| | h/H0' | 2.50 | |
| Allowable Overtopping Rate | q0 | **5.0.E-02** | **m3/s/m** |
| | q/√2g(H0')^3 | 1.2.E-02 | m3/s/m |
| Estimated Overtopping Rate | q | **4.7.E-02** | **m3/s/m** |



3) Revetment in Isdhoo

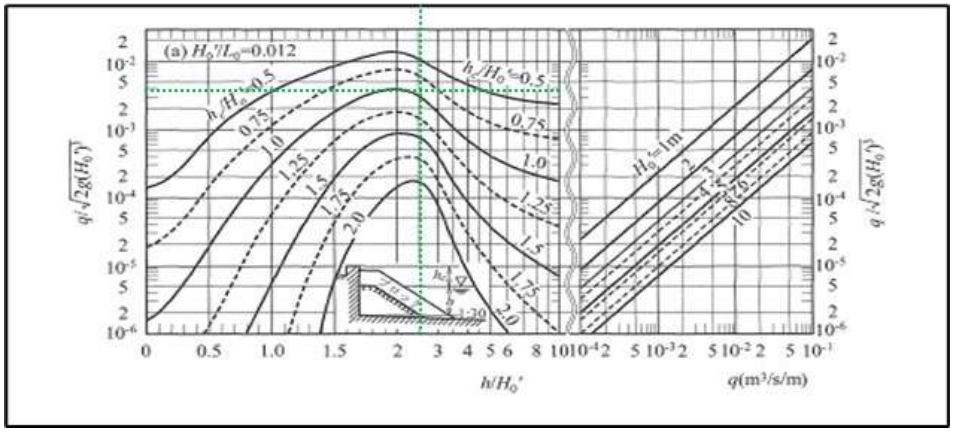
| | | | |
|---|---|---|---|
| Crest Height | | 1.70 | m |
| Design Water Level | | 1.05 | m |
| Hight from Water Level | hc | 0.65 | m |
| Bottom Slope | | 1/30 | |
| Ground Elevation | z | -2.20 | m |
| Water Depth | h | 3.25 | m |
| Equivalent Offshore Wave Height | H0' | 1.30 | m |
| Wave Period | T | 12 | s |
| Wave Length | L0 | 224.64 | m |
| Wave Steepness | H0'/L0 | 0.014 | |
| | hc/H0' | 0.50 | |
| | h/H0' | 2.50 | |
| Allowable Overtopping Rate | q0 | **5.0.E-02** | m3/s/m |
| | q/√2g(H0')^3 | 1.0.E-02 | |
| Estimated Overtopping Rate | q | **4.7.E-02** | m3/s/m |




4) Revetment in Gan

| | | | |
|---|---|---|---|
| Crest Height | | 1.70 | m |
| Design Water Level | | 1.05 | m |
| Hight from Water Level | hc | 0.65 | m |
| Bottom Slope | | 1/30 | |
| Ground Elevation | z | -0.65 | m |
| Water Depth | h | 1.70 | m |
| Equivalent Offshore Wave Height | H0' | 0.68 | m |
| Wave Period | T | 12 | s |
| Wave Length | L0 | 224.64 | m |
| Wave Steepness | H0'/L0 | 0.013 | |
| | hc/H0' | 0.96 | |

| | | | |
|---|---|---|---|
| | h/H0' | 2.50 | |
| Allowable Overtopping Rate | q0 | **5.0.E-02** | m3/s/m |
| | q/√2g(H0')^3 | 4.0.E-03 | |
| Estimated Overtopping Rate | q | **1.3.E-02** | m3/s/m |




**(5) Determination of Required Weight and Thickness of Armor Rock**

1) Weight of Armor for Groin, Revetment and Reclamation

The required weight for armor units (stones) for structure with crest level higher than H.W.L is estimated by Hudson formula as shown follows.

Hudson Formula:

$$W = \frac{\gamma_r H^3}{K_D (S_r - 1)^3 \cot\theta} \quad \text{.....(Eq.1)}$$

Where, W : Minimum weight in ton of an individual armor unit in the primary cover layer.

$\gamma_r$ : Unit weight of armor material in ton/m3.

Sr : Specific gravity of armor material relatively to seawater = (W / Ww)

Ww : Unit weight of seawater at the site (1.03 ton/m3)

$\theta$ : Angle in degree of structure slope measured from horizontal

H : Design wave height in meter at the site of the structure

KD : Stability coefficient that varies with type of armor units, shape of armor units, roughness of the armor unit surface, number of layers of armor units and magnitude of damage (see Table 5.5.7 ).

**Table 5.5.7 List of KD Value for Determination of Armor Unit Weight**

| No- Damage Criteria and Minor Overtopping | | | | | | | |
|---|---|---|---|---|---|---|---|
| Armor Units | n[3] | Placement | Structure Trunk $K_D$[2] | | Structure Head $K_D$ | | Slope |
| | | | Breaking Wave | Nonbreaking Wave | Breaking Wave | Nonbreaking Wave | Cot θ |
| Quarrystone | | | | | | | |
| Smooth rouded | 2 | Random | *1.2* | 2.4 | *1.1* | 1.9 | 1.5 to 3.0 |
| Smooth rouded | >3 | Random | *1.6* | *3.2* | *1.4* | *2.3* | [5] |
| Rough angular | 1 | Random 4 | [4] | *2.9* | [4] | *2.3* | [5] |
| Rough angular | 2 | Random | 2.0 | 4.0 | *1.9*<br>*1.6*<br>1.3 | 3.2<br>2.8<br>2.3 | 1.5<br>2.0<br>3.0 |
| Rough Angular | >3 | Random | *2.2* | *4.5* | 2.1 | *4.2* | [5] |
| Rough Angular | 2 | Special | 5.8 | 7.0 | 5.3 | 6.4 | [5] |
| Parallepiped 7 | 2 | Special | 7.0 -20.0 | *8.5 -24.0* | ---- | ----- | |
| Tetrapod and Quadripod | 2 | Random | 7.0 | 8.0 | *5.0*<br>*4.5*<br>*3.5* | 6.0<br>5.5<br>4.0 | 1.5<br>2.0<br>3.0 |
| Tribar | 2 | Random | *9.0* | 10.0 | *8.3*<br>*7.8*<br>6.0 | 9.0<br>8.5<br>6.5 | 1.5<br>2.0<br>3.0 |
| Dolos | 2 | Random | 15.8 [8] | 31.8 [8] | *8.0*<br>7.0 | *16.0*<br>*14.0* | 2.0 [9]<br>3.0 |
| Modified cube | 2 | Random | *6.5* | 7.5 | ----- | *5.0* | [5] |
| Hexapod | 2 | Random | *8.0* | 9.5 | *5.0* | *7.0* | [5] |
| Toskane | 2 | Random | *11.0* | 22.0 | | | [5] |
| Tribar | 1 | Unifarm | 12.0 | 15.0 | *7.5* | *9.5* | [5] |
| Quarrystone ($K_{RR}$) | | | | | | | |
| Graded angular | | Random | 2.2 | 2.5 | ---- | ---- | ---- |

1. CAUTION: Those $K_D$ values shown in italics are unsupported by test results and are only provided for preliminary design purposes
2. Applicable to slopes ranging from 1 on 1.5 to 1 on 5
3. n is the number of units comprising the thickness of the armor layer
4. The use of singel layer of quarrystone armor units is not recommended for structure subject to breaking waves and
5. Until more information is available on the variation of $K_D$ value with slope, the use of $K_D$ should be limited to slopes ranging from 1 on 1.5 to 1 on 3 some armor units tested on a structure head indicated a KD - slope dependence
6. Special placement with long axis of stone placed perpendicular to structure face.
7. Parallelepiped - shaped stone: long slab - like stone dimension about 3 times the shortest dimension (Mrkle and Davidson, 1979).
8. Refers to no - damage criteria (<5 percent displacement, rocking, etc); if no rocking (<2 percent) is desired, reduce $K_D$ 50 percent (Zwamborn and Van Niekern, 1982).
9. Stability of dolosse on slopes steeper than 1 and 2 should be substantianed by site-specific model test.

Source: JICA Expert Team

**Table 5.5.8 Summary of Required Weight of Armor Rock**

| Symbol | unit | Maamendhoo (West) | Maamendhoo (East) | Gan | Isdhoo | Meedhoo |
|---|---|---|---|---|---|---|
| M | t | **0.216** | **0.113** | **0.043** | **0.450 *** | **0.056** |
| ρb | t/m3 | 2.65 | 2.65 | 2.65 | 2.65 | 2.65 |
| ρw | t/m3 | 1.03 | 1.03 | 1.03 | 1.03 | 1.03 |
| Sr=ρb/ρw | t/m3 | 2.57 | 2.57 | 2.57 | 2.57 | 2.57 |
| $H_{1/3}$ | m | **1.17** | **0.94** | **0.68** | **0.68** | **0.68** |
| Kd | | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Gradient | | 1:2.5 | 1:2.5 | 1:2.5 | 1:2.5 | 1:2.5 |

Source: JICA Expert Team

2) Thickness of Armor Layer

The thickness of the armor layer or any of the subsequent under layers is calculated by the following equation:

$$r = n \cdot K_{\Delta} \cdot \left(\frac{W}{W_r}\right)^{1/3} \quad \text{.....(Eq.2)}$$

Where: r = the average thickness of the armor layer, or underlayer (m)
n = the number of armor units in the layer (minimum n = 2)
W = mass of individual armor unit in the layer (Ton)
Wr = mass density of armor unit (Ton/m3)
Kd : Stability coefficient that varies with type of armor units, shape of armor units, roughness of the armor unit surface, number of layers of armor units and magnitude of damage.

**Table 5.5.9 Summary of Required Thickness of Armor Rock**

| Symbol | unit | Maamendhoo (West) | Maamendhoo (East) | Gan | Isdhoo | Meedhoo |
|---|---|---|---|---|---|---|
| W | t | 0.216 | 0.113 | 0.043 | 0.450 | 0.056 |
| r | m | 1.0 | 0.7 | 0.7 | 1.2 | 0.7 |

Source: JICA Expert Team

### 5.5.4 Layout Plan and Typical Cross Section

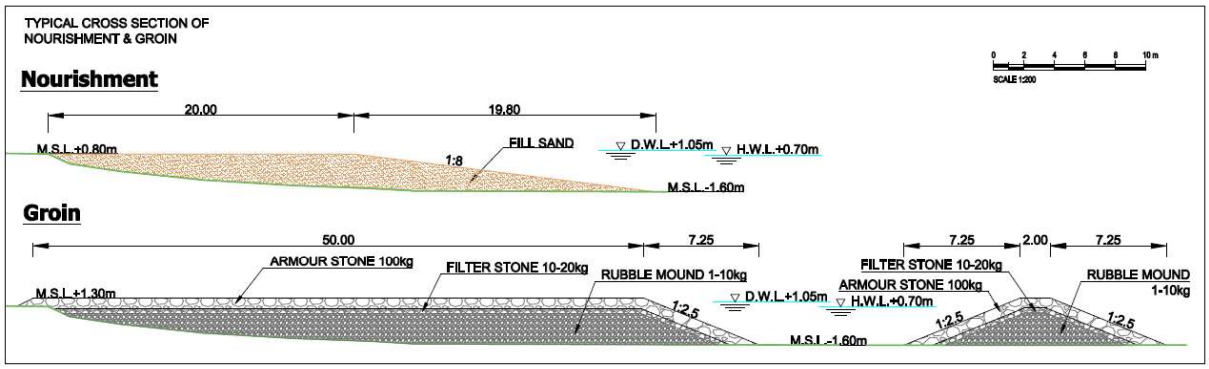
Based on the above conditions and design concept, the layout plan and typical cross section at each Project site are determined as follows.

**(1) Maamendhoo**


Source: JICA Expert Team

**Figure 5.5.7 Layout Plan of Maamendhoo**

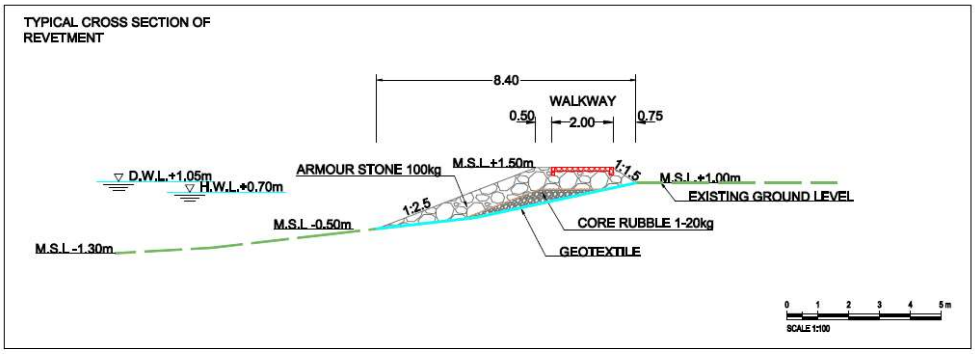
1) West coast




Source: JICA Expert Team

**Figure 5.5.8 Typical Cross Section of Nourishment and Groin at Maamendhoo West Coast**

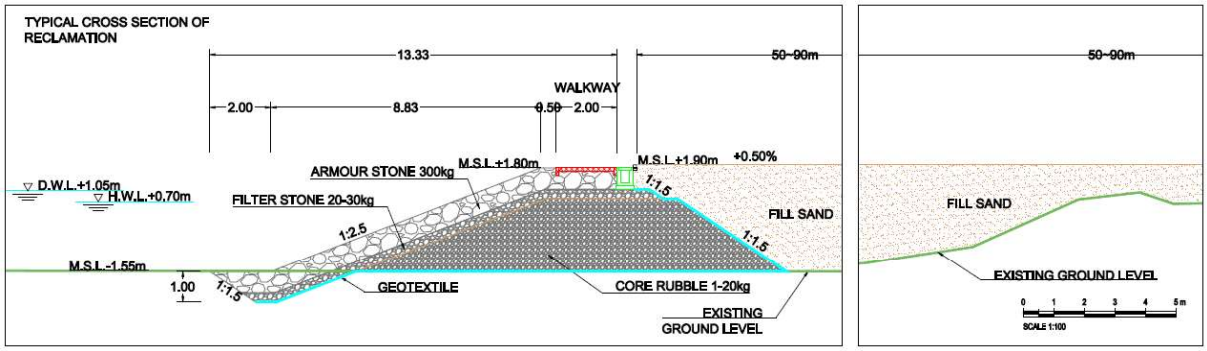
2) East coast




Source: JICA Expert Team

**Figure 5.5.9 Typical Cross Section of Revetment at Maamendhoo East Coast**

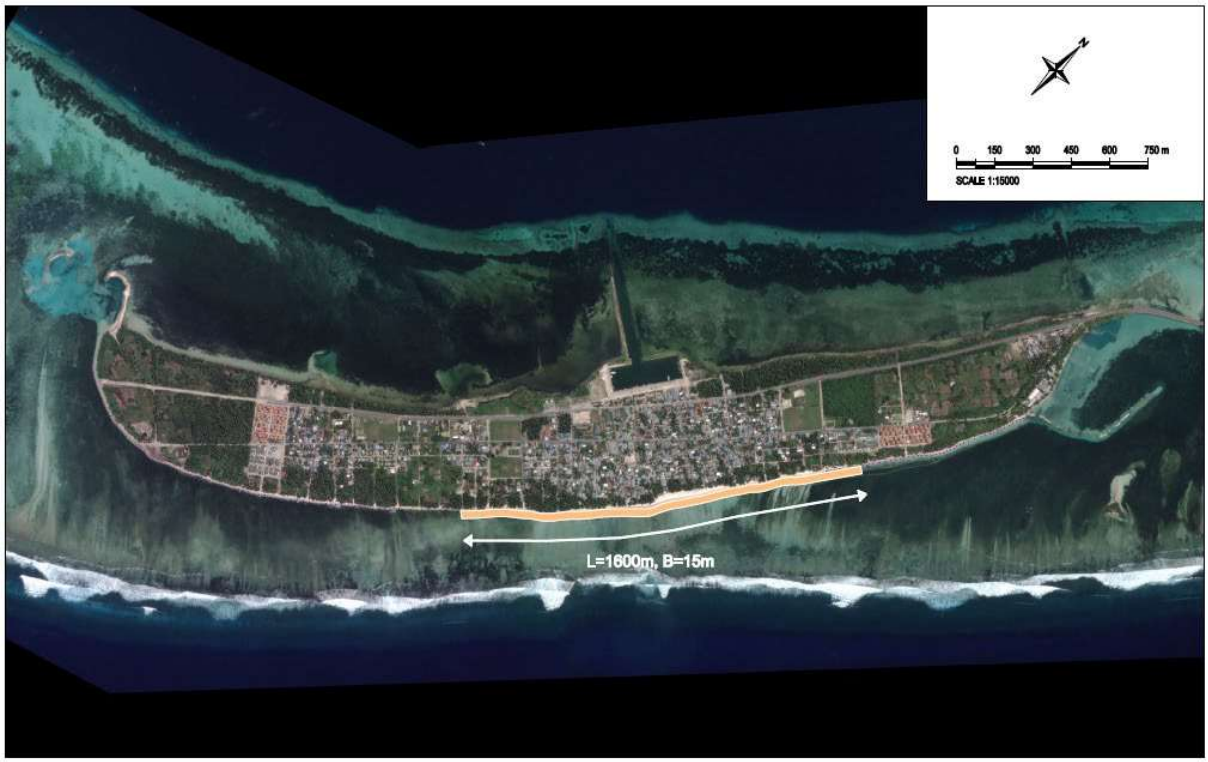
3) North coast




Source: JICA Expert Team

**Figure 5.5.10 Typical Cross Section of Reclamation at Maamendhoo North Coast**

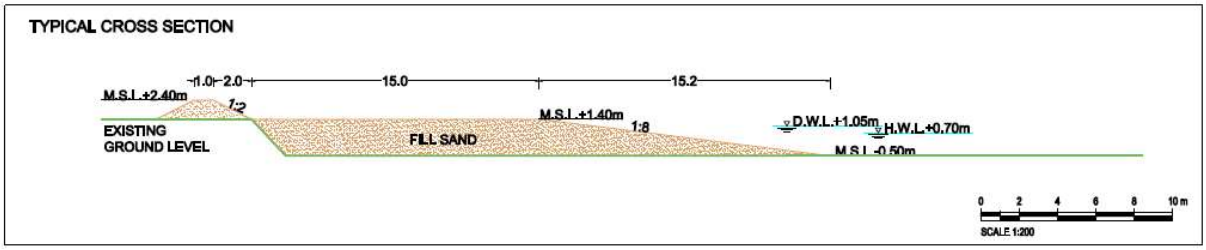
### (2) Fonadhoo




Source: JICA Expert Team

**Figure 5.5.11 Layout Plan of Fonadhoo**

1) Ocean Side



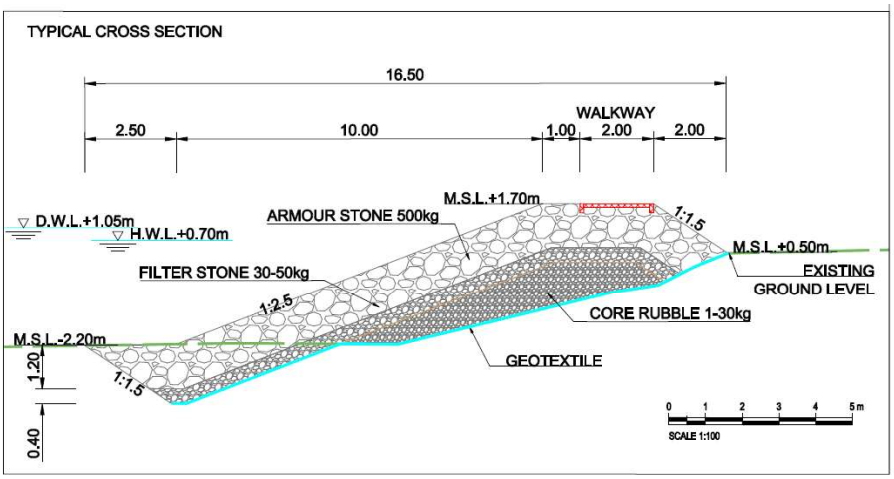

Source: JICA Expert Team

**Figure 5.5.12 Typical Cross Section of Nourishment at Fonadhoo**

### (3) Isdhoo


Source: JICA Expert Team

**Figure 5.5.13 Layout Plan of Isdhoo**



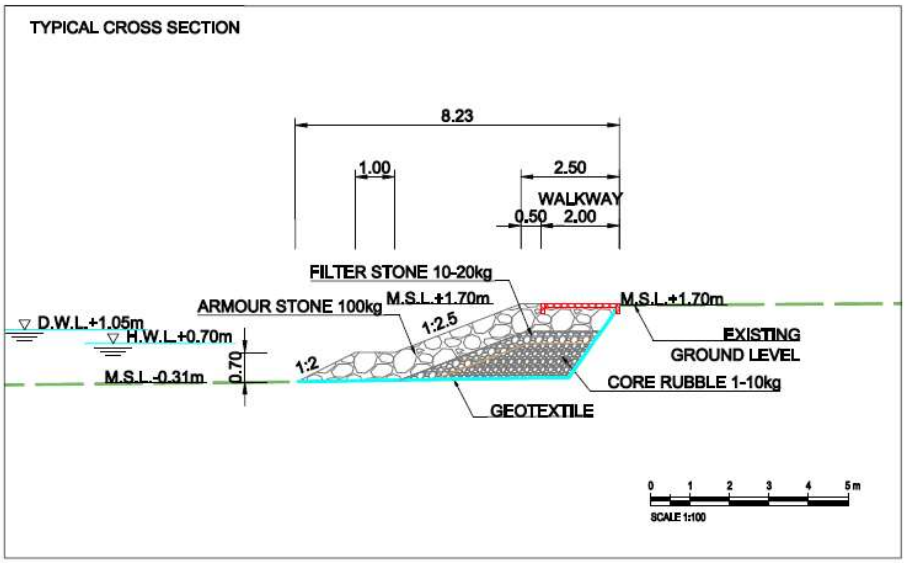

Source: JICA Expert Team

**Figure 5.5.14 Typical Cross Section of Revetment at Isdhoo**

### (4) Gan


Source: JICA Expert Team

**Figure 5.5.15 Layout Plan of Gan**



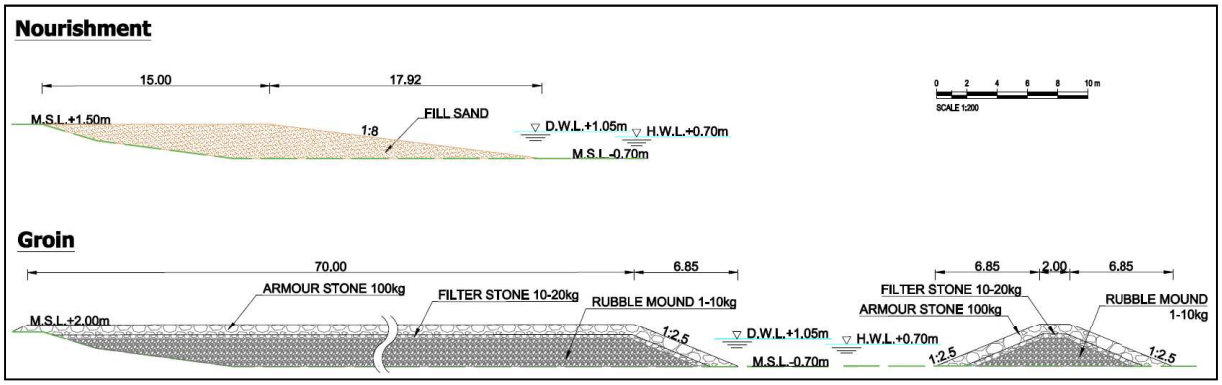

Source: JICA Expert Team

**Figure 5.5.16 Typical Cross Section of Revetment at Gan**

### (5) Meedhoo


Source: JICA Expert Team

**Figure 5.5.17 Layout Plan of Meedhoo**




Source: JICA Expert Team

**Figure 5.5.18 Typical Cross Section of Nourishment and Groin at Meedhoo**

## 5.6 Beach Maintenance

### 5.6.1 Current Status and Issues of Beach Maintenance and Management

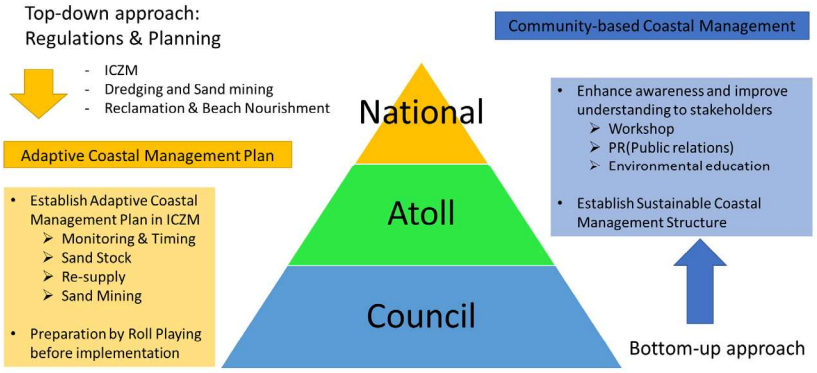
In the Maldives, the current status and issues related to the maintenance and management of sandy beaches are as follows.

- The beach nourishment measures that have been implemented up to the present are related to the maintenance of artificial sandy beaches on resort islands and those that have been nourished for their maintenance, etc. Beach nourishment has not been implemented on resident islands.
- Therefore, the organization necessary for maintenance and management about beach is unclear, and human resources and technology are not developed.
- Activities about beach maintenance involving local residents are only partially implemented, and it is necessary to establish a policy to build a maintenance and management system in beach.
- The legal system that defines the regulations and scope of new excavation and dredging, and the EIA process have been established, but the extraction of sediment for maintenance and management is not envisioned, and a new concept regarding beach maintenance needs to be established in the Maldives.
- Despite the limited sand source areas within each atoll, information sharing and collaboration on sand stocking and exchange has not been implemented in actual projects, such as excavation and dredging projects and reclamation projects.

### 5.6.2 Basic Direction for this Project

#### (1) Basic direction

The basic direction for beach maintenance in this project is shown in Figure 5.6.1. As mentioned above, in order to effectively implement maintenance and management for beach nourishment projects on inhabited islands that have not been implemented much in the past, it is necessary to build a community-based beach maintenance and management system with local residents at its core role and with the involvement of government agencies. However, to continue such activities, it is necessary to encourage such activities through regulations and plans by the central government. As for the maintenance and management of sandy beaches in this project, we will study the implementation of maintenance and management on two main approaches: (1) a top-down approach by the central government and (2) a bottom-up approach by local residents.




Source: JICA Expert Team

**Figure 5.6.1 Basic Direction on Sandy Beach Maintenance and Management**

### (2) Top-down approach

A top-down approach from the central government would include the following items. It may be difficult to establish a new system during the project period because it will take time to establish it as a legal system. However, it is very important to provide an opportunity to consider a maintenance and management system for the Maldives as a country. It is also envisioned that this approach will be formulated within the Integrated Coastal Management (ICZM) to accelerate its implementation.

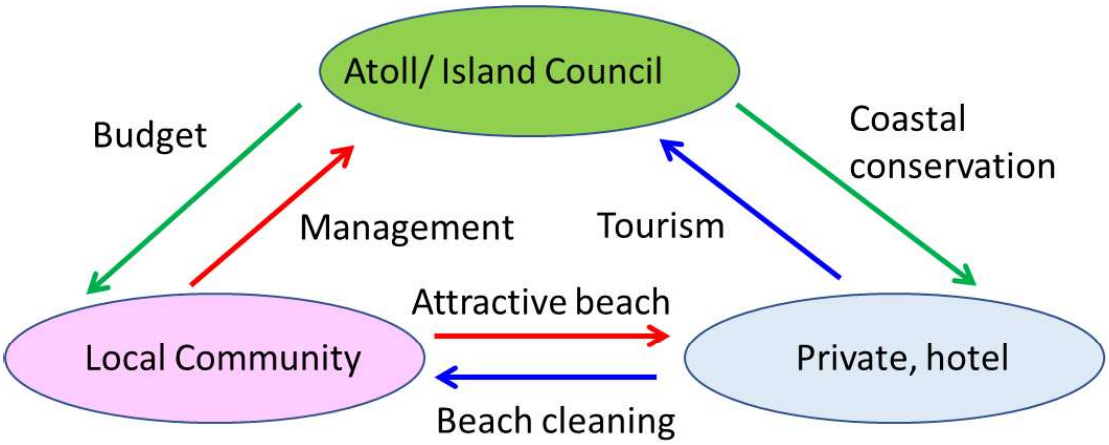
- Discussions among relevant agencies for institutionalization of small-scale, repeated excavation and dredging not covered by the current legal system
- Discussions among relevant agencies to establish a plan and system for long-term management within each atoll of sediment generated by excavation/ dredging projects and sediment used by reclamation projects.

These activities require consultation and consensus building not only by the central government, but also by the atoll councils, island councils, local residents, private companies, and other related organizations. In addition, the intra-atoll sediment management includes ancillary issues such as sand stockyards, its maintenance and management. We assume that the establishment of a system will be promoted by embodying this approach using the actual beach nourishment project on the subject island as a model case, which is explained later.

### (3) Bottom-up approach

It is difficult to properly implement the maintenance and management of sandy beaches only through the activities of the central government regulations and plans of a top-down approach, and a bottom-up approach by local residents is essential. The bottom-up approach is assumed to include the following activities. An image of the interaction between the parties involved is shown in Figure 5.6.2.

- Daily cleaning of beaches and daily deformation management based on such cleaning
- Establishment of a regular coastal monitoring system (local residents, councils, private operators, etc.)
- Consensus building and awareness building through workshops, stakeholder meetings, environmental education, etc.




Source: JICA Expert Team

**Figure 5.6.2 Image of stakeholder interaction in the bottom-up approach**

This approach will be implemented as an on-the-job training activity for the three beaches where the beach nourishment project is actually implemented in this project, targeting local residents, atoll & island councils, private sectors, and others to realize community-based coastal management and its sustainable operation. By involving local residents in the implementation of these activities by government agencies, a sense of unity will be fostered through the establishment of a system and the sharing of successful experiences, and this will be promoted so that active maintenance and management activities will be realized as their own beaches to which they are attached.

Source: JICA Expert Team

**Figure 5.6.3 Examples of bottom-up activities**
**(L: cleanup, M: education for elementary school students, R: stakeholder meeting)**

### 5.6.3 Maintenance Policy for Target Islands

The target islands where beach nourishment measures will be implemented in this project are Meedhoo, Fonadhoo, and Maamendhoo islands. Each of these islands will be stocked with sediment in nearby stockyards in consideration of the amount of sediment that will be required in the future. The policy is to properly maintain and manage these beaches through regular beach monitoring by local residents and additional beach nourishment sand by atoll & island councils and the central government in response to the results of such monitoring. The specific potential stockyard sites on each coast are detailed in Capture 5.8, and the plan is to reserve 30,000 $m^3$ of beach nourishment sand for each target island for maintenance and 15,000 $m^2$ (assuming a height of 2 m) for stockyards.

| Year | Activities | Sand Volume to be added (m3) | | Remaining Sand Volume |
|---|---|---|---|---|
| | | per times | accumulated | (m3) |
| 0 | Construction | 0 | 0 | 30,000 |
| 1-4 | Monitoring | | | |
| 5 | Maintenance | 3,000 | 3,000 | 27,000 |
| 6-9 | Monitoring | | | |
| 10 | Maintenance | 3,000 | 6,000 | 24,000 |
| 11-14 | Monitoring | | | |
| 15 | Maintenance | 3,000 | 9,000 | 21,000 |
| 16-19 | Monitoring | | | |
| 20 | Maintenance | 3,000 | 12,000 | 18,000 |
| 21-24 | Monitoring | | | |
| 25 | Maintenance | 3,000 | 15,000 | 15,000 |
| 26-29 | Monitoring | | | |
| 30 | Maintenance | 3,000 | 18,000 | 12,000 |
| 31-34 | Monitoring | | | |
| 35 | Maintenance | 3,000 | 21,000 | 9,000 |
| 36-39 | Monitoring | | | |
| 40 | Maintenance | 3,000 | 24,000 | 6,000 |
| 41-44 | Monitoring | | | |
| 45 | Maintenance | 3,000 | 27,000 | 3,000 |
| 46-49 | Monitoring | | | |
| 50 | Maintenance | 3,000 | 30,000 | 0 |

Source: JICA Expert Team

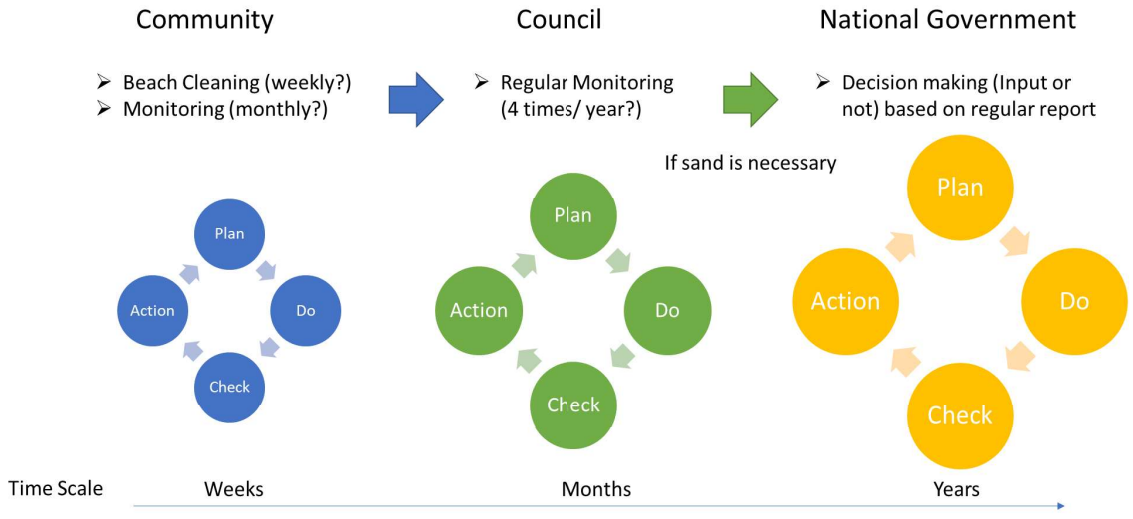
**Table 5.6.1 Input image of beach sand for maintenance**

| Year | Activities | Sand Volume to be added (m3) | | Remaining Sand Volume |
|---|---|---|---|---|
| | | per times | accumulated | (m3) |
| 0 | Construction | 0 | 0 | 30,000 |
| 1-4 | Monitoring | | | |
| 5 | Maintenance | 3,000 | 3,000 | 27,000 |
| 6-9 | Monitoring | | | |
| 10 | Maintenance | 3,000 | 6,000 | 24,000 |
| 11-14 | Monitoring | | | |
| 15 | Maintenance | 3,000 | 9,000 | 21,000 |
| 16-19 | Monitoring | | | |
| 20 | Maintenance | 3,000 | 12,000 | 18,000 |
| 21-24 | Monitoring | | | |
| 25 | Maintenance | 3,000 | 15,000 | 15,000 |
| 26-29 | Monitoring | | | |
| 30 | Maintenance | 3,000 | 18,000 | 12,000 |
| 31-34 | Monitoring | | | |
| 35 | Maintenance | 3,000 | 21,000 | 9,000 |
| 36-39 | Monitoring | | | |
| 40 | Maintenance | 3,000 | 24,000 | 6,000 |
| 41-44 | Monitoring | | | |
| 45 | Maintenance | 3,000 | 27,000 | 3,000 |
| 46-49 | Monitoring | | | |
| 50 | Maintenance | 3,000 | 30,000 | 0 |

Source: JICA Expert Team

**Table 5.6.1 Input image of beach sand for maintenance**

As an example, the image shown in Figure 5.6.1, assuming a maintenance management system in which about 3,000 $m^3$ is added every five years. It is assumed that the monitoring will be carried out periodically for 1-4 years after construction, and about 3,000 $m^3$ will be added in the 5th year; further monitoring will be continued for 6-9 years, and about 3,000 $m^3$ will be added again in the 10th year, and so on, for 50 years. The most important factor in this process will be the timing and location of additional beach nourishment sand application. The roles of the related agencies will be clarified in the course of future activities, and a maintenance and management policy will be agreed upon, taking into consideration the characteristics of each target island. The roles and maintenance approaches at this time are shown in Figure 5.6.4. It is assumed that local residents will be responsible for routine beach cleaning and associated simple monitoring of beach change. In addition, the atoll & island councils will be responsible for regular monitoring, approximately four times a year, to accumulate basic data on beach change. After reviewing such periodic data, the national government is expected to make decisions on whether or not to inject additional beach nourishment sand as needed, and if deemed necessary, to actually implement the beach nourishment project. This system will be discussed among the agencies concerned in this project to clarify the roles of each agency and to organize the details of implementation, frequency, reporting system, etc.




Source: JICA Expert Team

**Figure 5.6.4 Image of stakeholder interaction in the bottom-up approach**

## 5.7 Study for Sand Barrow Area

### 5.7.1 Objective of The Survey

JET propose candidate sand barrow sites for use in beach nourishment and reclamation projects on the project islands. In addition, relevant information on each proposed sand barrow site is organized, and if there are any concerns with each proposed sand barrow site, the items to be considered during future detailed studies are indicated.

### 5.7.2 Requirements for Potential Sand Barrow Sites

#### (1) Perspective from Sand Quality

The table below shows the items to be considered for candidate sand barrow sites. In general, beach nourishment projects consider 1) As the quality of the sand, whether the grain size of the sand is coarse as beach nourishment sand, and 2) As the quantity of sand, whether a sufficient quantity of sand can be procured for the project from the selected candidate sites.

1) In terms of sand quality, the grain size of the nourishing sand was checked to ensure that it was not too fine, as grain size affects the anchorage of the sand on the beach and too fine sand tends to run offshore and coastal direction. 2) In terms of sand quantity, the amount of sand that could be procured from each potential site could be estimated by the area of the sand barrow area and the layer thickness. The sand barrow area was considered to be less than 50 m depth in terms of dredging method. The dredging methods and water depths are described in Capture 5.8.

In addition, in the Maldives, 3) Related Legislation for Sand Barrow (described later) has been established, which defines areas within the lagoon where dredging is prohibited, and therefore consideration was given to ensure that the potential site was not included in the dredging prohibited area. In addition, the impact on ecosystems during dredging needs to be fully considered, therefore the impact on other ecosystems, including coral reefs, was examined. During the candidate site review, areas where coral reefs were found on the seabed were excluded from the candidate sites, and the need for detailed studies was described where there was concern about environmental impact on the surrounding area.

**Table 5.7.1 Items of Sand Barrow Area Consideration**

| Item | Contents of Consideration |
|---|---|
| 1) Sand Quality | - Whether the sand at the candidate site have an appropriate grain size for beach nourishment sand |
| 2) Sand Quantity | - Whether the necessary quantity of sand could be procured from candidate site<br>- Whether the area sufficiently extensive within a depth of 50 m |
| 3) Legislation | - Whether candidate site fall within a dredging prohibited area (described later) |
| 4) Environmental Consideration | - Whether the seabed of Candidate site have coral reefs<br>- Whether there are concerns about environmental impacts on nearby coral reefs and other ecosystems |

Source: JICA Expert Team

### (2) Related Legislation for Sand Barrow

In the Maldives, the "Regulation on Reclamation and Dredging of Islands and Lagoons (No: R-15/2013)" governs dredging within lagoons. The Regulation will therefore also be taken into account when considering the dredging of beach sand in the project. Details of the Regulation are provided in Chapter 2.4 'Relevant Legislation, Policy and Plan of ICZM'.

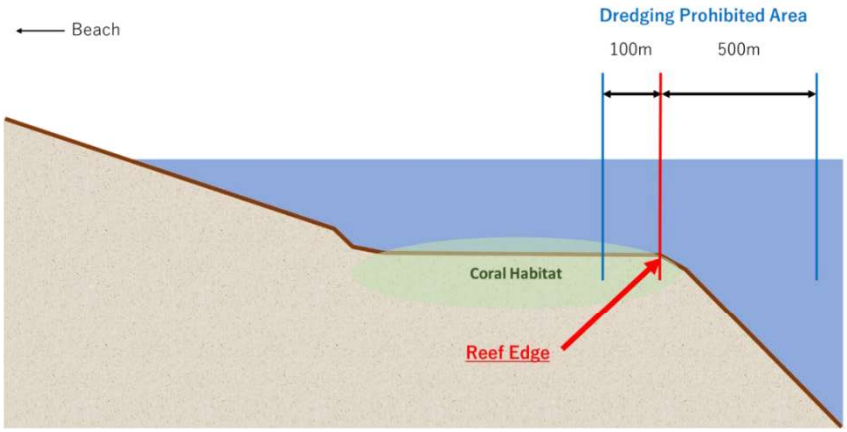
In considering the dredging area, the following provisions for dredging prohibited area should be noted.

a) Area 100 m from the reef edge towards the island's shoreline (Refer to Figure 5.7.1)

b) Area 500 m from the reef edge towards the inside of the atoll (Refer to Figure 5.7.1)

c) Environmental Protected Area and Environmental Sensitive Area as defined under EPPA 5/93

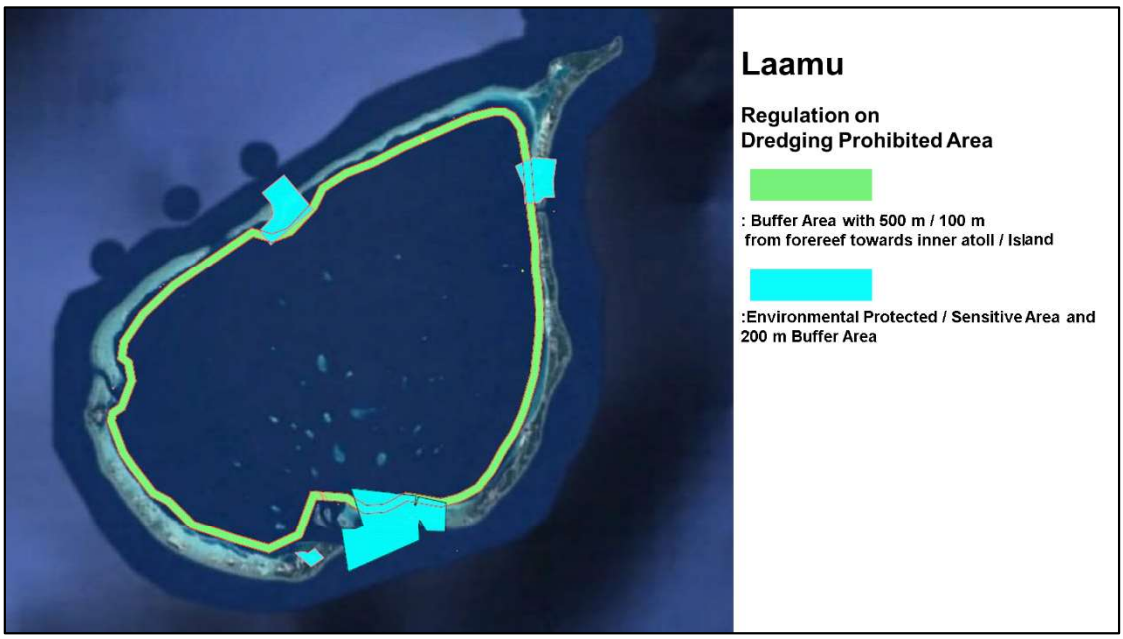
d) Buffer zone 200 m from the boundary of the area defined in c)




Source: JICA Expert Team

**Figure 5.7.1 Provision of Buffer Zone from Reef Edge**

The Figures below show the dredging prohibited areas in Addu and Laamu atolls as a) though d) mentioned above.




Source: JICA Expert Team

**Figure 5.7.2 Dredging Prohibited Area in Laamu Atoll**


Source: JICA Expert Team

**Figure 5.7.3 Dredging Prohibited Area in Addu Atoll**

### 5.7.3 Outline of The Survey

Table 5.7.2 lists the survey items, survey objectives and survey methodology. The survey was conducted to ensure that the above-mentioned items for consideration of the candidate sand barrow site were met. For the seabed condition survey, a remote underwater camera survey was conducted as well as a diving survey in order to efficiently assess the seabed condition over a wide area.

**Table 5.7.2 Outline of the Survey**

| Survey Item | Survey Objective | Survey Methodology |
|---|---|---|
| Diving Survey* | Environmental Survey<br>Sand Quality Survey<br>Sand Quantity Survey | Diving surveys were conducted by divers to check seabed conditions and collect sediment samples. |
| Remote Underwater Camera Survey* | Environmental Survey<br>Sand Quantity Survey | In order to assess the areal sand seabed extent, the seabed was checked by a camera deployed from the vessel. |
| Bathymetric Survey | Sand Quality Survey | Bathymetry was measured in the offshore direction by a bathymetric instrument to identify the seabed topography. |
| Sand Layer Thickness Survey | Sand Quantity Survey | Sand layer thickness was measured according to the depth at which the iron piles were inserted into the seabed during the diving survey. |
| Grain Size Test with Sieves | Sand Quality Survey | Grain size tests were conducted on the sampled sand. |

Source: JICA Expert Team

*However, the diving survey was limited to a depth of 40 m. For depths deeper than 40 m, the remote underwater camera survey was conducted.

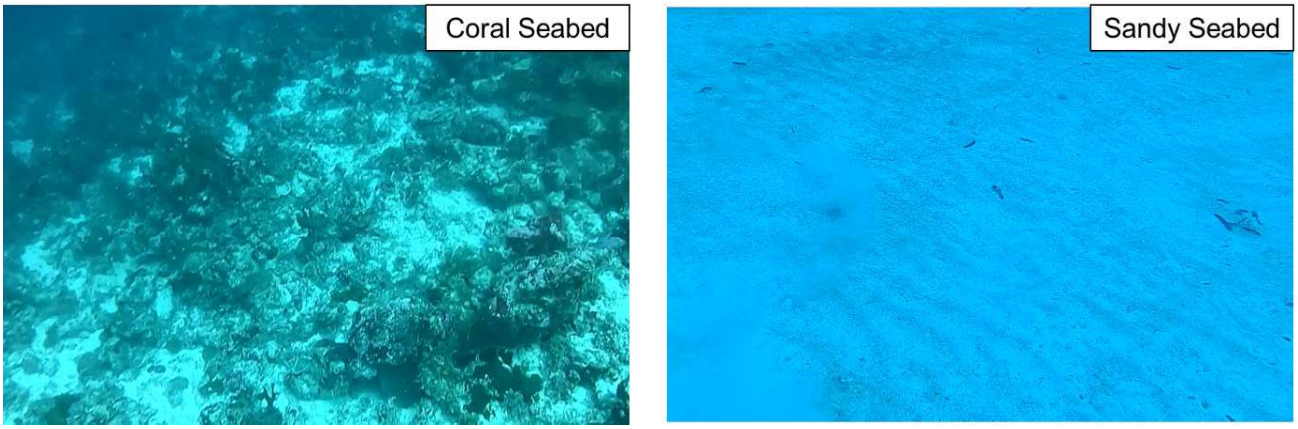
Figure 5.7.4 shows photographs of the diving survey. The left is a photograph of the steel piles used to measure the layer thickness. The steel piles, marked at 0.1 m intervals, were driven into the seabed with a hammer to measure the sand layer thickness. The right figure shows a photograph of diver taking seabed samples.


Source: JICA Expert Team

**Figure 5.7.4 Photographs of Diving Survey**

**(Left: Sand Layer Thickness Survey, right: Sediment Sampling)**

Figure 5.7.5 shows an example of a photograph of the seabed situation taken by remote underwater camera survey. In the case of the coral reef seabed as shown on the left photograph, the area was judged to be unsuitable for sand barrow from construction and environmental aspects. On the other hand, in the case of extensive sandy seabed, as shown on the right photograph, the area was judged as suitable for dredging.




Source: JICA Expert Team

**Figure 5.7.5 Seabed Condition Photographs by Remote Underwater Camera Survey**

### 5.7.4 Survey Area

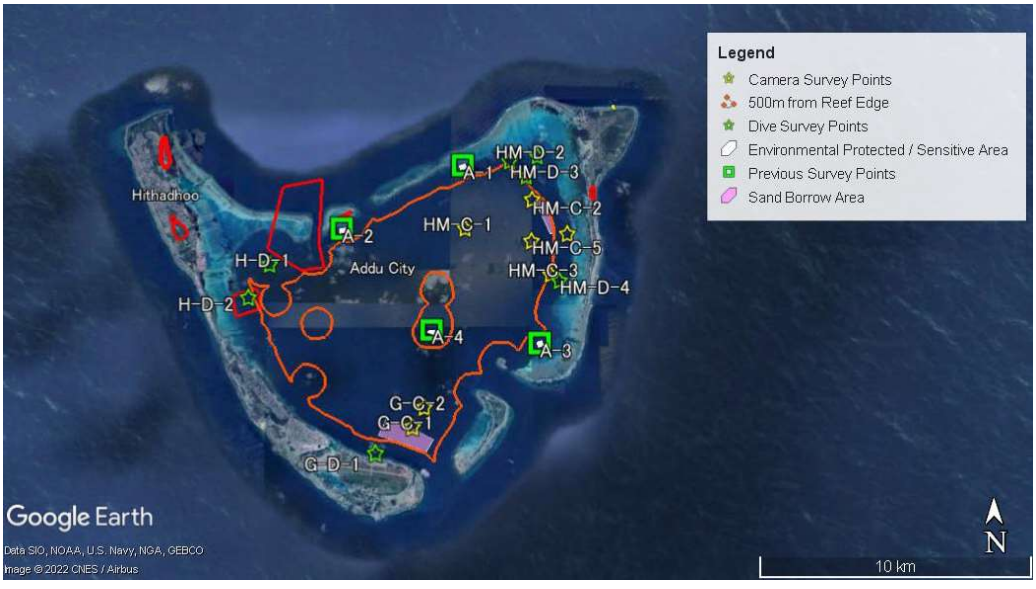
Based on satellite imagery, local topography and local coral reef distribution, the areas considered to satisfy the above consideration items were set as the survey area. The survey was conducted in two phases: phase 1 (February to March 2022) and phase 2 (July to August 2022).

#### (1) Addu Atoll

In Addu Atoll, 2 surveys were conducted, in 18 points for total.

- Phase 1 Survey: diving survey in 4 points

- Phase 2 Survey: driving survey in 7 points, remote underwater camera survey in 7 points




Source: JICA Expert Team

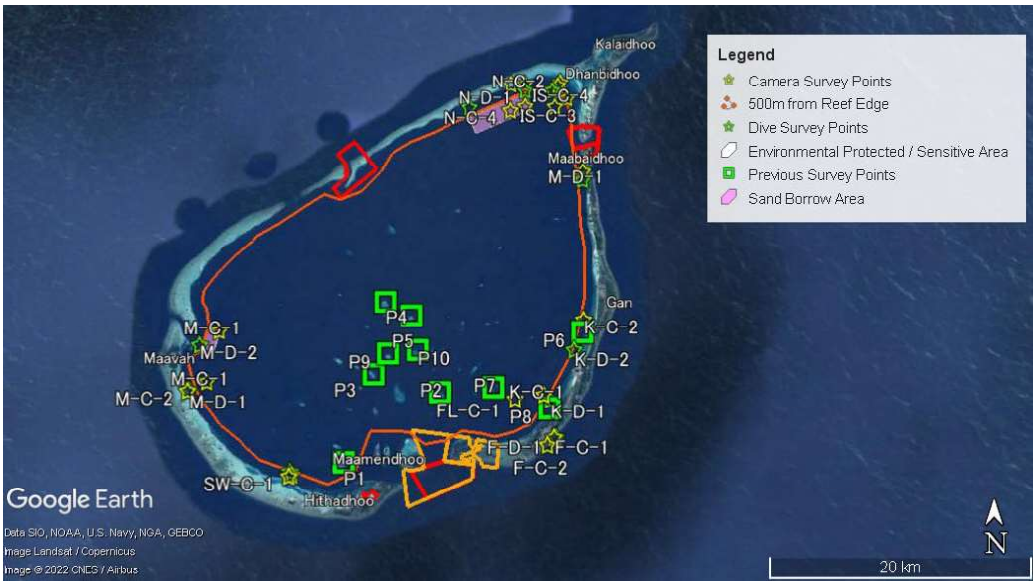
**Figure 5.7.6 Sand Barrow Survey Area in Addu Atoll**

### (2) Laamu Atoll

In Laamu Atoll, 2 surveys were conducted, in 39 points for total.

- Phase 1 Survey: diving survey in 10 points

- Phase 2 Survey: driving survey in 10 points, remote underwater camera survey in 19 points




Source: JICA Expert Team

**Figure 5.7.7 Sand Barrow Survey Area in Laamu Atoll**

## 5.7.5 Survey Results and Candidate Sites

Based on the survey results, the first and second candidate sites for beach nourishment sand barrow are proposed. Mainly, seabed conditions with coral reefs and the areas where the grain size of the sampled sand was too fine were excluded from the candidate sites for sand barrow. Detailed results for each site are described in ANNEX-2.

In selecting candidate sites for beach nourishment sand barrow, the distribution of similar sand within each atoll was estimated based on the wide-area seabed conditions identified by remote underwater camera survey and the bathymetric survey. After comparing the estimated sand distribution with the bathymetric distribution, sites where sufficient high-quality sand could be secured were proposed as candidate sites.

### (1) Addu Atoll Option 1

For Option 1, the north-east of Gan Island is proposed. (Refer to Figure 5.7.8)

**1)** Legislation

- As it is more than 500m offshore from the reef edge, it is not included in the dredging prohibition area described in (2) Related Legislation for Sand Barrow.

**2)** Quantity of Sand

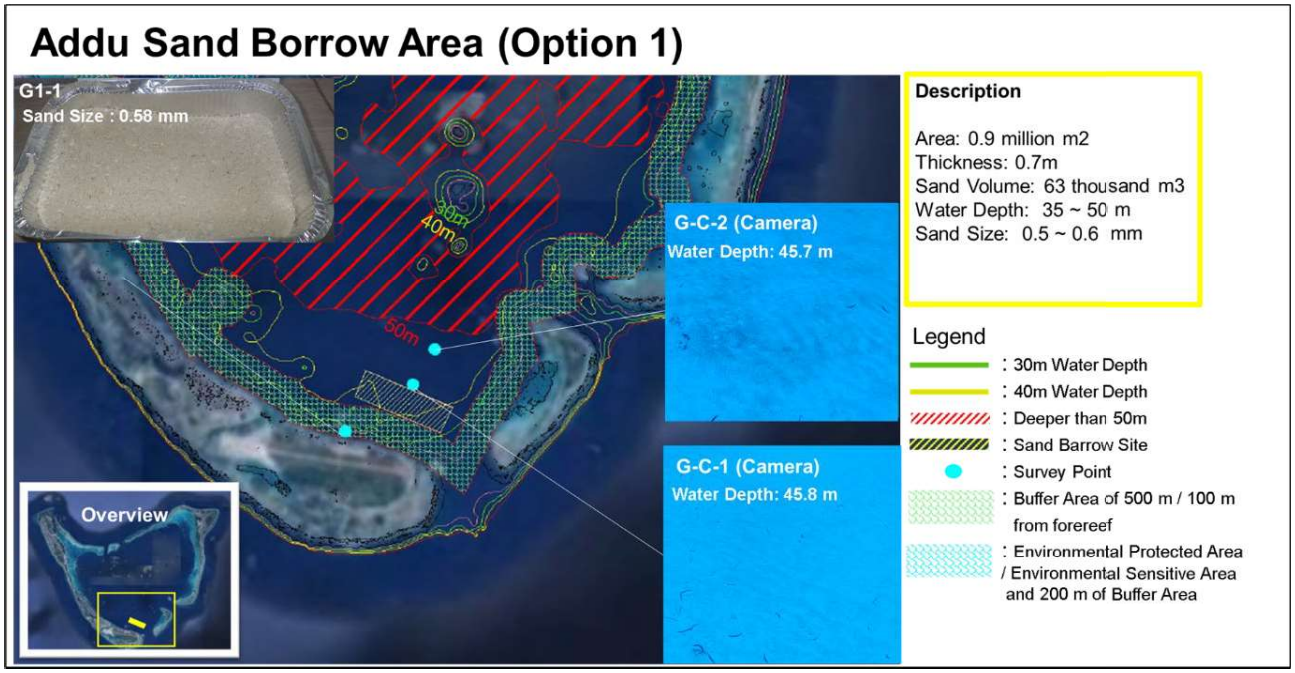
- Area of 35 m - 50 m depth is widespread (0.9 million $m^2$).

- The expected volume is 0.63 million $m^3$, as the results of sand layer thickness survey indicate a layer thickness of more than 0.7 m.

- Remote underwater camera survey results show similar sand over an extensive area.

**3)** Sand Quality

- Good quality sand with a relatively coarse grain size can be obtained.




Source: JICA Expert Team

**Figure 5.7.8 Sand Barrow Area Option 1 (Addu Atoll)**

**(2) Addu Atoll Option 2**

For Option 2, the south-east of Hulmeedhoo Island is proposed. (Refer to Figure 5.7.9)

**1)** Legislation

- As it is more than 500m offshore from the reef edge, it is not included in the dredging prohibition area described in (2) Related Legislation for Sand Barrow.

**2)** Quantity of Sand

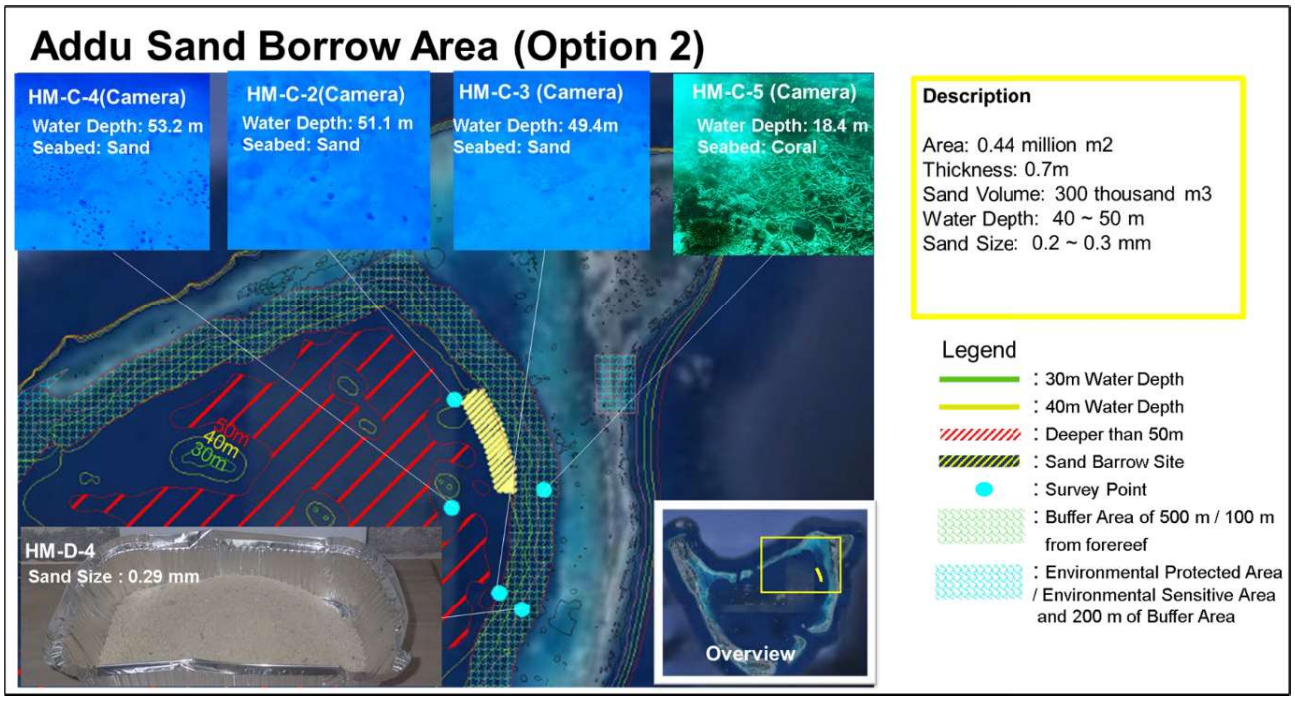
- The results of the bathymetric survey confirm that the seabed gradient is steep from the reef edge to offshore, which raises concerns that the expected sand barrow area is small (0.44 million $m^2$). On the other hand, it was confirmed that the area is sufficient for the amount of sand required by the project.

- Sand layer thickness surveys indicate a layer thickness of more than 0.7 m; therefore, the expected sand volume is 0.3 million $m^3$.

- Although there are only a small number of survey sites within the proposed site, it is estimated from remote underwater camera surveys and bathymetry distribution that there is a broad similar sandy seabed, including the surrounding area.

**3)** Sand Quality

- Although fine sand appears to be deposited in the surface layer, sand of coarse grain size can be obtained by collecting sand from a lower layer of about 0.5 m. It is recommended that the vertical distribution of the sand layer is verified by boring or other means during the detailed study.




Source: JICA Expert Team

**Figure 5.7.9 Sand Barrow Area Option 2 (Addu Atoll)**

### (3) Laamu Atoll Option 1

For Option 1, the south-west of Isdhoo Island is proposed. (Refer to Figure 5.7.10)

**1)** Legislation

- As it is more than 500m offshore from the reef edge, it is not included in the dredging prohibition area described in (2) Related Legislation for Sand Barrow.

**2)** Sand Quantity

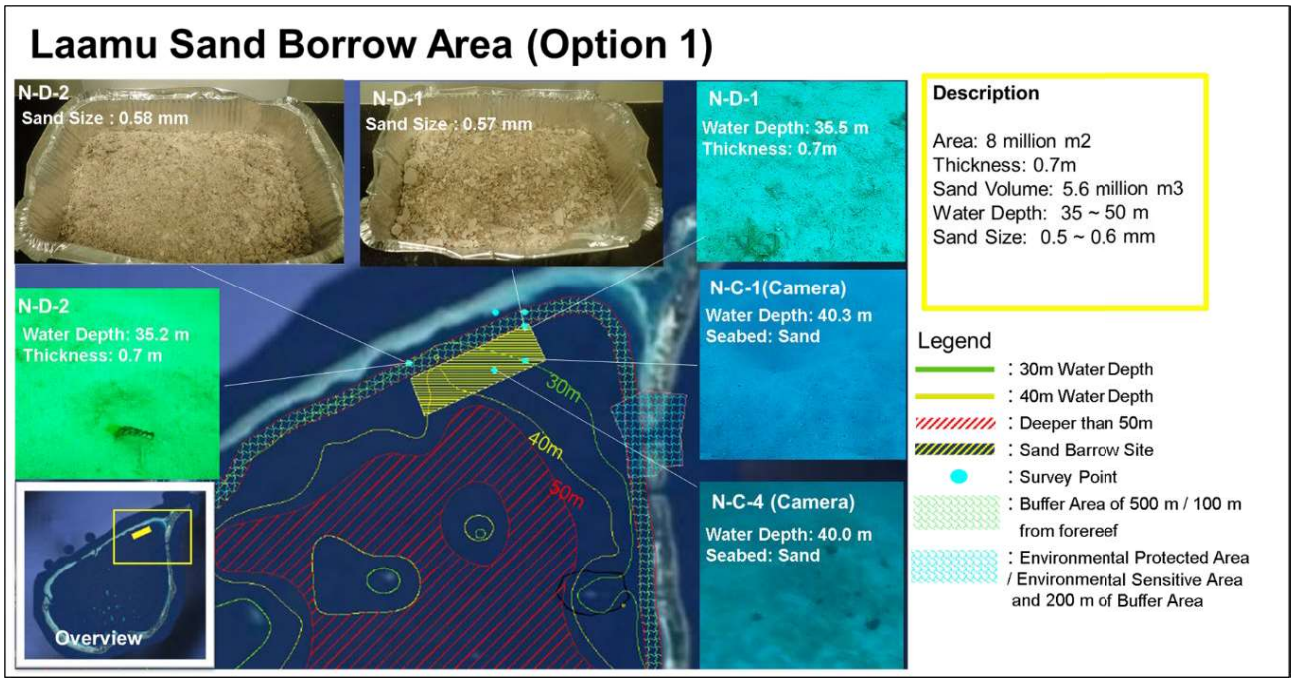
- Area of 35 m - 50 m depth is widespread (8.0 million $m^2$).

- Sand layer thickness surveys indicate a layer thickness of more than 0.7m, therefore the expected sand volume is 5.6 million $m^3$.

- Remote underwater camera survey results show similar sand over an extensive area.

**3)** Sand Quality

- Good quality sand with a relatively coarse grain size can be obtained.




Source: JICA Expert Team

**Figure 5.7.10 Sand Barrow Area Option 1 (Laamu Atoll)**

### (4) Laamu Atoll Option 2

For Option 2, the west of Maavah Island is proposed. (Refer to Figure 5.7.11)

**1)** Legislation

- As it is more than 500m offshore from the reef edge, it is not included in the dredging prohibition area described in (2) Related Legislation for Sand Barrow.

**2)** Sand Quantity

- Area of 40 m - 50 m depth is widespread (2.0 million $m^2$).

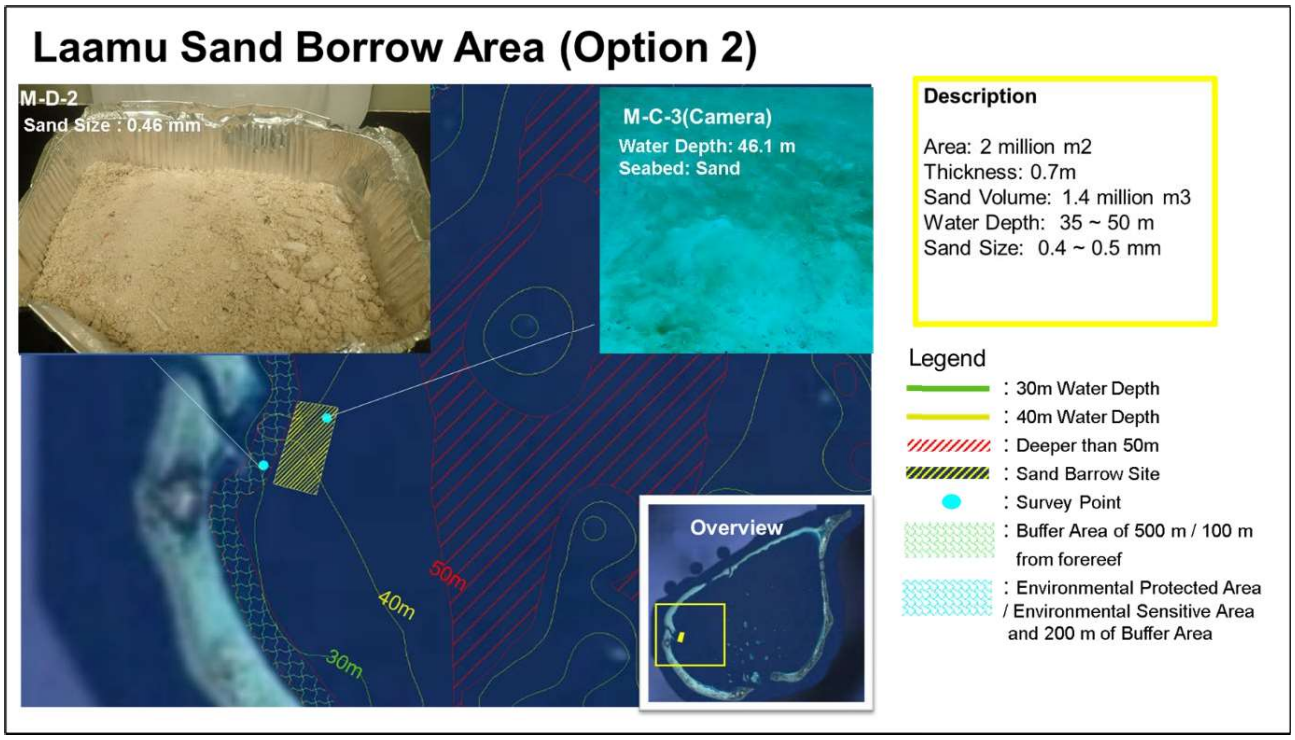
- Sand layer thickness surveys indicate a layer thickness of more than 0.7m, therefore the expected sand volume is 1.4 million $m^3$.

**3)** Sand Quality

- Sand grain is finer than Laamu atoll Option 1, but sufficient good quality sand can be obtained.

**4)** Others

- From the perspective of environment, the ocean side of Maavah Island is a dolphin dive spot and there is concern about the impact of turbidity from dredging in the lagoon. In the detail study phase, it is recommended that the site needs to be selected after a thorough study of the environmental impact of turbidity.




Source: JICA Expert Team

**Figure 5.7.11 Sand Barrow Area Option 2 (Laamu Atoll)**

## 5.8 Consideration of construction plan and cost estimation

### 5.8.1 Consideration of construction plan

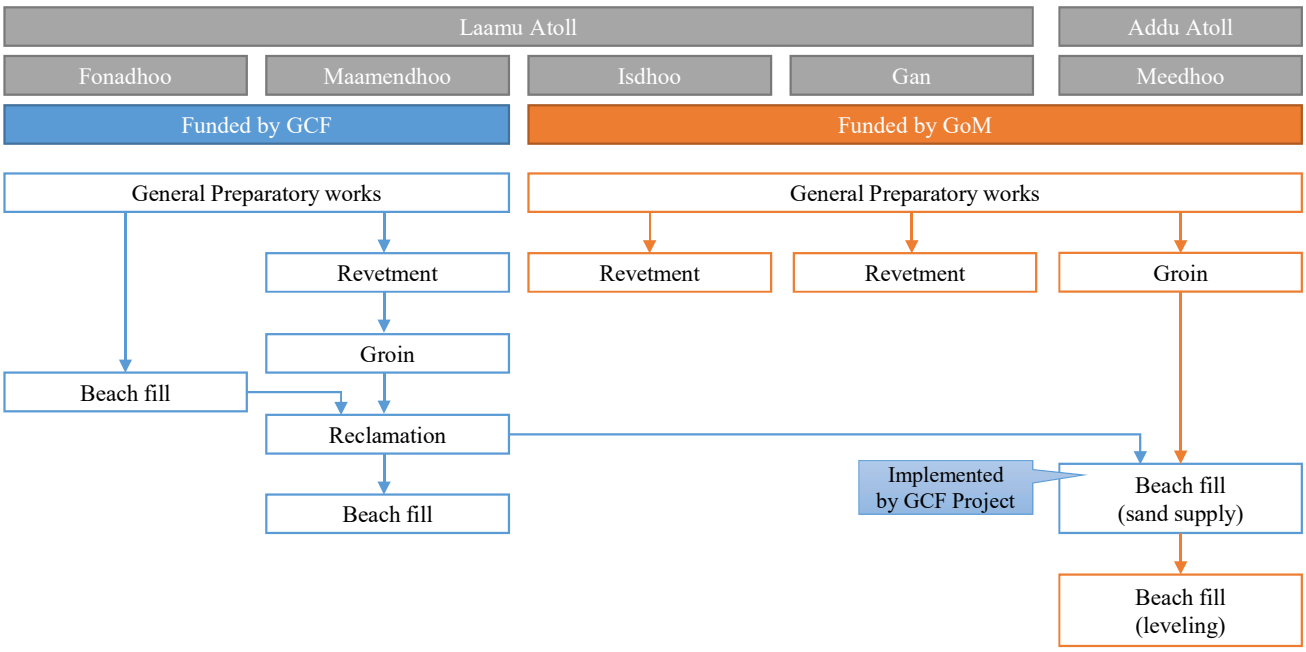
(1) Construction flow

1) Overall construction flow

The following figure shows the construction flowchart of Maamendhoo Island, Fonadhoo Island, Gan Island, Isdhoo Island and Meedhoo Island, which are the targets of the project.

As for the order of construction, revetment works and groin works using rock will be carried out in advance, and beach fill works and reclamation works using sand are planned to be carried out after the rock installation is completed.

It should be noted that the mobilization and demobilization cost of trailing suction hopper dredgers (TSHD) is expensive, and twice as much cost is required when divided by GCF project and the Maldives government co-finance project. For this reason, it was decided that the beach fill work on Meedhoo Island would be carried out with the budget of the GCF project, and after the Laamu Atoll construction, a dredger would be brought to Addu Atoll to carry out the beach fill work on Meedhoo. (It is also calculated in the same way in the Proposal Funding)




Source: JICA Expert Team

**Figure 5.8.1 Construction Flow of the Overall Project**

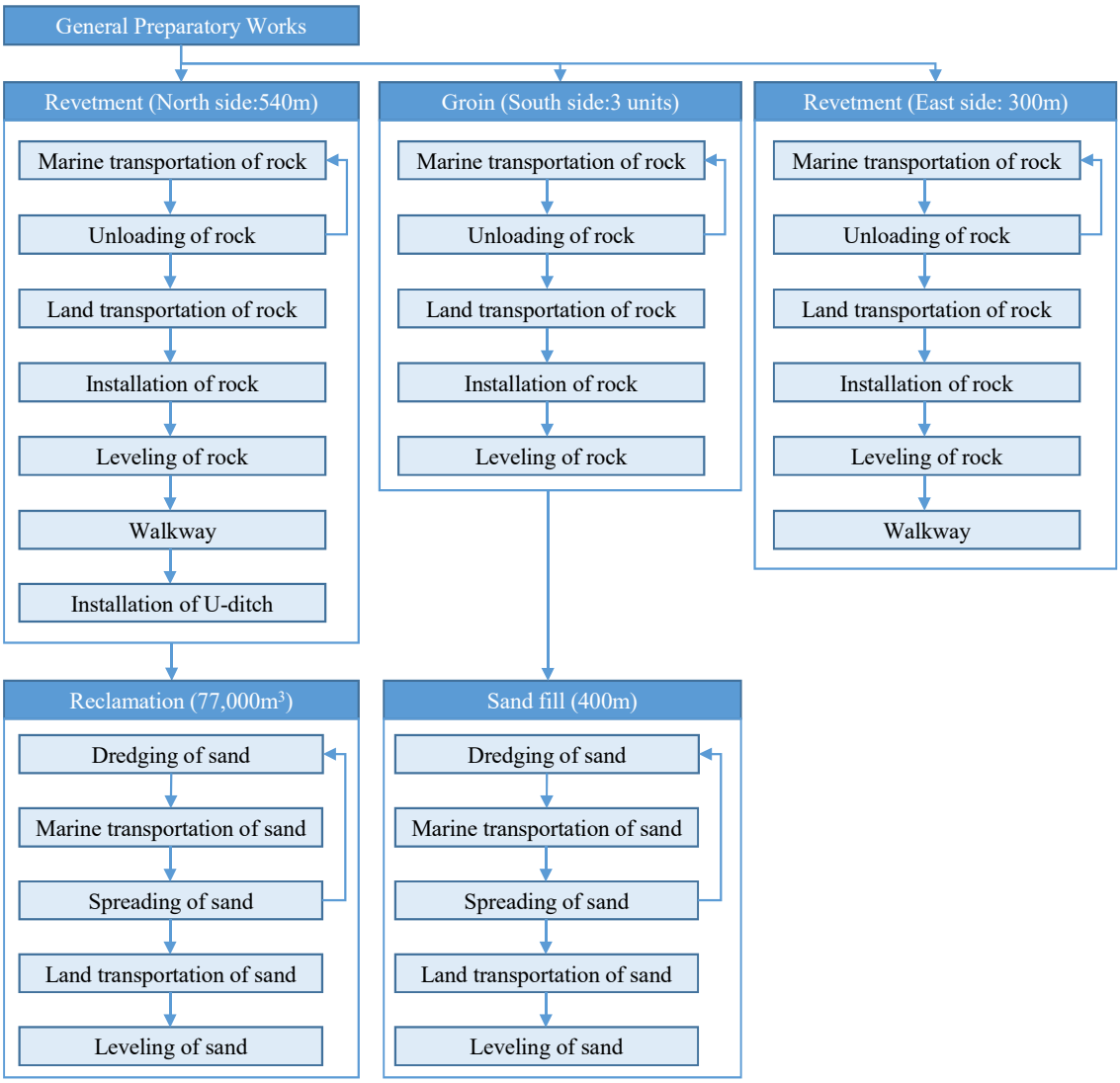
2) Construction flow by target island

a) Construction procedure on Maamendhoo Island

As for the construction procedure on Maamendhoo Island, revetment work and groin work will be carried out first, and then sand using works such as reclamation work and beach fill work will be carried out after rock installation.

The rock used for revetments and groin is imported from India, transported by sea, unloaded, and transported to the installation location by dump truck. After that, the rock is thrown into the installation site, and the rock is leveled to complete the process.

The sand used for reclamation and beach nourishment is procured by dredging from the seabed. The sand dredged by the TSHD is transported by sea to the reef edge near the target site and discharged to the target site by the dredger's pump. The discharged sand is completed by laying it evenly over the landfill site or beach nourishment site.



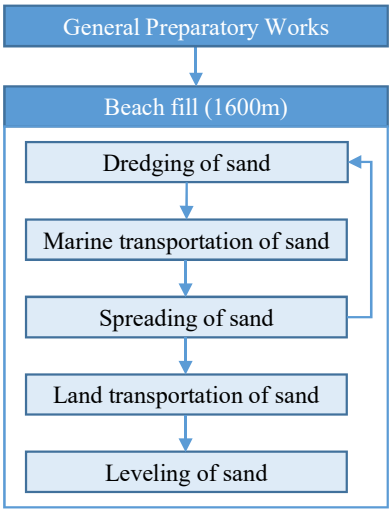

Source: JICA Expert Team

**Figure 5.8.2 Construction Flowchart of Maamendhoo Island**

b) Construction procedure on Fonadhoo Island

The only type of construction on Fonadhoo Island is a beach nourishment.

The sand used for beach nourishment is procured by dredging from the seabed. The sand dredged by the TSHD is transported by sea to the reef edge near the target site and discharged to the target site by the dredger's pump. The discharged sand is laid evenly on the beach nourishment site to complete the work.



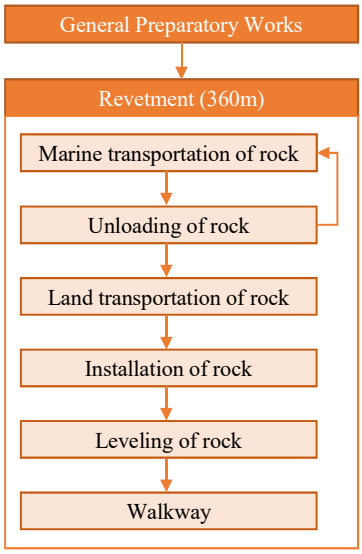

Source: JICA Expert Team

**Figure 5.8.3 Construction Flowchart of Fonadhoo Island**

c) Construction procedure on Isdhoo Island

The only type of construction on Isdhoo Island is revetment work.

The rock to be used for the revetment will be imported from India, transported by sea, unloaded, and transported to the installation location by dump truck. After that, the rock is thrown into the installation site, and the rock is leveled to complete the process.



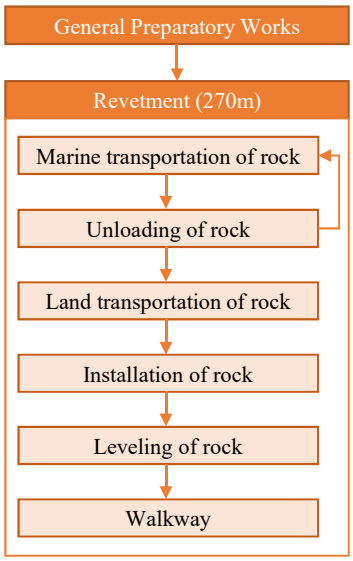

Source: JICA Expert Team

**Figure 5.8.4 Construction Flowchart of Isdhoo Island**

d) Construction procedure on Gan Island

The only type of construction on Gan Island is revetment work.

The rock to be used for revetment will be imported from India, transported by sea, unloaded, and transported to the installation location by dump truck. After that, the rock is thrown into the installation site, and the rock is leveled to complete the process.




Source: JICA Expert Team

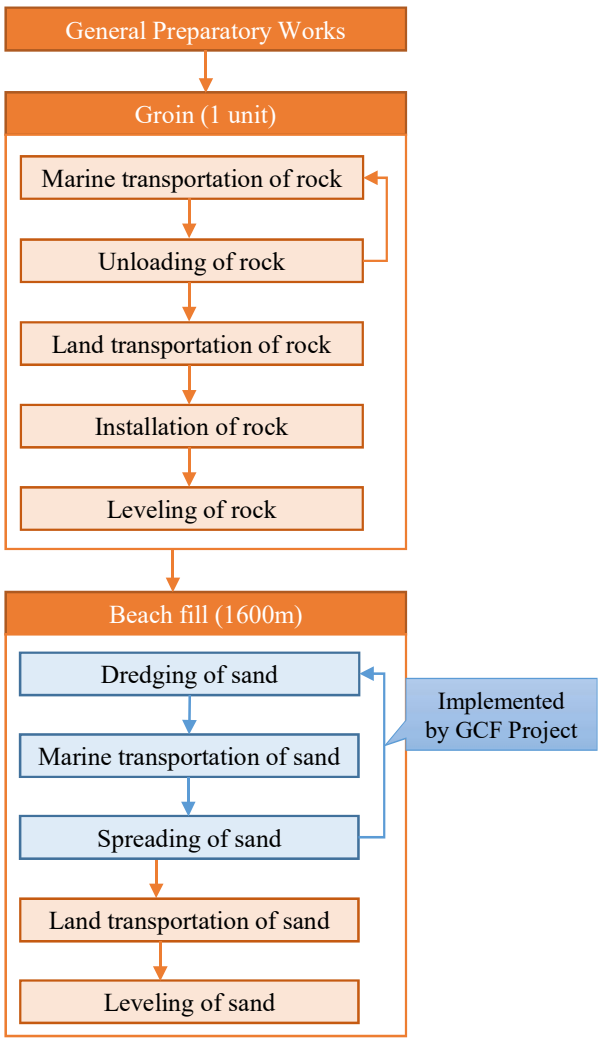
**Figure 5.8.5 Construction Flowchart of Gan Island**

e) Construction procedure on Meedhoo Island

On Meedhoo Island, groin and beach nourishment measures will be implemented.

The rock used for the groin is imported from India, transported by sea, unloaded, and transported to the installation location by dump truck. After that, the rock is thrown into the installation site, and the rock is leveled to complete the process.

The sand used for beach nourishment is procured by dredging from the seabed. The sand dredged by the TSHD is transported by sea to the reef edge near the target site and discharged to the target site by the dredger's pump. The discharged sand is laid evenly on the beach nourishment site to complete the work.




Source: JICA Expert Team

**Figure 5.8.6 Construction Flowchart of Meedhoo Island**

(2) Construction method by construction items

1) Beach fill work and reclamation work

a) Procurement method of beach fill and reclamation sand

There are sedimented sands on the seabed within the lagoon. The sand used for beach nourishment and reclamation will be secured by dredging sand deposited on the seabed with a dredger.

Source: JICA Expert Team

**Figure 5.8.7 Sand Sedimented on the Seabed (Laamu Atoll)**

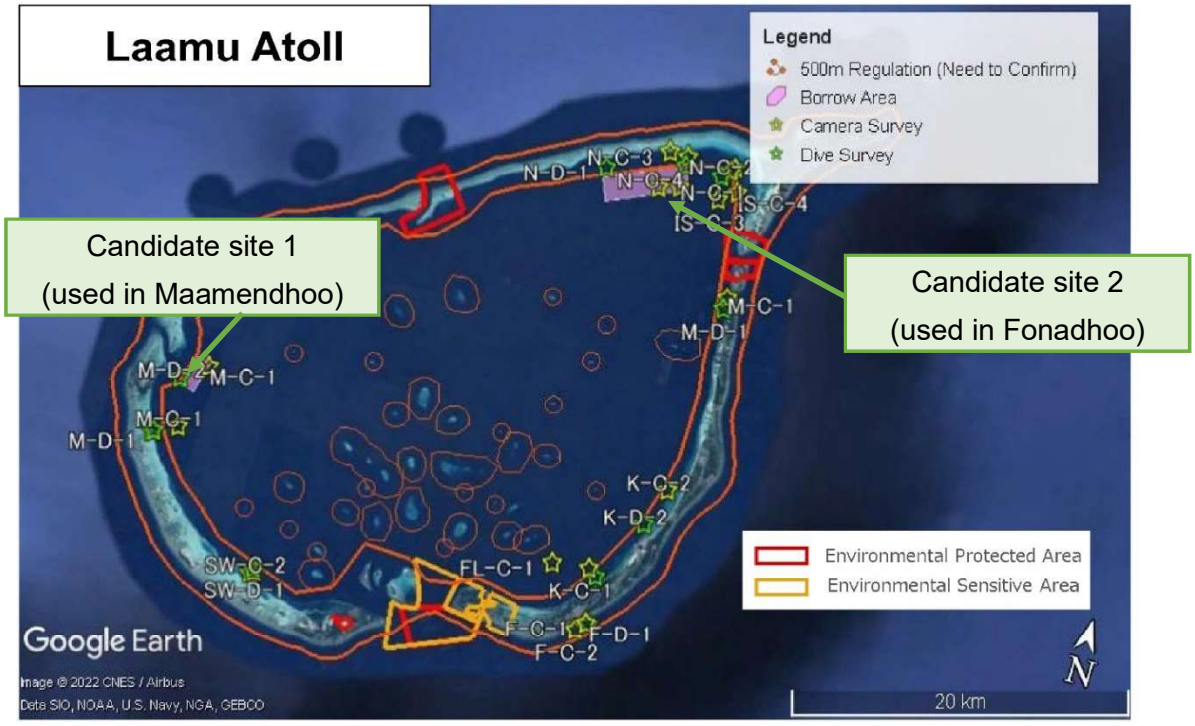
At the time of maintenance, sand dredged for maintenance and management in this project and sand generated periodically during the maintenance dredging of the channel will be used. (Maintenance dredging is performed every 6 to 10 years according to the data from MNPHI.)

Source: JICA Expert Team

**Figure 5.8.8 Statud of Sand Stock (Left: Feydhoo Island, Right: Hulhu-male Island phase 2)**

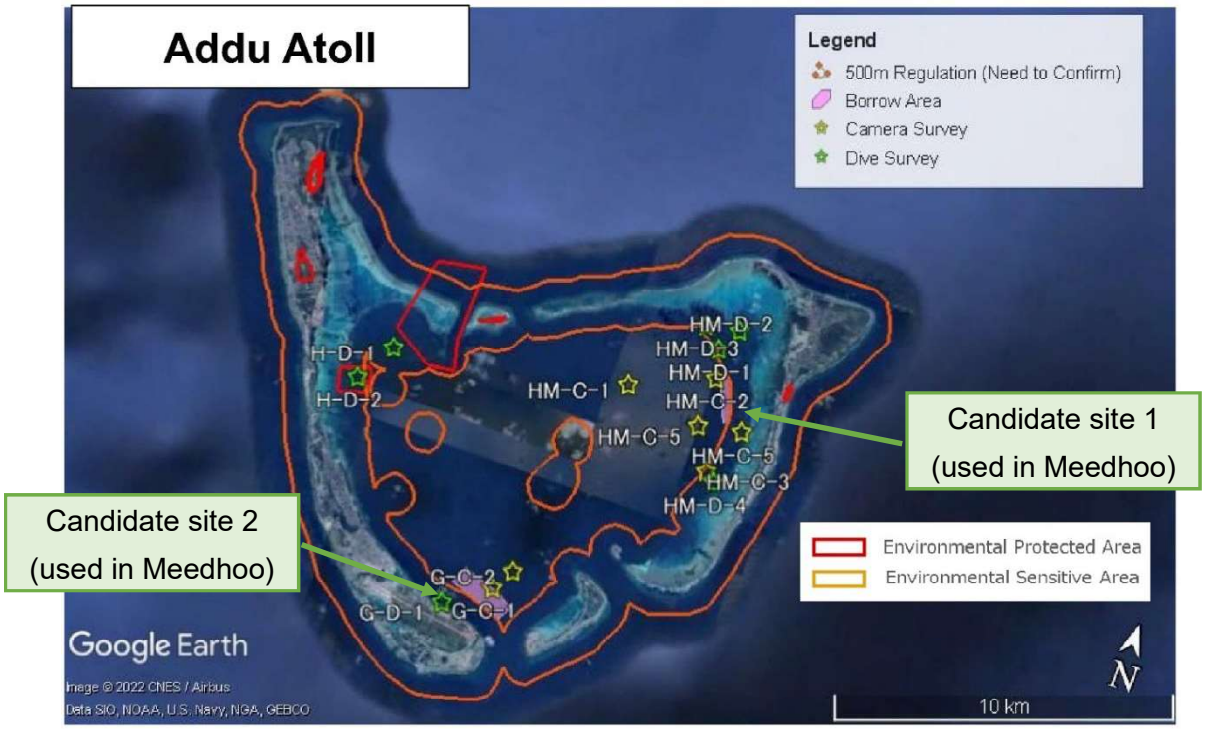
b) Candidate sites for sand borrow

At the basic design stage, candidate sand borrow area shown in the figure below were selected from the perspectives of sand grain size, environmental impact, dredging water depth, and sea transport distance. However, it is necessary to confirm the sand potential in the detailed design.




Source: JICA Expert Team

**Figure 5.8.9 Sand Extraction Candidate Sites of Laamu Atoll**




Source: JICA Expert Team

**Figure 5.8.10 Sand Extraction Candidate Sites of Addu Atoll**

c) Dredging method for beach nourishment and reclamation sand

As for the dredging methods, "trailing suction", "cutter suction", and "excavation dredge" are the mainstream in the construction works in Maldives. There is also a "sand pump", but it is applied only for small-scale beach nourishment such as resort maintenance.

In this project, trailing suction dredging will be adopted as the dredging depth is about - 40m.

[Trailing suction]

Trailign suction is a dredging method that sucks up seabed sediment and sea water while towing a drag head attached to the tip. It can be transported by sea with sand inside the ship and spread to the stop yard.


Source: Van Oord

**Figure 5.8.11 Example of a Trailing Suction Dredger**

[Cutter suction]

Cutter suction is a dredging method that sucks up seawater with a pump while excavating the seabed with a cutter attached to the tip. Since there is no function to hold the sand inside the ship, it is necessary to discharge it directly into the stockpile or use it together with a ship that has a transport function such as a barge. In the Maldives, actual discharge to barges was not confirmed.


Source:Van Oord

**Figure 5.8.12 Example of a Cutter Suction Dredger**

[Excavation dredge]

Excavation dredging is a method of excavating the seabed with a excavator bucket using a dredger in which a excavator is mounted on a barge with a sputter. It is necessary to use it in conjunction with vessels with a hauling function such as a barge.

Source: Mikuniya Construction Company

**Figure 5.8.13 Example of an Excavation Dredger**

**Table 5.8.1 Comparison of Dredging Methods**

| Evaluation items | Trailing suction dredging | Cutter suction dredging | Excavation dredging |
|---|---|---|---|
| Available water depth | Depending on the size of the dredger, can handle up to around -70m. | Depending on the size of the dredger, can handle up to around -18m. | Less than -5m |
| Subject soil | Sandy soil | Sandy soil, rock | Sandy soil, rock* breaker required |
| Workability | ・The dredging capacity depends on the capacity of the dredger used, but even a small dredger has a capacity of about 6000 $m^3$/day at 3000 $m^3$ × 2 times/day.<br>・One ship has functions of dredging, transport, and discharge, enabling flexible response in stormy weather. | ・The dredging capacity is typically 1000 $m^3$ to 2000 $m^3$/day, depending on the capacity of the dredger used.<br>・When the dredging area and the discharge area are far apart, a platform for transportation and a backhoe for landing, etc. are required. | ・The dredging capacity is about 300 to 500 $m^3$ per day.<br>・Combined use with a barge is mandatory for transport. In addition, it is necessary to take measures such as surrounding the edge of the barge to drain the dredged sediment.<br>・For unloading sand, it is necessary to separately use a backhoe, etc.. |
| Economic efficiency | ・Mobilization and demobilization cost and rental fee of the dredger is the most expensive.<br>・Since the construction speed is the fastest and all functions can be covered by a single vessel, it will be cheaper depending on the construction conditions. | ・It is inexpensive compared with the Mobilization and demobilization cost and rental fee of the trailing suction dredger. | ・It is cheap compared to the rental fee of other dredgers.<br>・Since the construction speed is slowest and requires many ships and heavy machinery, it becomes expensive depending on the construction conditions. |
| Environmental impact | ・The environmental impact is small because it can collect from deep locations. | ・Since it is necessary to collect from shallow fields, the environmental impact is large. | ・Since it is necessary to collect from shallow fields, the environmental impact is large. |
| Companies own dredgers | MTCC, Golf Cobla, Boskalis, Van Oord | MTCC, Golf Cobla, Boskalis, Van Oord | SASe, Heavy Force, Boskalis |

e) Dredger standards

The trailing suction dredger to be used cannot be selected at this time, as it depends on the usage situation of the contractor's dredger. However, a relatively small dredger is suitable, considering that the use of sand in this project is less than that of a large-scale landfill project and that the dredged water depth is only -40m.

For this reason, it is assumed that a dredger with a capacity of 10,000m$^3$, which can be used even at a water depth of -40m and is a representative ship type of relatively small dredger will be used. The following table shows the calculation results of the required time per cycle which supposed distance of sand borrow area and stockpile is 20km in oneway.

**Table 5.8.2 Setting of the Dredger Cycle Time**

| 1.Caliculation of dredging time | Unit | Value | Remarks |
|---|---|---|---|
| ①Pump power | kW | 3,400 | Catalog value |
| ②coefficient of pump power | | 6 | Interview to contractor |
| ③pumping capacity | m3/h | 20,400 | ①x② |
| ④soil contain rate | % | 10 | Interview to contractor |
| ⑤Dredging capacity | m3/h | 2,040 | ③x④ |
| ⑥Hopper capacity | m3 | 11,300 | Catalog value |
| ⑦Loading rate | % | 80 | Interview to contractor |
| ⑧Loading valume | m3 | 9,040 | ⑥x⑦ |
| ⑨Dredging time | h | 4.4 | ⑧/⑤ |

| 2.Caliculation of discharging time | Unit | Value | Remarks |
|---|---|---|---|
| ①Pump power | kW | 7,500 | Catalog value |
| ②coefficient of pump power | | 6 | Interview to contractor |
| ③pumping capacity | m3/h | 45,000 | ①x② |
| ④soil contain rate | % | 10 | Interview to contractor |
| ⑤Discharging capacity | m3/h | 4,500 | ③x④ |
| ⑥Hopper capacity | m3 | 11,300 | Catalog value |
| ⑦Loading rate | % | 80 | Interview to contractor |
| ⑧Loading valume | m3 | 9,040 | ⑥x⑦ |
| ⑨Discharging time | h | 2.0 | ⑧/⑤ |

| 3.Caliculation of transportation time | Unit | Value | Remarks |
|---|---|---|---|
| ①Transportation distance | km | 40 | measured value(round trip) |
| ②Sailing speed | knot | 9.18 | 60% of Catalog value |
| ③Transportation time | h | 2.4 | ①x② |

| 4.Caliculation of cycle time | Unit | Value | Remarks |
|---|---|---|---|
| 1.Dredging time | h | 4.4 | 1.① |
| 2.Discharging time | h | 2.0 | 2.① |
| 3.Transportation time | h | 2.4 | 3.① |
| 4.Cycle time | h | 8.8 | 1+2+3 |

Source: JICA Expert Team

f) Stockyard of beach nourishment sand for maintenance

The candidate sites for beach nourishment stockyards are required to meet the requirements shown in the table below from the viewpoint of land use, construction efficiency, and environmental impact. The amount of beach nourishment sand for maintenance is assumed to be about 30,000 $m^3$ on each target island, and assuming that it will be piled up to a height of about 2 m, an area of about 15,000 $m^2$ will be required.

**Table 5.8.3 Stockyard Requirements**

| Category | Requirements |
|---|---|
| Land use | Area under the management of the island, that do not have clear purposes such as residential areas, private property, and public facilities [mandatory] |
| Construction efficiency | Area where the distance from the reef edge to the stockyard is short (approx. max. 3.0km)<br>Area facing the coastline or easy to land from the target area of the beach |
| Environmental impact | Area not designated as the Environment Protection Area [mandatory]<br>Area with few trees to be cut (check aerial photographs and on-site) |

Source: JICA Expert Team

[Candidate sites on Maamendhoo Island]

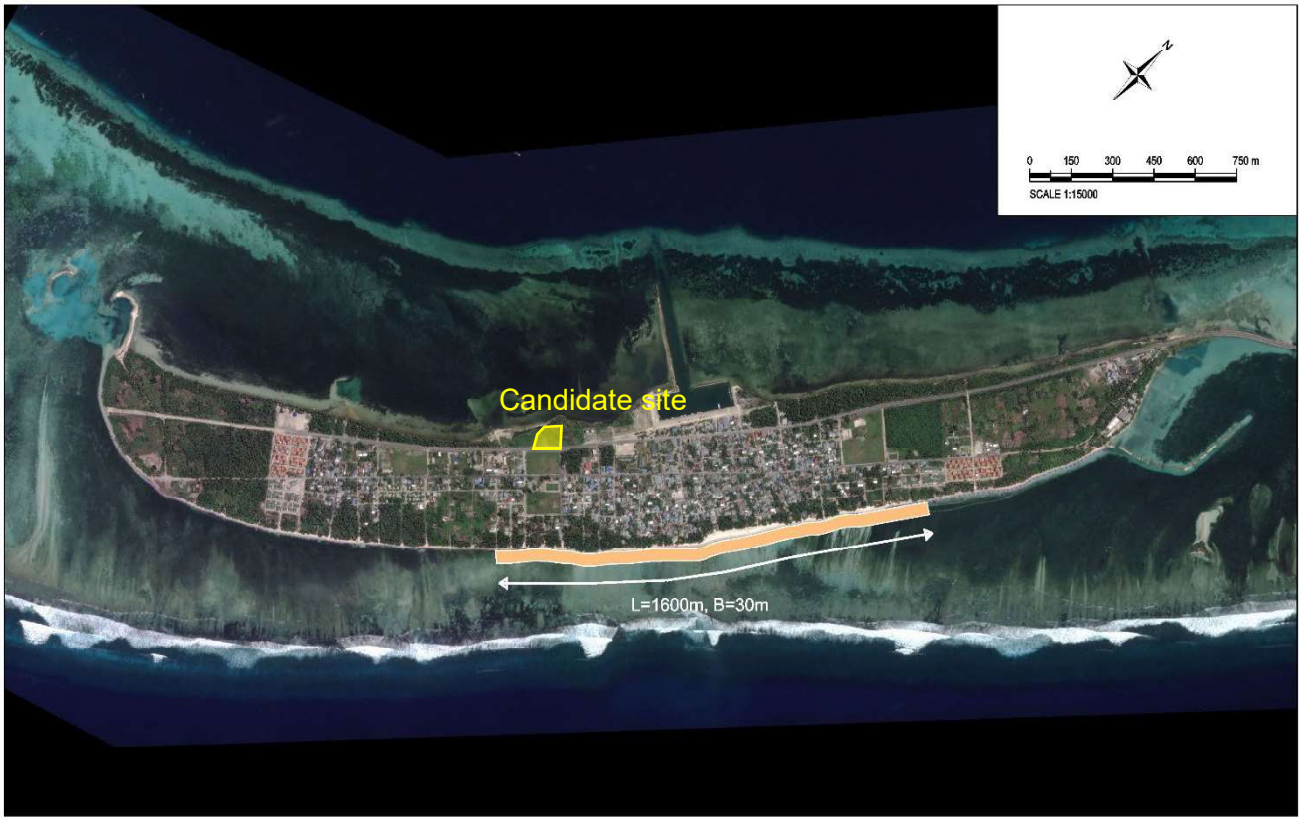
The area of the whole island is very small in Maamendhoo Island, and there is no land to secure the stockyard for beach nourishment for maintenance. For this reason, it is planned to make effective use of the reclaimed land that is used as an evacuation area and also to use it as a stockyard for maintanace sand.


Source: JICA Expert Team

**Figure 5.8.14 Stockyard Candidates Sites on Maamendhoo Island**

[Candidate sites on Fonadhoo Islands]

In Fonadhoo Island, there is an unused area under the control of the island along the coastline, and it has been informed by the Fonadhoo Council that there is no clear future land use plan for that area. For this reason, the site concerned was selected as a stockyard candidate site on Fonadhoo Island.



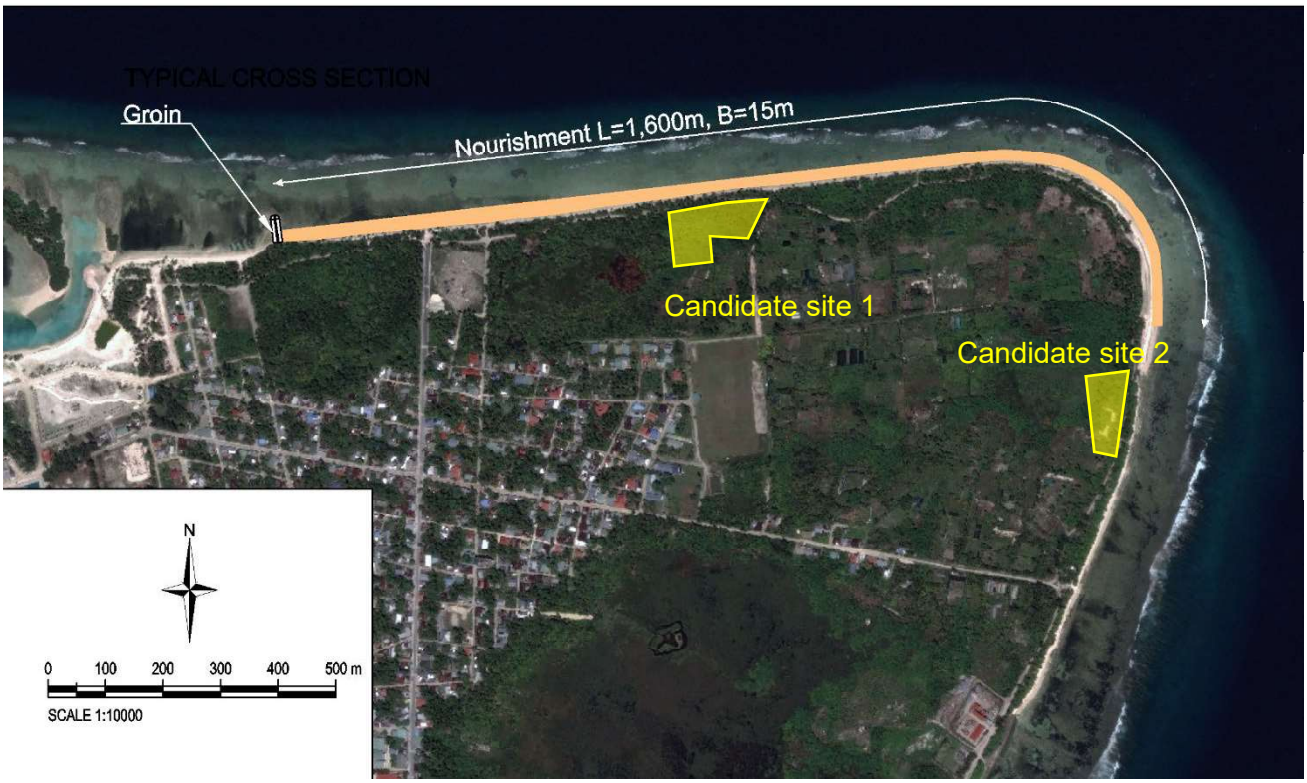

Source: JICA Expert Team

**Figure 5.8.15 Stockyard Candidate Site 1 on Fonadhoo Island**


**Figure 5.8.16 Stockyard Candidate Site 2 on Fonadhoo Island**

[Candidate sites on Meedhoo Islands]

In Meedhoo Island, stockyards cannot be secured on the land along the coastline because the coastline area is surrounded by an Environment Protection Area. For this reason, unused Green Buffer Areas were selected as candidate sites to provide stockyards on the areas approaching the coast.




Source: JICA Expert Team

**Figure 5.8.17 Stockyard Candidate Site 1 on Meedhoo Island**

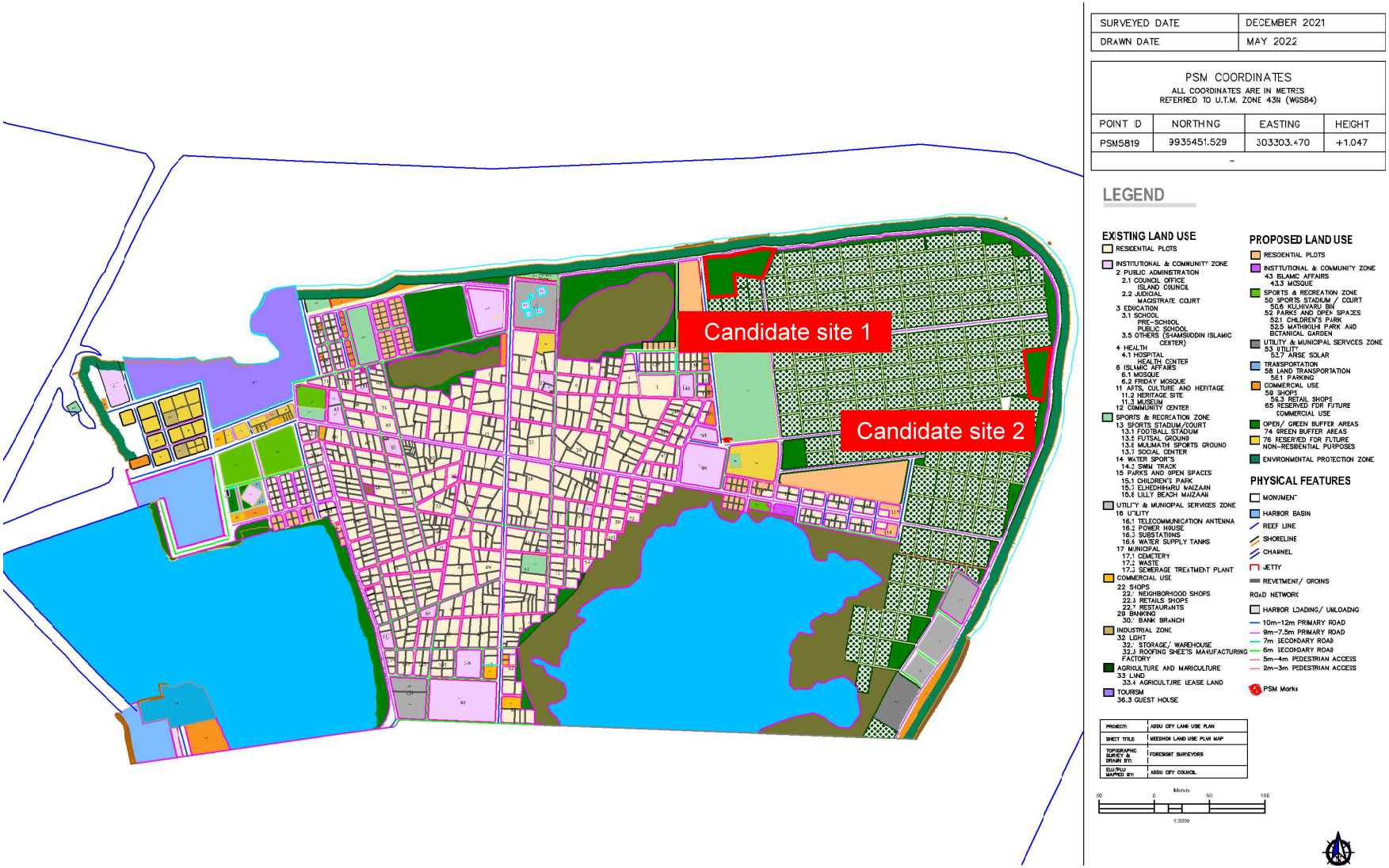



**Figure 5.8.18 Stockyard Candidate Site 2 on Meedhoo Island**

g) Sand discharge location

[Discharge location on Meedhoo island]

On Maamendhoo Island, a TSHD is berthed offshore around the reef edge offshore of the target area, and sand is discharged to the area through a pipeline. Since it takes time to relocate the offshore berthed position, it is necessary to reduce the number of relocations. Therefore, if the length of the pipeline is less than 1 km, it is necessary to reduce the number of relocations by extending the pipeline on the land side.

In Maamendhoo Island, since the length of the pipeline from the dredger to the discharge point is within 1km on one side, pipeline should be extended without relocating the offshore berthed position.


Source: JICA Expert Team

**Figure 5.8.19 Sand Discharge Location on Maamendhoo island**

[Discharge location on Fonadhoo island]

On Fonadhoo Island, a TSHD is berthed offshore around the reef edge offshore of the target area, and sand is discharged to the area through a pipeline.

Beach nourishment area and stockpile are in Fonadhoo Island, since both pipelines can be corresponded with a pipeline length of about 1.0km, pipeline should be extended without relocating the offshore berthed position.

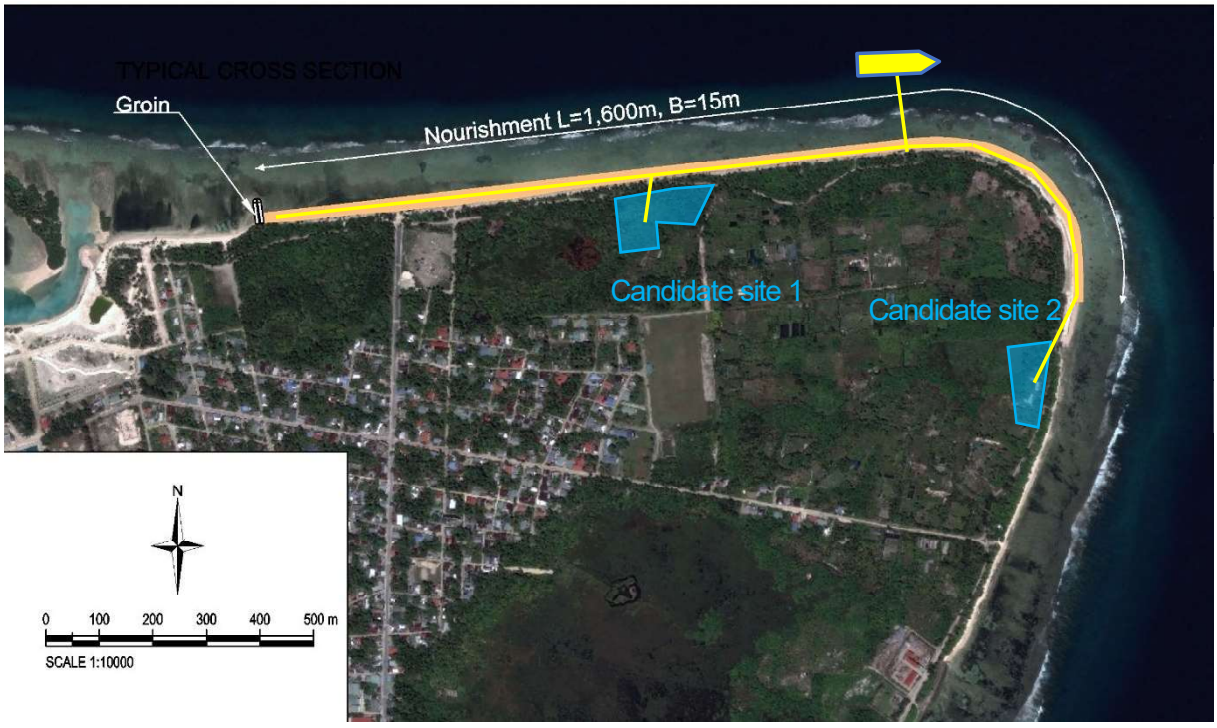

Source: JICA Expert Team

**Figure 5.8.20 Sand Discharge Location on Fonadhoo island**

[Sand discharge location on Meedhoo island]

On Meedhoo Island, a trailing suction dredger is berthed offshore around the reef edge offshore of the target area, and sand is exhaled to the area through a pipeline.

In Meedhoo Island, since pipelines can be corresponded with a pipeline length of about 1.0km, pipeline should be extended without relocating the offshore berthed position.



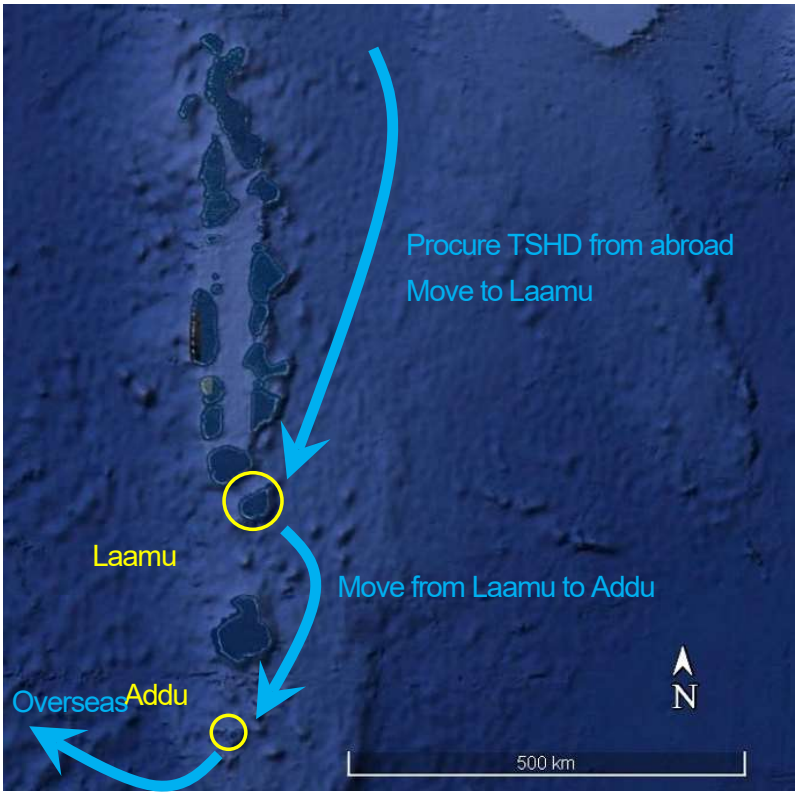

Source: JICA Expert Team

**Figure 5.8.21 Sand Discharge Location on Meedhoo Island**

h) Navigation route of the dredger

[The navigation route of TSHD for the entire project]

TSHD needs to be procured from outside the Maldives, because there is only one 3000m$^3$ class small dredger in the Maldives. TSHD procured from foreign countries will carry out the work in Maamendhoo island and Fonadhoo island of Laamu Atoll, and then work in Meedhoo island of Addu Atoll.




Source: JICA Expert Team

**Figure 5.8.22 Trailing Suction Dredger Navigation Route for the Entire Project**

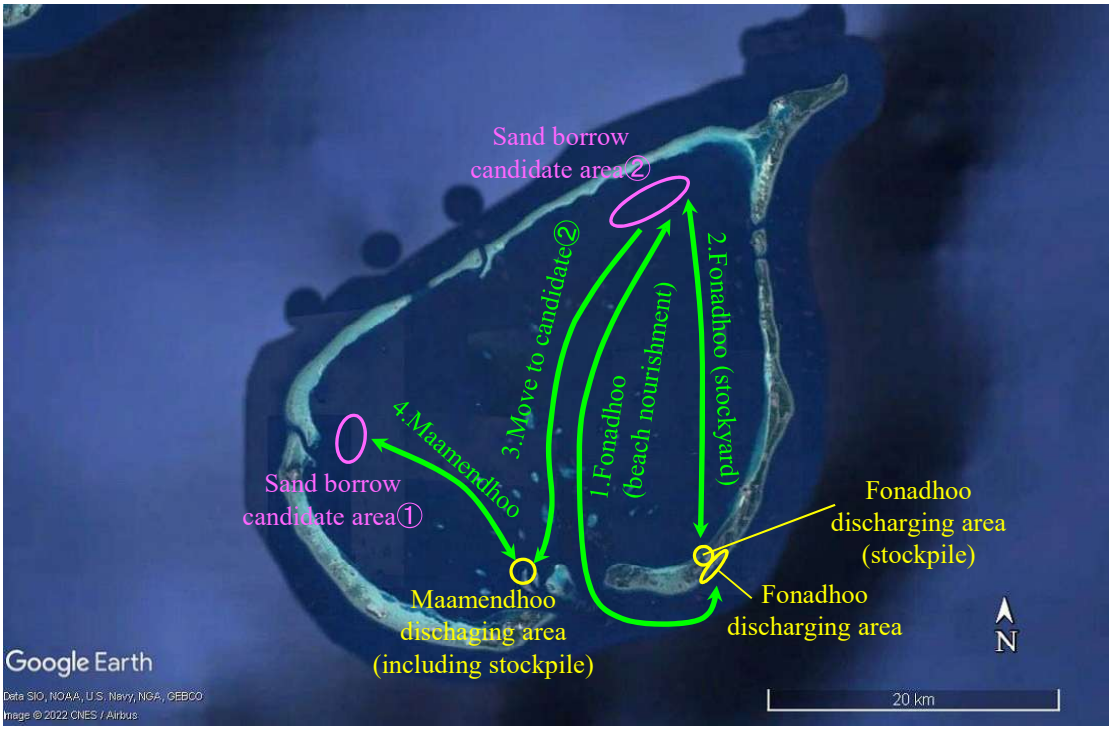
[The navigation route of TSHD in Laamu Atoll]

At Laamu Atoll, it is assumed that sand will be collected from a candidate site within the atoll, and TSHD will travel back and forth from the collection site to the discharge point. As for the order of construction, it is assumed that Maamendhoo Island will be constructed first, followed by the beach nourishment area on Fonadhoo Island, and finally the stockyard on Fonadhoo Island.

**Table 5.8.4 Transportation Distances and Volumes by Transportation Route within Laamu Atoll**

| Transportation route | Method of transportation | Transportation distance (oneway) | Sand transport volume |
|---|---|---|---|
| Sand borrow candidate area 1 ⇔Maamendhoo beach nourishment and reclamation area | Marine transport | Approx. 20km | 130,000m$^3$ |
| Sand borrow candidate area 2 ⇔Fonadhoo beach mourishment area | Marine transport | Approx. 40km | 64,000m$^3$ |
| Sand borrow candidate area 2 ⇔ Fonadhoo stockyard | Marine transport | Approx. 30km | 36,000m$^3$ |

Source: JICA Expert Team




Source: JICA Expert Team

**Figure 5.8.23 Travel Route of TSHD in Laamu Atoll**

[The navigation route of TSHD in Addu Atoll]

At Addu Atoll, it is assumed that sand will be collected from a candidate site within the atoll, and the sand will travel back and forth from the collection site to the discharge point. There are two candidate area for sand borrow, it would be decided the priority based on the result of sand potential survey.

**Table 5.8.5 Transportation Distances and Volumes by Transportation Route within Addu Atoll**

| Transportation route | Method of transportation | Transportation distance (Oneway) | Sand transport volume |
|---|---|---|---|
| Sand extraction candidate site 1 ⇔Meedhoo beach nourishment area | Marine transport | Approx. 20km | 116,000m$^3$ |
| Sand extraction candidate site 2 ⇔Meedhoo beach nourishment area | Marine transport | Approx. 20km | |


Source: JICA Expert Team

**Figure 5.8.24 Travel Route of TSHD in Addu Atoll**

i) Setting of sand leveling

The beach nourishment sand unloaded from the dump truck is leveled with a wheel loader (1.5m$^3$ class).


Source: JICA Expert Team

**Figure 5.8.25 Wheel Loaders Used in the Maldives**

2) Revetment work and groin work

a) Methods of procurement of rock materials

In Maldives, rock materials (granite) imported from India are commonly used, and they are used in seawalls for landfill projects, breakwaters for port development projects, and breakwaters for coastal projects.

Rock materials used in the Maldives are imported from quarries in Tuticorin in southern India. They are generally imported directly from suppliers. They can also be purchased from trading companies, but there are often delays in the supply of materials.

Source: JICA Expert Team

**Figure 5.8.26 Rock Materials Used in the Maldives (Hulhumale)**

In this project, it is planned to procure rock materials of the following sizes. However, Isdhoo Island suffered damage to breakwaters weighing 400kg～800kg/piece in nearby ports and harbors, so a detailed study is required in the detailed design.

It has been confirmed by local constructors that rock materials of the following sizes can be procured from India.

**Table 5.8.6 List of Rock Size for Each Island**

| Island | Facility | CORE RUBBLE | FILTER STONE | ARMOUR STONE |
|---|---|---|---|---|
| Maamendhoo | Groin 3 units (West) | 1kg～10kg/N | 10kg～20kg/N | 100kg/N |
| | Revetment 540m (North) | 1kg～20kg/N | 20kg～30kg/N | 300kg/N |
| | Revetment 300m (East) | 1kg～20kg/N | - | 100kg/N |
| Isdhoo | Revetment 360m | 1kg～50kg/N | - | 500kg/N |
| Gan | Revetment 270m | 1kg～10kg/N | 10kg～20kg/N | 100kg/N |
| Meedhoo | Groin 1 unit | 1kg～10kg/N | 10kg～20kg/N | 100kg/N |

b) Method of unloading rock

There are three ways to unload rock materials.

1. Unload at a quay (verification of barge size required)

2. A large barge (3,000 to 10,000 tons) should be anchored around the reef edge and unloaded around the reef edge (a temporary access road (jetty) by sand is required).

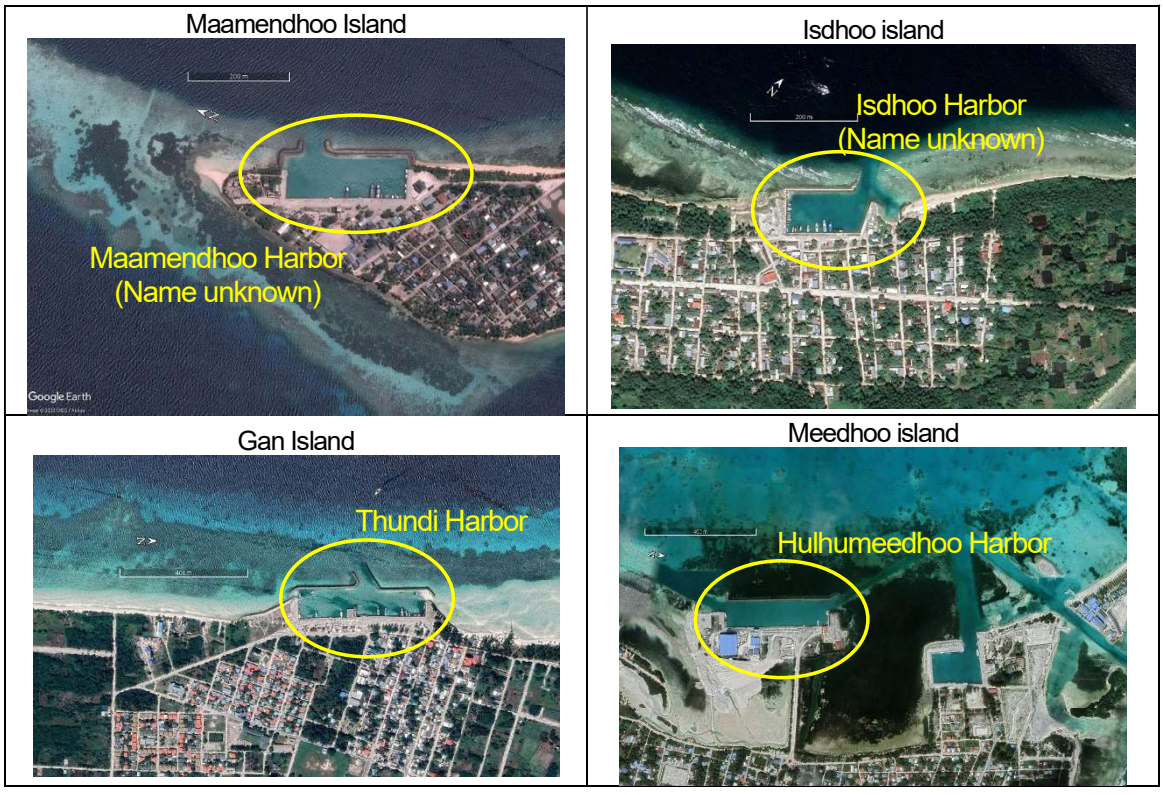
3. Transfer from a large barge (3,000t to 10,000t) to a small ferry barge (less than 1,000t) and unloaded near the installation area at HWL

There are no quays that can moor large barges (3,000t to 10,000t) on the target islands, so that relatively small barges should be selected in case of unloading at quays. Therefore, marine transportation will be inefficient.

In case the method of transfer to small ferry barges, it has issues in terms of construction efficiency and safety. For this reason, a method of anchoring a large barge around the reef edge and carrying out landing around the reef edge is selected.

For the reference, candidates for unloading ports on each target island are shown in the table below.

**Table 5.8.7 Candidates for Rock Unloading Ports on Each Target Islands**




Source: JICA Expert Team

c) Method of land transportation of rock

For reference, the land transportation route for unloading at a port is shown in below.

[Transportation route of rock material in Maamendhoo Island]

A 10-ton class dump truck will be used for land transportation from Maamendhoo Harbor to the area where the revetment and groin are installed. A 10-ton truck, which can turn in a small radius, will be used because it includes narrow roads.

As for the land transportation route for rock materials, existing roads pass through to each target area, so there is no need to develop new access roads.


Source: JICA Expert Team

**Figure 5.8.27 Land Transportation Route for Rock Materials on Maamendhoo Island**

The table below shows the calculation results of the number of days required for land transportation. When five dump trucks are in operation, transportation of rock materials will take a total of 65 days for three locations.

**Table 5.8.8 Calculation of Days Required for Land Transportation of Rock Materials on Maamendhoo Island**

| Items | Unit | Value | | | Remarks |
|---|---|---|---|---|---|
| | | Rote 1 | Rote 2 | Rote 3 | |
| ①Loading time | h/cycle | 1.0 | 1.0 | 1.0 | |
| ②Transportation distance | km | 0.1 | 0.2 | 0.9 | round trip |
| ③Transportation speed | km/h | 10.0 | 10.0 | 10.0 | |
| ④Transportation time | h/cycle | 0.0 | 0.0 | 0.1 | ②/③ |
| ⑤Unoading time | h/cycle | 0.3 | 0.3 | 0.3 | |
| ⑥Cycle time | h/cycle | 1.3 | 1.3 | 1.4 | ①+④+⑤ |
| ⑦Transportation volume | m3 | 12,474 | 4,274 | 2,145 | |
| ⑧Loading capacity | m3/Num | 10 | 10 | 10 | |
| ⑨Necessity round number | cycle | 1,248 | 428 | 215 | ⑦/⑧ |
| ⑩Operation hour | h/d | 8 | 8 | 8 | |
| ⑪Daily round number | cycle/d | 6 | 6 | 6 | ⑩/⑥ |
| ⑫Operation number of truck | Num/d | 5 | 5 | 5 | |
| ⑬Necessity day | d | 42 | 15 | 8 | ⑧/⑪/⑫ |
| Necessity day (total) | d | | | 65 | |

Source: JICA Expert Team

[Transportation route of rock material in Isdhoo Island]

A 10-ton class dump truck will be used for land transportation from Isdhoo Harbor to the revetment installation area. A 10-ton truck, which can turn in a small radius, will be used because it includes narrow roads.

As for the land transport route for rock materials, the existing road runs to the end of the revetment area, so no new access roads need to be constructed.


Source: JICA Expert Team

**Figure 5.8.28 Land Transportation Routes for Rock Materials on Isdhoo Island**

The table below shows the calculation results of the number of days required for land transportation. When five dump trucks are in operation, it will take 37 days to transport rock.

**Table 5.8.9 Calculation of Days Required for Land Transportation of Rock Materials on Isdhoo Island**

| Items | Unit | Value | Remarks |
|---|---|---|---|
| ①Loading time | h/cycle | 1.0 | |
| ②Transportation distance | km | 0.9 | round trip |
| ③Transportation speed | km/h | 10.0 | |
| ④Transportation time | h/cycle | 0.1 | ②/③ |
| ⑤Unoading time | h/cycle | 0.3 | |
| ⑥Cycle time | h/cycle | 1.4 | ①+④+⑤ |
| ⑦Transportation volume | m3 | 11,088 | |
| ⑧Loading capacity | m3/Num | 10 | |
| ⑨Necessity round number | cycle | 1,109 | ⑦/⑧ |
| ⑩Operation hour | h/d | 8 | |
| ⑪Daily round number | cycle/d | 6 | ⑩/⑥ |
| ⑫Operation number of truck | Num/d | 5 | |
| ⑬Necessity day | d | 37 | ⑧/⑪/⑫ |

Source: JICA Expert Team

[Transportation route of rock materials in Gan Island]

A 10-ton class dump truck will be used for land transportation from Thundi Harbor to the revetment installation area. A 10-ton truck, which can turn in a small radius, will be used as there are narrow roads.

As for the land transport route for rock materials, although the existing road runs to the revetment area, there are places where the width is narrow around the revetment area. Therefore, it is necessary to consider whether or not to widen the access road in the detailed design.


Source: JICA Expert Team

**Figure 5.8.29 Land Transportation Routes for Rock Materials on Gan Island**

Source: JICA Expert Team

**Figure 5.8.30 Narrow Area of the Existing Road on Gan Island**

The table below shows the calculation results of the number of days required for land transportation. When five dump trucks are in operation, it will take 15 days to transport the rock.

**Table 5.8.10 Calculation of Days Required for Land Transportation of Rock Materials on Gan Island**

| Items | Unit | Value | Remarks |
|---|---|---|---|
| ①Loading time | h/cycle | 1.0 | |
| ②Transportation distance | km | 5.2 | round trip |
| ③Transportation speed | km/h | 10.0 | |
| ④Transportation time | h/cycle | 0.5 | ②/③ |
| ⑤Unoading time | h/cycle | 0.3 | |
| ⑥Cycle time | h/cycle | 1.8 | ①+④+⑤ |
| ⑦Transportation volume | m3 | 2,835 | |
| ⑧Loading capacity | m3/Num | 10 | |
| ⑨Necessity round number | cycle | 284 | ⑦/⑧ |
| ⑩Operation hour | h/d | 8 | |
| ⑪Daily round number | cycle/d | 4 | ⑩/⑥ |
| ⑫Operation number of truck | Num/d | 5 | |
| ⑬Necessity day | d | 15 | ⑧/⑪/⑫ |

Source: JICA Expert Team

[Transportation route of rock material in Meedhoo Island]

From Hulhumeedhoo Harbor to the groin installation area, a 10-ton class dump truck will be used for overland transportation. A 10-ton truck, which can turn in a small radius, will be used as it includes narrow roads.

As for the land transport route for rock materials, the existing road passes through to the jetty area, so no new access roads need to be constructed.


Source: JICA Expert Team

**Figure 5.8.31 Land Transportation Routes for Rock Materials on Meedhoo Island**

The table below shows the calculation results of the number of days required for land transportation. When five dump trucks are in operation, it will take five days to transport rock.

**Table 5.8.11 Calculation of Days Required for Land Transportation of Rock Materials on Meedhoo Island**

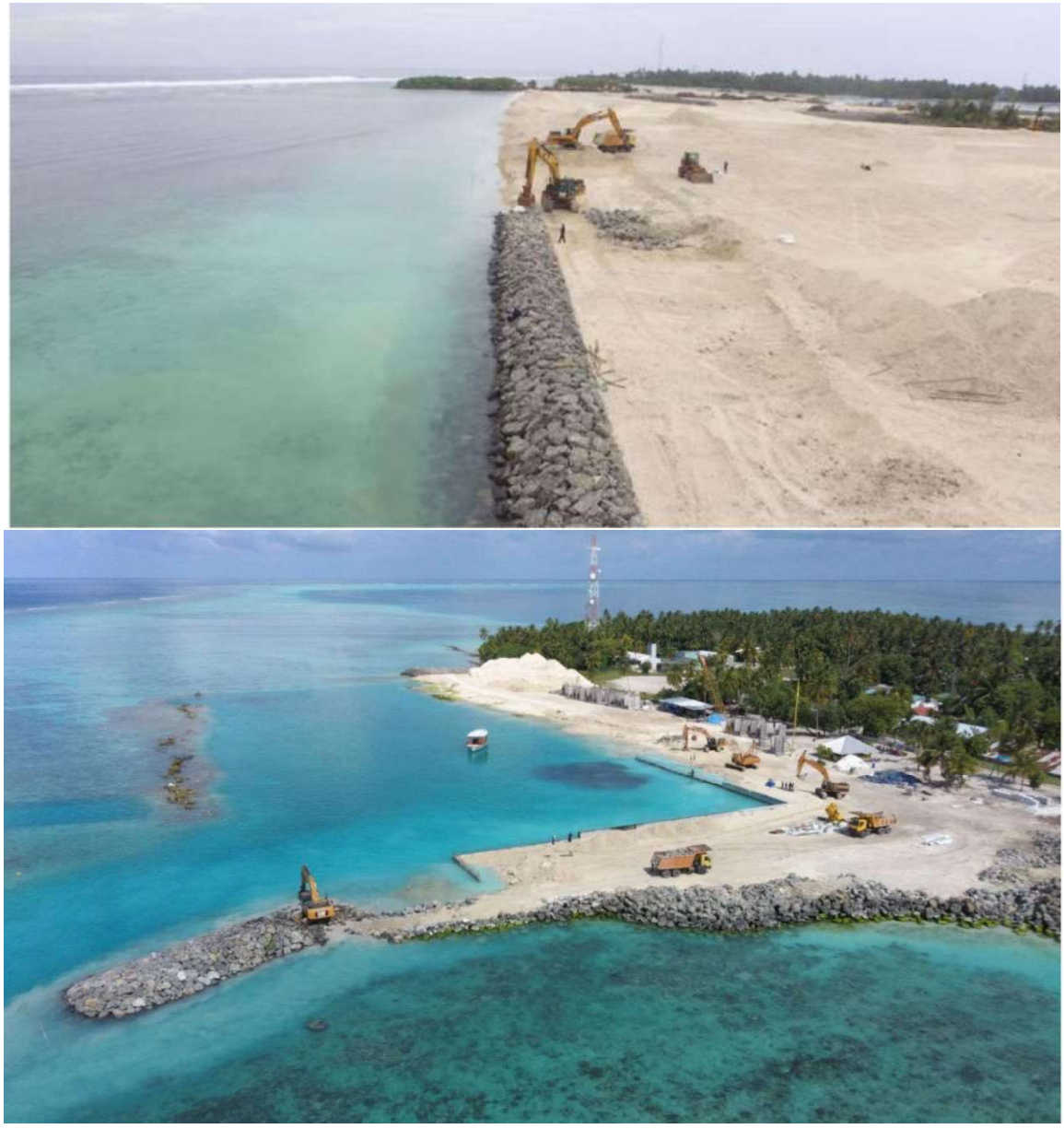
| Items | Unit | Value | Remarks |
|---|---|---|---|
| ①Loading time | h/cycle | 1.0 | |
| ②Transportation distance | km | 1.8 | round trip |
| ③Transportation speed | km/h | 10.0 | |
| ④Transportation time | h/cycle | 0.2 | ②/③ |
| ⑤Unoading time | h/cycle | 0.3 | |
| ⑥Cycle time | h/cycle | 1.5 | ①+④+⑤ |
| ⑦Transportation volume | m3 | 1,042 | |
| ⑧Loading capacity | m3/Num | 10 | |
| ⑨Necessity round number | cycle | 105 | ⑦/⑧ |
| ⑩Operation hour | h/d | 8 | |
| ⑪Daily round number | cycle/d | 5 | ⑩/⑥ |
| ⑫Operation number of truck | Num/d | 5 | |
| ⑬Necessity day | d | 5 | ⑧/⑪/⑫ |

Source: JICA Expert Team

d) Method of throwing and leveling rock materials

The rocks are unloaded from the dump truck near the installation site and thrown in by an excavator. For structures extending offshore like a groin, a temporary access road for dump trucks can be constructed and rock materials can be unloaded from the temporary road, thereby making it possible to load them efficiently.

The rock material that has been put in is completed by leveling the surface with a backhoe while inserting the filling rock.



Source: provided by MTCC

**Figure 5.8.32 Installation of the Jetty and Revetment**

e) Method of removing the existing revetment

[How to remove the existing revetment (cement bag) of Gan Island and Meedhoo Island]

At the revetment installation position on Gan Island and beach fill position on Meedhoo Island , there is an existing revetment constructed by cement bags. Some existing revetments have already collapsed due to waves, so it is necessary to form a new revetment by breaking it down with an excavator.

There is a possibility that the demolished cement bag can be reused as a new CORE BUBBLE (1 kg to 20 kg). It is necessary to examine whether or not it can be reused in the detailed design.

Source: JICA Expert Team

**Figure 5.8.33 Installation Situation of the Cement Bag Revetment (left: Gan Island, right: Meedhoo Island)**

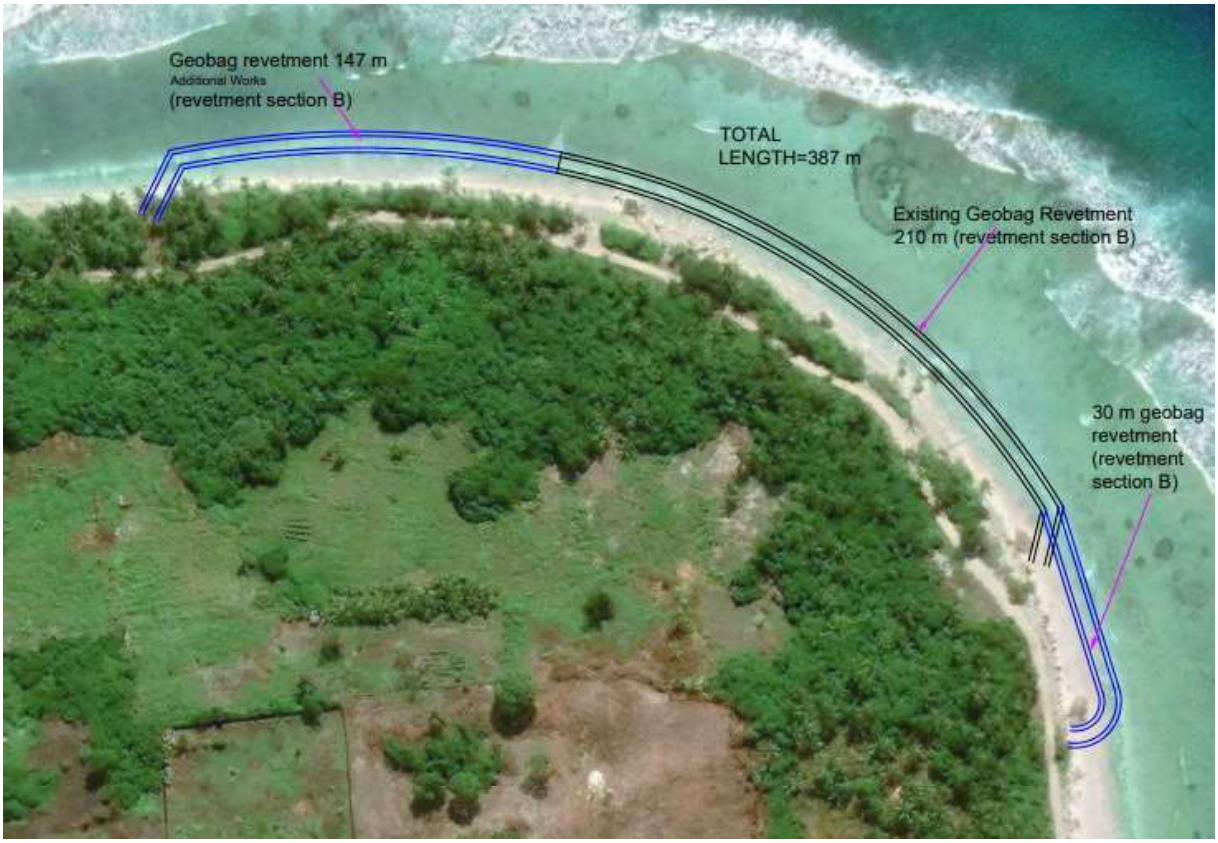
[How to remove the existing revetment (sandbag) of Meedhoo Island]

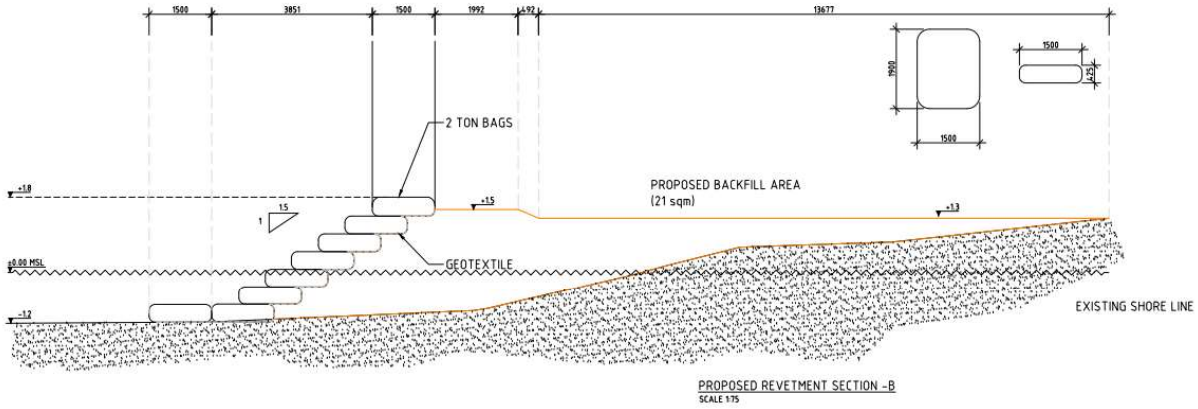
In the beach nourishment area on Meedhoo Island, temporary revetment is planned to be constructed using sandbags as an emergency countermeasure against coastal erosion, and the construction has been completed in some areas. If the temporary revetment is left in place, it may affect the sand supply on the downstream side.

There is a possibility that the sand material for sandbags can be reused as beach nourishment sand. It is necessary to examine whether or not it can be reused in the detailed design.

Source: JICA Expert Team

**Figure 5.8.34 Installation Situation of the Existing Revetment on Gan Island**




Sorce: provided by MNPHI

**Figure 5.8.35 Temporary Revetment Plan on Meedhoo Island**

f) Method of laying the sandproof sheet

A geotexitile as shown in the figure below shall be laid between the site ground and CORE BUBBLE.

Source: provided by MTCC

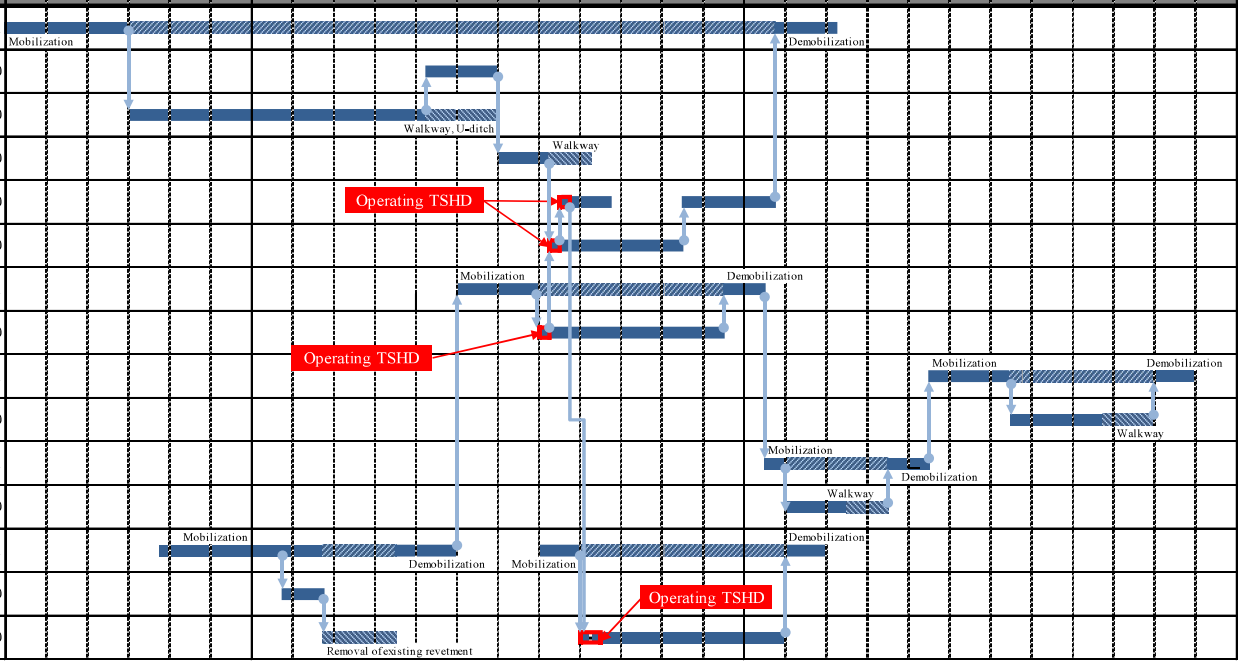
**Figure 5.8.36 Installation Situation of Geotexitile**

(3) Construction schedule

The following pages show the construction schedule for the overall project and for each target island. Construction schedule is considered by 1 package case and 2 packages case. Note that the blue bar indicates GFC projects and the orange bar indicates the Maldives government cofinancing projects.

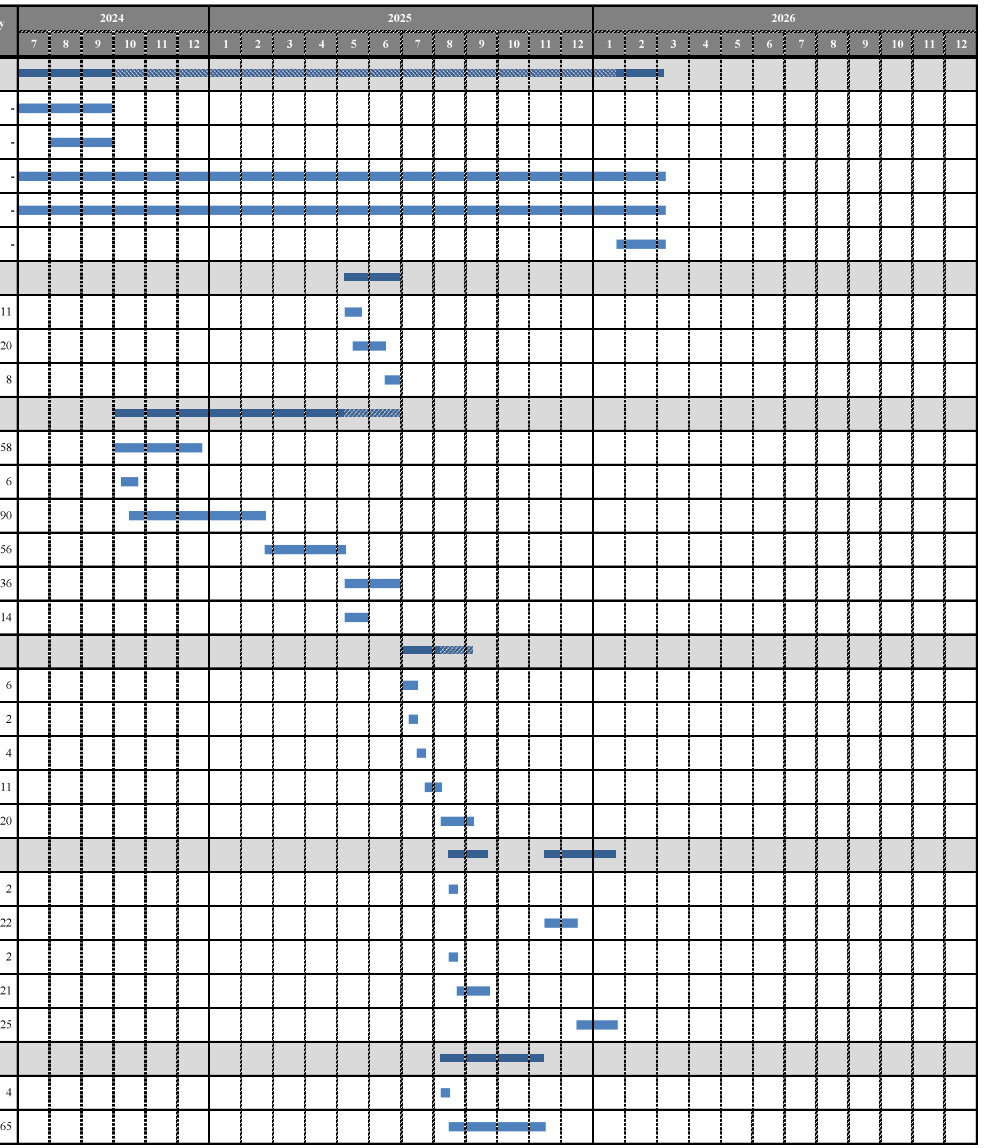
## Table 5.8.12 Construction Schedule for the Overall Project (1 package case)

| Island | Construction Items | Unit | Volume |
|---|---|---|---|
| Maamendhoo | 1. General and Preparatory Works | Sum | 1 |
| | 2. Groin (West side: 3 units) | m | 150 |
| | 3. Revetment (North side (Reclamation) :540m) | m | 540 |
| | 4. Revetment (East side :300m) | m | 300 |
| | 5. Beach Fill (West side: 400m) | m | 400 |
| | 6. Reclamation (North side: 22,000m$^2$) | m$^2$ | 22,000 |
| Fonadhoo | 1. General and Preparatory Works | Sum | 1 |
| | 2. Beach Fill (1600m) | m | 1,600 |
| Isdhoo | 1. General and Preparatory Works | Sum | 1 |
| | 2. Revetment (360m) | m | 360 |
| Gan | 1. General and Preparatory Works | Sum | 1 |
| | 2. Revetment (270m) | m | 270 |
| Meedhoo | 1. General and Preparatory Works | Sum | 1 |
| | 2. Groin (1unit) | m | 50 |
| | 3. Beach Fill (1600m) | m | 1,600 |



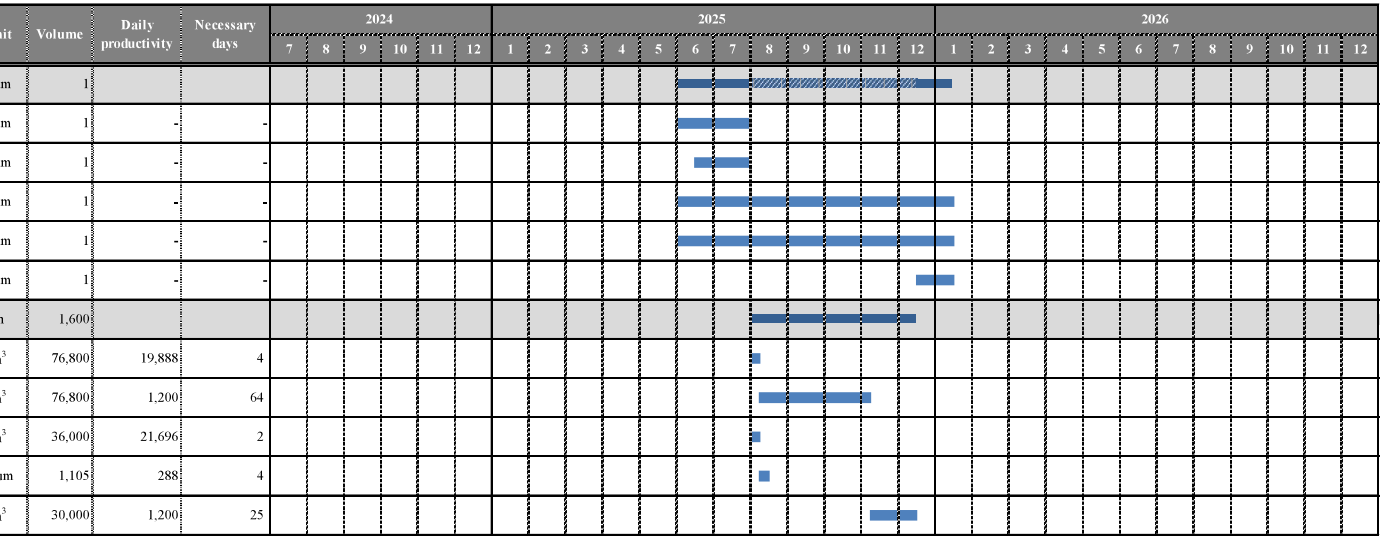
## Table 5.8.13 Construction Schedule for Maamendhoo Island (1 package case)

| Construction Items | Operation rate | Unit | Volume | Daily productivity | Necessary days |
|---|---|---|---|---|---|
| **1. General and Preparatory Works** | | sum | 1 | | |
| 1.1 Mobilization | 1.0 | sum | 1 | - | - |
| 1.2 Common Temporary Works | 1.0 | sum | 1 | - | - |
| 1.3 Survey and Monitoring Works | 1.0 | sum | 1 | - | - |
| 1.4 Preparation of Report, Drawings and others | 1.0 | sum | 1 | - | - |
| 1.5 Demobilization | 1.0 | sum | 1 | - | - |
| **2. Groin (South side: 3 units)** | | m | 150 | | |
| 2.1 Unloading of rock | 0.8 | $m^3$ | 4,274 | 500 | 11 |
| 2.2 Installation and leveling of rock (CORE RUBBLE, FILTETR STONE) | 0.8 | $m^3$ | 3,053 | 200 | 20 |
| 2.3 Installation and leveling of rock (ARMOUR STONE) | 0.8 | $m^3$ | 1,221 | 200 | 8 |
| **3. Revetment (North side (Reclamation) :540m)** | | m | 540 | | |
| 3.1 Unloading of rock | 0.8 | $m^3$ | 23,166 | 500 | 58 |
| 3.2 Installation of Geotextile | 0.8 | $m^2$ | 14,256 | 3,000 | 6 |
| 3.3 Installation and leveling of rock (CORE RUBBLE, FILTETR STONE) | 0.8 | $m^3$ | 14,256 | 200 | 90 |
| 3.4 Installation and leveling of rock (ARMOUR STONE) | 0.8 | $m^3$ | 8,910 | 200 | 56 |
| 3.5 Walkway | 1.0 | $m^2$ | 1,080 | 30 | 36 |
| 3.6 Installation of U-ditch | 1.0 | m | 540 | 40 | 14 |
| **4. Revetment (East side :300m)** | | m | 300 | | |
| 4.1 Unloading of rock | 0.8 | $m^3$ | 2,145 | 500 | 6 |
| 4.2 Installation of Geotextile | 0.8 | $m^3$ | 2,805 | 3,000 | 2 |
| 4.3 Installation and leveling of rock (CORE RUBBLE) | 0.8 | $m^3$ | 495 | 200 | 4 |
| 4.4 Installation and leveling of rock (ARMOUR STONE) | 0.8 | $m^3$ | 1,650 | 200 | 11 |
| 4.5 Walkway | 1.0 | $m^2$ | 600 | 30 | 20 |
| **5. Beach Fill (West side: 400m)** | | m | 400 | | |
| 5.1 Dredging and spreading of sand | 0.8 | $m^3$ | 25,920 | 24,408 | 2 |
| 5.2 Leveling of sand | 1.0 | $m^3$ | 25,920 | 1,200 | 22 |
| 5.3 Dredging and spreading of sand (for maintenance sand) | 0.8 | $m^3$ | 30,000 | 24,408 | 2 |
| 5.4 Produce and piling up of sandbag (for maintenance sand, as temporary revetment) | 1.0 | Num | 5,968 | 288 | 21 |
| 5.5 Leveling of sand (for maintenance sand, piling up) | 1.0 | $m^3$ | 30,000 | 1,200 | 25 |
| **6. Reclamation (North side: 22,000$m^2$)** | | $m^2$ | 22,000 | | |
| 6.1 Dredging and spreading of sand | 0.8 | $m^3$ | 77,000 | 24,408 | 4 |
| 6.2 Leveling of sand | 1.0 | $m^3$ | 77,000 | 1,200 | 65 |



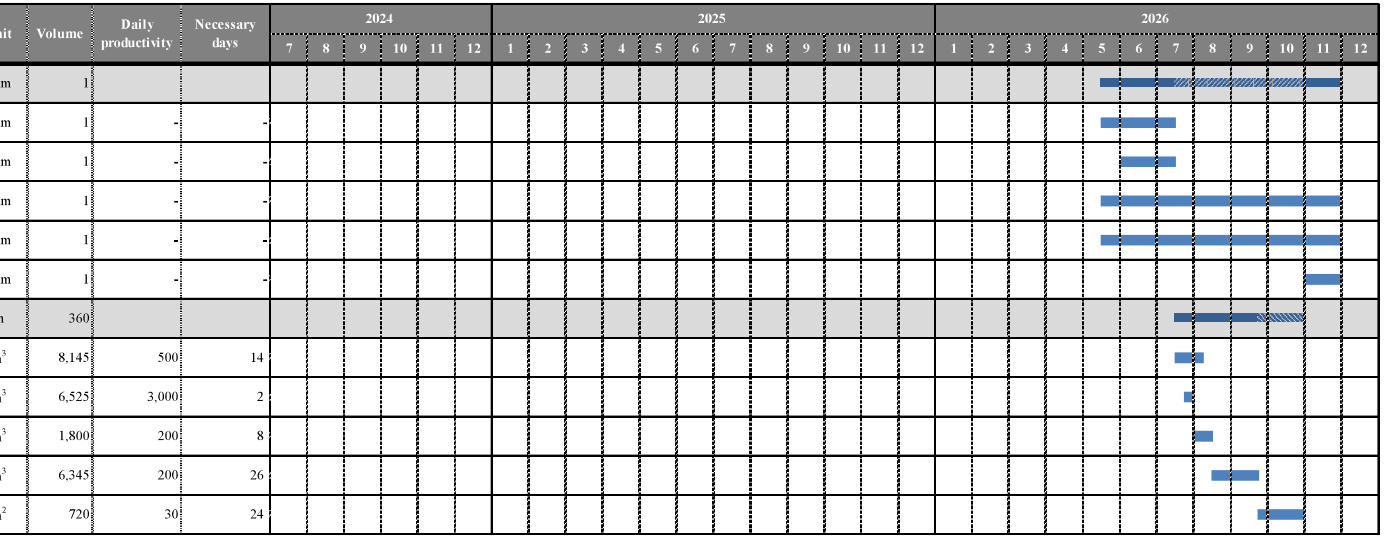
## Table 5.8.14 Construction Schedule for Fonadhoo Island (1 package case)

| Construction Items | Operation rate | Unit | Volume | Daily productivity | Necessary days |
|---|---|---|---|---|---|
| **1. General and Preparatory Works** | | sum | 1 | | |
| 1.1 Mobilization | 1.0 | sum | 1 | - | - |
| 1.2 Common Temporary Works | 1.0 | sum | 1 | - | - |
| 1.3 Survey and Monitoring Works | 1.0 | sum | 1 | - | - |
| 1.4 Preparation of Report, Drawings and others | 1.0 | sum | 1 | - | - |
| 1.5 Demobilization | 1.0 | sum | 1 | - | - |
| **2. Beach Fill (1600m)** | | m | 1,600 | | |
| 2.1 Dredging and spreading of sand | 0.8 | $m^3$ | 76,800 | 19,888 | 4 |
| 2.2 Leveling of sand | 1.0 | $m^3$ | 76,800 | 1,200 | 64 |
| 2.3 Dredging and spreading of sand (for maintenance sand) including sand for Gan | 0.8 | $m^3$ | 36,000 | 21,696 | 2 |
| 2.4 Produce and piling up of sandbag (for maintenance sand, as temporary revetment) | 1.0 | Num | 1,105 | 288 | 4 |
| 2.5 Leveling of sand (for maintenance sand, piling up) | 1.0 | $m^3$ | 30,000 | 1,200 | 25 |




## Table 5.8.15 Construction Schedule for Isdhoo Island (1 package case)

| Construction Items | Operation rate | Unit | Volume | Daily productivity | Necessary days |
|---|---|---|---|---|---|
| **1. General and Preparatory Works** | | sum | 1 | | |
| 1.1 Mobilization | 1.0 | sum | 1 | - | - |
| 1.2 Common Temporary Works | 1.0 | sum | 1 | - | - |
| 1.3 Survey and Monitoring Works | 1.0 | sum | 1 | - | - |
| 1.4 Preparation of Report, Drawings and others | 1.0 | sum | 1 | - | - |
| 1.5 Demobilization | 1.0 | sum | 1 | - | - |
| **2. Revetment (360m)** | | m | 360 | | |
| 2.1 Unloading of rock | 0.8 | $m^3$ | 8,145 | 500 | 14 |
| 2.2 Installation of Geotextile | 0.8 | $m^3$ | 6,525 | 3,000 | 2 |
| 2.3 Installation and leveling of rock (CORE RUBBLE, FILTETR STONE) | 0.8 | $m^3$ | 1,800 | 200 | 8 |
| 2.4 Installation and leveling of rock (ARMOUR STONE) | 0.8 | $m^3$ | 6,345 | 200 | 26 |
| 2.5 Walkway | 1.0 | $m^2$ | 720 | 30 | 24 |

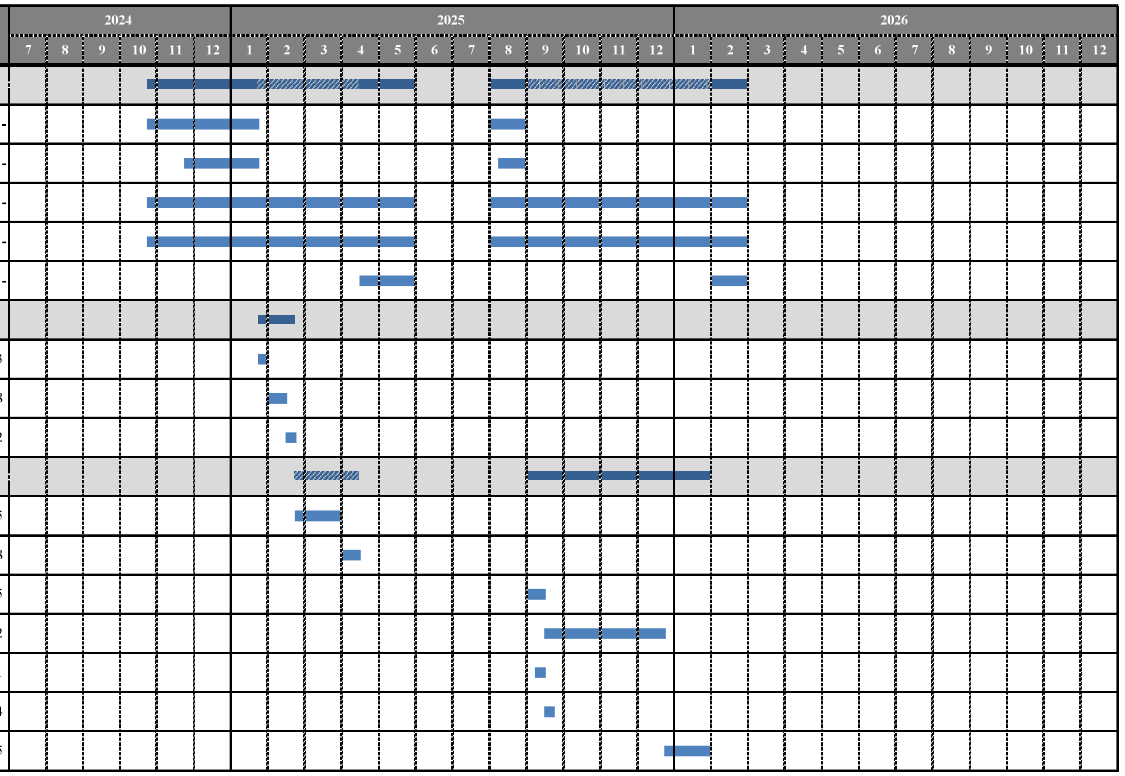


## Table 5.8.16 Construction Schedule for Gan Island (1 package case)

| Construction Items | Operation rate | Unit | Volume | Daily productivity | Necessary days | 2024 | | | | | | 2025 | | | | | | | | | | | | 2026 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| **1. General and Preparatory Works** | | sum | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.1 Mobilization | 1.0 | sum | 1 | - | - | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.2 Common Temporary Works | 1.0 | sum | 1 | - | - | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.3 Survey and Monitoring Works | 1.0 | sum | 1 | - | - | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.4 Preparation of Report, Drawings and others | 1.0 | sum | 1 | - | - | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.5 Demobilization | 1.0 | sum | 1 | - | - | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **2. Revetment (270m)** | | m | 270 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.1 Removal of existing revetment (cement bag) | 0.8 | $m^3$ | 864 | 150 | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.2 Unloading of rock | 0.8 | $m^3$ | 2,673 | 500 | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.3 Installation of Geotexitile | 0.8 | $m^3$ | 2,822 | 3,000 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.4 Installation and leveling of rock (CORE RUBBLE, FILTETR STONE) | 0.8 | $m^3$ | 1,188 | 200 | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.5 Installation and leveling of rock (ARMOUR STONE) | 0.8 | $m^3$ | 1,485 | 200 | 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.6 Walkway | 1.0 | $m^2$ | 540 | 30 | 18 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

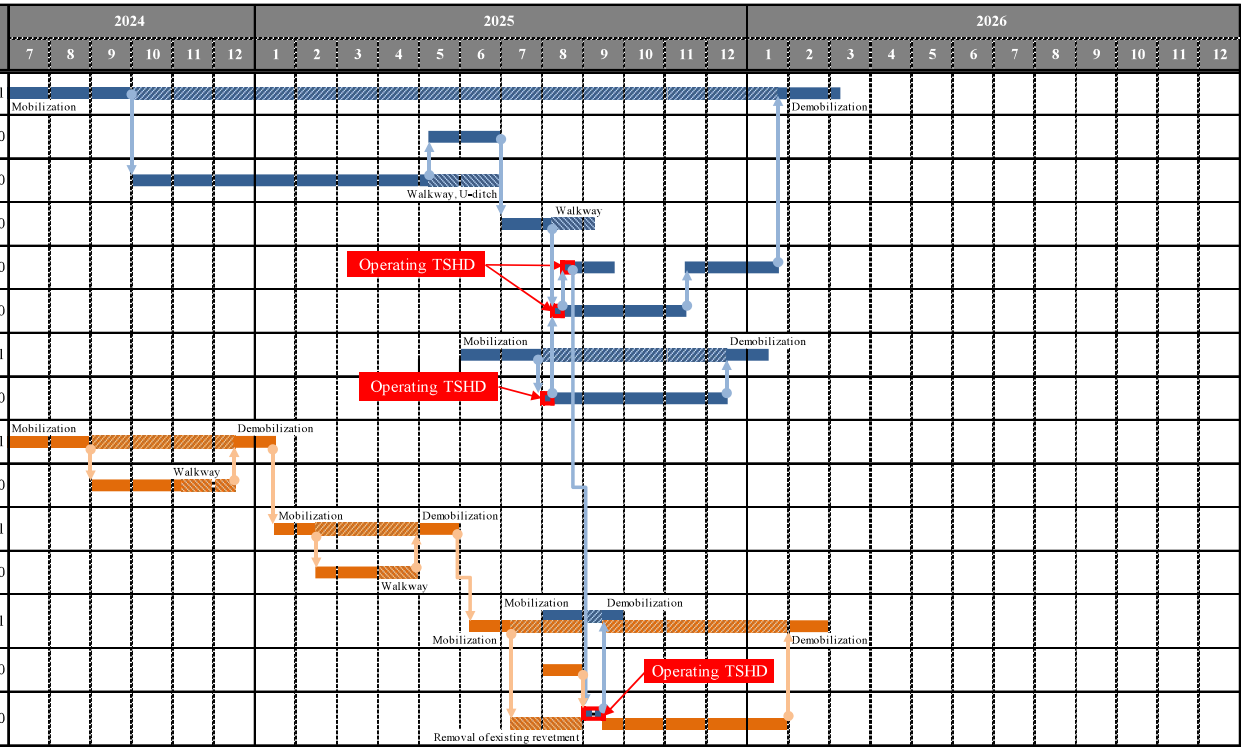
## Table 5.8.17 Construction Schedule for Meedhoo Island (1 package case)

| Construction Items | Operation rate | Unit | Volume | Daily productivity | Necessary days |
|---|---|---|---|---|---|
| **1. General and Preparatory Works** | | sum | 1 | | - |
| 1.1 Mobilization | 1.0 | sum | 1 | - | - |
| 1.2 Common Temporary Works | 1.0 | sum | 1 | - | - |
| 1.3 Survey and Monitoring Works | 1.0 | sum | 1 | - | - |
| 1.4 Preparation of Report, Drawings and others | 1.0 | sum | 1 | - | - |
| 1.5 Demobilization | 1.0 | sum | 1 | - | - |
| **2. Groin (1unit)** | | m | 50 | | |
| 2.1 Unloading of rock | 0.8 | $m^3$ | 1,668 | 500 | 3 |
| 2.2 Installation and leveling of rock (CORE RUBBLE, FILTETR STONE) | 0.8 | $m^3$ | 1,195 | 200 | 8 |
| 2.3 Installation and leveling of rock (ARMOUR STONE) | 0.8 | $m^3$ | 473 | 200 | 2 |
| **3. Beach Fill (1600m)** | | m | 1,600 | | - |
| 3.1 Removal of existing revetment (sand bag) | 1.0 | Num | 2,375 | 96 | 25 |
| 3.2 Removal of existing revetment (cement bag) | 0.8 | $m^3$ | 960 | 150 | 8 |
| 3.3 Dredging and spreading of sand | 0.8 | $m^3$ | 86,400 | 24,408 | 5 |
| 3.4 Leveling of sand | 1.0 | $m^3$ | 86,400 | 1,200 | 72 |
| 3.5 Dredging and spreading of sand (for maintenance sand) | 0.8 | $m^3$ | 30,000 | 24,408 | 1 |
| 3.6 Produce and piling up of sandbag (for maintenance sand, as temporary revetment) | 1.0 | $m^3$ | 1,105 | 288 | 4 |
| 3.7 Leveling of sand (for maintenance sand, piling up) | 1.0 | $m^3$ | 30,000 | 1,200 | 25 |



## Table 5.8.18 Construction Schedule for the Overall Project (2 packages case)

| Island | Construction Items | Unit | Volume |
|---|---|---|---|
| Maamendhoo | 1. General and Preparatory Works | Sum | 1 |
| | 2. Groin (West side: 3 units) | m | 150 |
| | 3. Revetment (North side (Reclamation) :540m) | m | 540 |
| | 4. Revetment (East side :300m) | m | 300 |
| | 5. Beach Fill (West side: 400m) | m | 400 |
| | 6. Reclamation (North side: 22,000m$^2$) | m$^2$ | 22,000 |
| Fonadhoo | 1. General and Preparatory Works | Sum | 1 |
| | 2. Beach Fill (1600m) | m | 1,600 |
| Isdhoo | 1. General and Preparatory Works | Sum | 1 |
| | 2. Revetment (360m) | m | 360 |
| Gan | 1. General and Preparatory Works | Sum | 1 |
| | 2. Revetment (270m) | m | 270 |
| Meedhoo | 1. General and Preparatory Works | Sum | 1 |
| | 2. Groin (1unit) | m | 50 |
| | 3. Beach Fill (1600m) | m | 1,600 |

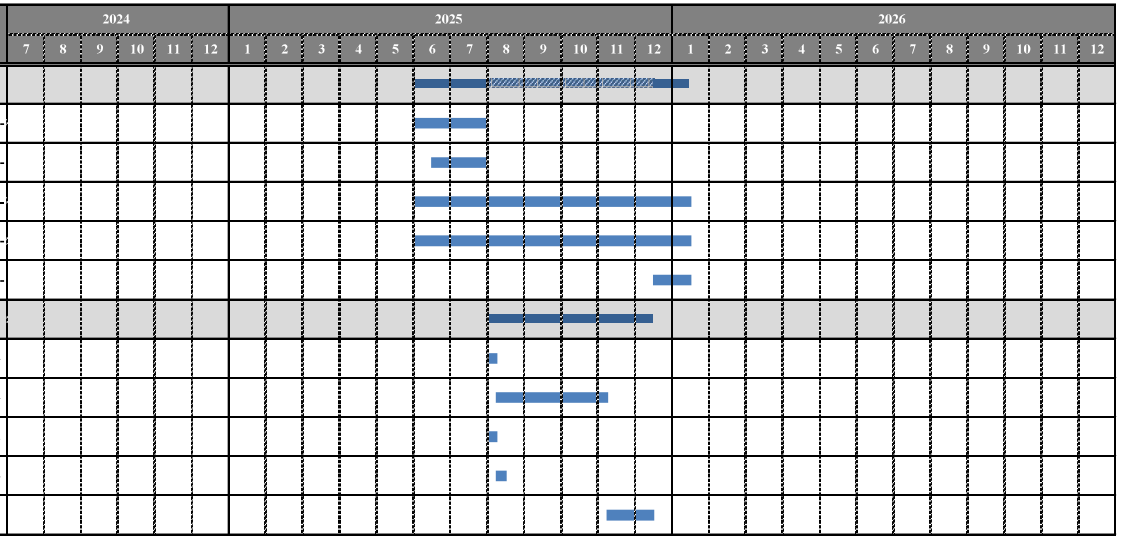


## Table 5.8.19 Construction Schedule for Maamendhoo Island (2 packages case)

| Construction Items | Operation rate | Unit | Volume | Daily productivity | Necessary days | 2024 | | | | | | 2025 | | | | | | | | | | | | 2026 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| **1. General and Preparatory Works** | | sum | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.1 Mobilization | 1.0 | sum | 1 | - | - | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.2 Common Temporary Works | 1.0 | sum | 1 | - | - | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.3 Survey and Monitoring Works | 1.0 | sum | 1 | - | - | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.4 Preparation of Report, Drawings and others | 1.0 | sum | 1 | - | - | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.5 Demobilization | 1.0 | sum | 1 | - | - | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **2. Groin (South side: 3 units)** | | m | 150 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.1 Unloading of rock | 0.8 | $m^3$ | 4,274 | 500 | 11 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.2 Installation and leveling of rock (CORE RUBBLE, FILTETR STONE) | 0.8 | $m^3$ | 3,053 | 200 | 20 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.3 Installation and leveling of rock (ARMOUR STONE) | 0.8 | $m^3$ | 1,221 | 200 | 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **3. Revetment (North side (Reclamation) :540m)** | | m | 540 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3.1 Unloading of rock | 0.8 | $m^3$ | 23,166 | 500 | 58 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3.2 Installation of Geotextile | 0.8 | $m^2$ | 14,256 | 3,000 | 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3.3 Installation and leveling of rock (CORE RUBBLE, FILTETR STONE) | 0.8 | $m^3$ | 14,256 | 200 | 90 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3.4 Installation and leveling of rock (ARMOUR STONE) | 0.8 | $m^3$ | 8,910 | 200 | 56 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3.5 Walkway | 1.0 | $m^2$ | 1,080 | 30 | 36 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3.6 Installation of U-ditch | 1.0 | m | 540 | 40 | 14 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **4. Revetment (East side :300m)** | | m | 300 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4.1 Unloading of rock | 0.8 | $m^3$ | 2,145 | 500 | 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4.2 Installation of Geotextile | 0.8 | $m^3$ | 2,805 | 3,000 | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4.3 Installation and leveling of rock (CORE RUBBLE) | 0.8 | $m^3$ | 495 | 200 | 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4.4 Installation and leveling of rock (ARMOUR STONE) | 0.8 | $m^3$ | 1,650 | 200 | 11 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4.5 Walkway | 1.0 | $m^2$ | 600 | 30 | 20 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **5. Beach Fill (West side: 400m)** | | m | 400 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5.1 Dredging and spreading of sand | 0.8 | $m^3$ | 25,920 | 24,408 | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5.2 Leveling of sand | 1.0 | $m^3$ | 25,920 | 1,200 | 22 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5.3 Dredging and spreading of sand (for maintenance sand) | 0.8 | $m^3$ | 30,000 | 24,408 | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5.4 Produce and piling up of sandbag (for maintenance sand, as temporary revetment) | 1.0 | Num | 5,968 | 288 | 21 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5.5 Leveling of sand (for maintenance sand, piling up) | 1.0 | $m^3$ | 30,000 | 1,200 | 25 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **6. Reclamation (North side: 22,000$m^2$)** | | $m^2$ | 22,000 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6.1 Dredging and spreading of sand | 0.8 | $m^3$ | 77,000 | 24,408 | 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6.2 Leveling of sand | 1.0 | $m^3$ | 77,000 | 1,200 | 65 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

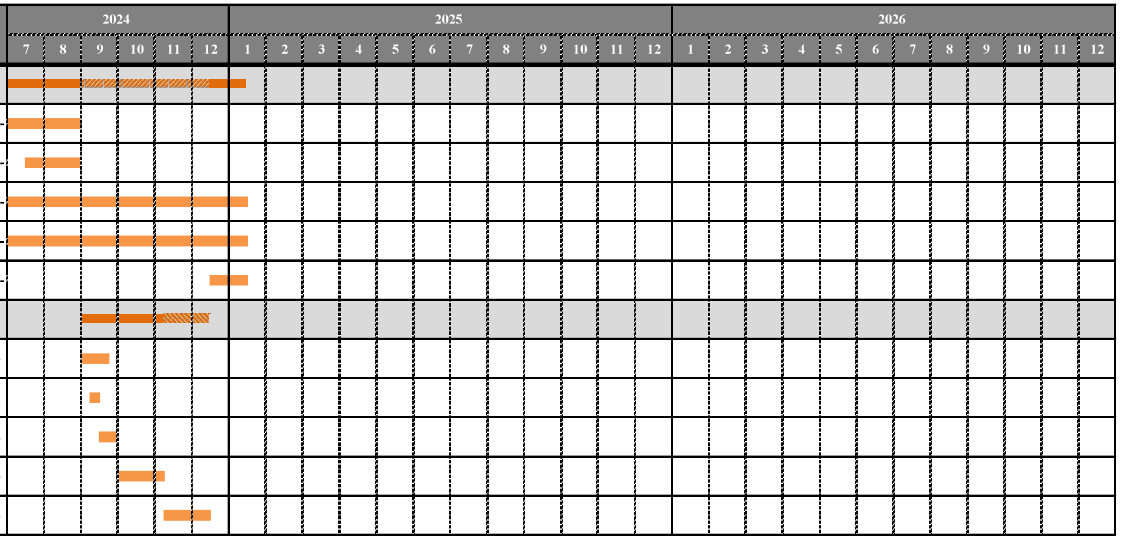
## Table 5.8.20 Construction Schedule for Fonadhoo Island (2 packages case)

| Construction Items | Operation rate | Unit | Volume | Daily productivity | Necessary days |
|---|---|---|---|---|---|
| **1. General and Preparatory Works** | | sum | 1 | | |
| 1.1 Mobilization | 1.0 | sum | 1 | - | - |
| 1.2 Common Temporary Works | 1.0 | sum | 1 | - | - |
| 1.3 Survey and Monitoring Works | 1.0 | sum | 1 | - | - |
| 1.4 Preparation of Report, Drawings and others | 1.0 | sum | 1 | - | - |
| 1.5 Demobilization | 1.0 | sum | 1 | - | - |
| **2. Beach Fill (1600m)** | | m | 1,600 | | |
| 2.1 Dredging and spreading of sand | 0.8 | $m^3$ | 76,800 | 19,888 | 4 |
| 2.2 Leveling of sand | 1.0 | $m^3$ | 76,800 | 1,200 | 64 |
| 2.3 Dredging and spreading of sand (for maintenance sand) including sand for Gan | 0.8 | $m^3$ | 36,000 | 21,696 | 2 |
| 2.4 Produce and piling up of sandbag (for maintenance sand, as temporary revetment) | 1.0 | Num | 1,105 | 288 | 4 |
| 2.5 Leveling of sand (for maintenance sand, piling up) | 1.0 | $m^3$ | 30,000 | 1,200 | 25 |




## Table 5.8.21 Construction Schedule for Isdhoo Island (2 packages case)

| Construction Items | Operation rate | Unit | Volume | Daily productivity | Necessary days |
|---|---|---|---|---|---|
| **1. General and Preparatory Works** | | sum | 1 | | |
| 1.1 Mobilization | 1.0 | sum | 1 | - | - |
| 1.2 Common Temporary Works | 1.0 | sum | 1 | - | - |
| 1.3 Survey and Monitoring Works | 1.0 | sum | 1 | - | - |
| 1.4 Preparation of Report, Drawings and others | 1.0 | sum | 1 | - | - |
| 1.5 Demobilization | 1.0 | sum | 1 | - | - |
| **2. Revetment (360m)** | | m | 360 | | |
| 2.1 Unloading of rock | 0.8 | $m^3$ | 8,145 | 500 | 14 |
| 2.2 Installation of Geotexitile | 0.8 | $m^3$ | 6,525 | 3,000 | 2 |
| 2.3 Installation and leveling of rock (CORE RUBBLE, FILTETR STONE) | 0.8 | $m^3$ | 1,800 | 200 | 8 |
| 2.4 Installation and leveling of rock (ARMOUR STONE) | 0.8 | $m^3$ | 6,345 | 200 | 26 |
| 2.5 Walkway | 1.0 | $m^2$ | 720 | 30 | 24 |

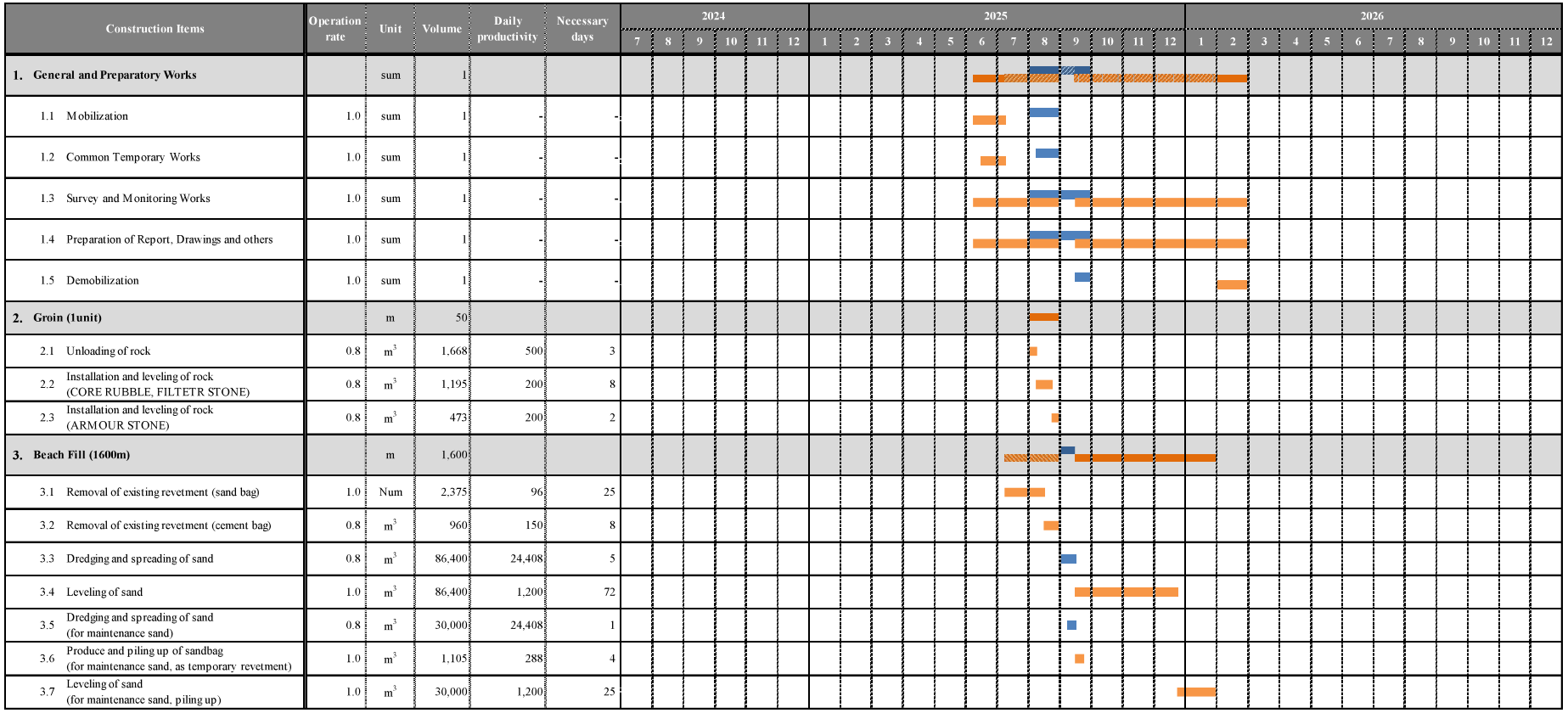


## Table 5.8.22 Construction Schedule for Gan Island (2 packages case)

| Construction Items | Operation rate | Unit | Volume | Daily productivity | Necessary days | 2024 | | | | | | 2025 | | | | | | | | | | | | 2026 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| **1. General and Preparatory Works** | | sum | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.1 Mobilization | 1.0 | sum | 1 | - | - | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.2 Common Temporary Works | 1.0 | sum | 1 | - | - | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.3 Survey and Monitoring Works | 1.0 | sum | 1 | - | - | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.4 Preparation of Report, Drawings and others | 1.0 | sum | 1 | - | - | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.5 Demobilization | 1.0 | sum | 1 | - | - | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **2. Revetment (270m)** | | m | 270 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.1 Removal of existing revetment (cement bag) | 0.8 | $m^3$ | 864 | 150 | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.2 Unloading of rock | 0.8 | $m^3$ | 2,673 | 500 | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.3 Installation of Geotexitile | 0.8 | $m^3$ | 2,822 | 3,000 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.4 Installation and leveling of rock (CORE RUBBLE, FILTETR STONE) | 0.8 | $m^3$ | 1,188 | 200 | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.5 Installation and leveling of rock (ARMOUR STONE) | 0.8 | $m^3$ | 1,485 | 200 | 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.6 Walkway | 1.0 | $m^2$ | 540 | 30 | 18 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

## Table 5.8.23 Construction Schedule for Meedhoo Island (2 packages case)

| Construction Items | Operation rate | Unit | Volume | Daily productivity | Necessary days |
|---|---|---|---|---|---|
| **1. General and Preparatory Works** | | sum | 1 | | |
| 1.1 Mobilization | 1.0 | sum | 1 | - | - |
| 1.2 Common Temporary Works | 1.0 | sum | 1 | - | - |
| 1.3 Survey and Monitoring Works | 1.0 | sum | 1 | - | - |
| 1.4 Preparation of Report, Drawings and others | 1.0 | sum | 1 | - | - |
| 1.5 Demobilization | 1.0 | sum | 1 | - | - |
| **2. Groin (1unit)** | | m | 50 | | |
| 2.1 Unloading of rock | 0.8 | $m^3$ | 1,668 | 500 | 3 |
| 2.2 Installation and leveling of rock (CORE RUBBLE, FILTETR STONE) | 0.8 | $m^3$ | 1,195 | 200 | 8 |
| 2.3 Installation and leveling of rock (ARMOUR STONE) | 0.8 | $m^3$ | 473 | 200 | 2 |
| **3. Beach Fill (1600m)** | | m | 1,600 | | |
| 3.1 Removal of existing revetment (sand bag) | 1.0 | Num | 2,375 | 96 | 25 |
| 3.2 Removal of existing revetment (cement bag) | 0.8 | $m^3$ | 960 | 150 | 8 |
| 3.3 Dredging and spreading of sand | 0.8 | $m^3$ | 86,400 | 24,408 | 5 |
| 3.4 Leveling of sand | 1.0 | $m^3$ | 86,400 | 1,200 | 72 |
| 3.5 Dredging and spreading of sand (for maintenance sand) | 0.8 | $m^3$ | 30,000 | 24,408 | 1 |
| 3.6 Produce and piling up of sandbag (for maintenance sand, as temporary revetment) | 1.0 | $m^3$ | 1,105 | 288 | 4 |
| 3.7 Leveling of sand (for maintenance sand, piling up) | 1.0 | $m^3$ | 30,000 | 1,200 | 25 |



### 5.8.2 Calculation of the approximate construction cost

(1) Summary of construction cost

Construction cost for GCF Project is 19,478 thousand USD in total of three islands and total cost is increased 2,834 thousand USD (1.5% increased) compare with funding proposal.

On the other hands, construction cost for Maldivian government cofinancing is 3,884 thousand USD in total of three islands and total cost is decreased 460 thousand USD (10.6% decreased) compare with funding proposal.

The calculated construction cost is temporary result on the basic design phase, and it is necessary to revise on the detail design phase. The total construction cost for funding proposal and final proposal by project fund by target islands is as bellow.

**Table 5.8.24 Summary of Construction Cost by Project Fund by Target Islands**

**(Comparison Funding Proposal and Final Proposal)**

unit:USD

| Fund | Island | Amount | | |
|---|---|---|---|---|
| | | Original Plan | Final Proposal | Difference |
| GCF | 1 Maamendhoo | 11,388,500 | 12,747,725 | +1,359,225 (111.9%) |
| | 2 Fonadhoo | 6,194,400 | 4,712,393 | -1,482,007 (76.1%) |
| | 3 Meedhoo | 1,611,300 | 2,017,440 | +406,140 (125.2%) |
| | Total | 19,194,200 | 19,477,558 | +283,358 (101.5%) |
| GoM | 1 Ishdhoo | 886,000 | 2,126,755 | +1,240,755 (240.0%) |
| | 2 Gan | 886,000 | 746,812 | -139,188 (84.3%) |
| | 3 Meedhoo | 2,572,000 | 1,010,855 | -1,561,145 (39.3%) |
| | Total | 4,344,000 | 3,884,423 | -459,577 (89.4%) |

The comparison results of the construction cost for funding proposal and final proposal by target facilities for GCF Project and Maldives government cofinancing project is as follow.

**Table 5.8.25 Comparison Result of the Construction Cost for Funding Proposal and Final Proposal by Islands by Facilities (GCF Project)**

| Fund | Island | Item | Unit | Original Plan | | Final Proposal | |
|---|---|---|---|---|---|---|---|
| | | | | Oty | Amount(USD) | Oty | Amount(USD) |
| GCF | **1 Maamendhoo** | 1.General and Preparatory Works | sum | 1 | 3,069,500 | 1 | 3,662,159 |
| | | 2.1 Groin (W+E) ⇒ (W) | unit | 7 | 1,917,797 | 3 | 630,853 |
| | | 2.2 Revetment (N) | m | 540 | 1,682,935 | 540 | 3,582,306 |
| | | 2.3 Revetment (E) | m | - | - | 300 | 366,242 |
| | | 3.1 Beach Fill (W+E) ⇒ (W) | m | 900 | 751,200 | 400 | 592,804 |
| | | 3.2 Reclamation (N) | $m^2$ | 22,000 | 1,120,000 | 22,000 | 726,431 |
| | | 4.Other Works (10% of Total) | sum | 1 | 949,048 | 1 | 1,062,310 |
| | | Total | | | 9,490,479 | | 10,623,104 |
| | | Others (20% of direct construction cost) | | | 1,898,096 | | 2,124,621 |
| | | **Total (including other works)** | | | **11,388,500** | | **12,747,725** |
| | **2 Fonadhoo** | 1.General and Preparatory Works | sum | 1 | 2,420,000 | 1 | 2,456,859 |
| | | 2.1 Groin | unit | 5 | 1,471,671 | - | - |
| | | 3.1 Beach Fill | m | 850 | 754,320 | 1,600 | 1,077,436 |
| | | 4.Other Works (10% of Total) | sum | 1 | 516,000 | 1 | 392,699 |
| | | Total | | | 5,161,991 | | 3,926,994 |
| | | Others (20% of direct construction cost) | | | 1,032,398 | | 785,399 |
| | | **Total (including other works)** | | | **6,194,400** | | **4,712,393** |
| | **3 Meedhoo** | 1.General and Preparatory Works | sum | 1 | 470,800 | 1 | 750,000 |
| | | 3.1 Beach Fill | m | 1,400 | 872,000 | 1,600 | 931,200 |
| | | Total | | | 1,342,800 | | 1,681,200 |
| | | Others (20% of direct construction cost) | | | 268,560 | | 336,240 |
| | | **Total (including other works)** | | | **1,611,300** | | **2,017,440** |
| | **Total** | | | | **19,194,200** | | **19,477,558** |

**Table 5.8.26 Comparison Result of the Construction Cost for Funding Proposal and Final Proposal by Islands by Facilities (Maldives Government Cofinancing Project)**

| Fund | Island | Item | Unit | Original Plan | | Final Proposal | |
|---|---|---|---|---|---|---|---|
| | | | | Oty | Amount(USD) | Oty | Amount(USD) |
| GoM | **1 Ishdhoo** | 1.General and Preparatory Works | sum | 1 | | 1 | 319,013 |
| | | 2.1 Revetment | m | 270 | | 360 | 1,276,053 |
| | | 4.Other Works (10% of Total) | sum | 1 | | 1 | 177,230 |
| | | Total | | | 738,333 | | 1,772,296 |
| | | Others (20% of direct construction cost) | | | 147,667 | | 354,459 |
| | | **Total (including other works)** | | | **886,000** | | **2,126,755** |
| | **2 Gan** | 1.General and Preparatory Works | sum | 1 | | 1 | 112,022 |
| | | 2.1 Revetment | m | 270 | | 270 | 448,087 |
| | | 4.Other Works (10% of Total) | Sum | 1 | | 1 | 62,234 |
| | | Total | | | 738,333 | | 622,344 |
| | | Others (20% of direct construction cost) | | | 147,667 | | 124,469 |
| | | **Total (including other works)** | | | **886,000** | | **746,812** |
| | **3 Meedhoo** | 1.General and Preparatory Works | sum | 1 | | 1 | 151,628 |
| | | 2.1 Groin | unit | 7 | | 1 | 433,182 |
| | | 3.1 Beach Fill | m | 1,400 | | 1,600 | 173,331 |
| | | 4.Other Works (10% of Total) | sum | 1 | | 1 | 84,238 |
| | | Total | | | 2,143,333 | | 842,379 |
| | | Others (20% of direct construction cost) | | | 428,667 | | 168,476 |
| | | **Total (including other works)** | | | **2,572,000** | | **1,010,855** |
| | **Total** | | | | **4,343,999** | | **3,884,423** |

(2) Construction cost by islands

1) Construction cost for Maamendhoo Island

Construction cost for Maamendhoo Island implemented as GCF Project is 12,748 thousand USD.

**Table 5.8.27 Breakdown of Construction Cost for Maamendhoo Island**

| Bill. No. | Item | Unit | Qty | Unit Price (USD) | Amount (USD) | Remarks |
|---|---|---|---|---|---|---|
| **1** | **General and Preparatory Works** | | | | | |
| 101 | Mobilization and demobilization (TSHD) | Sum | 0.5 | 3,500,000.00 | 1,750,000 | |
| 102 | Mobilization and demobilization | Sum | 1.0 | 318,693.13 | 318,693 | 3% of Total |
| 103 | Common Temporary works | Sum | 1.0 | | | |
| 104 | Survey and monitoring works before, during and after construction | Sum | 1.0 | | 1,593,466 | 15% of Total |
| 105 | Preparation of report, drawing, photo, video and others | Sum | 1.0 | | | |
| | **Sub-total** | | | | 3,662,159 | |
| **2.1** | **Groin (3 unit(W), L=50m/unit)** | | | | | |
| 201a | Supply and unloading of core robble and filter stone | cu.m | 3,053 | 123.54 | 377,168 | Overfill factor 10% |
| 201b | Supply and unloading of armour stone | cu.m | 1,221 | 123.54 | 150,842 | Overfill factor 10% |
| 202a | Installation and leveling of core robble and filter stone | cu.m | 3,053 | 24.06 | 73,463 | |
| 202b | Installation and leveling of armour stone | cu.m | 1,221 | 24.06 | 29,380 | |
| | **Sub-total** | | | | 630,853 | |
| **2.2** | **Revetment (L=540m(N))** | | | | | |
| 201a | Supply and unloading of core robble and filter stone | cu.m | 14,256 | 123.54 | 1,761,186 | Overfill factor 10% |
| 201b | Supply and unloading of armour stone | cu.m | 8,910 | 123.54 | 1,100,741 | Overfill factor 10% |
| 202a | Installation and leveling of core robble and filter stone | cu.m | 14,256 | 24.06 | 343,035 | |
| 202b | Installation and leveling of armour stone | cu.m | 8,910 | 24.06 | 214,397 | |
| 203 | Supply and installation of geotextile | sq.m | 14,256 | 4.52 | 64,396 | |
| 204 | Pavament for walkway | sq.m | 1,080 | 61.61 | 66,535 | |
| 205 | Suppy and installation of U-ditch | ln.m | 540 | 59.29 | 32,015 | |
| | **Sub-total** | | | | 3,582,306 | |
| **2.3** | **Revetment (L=300m(E))** | | | | | |
| 201a | Supply and unloading of core robble and filter stone | cu.m | 495 | 123.54 | 61,152 | Overfill factor 10% |
| 201b | Supply and unloading of armour stone | cu.m | 1,650 | 123.54 | 203,841 | Overfill factor 10% |
| 202a | Installation and leveling of core robble and filter stone | cu.m | 495 | 24.06 | 11,911 | |
| 202b | Installation and leveling of armour stone | cu.m | 1,650 | 24.06 | 39,703 | |
| 203 | Supply and installation of geotextile | sq.m | 2,805 | 4.52 | 12,670 | |
| 204 | Pavament for walkway | sq.m | 600 | 61.61 | 36,964 | |
| | **Sub-total** | | | | 366,242 | |
| **3.1** | **Beach Fill (L=400m(W))** | | | | | |
| 301a | Supply, transporting and spreading of sand | cu.m | 25,920 | 8.00 | 207,360 | Overfill factor: 20% |
| 301a | Supply, transporting and spreading of sand | cu.m | 30,000 | 8.00 | 240,000 | for stockpile |
| 302a | Forming of beach | cu.m | 25,920 | 1.43 | 37,174 | |
| 302b | Forming of stockpile | cu.m | 30,000 | 1.83 | 55,035 | for stockpile |
| 303 | Forming temporary revetment by sand bag | num | 5,968 | 8.92 | 53,235 | for stockpile |
| | **Sub-total** | | | | 592,804 | |
| **3.2** | **Reclamation (A=22,000m2)** | | | | | |
| 301a | Supply, transporting and spreading of sand | cu.m | 77,000 | 8.00 | 616,000 | Overfill factor 10% |
| 302c | Leveling | cu.m | 77,000 | 1.43 | 110,431 | |
| | **Sub-total** | | | | 726,431 | |
| **4** | **Other works (10% of Total)** | Sum | | | 1,062,310 | |
| | Total | | | | 10,623,104 | |
| | Others (20% of direct construction cost) | | | | 2,124,621 | |
| | **Total (including other works)** | | | | **12,747,725** | |

2) Construction cost for Fonadhoo Island

Construction cost for Fonadhoo Island implemented as GCF Project is 4,712 thousand USD.

**Table 5.8.28 Breakdown of Construction Cost for Fonadhoo Island**

| Bill. No. | Item | Unit | Qty | Unit Price (USD) | Amount (USD) | Remarks |
|---|---|---|---|---|---|---|
| **1** | **General and Preparatory Works** | | | | | |
| 101 | Mobilization and demobilization (TSHD) | Sum | 0.5 | 3,500,000.00 | 1,750,000 | |
| 102 | Mobilization and demobilization | Sum | 1.0 | 117,809.82 | 117,810 | 3% of Total |
| 103 | Common Temporary works | Sum | 1.0 | | | |
| 104 | Survey and monitoring works before, during and after construction | Sum | 1.0 | | 589,049 | 15% of Total |
| 105 | Preparation of report, drawing, photo, video and others | Sum | 1.0 | | | |
| | **Sub-total** | | | | 2,456,859 | |
| **3.1** | **Beach Fill (L=1600m)** | | | | | |
| 301b | Supply, transporting and spreading of sand | cu.m | 76,800 | 8.00 | 614,400 | Overfill factor: 20% |
| 301c | Supply, transporting and spreading of sand | cu.m | 36,000 | 8.00 | 288,000 | for stockpile |
| 302a | Forming of beach | cu.m | 76,800 | 1.43 | 110,144 | |
| 302b | Forming of stockpile | cu.m | 30,000 | 1.83 | 55,035 | |
| 303 | Forming temporary revetment by sand bag | num | 1,105 | 8.92 | 9,857 | |
| | **Sub-total** | | | | 1,077,436 | |
| **4** | **Other works (10% of Total)** | Sum | | | 392,699 | |
| | Total | | | | 3,926,994 | |
| | Other works (20% of direct construction cost) | | | | 785,399 | |
| | **Total (including other works)** | | | | **4,712,393** | |

3) Construction cost for Isdhoo Island

Construction cost for Isdhoo Island implemented as Maldives government cofinancing project is 2,127 thousand USD.

Overfill of rock material is increased to 25% because there is possibility to move the normal line to offshore side to protect vegetation which grown by target area on detail design phase.

**Table 5.8.29 Breakdown of Construction Cost for Isdhoo Island**

| Bill. No. | Item | Unit | Qty | Unit Price (USD) | Amount (USD) | Remarks |
|---|---|---|---|---|---|---|
| **1** | **General and Preparatory Works** | | | | | |
| 102 | Mobilization and demobilization | Sum | 1.0 | 53,168.88 | 53,169 | 3% of Total |
| 103 | Common Temporary works | Sum | 1.0 | | | |
| 104 | Survey and monitoring works before, during and after construction | Sum | 1.0 | | 265,844 | 15% of Total |
| 105 | Preparation of report, drawing, photo, video and others | Sum | 1.0 | | | |
| | **Sub-total** | | | | 319,013 | |
| **2.1** | **Revetment (L=360m)** | | | | | |
| 201a | Supply and unloading of core robble and filter stone | cu.m | 1,800 | 123.54 | 222,372 | Overfill factor: 25% |
| 201b | Supply and unloading of armour stone | cu.m | 6,345 | 123.54 | 783,861 | Overfill factor: 25% |
| 202a | Installation and leveling of core robble and filter stone | cu.m | 1,800 | 24.06 | 43,313 | |
| 202b | Installation and leveling of armour stone | cu.m | 6,345 | 24.06 | 152,677 | |
| 203 | Supply and installation of geotextile | sq.m | 6,525 | 4.52 | 29,474 | |
| 204 | Pavament for walkway | sq.m | 720 | 61.61 | 44,357 | |
| | Sub-total | | | | 1,276,053 | |
| **4** | **Other works (10% of Total)** | Sum | | | 177,230 | |
| | Total | | | | 1,772,296 | |
| | Others (20% of direct construction cost) | | | | 354,459 | |
| | **Total (including other works)** | | | | **2,126,755** | |

4) Construction cost for Gan Island

Construction cost for Gan Island implemented as Maldives government cofinancing project is 747 thousand USD.

**Table 5.8.30 Breakdown of Construction Cost for Gan Island**

| Bill. No. | Item | Unit | Qty | Unit Price (USD) | Amount (USD) | Remarks |
|---|---|---|---|---|---|---|
| **1** | **General and Preparatory Works** | | | | | |
| 102 | Mobilization and demobilization | Sum | 1.0 | 18,670.31 | 18,670 | 3% of Total |
| 103 | Common Temporary works | Sum | 1.0 | | 93,352 | 15% of Total |
| 104 | Survey and monitoring works before, during and after construction | Sum | 1.0 | | | |
| 105 | Preparation of report, drawing, photo, video and others | Sum | 1.0 | | | |
| | **Sub-total** | | | | 112,022 | |
| **2.1** | **Revetment (L=270m(N))** | | | | | |
| 200b | Removal of existing revetment (cement bag) | cu.m | 864 | 8.72 | 7,531 | |
| 201a | Supply and unloading of core robble and filter stone | cu.m | 1,188 | 123.54 | 146,766 | Overfill factor:10% |
| 201b | Supply and unloading of armour stone | cu.m | 1,485 | 123.54 | 183,457 | Overfill factor:10% |
| 202a | Installation and leveling of core robble and filter stone | cu.m | 1,188 | 24.06 | 28,586 | |
| 202b | Installation and leveling of armour stone | cu.m | 1,485 | 24.06 | 35,733 | |
| 203 | Supply and installation of geotextile | sq.m | 2,822 | 4.52 | 12,747 | |
| 204 | Pavament for walkway | sq.m | 540 | 61.61 | 33,268 | |
| | **Sub-total** | | | | 448,087 | |
| **3** | **Other works (10% of Total)** | Sum | | | 62,234 | |
| | Total | | | | 622,344 | |
| | Others (20% of direct construction cost) | | | | 124,469 | |
| | **Total (including other works)** | | | | **746,812** | |

5) Construction cost for Meedhoo Island

Construction cost for Meedhoo Island implemented as GCF Project is 2,017 thousand USD, and Maldives government cofinancing project is 1,011 thousand USD.

**Table 5.8.31 Breakdown of Construction Cost for Meedhoo Island (GCF Project)**

| Bill. No. | Item | Unit | Qty | Unit Price (USD) | Amount (USD) | Remarks |
|---|---|---|---|---|---|---|
| **1** | **General and Preparatory Works** | | | | | |
| 101 | Mobilization and demobilization (TSHD) | Sum | 1.0 | 750,000.00 | 750,000 | |
| | **Sub-total** | | | | 750,000 | |
| **3.1** | **Beach Fill (L=1600m)** | | | | | |
| 301d | Supply, transporting and spreading of sand | cu.m | 86,400 | 8.00 | 691,200 | Overfill factor: 20% |
| 301d | Supply, transporting and spreading of sand | cu.m | 30,000 | 8.00 | 240,000 | |
| | **Sub-total** | | | | 931,200 | |
| | Total | | | | 1,681,200 | |
| | Other works (20% of direct construction cost) | | | | 336,240 | |
| | **Total (including other works)** | | | | **2,017,440** | |

**Table 5.8.32 Breakdown of Construction Cost for Meedhoo Island (Maldives Government Cofinancing Project)**

| Bill. No. | Item | Unit | Qty | Unit Price (USD) | Amount (USD) | Remarks |
|---|---|---|---|---|---|---|
| **1** | **General and Preparatory Works** | | | | | |
| 102 | Mobilization and demobilization | Sum | 1.0 | 25,271.37 | 25,271 | 3% of Total |
| 103 | Common Temporary works | Sum | 1.0 | | 126,357 | 15% of Total |
| 104 | Survey and monitoring works before, during and after construction | Sum | 1.0 | | | |
| 105 | Preparation of report, drawing, photo, video and others | Sum | 1.0 | | | |
| | **Sub-total** | | | | 151,628 | |
| **2.1** | **Groin (1 unit, L=70m/unit)** | | | | | |
| 201a | Supply and unloading of core robble and filter stone | cu.m | 1,835 | 123.54 | 226,696 | Overfill factor: 10% |
| 201b | Supply and unloading of armour stone | cu.m | 1,314 | 123.54 | 162,332 | Overfill factor: 10% |
| 202a | Installation and leveling of core robble and filter stone | cu.m | 1,314 | 24.06 | 31,618 | |
| 202b | Installation and leveling of armour stone | cu.m | 521 | 24.06 | 12,537 | |
| | **Sub-total** | | | | 433,182 | |
| **3.1** | **Beach Fill (L=1700m)** | | | | | |
| 200a | Removal of existing revetment (sand bag) | num | 2,375 | 17.29 | 41,051 | |
| 200b | Removal of existing revetment (cement bag) | cu.m | 960 | 8.72 | 8,368 | |
| 302a | Forming of beach | cu.m | 86,400 | 1.43 | 123,912 | Overfill factor: 20% |
| | **Sub-total** | | | | 173,331 | |
| **4** | **Other works (10% of Total)** | Sum | | | 84,238 | |
| | Total | | | | 842,379 | |
| | Other works (20% of direct construction cost) | | | | 168,476 | |
| | **Total (including other works)** | | | | **1,010,855** | |

(3) Setting of unit rate of machineries, materials and labor cost

Unit rate of machineries, materials and labor cost is set based on the result of interview to local contractors as follow.

**Table 5.8.33 List of Unit Rate of Machineries**

| Item | Description | Unit | Unit rate |
|---|---|---|---|
| Excavator | D 1.0m3 | USD/d | 350 |
| Bulldozer | D6 | USD/d | 600 |
| Wheel Loader | D 1.5m3 | USD/d | 500 |
| Dump Truck | 10t | USD/d | 250 |
| Baby Roller | 1t | USD/d | 700 |
| Generator | 50KvA | USD/d | 150 |

**Table 5.8.34 List of Unit Rate of Materials**

| Item | Description | Unit | Unit rate |
|---|---|---|---|
| Rock boulder | 1kg-30kg | USD/m3 | 120 |
| | 30kg-50kg | USD/m3 | 120 |
| | 50kg-100kg | USD/m3 | 120 |
| | 100kg-300kg | USD/m3 | 120 |
| | 300kg-500kg | USD/m3 | 120 |
| | Over than 500kg | USD/m3 | 120 |
| Crushed stones | | USD/m3 | 30 |
| Base Course | | USD/m3 | 30 |
| Sand for filling | | USD/m3 | 10 |
| Natural stone | | USD/m2 | 20 |
| Mortar | | USD/m3 | 40 |
| Geotextile | | USD/m2 | 4 |
| Precast U-ditch | | USD/ln | 40 |
| Sand bag | | USD/n | 5 |
| Fuel | | USD/L | 1.50 |

**Table 5.8.35 List of Unit Rate of Labor**

| Item | Unit | Unit rate |
|---|---|---|
| Supervisor | USD/d | 350 |
| Skilled labor | USD/d | 600 |
| Common labor | USD/d | 500 |
| Operator of Machinery | USD/d | 150 |
| Truck driver | USD/d | |